Spark Cluster Overview

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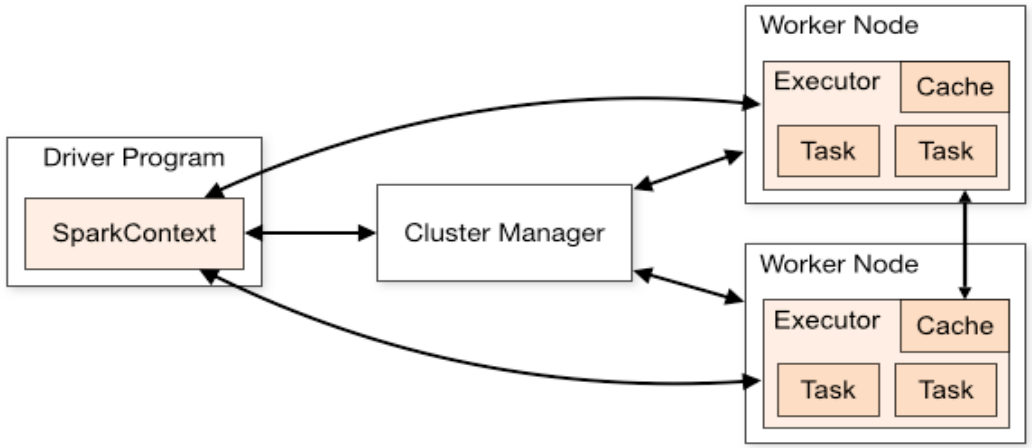
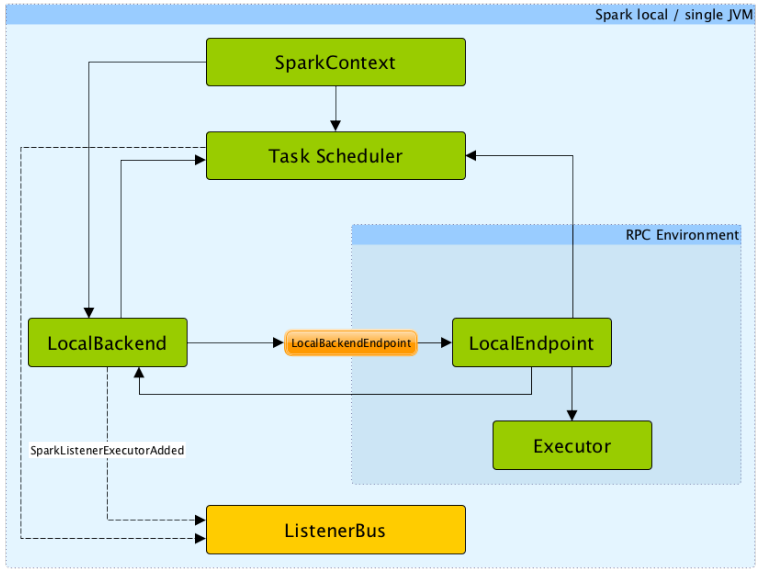
Spark Execution modes

It is possible to run a Spark application using cluster mode, local mode (pseudo-cluster) or with an interactive shell (pyspark or spark-shell).

