GENERAL ASSEMBLY

INTRO TO DATA SCIENCE

LECTURE 21: DISTRIBUTED SYSTEMS - SPARK

Using Apache Spark

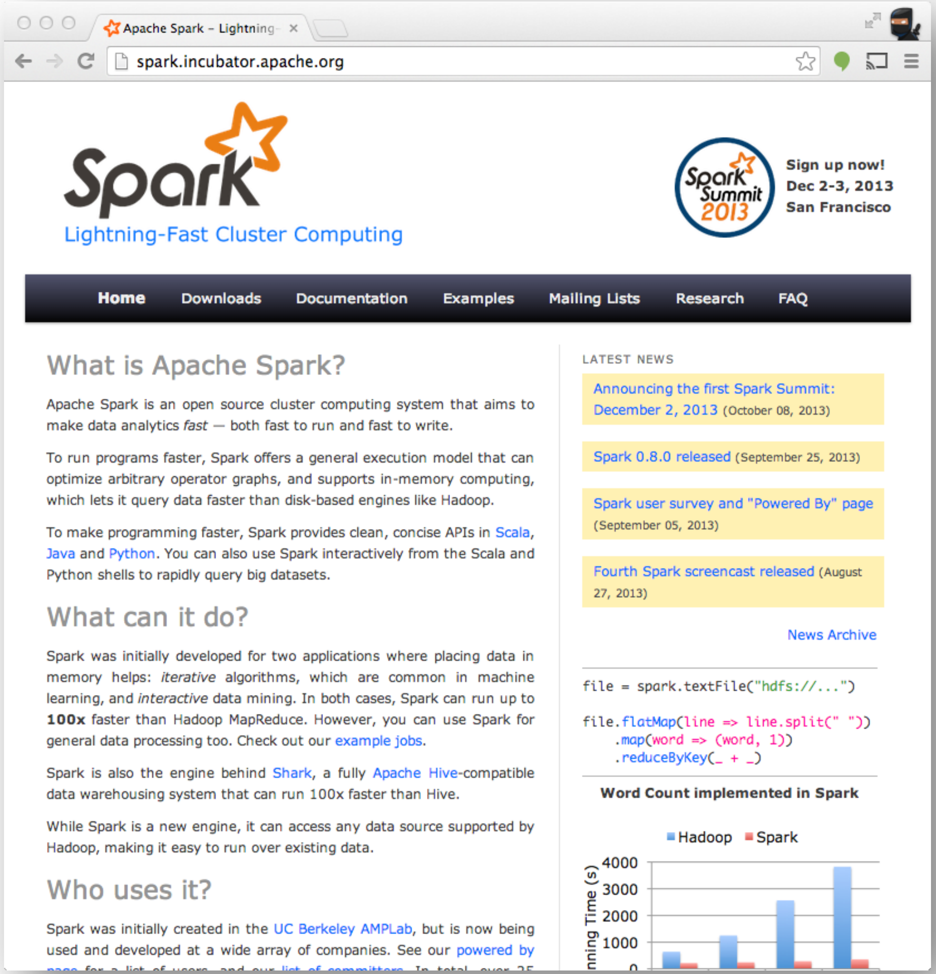
Pat McDonough - Databricks

Apache Spark

spark.apache.org

github.com/apache/spark

user@spark.apache.org



The Spark Community

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INTRODUCTION TO APACHE SPARK

What is Spark?

Fast and Expressive Cluster Computing System
Compatible with Apache Hadoop

Up to 10× faster on disk,
100× in memory

2-5× less code

Efficient

- General execution graphs
- In-memory storage

Usable

- Rich APIs in Java, Scala, Python
- Interactive shell

Key Concepts

Write programs in terms of transformations on distributed datasets

Resilient Distributed Datasets

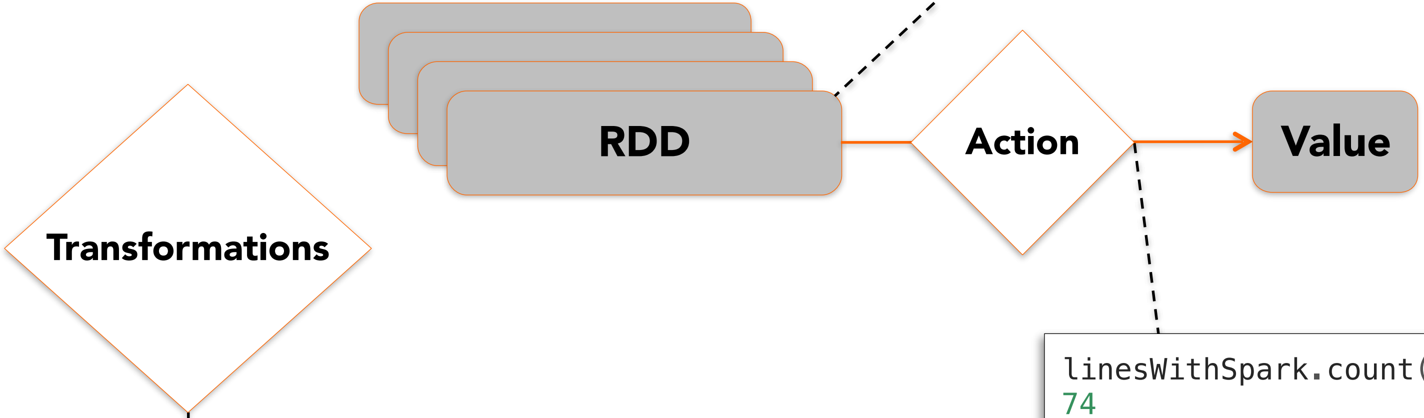
- Collections of objects spread across a cluster, stored in RAM or on Disk
- Built through parallel transformations
- Automatically rebuilt on failure

Operations

- Transformations (e.g. map, filter, groupBy)
- Actions (e.g. count, collect, save)