Cluster mode

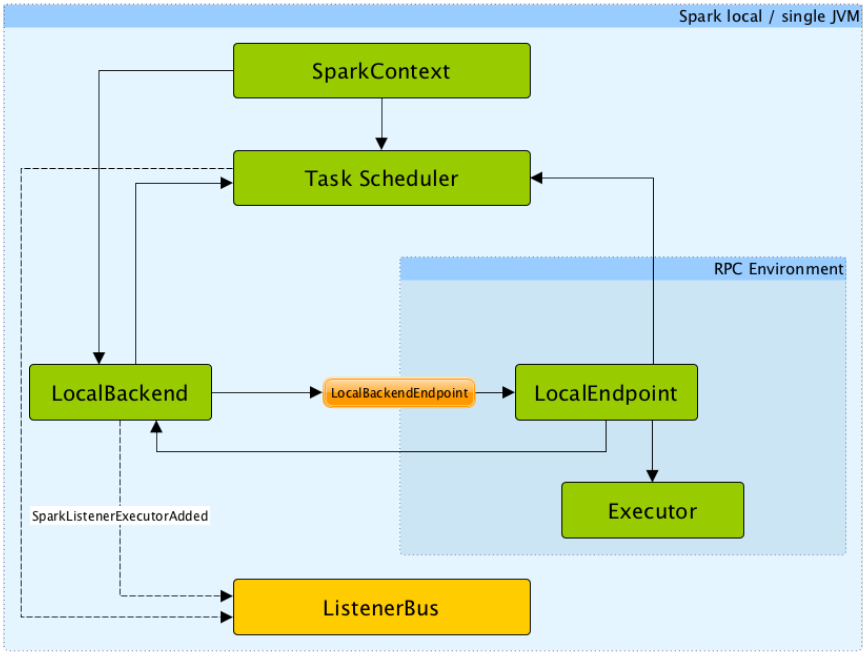


Local mode



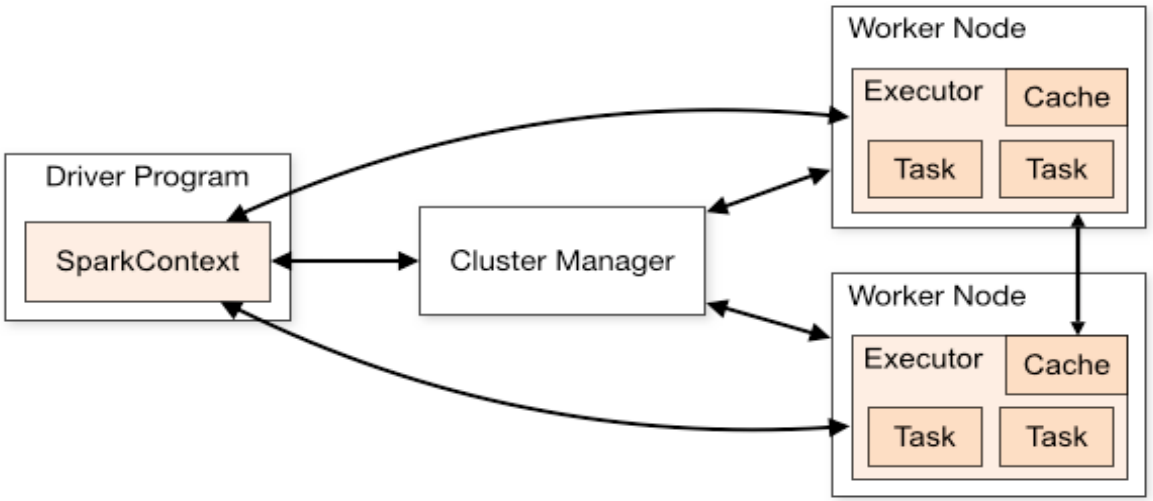
Spark Execution – Local Mode

- In this non-distributed single-JVM deployment mode.
- Spark spawns all the execution components - driver, executor, LocalSchedulerBackend, and master - in the same single JVM.
- The default parallelism is the number of threads as specified in the master URL.



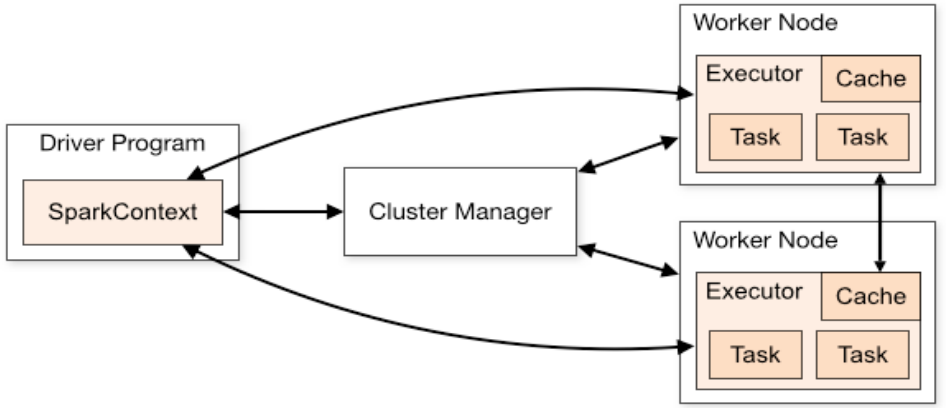
Standalone Deploy Mode

- Simplest way to deploy Spark on a private cluster
  - Apache Mesos
  - Hadoop YARN
  - Kubernetes