Working With RDDs

```python
textFile = sc.textFile("SomeFile.txt")
```




```python
linesWithSpark.count()
74

linesWithSpark.first()
# Apache Spark
```

```python
linesWithSpark = textFile.filter(lambda line: "Spark" in line)
```

Example: Log Mining

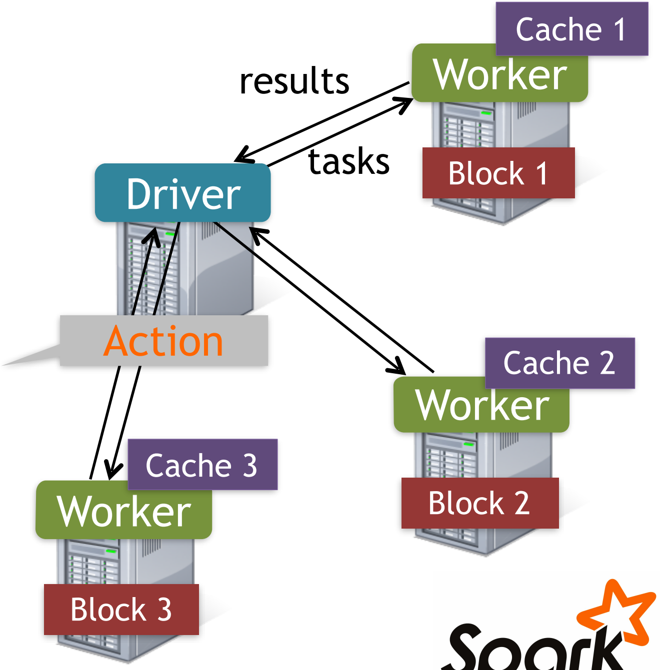
Load error messages from a log into memory, then interactively search for various patterns

B Transformed RDD

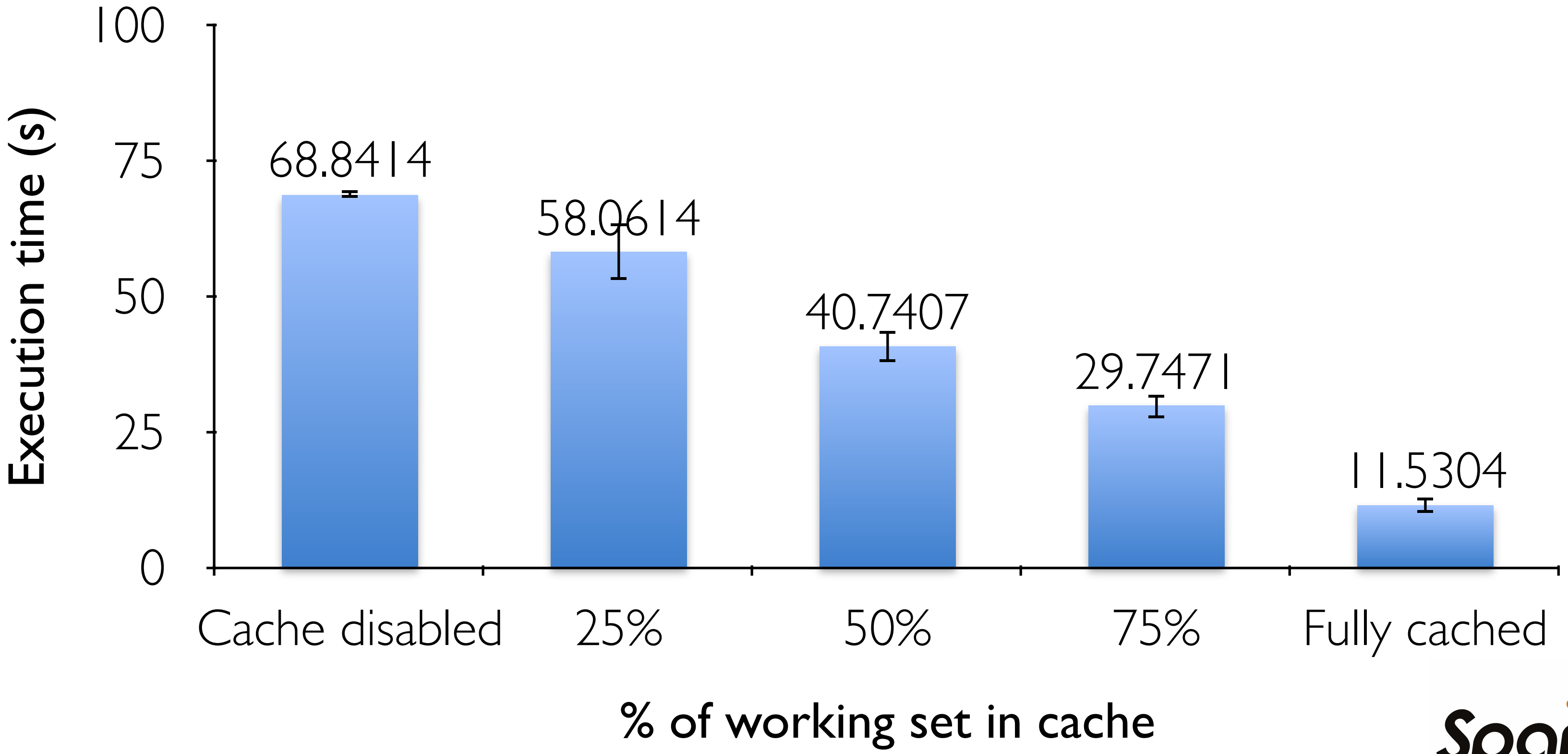
```
lines = spark.textFile(“hdfs://...”)
errors = lines.filter(lambda s: s.startswith(“ERROR”))
messages = errors.map(lambda s: s.split(“\t”)[2])
messages.cache()


messages.filter(lambda s: “mysql” in s).count()
messages.filter(lambda s: “php” in s).count()
. . .
```

Full-text search of Wikipedia

- 60GB on 20 EC2 machine
- 0.5 sec vs. 20s for on-disk



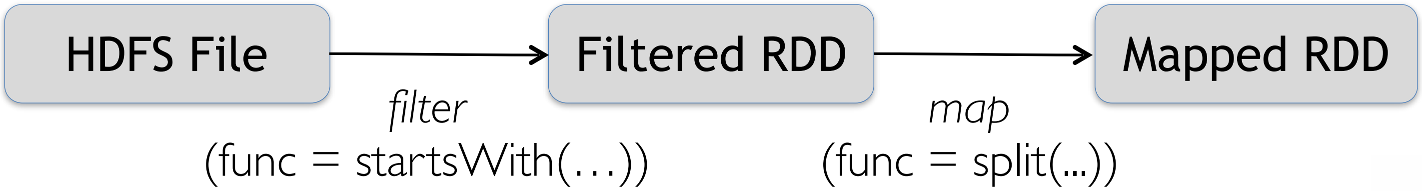
Scaling Down



Fault Recovery

RDDs track *lineage* information that can be used to efficiently recompute lost data

```
msgs = textFile.filter(lambda s: s.startsWith(“ERROR”))
               .map(lambda s: s.split(“\t”)[2])
```



Language Support

Python

```
lines = sc.textFile(...)
lines.filter(lambda s: "ERROR" in s).count()
```

Scala

```
val lines = sc.textFile(...)
lines.filter(x => x.contains("ERROR")).count()
```

Java

```
JavaRDD<String> lines = sc.textFile(...);
lines.filter(new Function<String, Boolean>() {
  Boolean call(String s) {
    return s.contains("error");
  }
}).count();
```