- Spark is agnostic to the underlying cluster manager

Spark Execution – Cluster mode

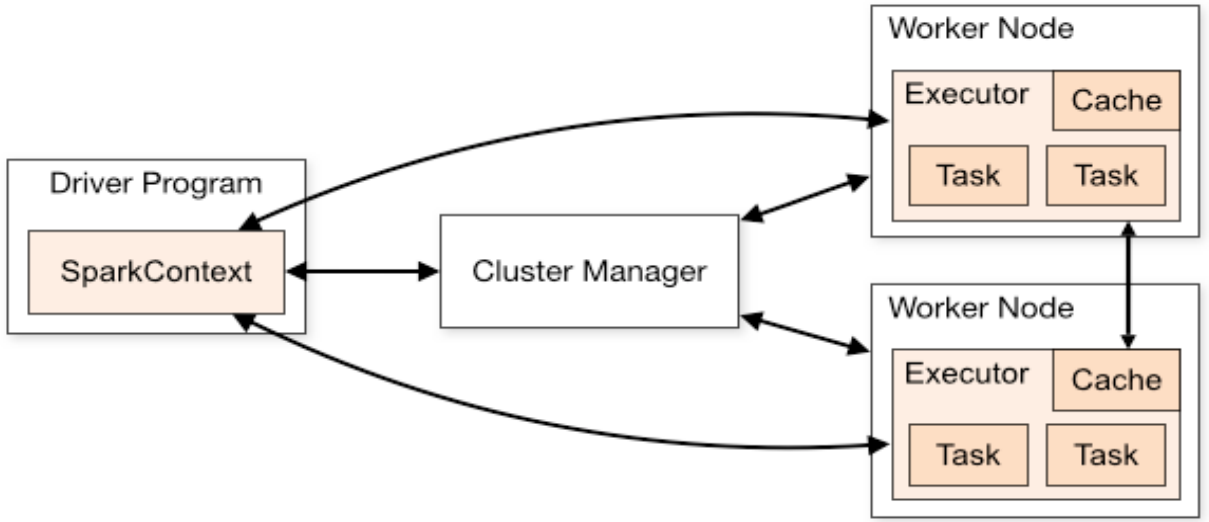


- Spark applications are run as independent sets of processes, coordinated by a SparkContext in a *driver* (*) program.
- The *context* connects to the cluster manager *which allocates resources*.
- Each *worker* in the cluster is managed by an *executor.*
- The *executor* manages computation as well as storage and caching on each machine.

(*) driver → process running the main() function of the application and creating the SparkContext

Spark Execution – Cluster mode

- The application code is sent from the *driver* to the *executors*, and the executors specify the context and the various *tasks* to be run.
- The *driver* program must listen for and accept incoming connections from its executors throughout its lifetime.



Spark App

Each SparkContext creates a Spark application, which includes a lot of scheduling components.

Upon an **Action**, the driver program submits the job to the cluster manager.

Cluster manager

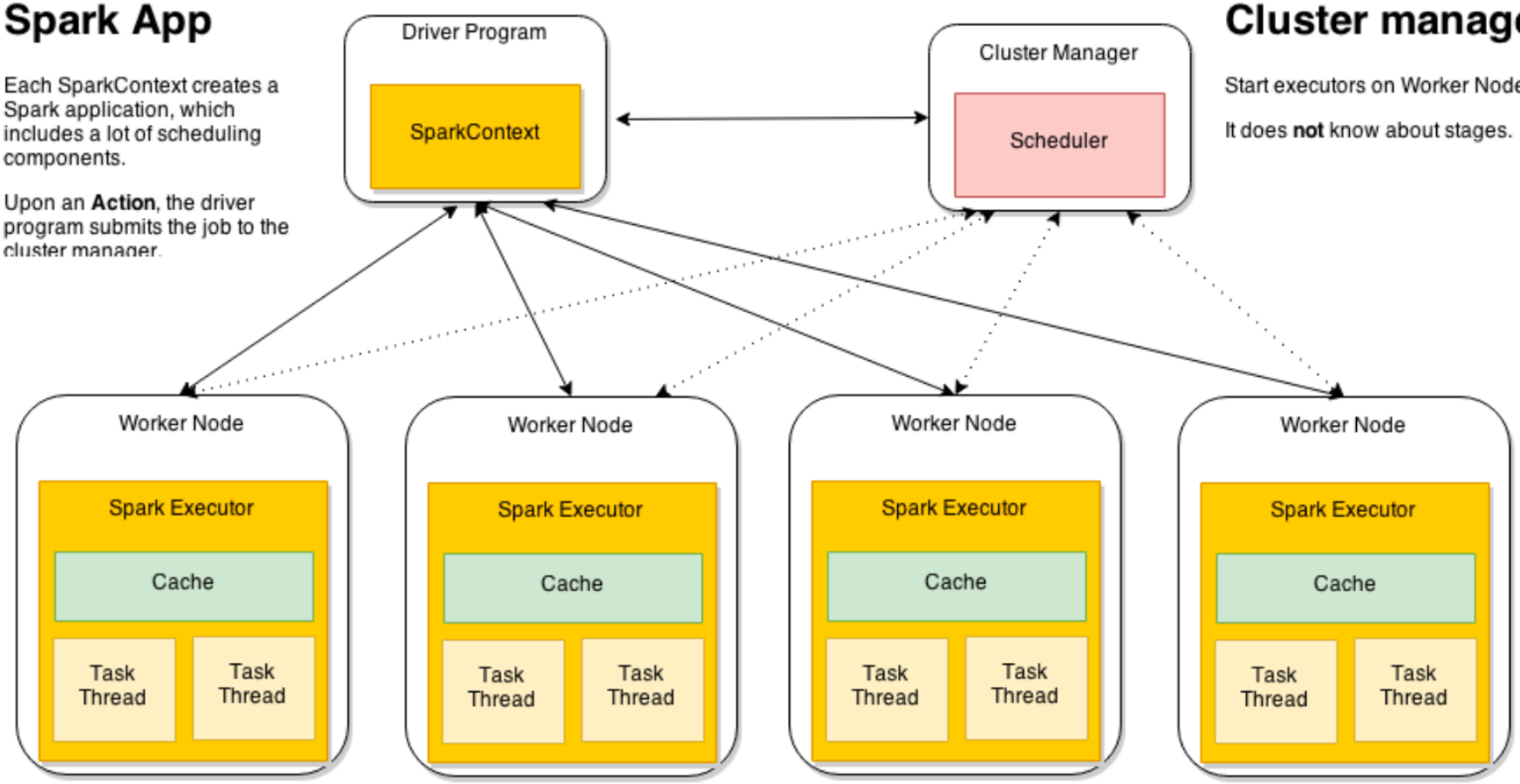
Start executors on Worker Nodes.