Standalone Programs

- Python, Scala, & Java

Interactive Shells

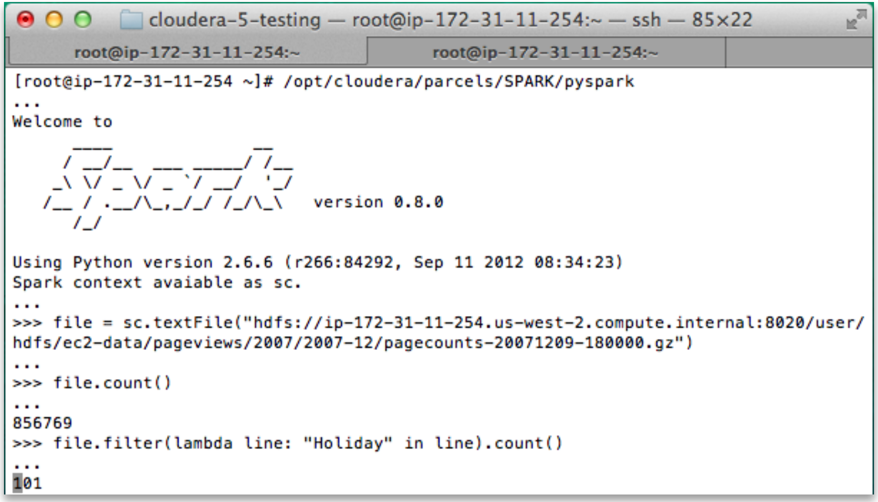
- Python & Scala

Performance

- Java & Scala are faster due to static typing
- …but Python is often fine

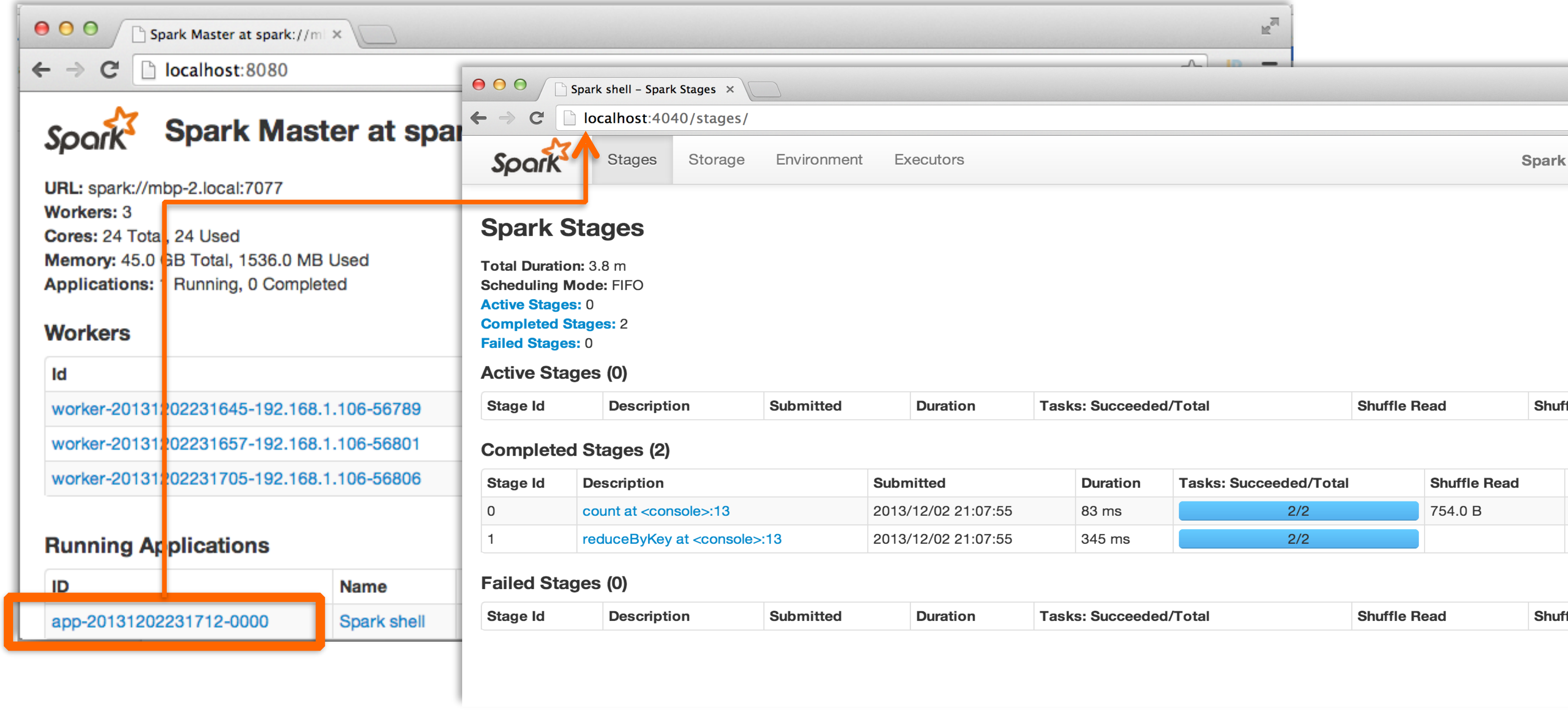
Interactive Shell

- The Fastest Way to Learn Spark
- Available in Python and Scala
- Runs as an application on an existing Spark Cluster…
- OR Can run locally



Administrative GUIs

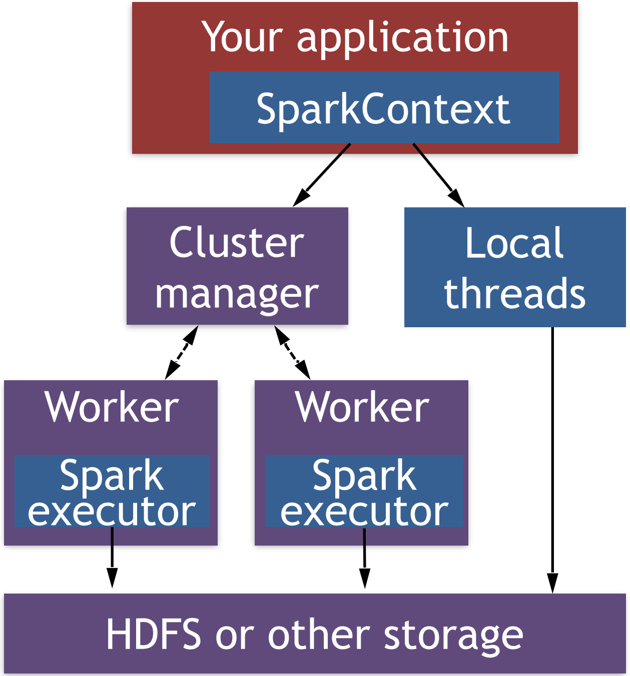
http://<Standalone Master>:8080 (by default)



JOB EXECUTION

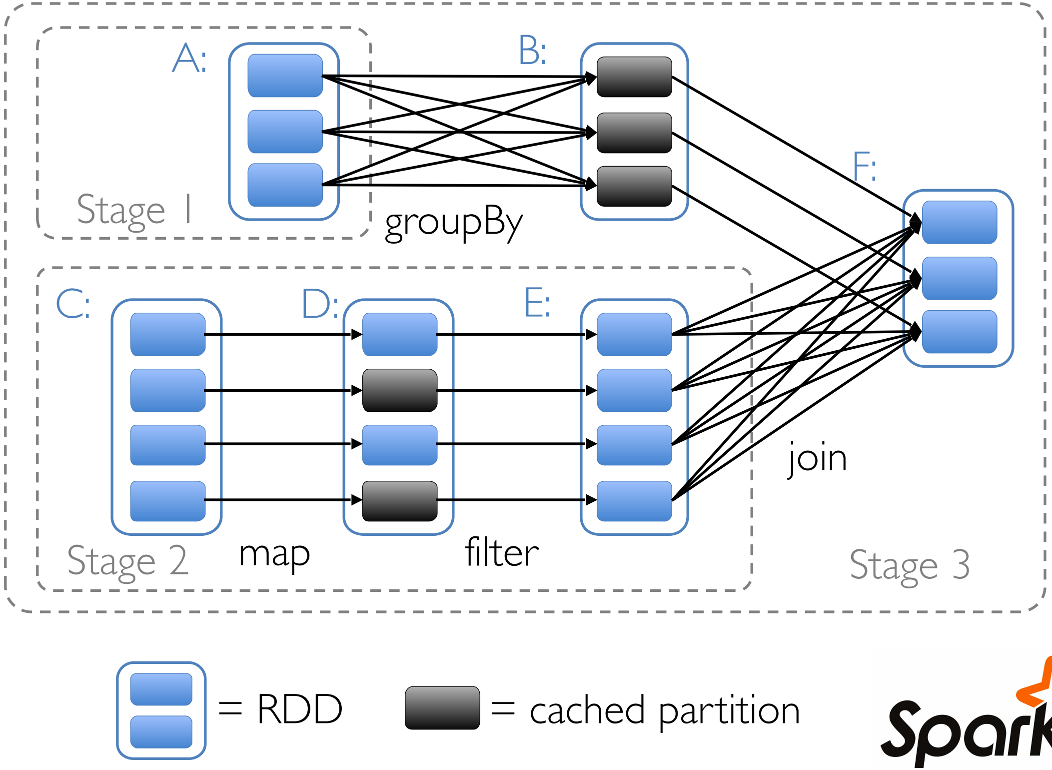
Software Components

- Spark runs as a library in your program (1 instance per app)
- Runs tasks locally or on cluster
  - Mesos, YARN or standalone mode
- Accesses storage systems via Hadoop InputFormat API
  - Can use HBase, HDFS, S3, …



Task Scheduler

- General task graphs
- Automatically pipelines functions
- Data locality aware
- Partitioning aware to avoid shuffles



Advanced Features

- Controllable partitioning
  - Speed up joins against a dataset
- Controllable storage formats
  - Keep data serialized for efficiency, replicate to multiple nodes, cache on disk
- Shared variables: broadcasts, accumulators
- See online docs for details!