It does **not** know about stages.

Worker

Launch Spark Executor in a process.

Tasks are launched in separate threads, one per each core on the worker node (can be configured)

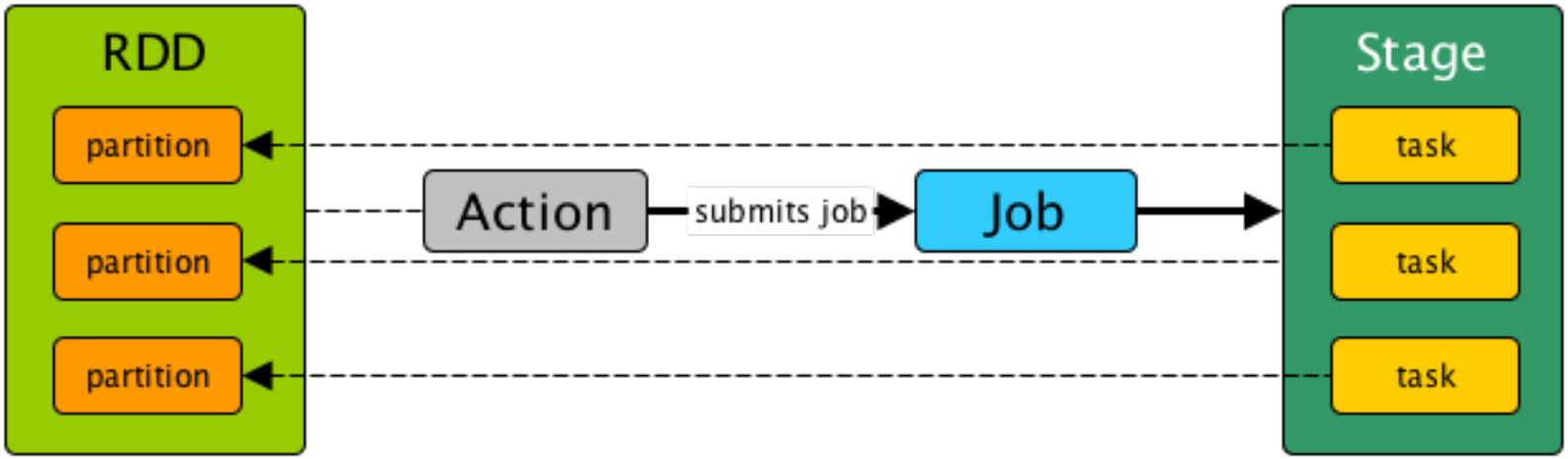


Spark: Standalone cluster – deploy modes

- For standalone clusters supports two deploy modes. They distinguish where the driver process runs:
  - *Client mode* (by default): the driver is launched in the same process as the client that submits the application.
  - *Cluster mode*: the driver is launched from one of the Worker processes inside the cluster.
    - The client process exits as soon as it fulfils its responsibility of submitting the application without waiting for the application to finish.
- Note: Currently, the **standalone mode** does not support **cluster mode** for **Python applications**.