WORKING WITH SPARK

Using the Shell

Launching:

spark-shell

pyspark (IPYTHON=1)

```
cloudera-5-testing — root@ip-172-31-11-254:~ — ssh — 85×22
root@ip-172-31-11-254:~    root@ip-172-31-11-254:~

[root@ip-172-31-11-254 ~]# /opt/cloudera/parcels/SPARK/pyspark
...
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 0.8.0
      /_/

Using Python version 2.6.6 (r266:84292, Sep 11 2012 08:34:23)
Spark context avaiable as sc.
...
>>> file = sc.textFile("hdfs://ip-172-31-11-254.us-west-2.compute.internal:8020/user/
hdfs/ec2-data/pageviews/2007/2007-12/pagecounts-20071209-180000.gz")
...
>>> file.count()
...
856769
>>> file.filter(lambda line: "Holiday" in line).count()
...
101
```

Modes:

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

SparkContext

- Main entry point to Spark functionality
- Available in shell as variable **sc**
- In standalone programs, you'd make your own (see later for details)

Creating RDDs

```
# Turn a Python 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 existing Hadoop InputFormat (Java/Scala only)
> sc.hadoopFile(keyClass, valClass, inputFmt, conf)
```

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(x))
      ># => {0, 0, 1, 0, 1, 2}
```

Range object (sequence of numbers 0, 1, …, x-1)

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")
```

Working with Key-Value Pairs

Spark's "distributed reduce" transformations operate on RDDs of key-value pairs

Python:

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

Scala:

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

Java:

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

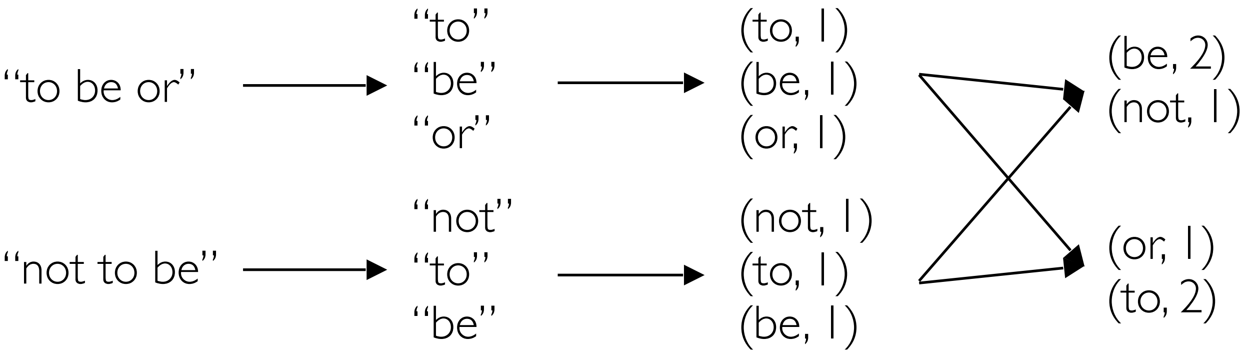
Some Key-Value Operations

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

reduceByKey also automatically implements combiners on the map side

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)
```



Other Key-Value Operations

```
> visits = sc.parallelize([ ("index.html", "1.2.3.4"),
                            ("about.html", "3.4.5.6"),
                            ("index.html", "1.3.3.1") ])

> pageNames = sc.parallelize([ ("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", (["1.2.3.4", "1.3.3.1"], ["Home"]))
  # ("about.html", (["3.4.5.6"], ["About"]))
```

Setting 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)
```

Using Local Variables

Any external variables you use in a closure will automatically be shipped to the cluster:

```
> query = sys.stdin.readline()
> pages.filter(lambda x: query in x).count()
```

Some caveats:

- Each task gets a new copy (updates aren't sent back)
- Variable must be Serializable / Pickle-able
- Don't use fields of an outer object (ships all of it!)

Closure Mishap Example

This is a problem:

```
class MyCoolRddApp {
  val param = 3.14
  val log = new Log(...)
  ...

  def work(rdd: RDD[Int]) {
    rdd.map(x => x + param)
      .reduce(...)
  }
}
```

NotSerializableException:
MyCoolRddApp (or Log)

How to get around it:

```
class MyCoolRddApp {
  ...
  ...

  def work(rdd: RDD[Int]) {
    val param_ = param
    rdd.map(x => x + param_)
      .reduce(...)
```

References only local variable
instead of this.param

More RDD Operators

- map
- filter
- groupBy
- sort
- union
- join
- leftOuterJoin
- rightOuterJoin

- reduce
- count
- fold
- reduceByKey
- groupByKey
- cogroup
- cross
- zip

sample

take

first

partitionBy

mapWith

pipe

save ...

CREATING SPARK APPLICATIONS

Add Spark to Your Project

- Scala / Java: add a Maven dependency on

groupId:	org.spark-project
artifactId:	spark-core_2.9.3
version:	0.8.0

- Python: run program with our pyspark script

Create a SparkContext

Scala

```
import org.apache.spark.SparkContext
import org.apache.spark.SparkContext._

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

Cluster URL, or local / local[N]

App name

Spark install path on cluster

List of JARs with app code (to ship)

Java

```
import org.a

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

Python

```
from pyspark import SparkContext

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

Complete Spark App in Python