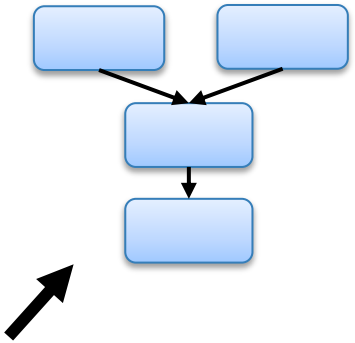
Spark Components

- Task: individual unit of work sent to one executor over a sequences of partitions
- Job : set of tasks executed as a result of an action
- Stage: set of tasks in a job that can be executed in parallel – at partition level
- RDD: Parallel dataset with partitions
- DAG: Logical Graph of RDD operations



Job scheduling

RDD Objects

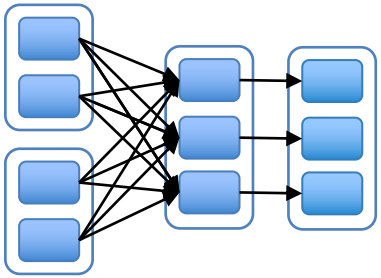


```
rdd1.join(rdd2)
    .groupBy(…)
    .filter(…)
```

build operator DAG

DAGScheduler

DAG

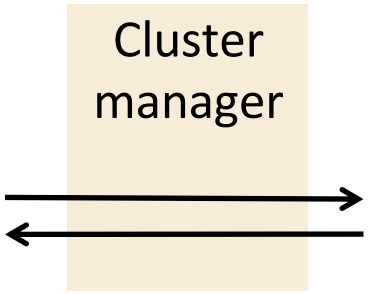


split graph into *stages* of tasks

submit each stage as ready

TaskScheduler

TaskSet

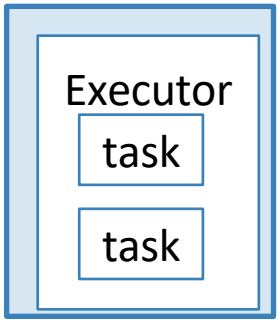


launch tasks via cluster manager

retry failed or straggling tasks

Worker

Tasks



execute tasks

Spark Application – wordcount.py

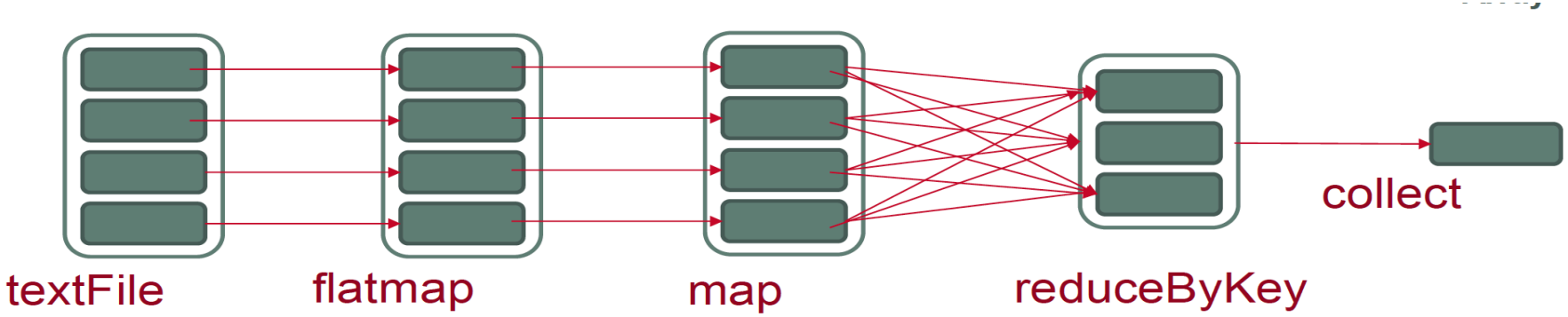
- The application that we are going to create is a simple “wordcount”:
  - Performs a **textFile** operation to read an input file in HDFS
  - **flatMap** operation to split each line into words
  - **map** operation to form (word, 1) pairs
  - **reduceByKey** operation to sum the counts (all the ’1’) for each word