```
import sys
from pyspark import SparkContext

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

    counts = lines.flatMap(lambda s: s.split(“ ”)) \
                  .map(lambda word: (word, 1)) \
                  .reduceByKey(lambda x, y: x + y)

    counts.saveAsTextFile(sys.argv[2])
```

EXAMPLE APPLICATION: PAGERANK

Example: PageRank

- Good example of a more complex algorithm
  - Multiple stages of map & reduce
- Benefits from Spark's in-memory caching
  - Multiple iterations over the same data

Basic Idea

Give pages ranks (scores) based on links to them

- Links from many pages ➔ high rank
- Link from a high-rank page ➔ high rank

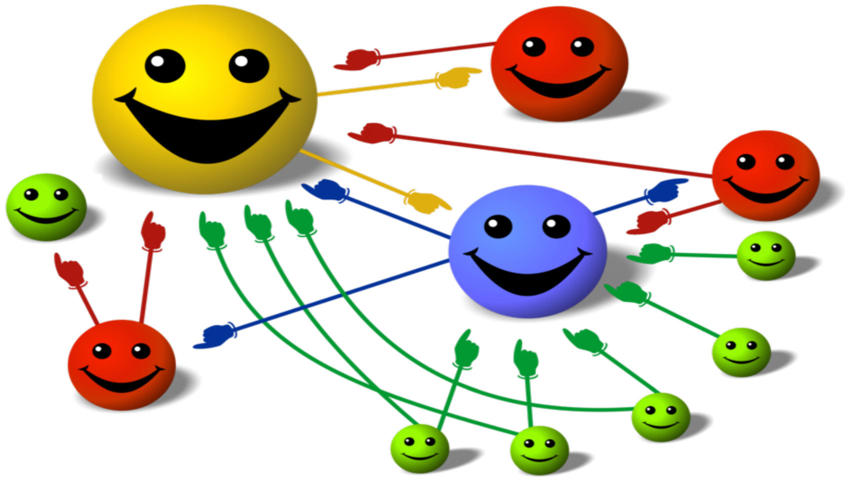
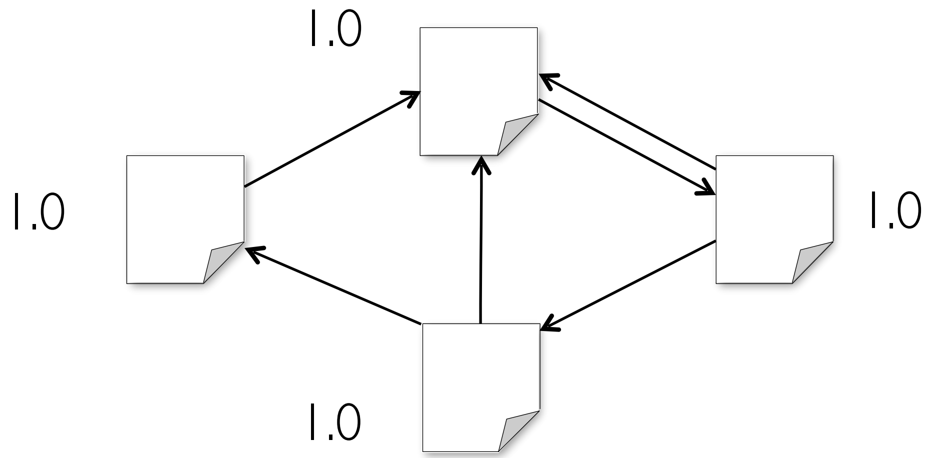


Image: en.wikipedia.org/wiki/File:PageRank-hi-res-2.png

Spark

Algorithm