Spark Application – wordcount.py

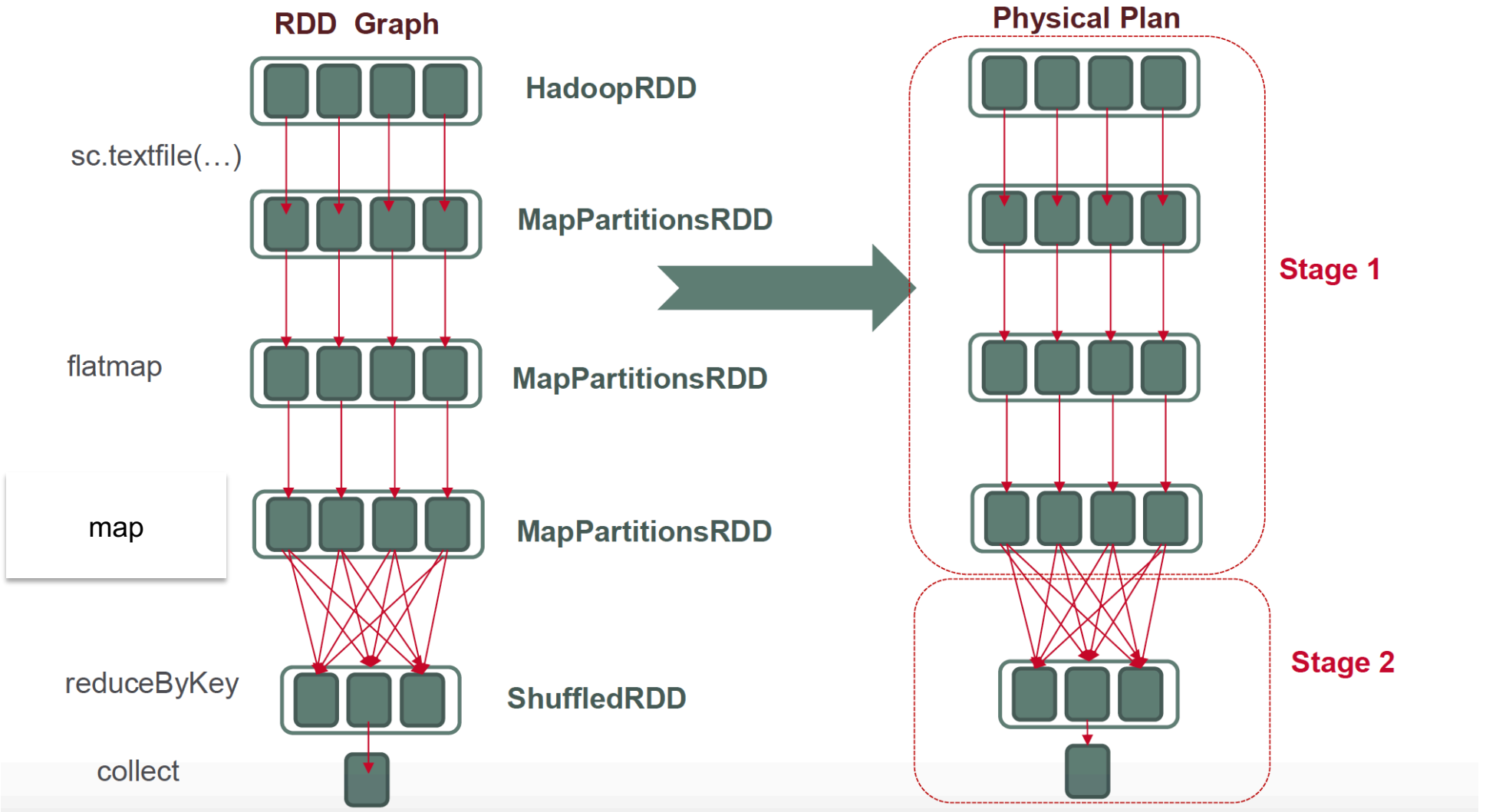
```
import sys
from pyspark import SparkContext, SparkConf


if __name__ == "__main__":
    conf = SparkConf().setAppName("Spark Count")
    sc = SparkContext(conf=conf)
    inputFile = sys.argv[1]
    textFile = sc.textFile(inputFile)
    wordCounts = textFile.flatMap(lambda line: line.split()).\
        map(lambda word: (word, 1)).reduceByKey(lambda a, b: a+b)
    output=wordCounts.collect()
    for (word, count) in output:
        print("%s: %i" % (word, count))
```

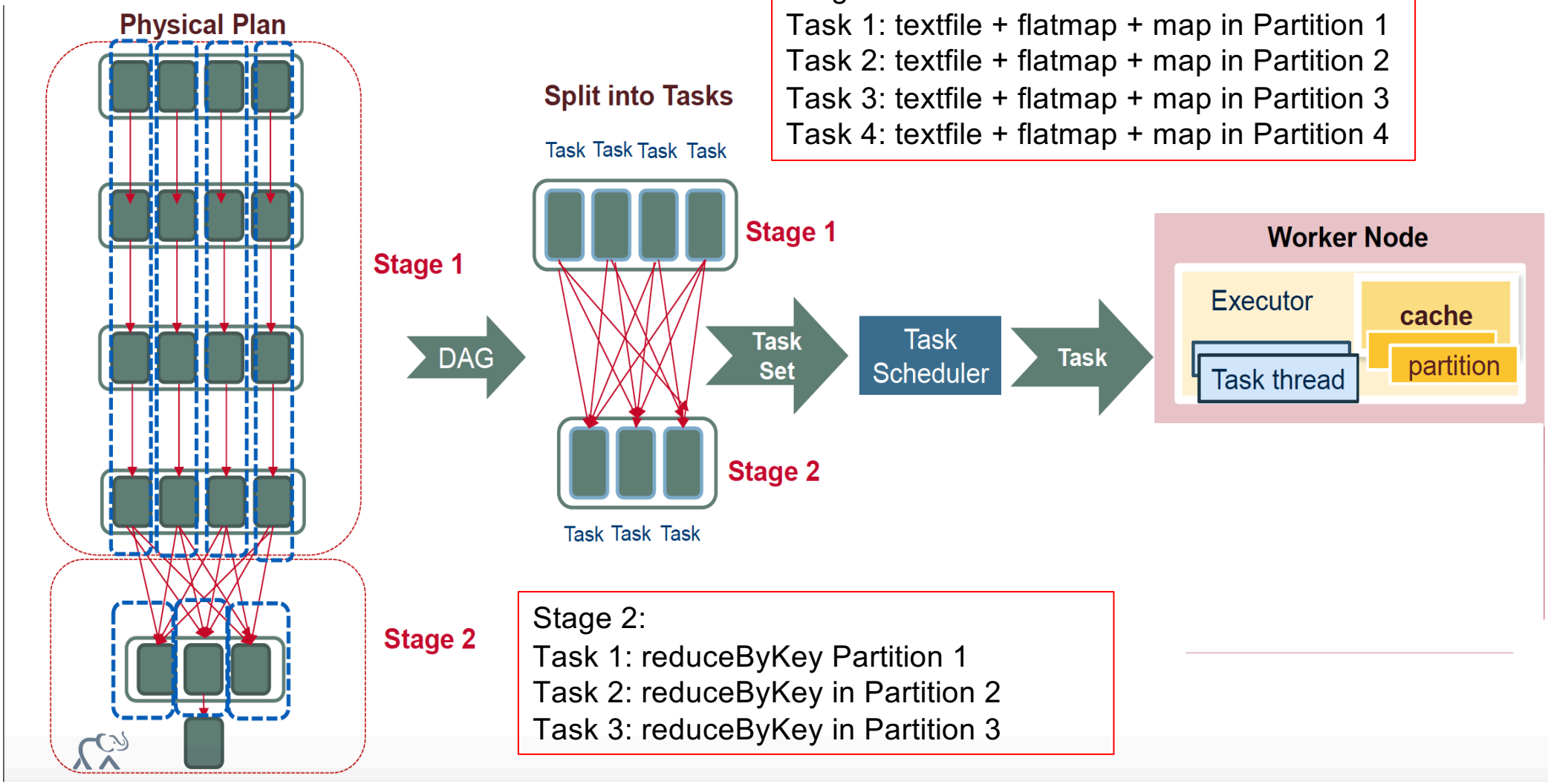
Spark Application – wordcount.py



RDD DAG -> Physical Execution plan



Initial RDD distributed among 4 partitions. Final RDD distributed among 3 partitions



Operations that can run on the same partition are executed in stages

Running Spark Applications

- **Notebooks** are great for:
  - developing and testing quickly experiment with the data
  - demos and collaborating with other people
- **Spark-submit** jobs are more likely to be used in **production**.

Running Spark with Jupyter Notebooks

- We are going to use Jupyter Notebooks for running our walkthroughs & lab exercises.

- First we need to do the following steps:
  - Copying all the necessary material in our accounts in Cirrus
  - Starting an interactive session in a node
  - Starting a spark cluster (standalone) in that node
  - Starting a Jupyter session connected with pyspark

- All the information can be found in “Get_Started_Notebooks_Cirrus”:
  https://github.com/EPCCed/prace-spark-for-data-scientists/blob/master/Get_Started_Notebooks_Cirrus.pdf

Submit job via spark-submit

spark-submit Syntax

```
spark-submit --option value \
  application jar | python file [application arguments]
```

Check the guide - Submitting Spark Applications:

https://github.com/EPCCed/prace-spark-for-data-scientists/blob/master/Spark_Applications/Submitting_Spark_Applications.pdf

Submit job via spark-submit

```
 $SPARK_HOME/bin/spark-submit \
--class <main-class> \
--master <master-url> \
--deploy-mode <deploy-mode>  \
--conf \
….
<application-jar> [arguments] |
<python file >[arguments]
```

Some spark-submit options

- master – Determines how to run the job:
  - spark://r1i2n5:7077
  - local
- driver-memory
  - amount memory available for the driver process.
- executor-memory
  - amount of memory allocated to the executor process
- executor-cores
  - total number of cores allocated to the executor process
- total-executor-cores
  - Total number of cores available for all executors.