1. Start each page at a rank of 1
2. On each iteration, have page p contribute $rank_p$ / $|neighbors_p|$ to its neighbors
3. Set each page's rank to $0.15 + 0.85 \times contribs$



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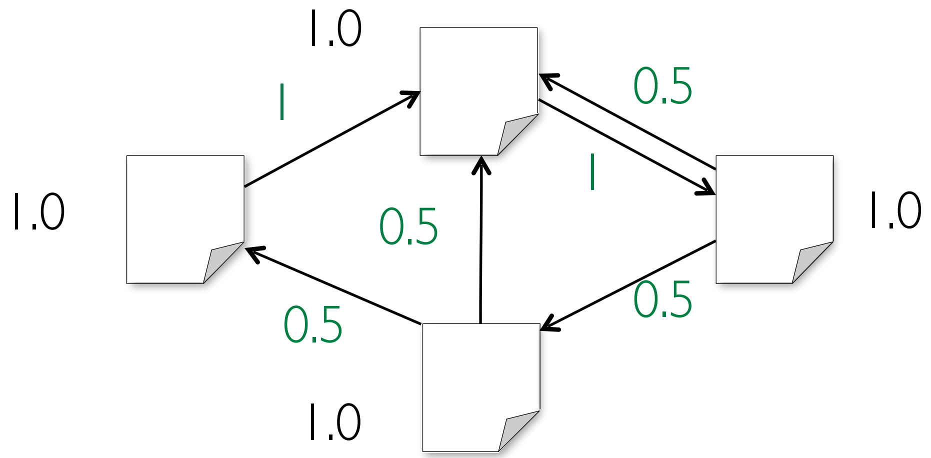

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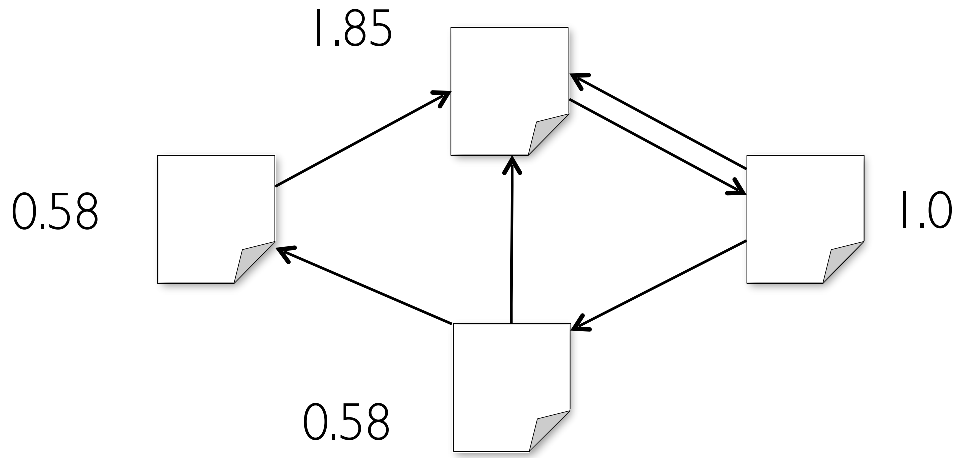

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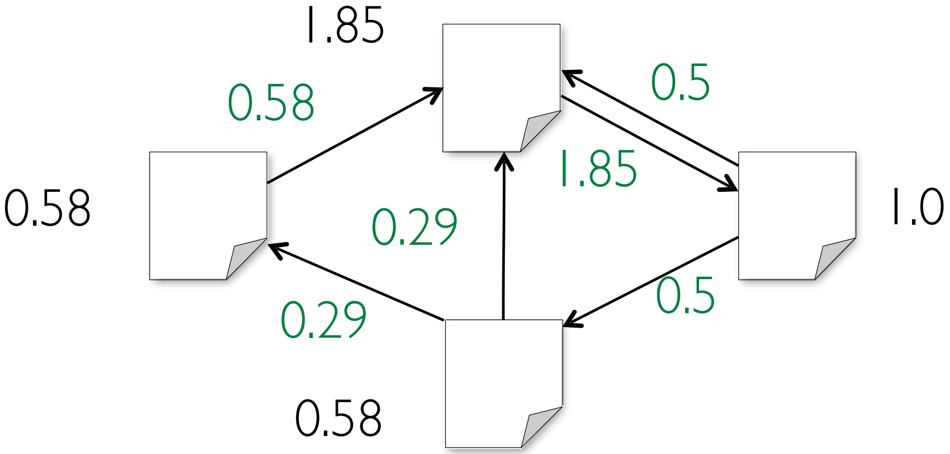

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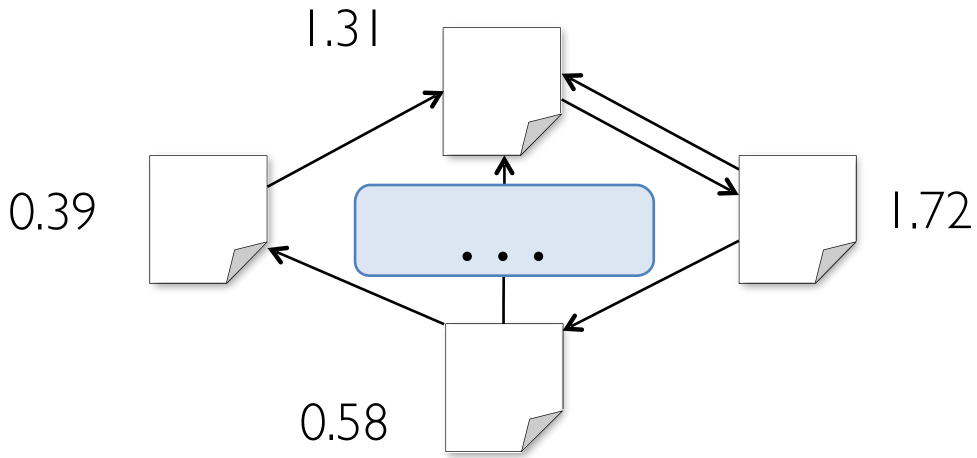

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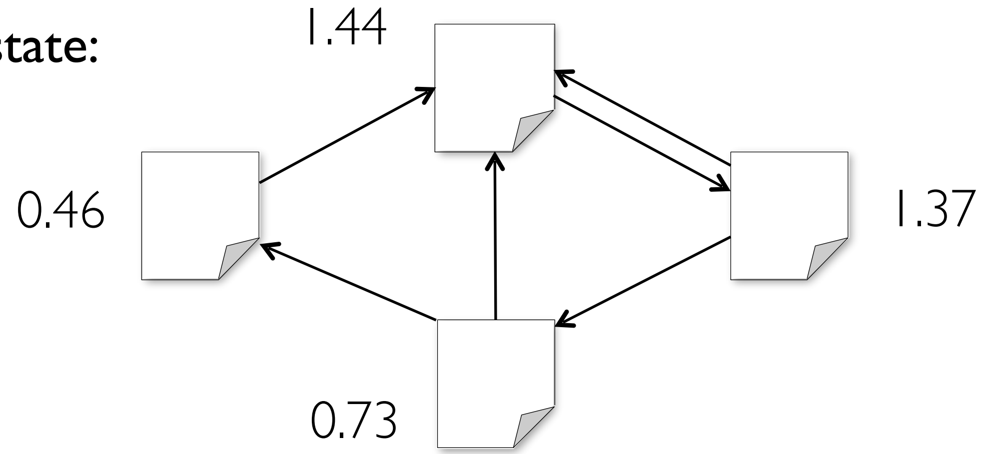
Final state:

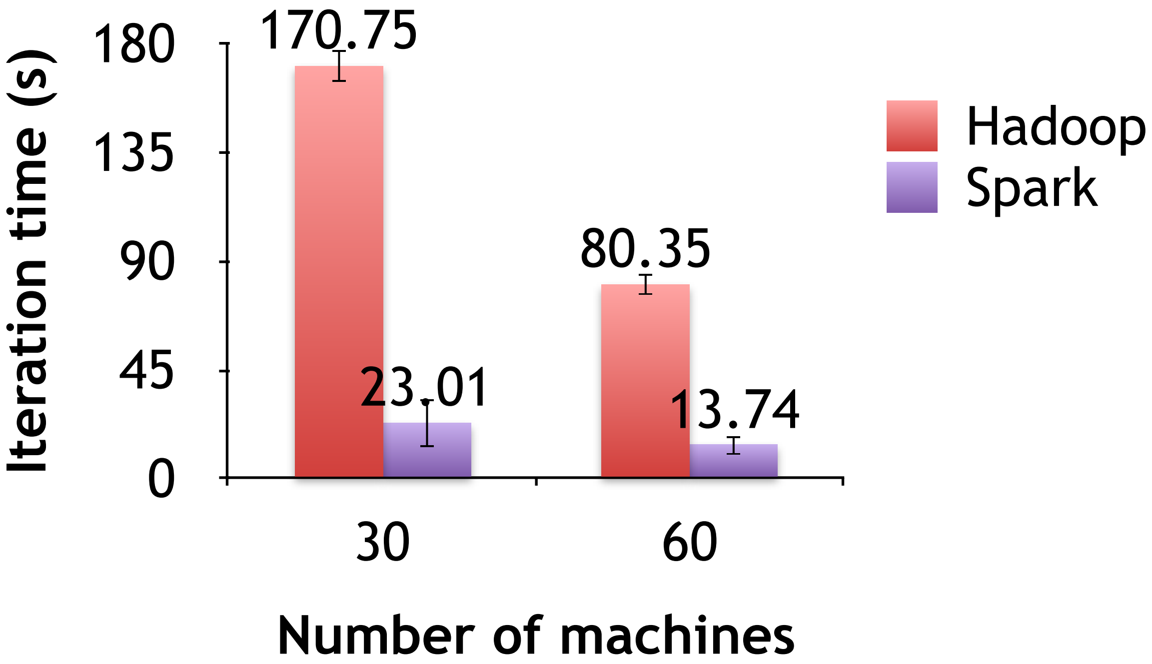


Scala Implementation

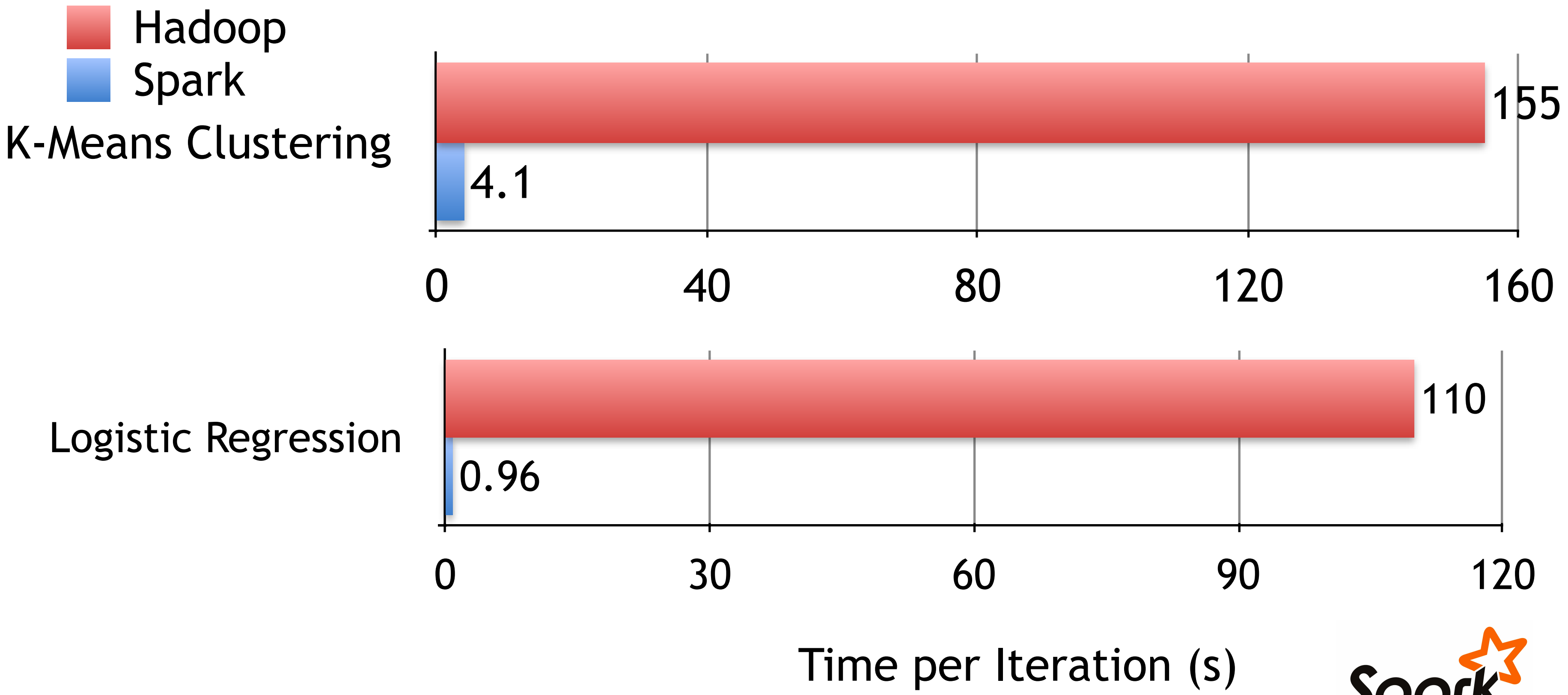
```
val links = // load RDD of (url, neighbors) pairs
var ranks = // load RDD of (url, rank) pairs

for (i <- 1 to ITERATIONS) {
  val contribs = links.join(ranks).flatMap {
    case (url, (links, rank)) =>
      links.map(dest => (dest, rank/links.size))
  }
  ranks = contribs.reduceByKey(_ + _)
                  .mapValues(0.15 + 0.85 * _)
}
ranks.saveAsTextFile(...)
```

PageRank Performance



Other Iterative Algorithms



CONCLUSION

Conclusion

- Spark offers a rich API to make data analytics *fast*: both fast to write and fast to run
- Achieves 100x speedups in real applications
- Growing community with 25+ companies contributing

Get Started

Up and Running in a Few Steps

- Download
- Unzip
- Shell

Project Resources

- Examples on the Project Site
- Examples in the Distribution
- Documentation

http://spark.apache.org