See: https://spark.apache.org/docs/latest/submitting-applications.html

Cirrus

- High-performance computing cluster
- One of the EPSRC Tier-2 National HPC Services.
- 280 nodes: 36 Intel Xeon CPUs, hyper threading, 256GB
  - Each node has (virtually) 72 cores
- 406 TB of storage – Lustre file system
- Link: http://www.cirrus.ac.uk/

https://cirrus.readthedocs.io/en/latest/user-guide/connecting.html

Cirrus

- Connecting to Cirrus

  `ssh [userID]@login.cirrus.ac.uk`

- Two types of nodes:
  - Login – access to outside network
  - Computing – only network between nodes (no access to outside world)

- For cloning the repository -> use the login node

- https://cirrus.readthedocs.io/en/latest/user-guide/connecting.html

Running jobs on Cirrus

- PBSPro to schedule jobs
  - Submission script to submit a job a queue
  - Interactive jobs are also available
    - To submit a request for an interactive job reserving 1 nodes (72 physical cores) for 1 hour you would issue the following qsub command from the command line

```
qsub -IVl select=3:ncpus=36,walltime=01:00:00,place=scatter:excl -A y15 -
q <reservation number> -j oe
```

- Your session will end:
  - It hits the requested walltime
  - Typing exit command within the session
- https://cirrus.readthedocs.io/en/latest/user-guide/batch.html#interactive-jobs

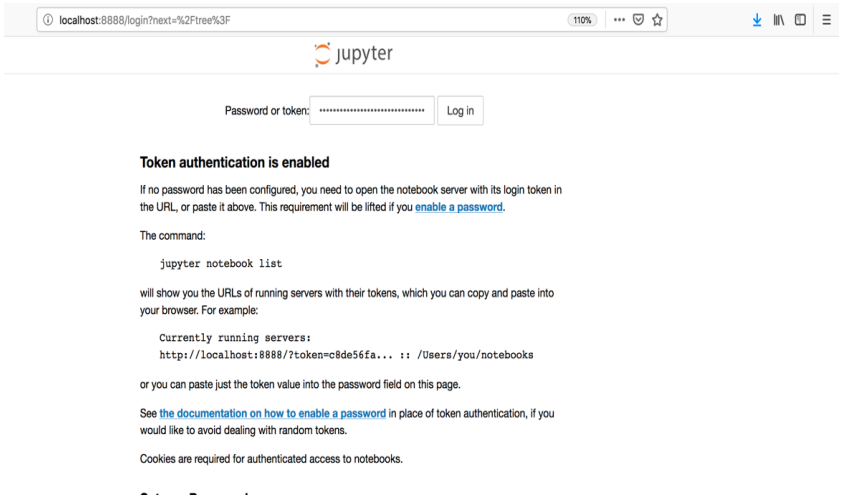
Jupyter notebooks

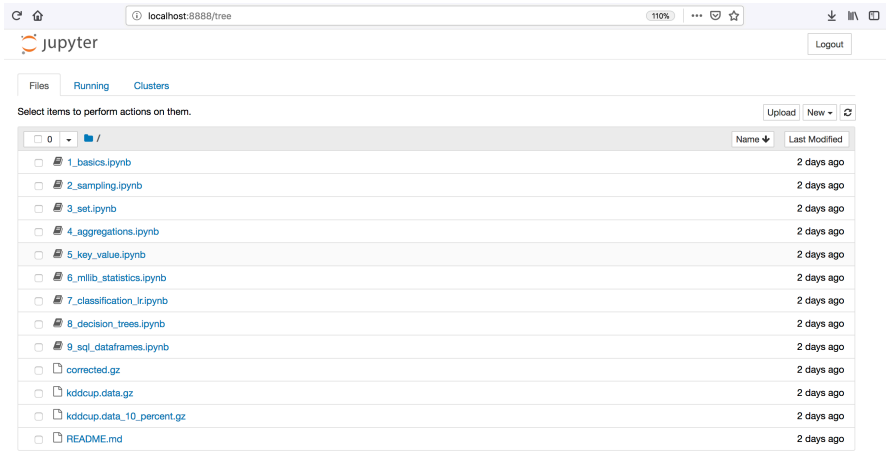
- Start the jupyter server:
  - ./start_Jupyter_local.sh will give you a token, like this one:

    http://0.0.0.0:8888/?token=2d5e554b2397355c334b8c3367503b06c4f6f95a26151795

- Open another terminal and type the following command

  ssh USER@login.cirrus.ac.uk -L8888:MASTER NODE:8888
- Got to a Web browser at http://localhost:8888





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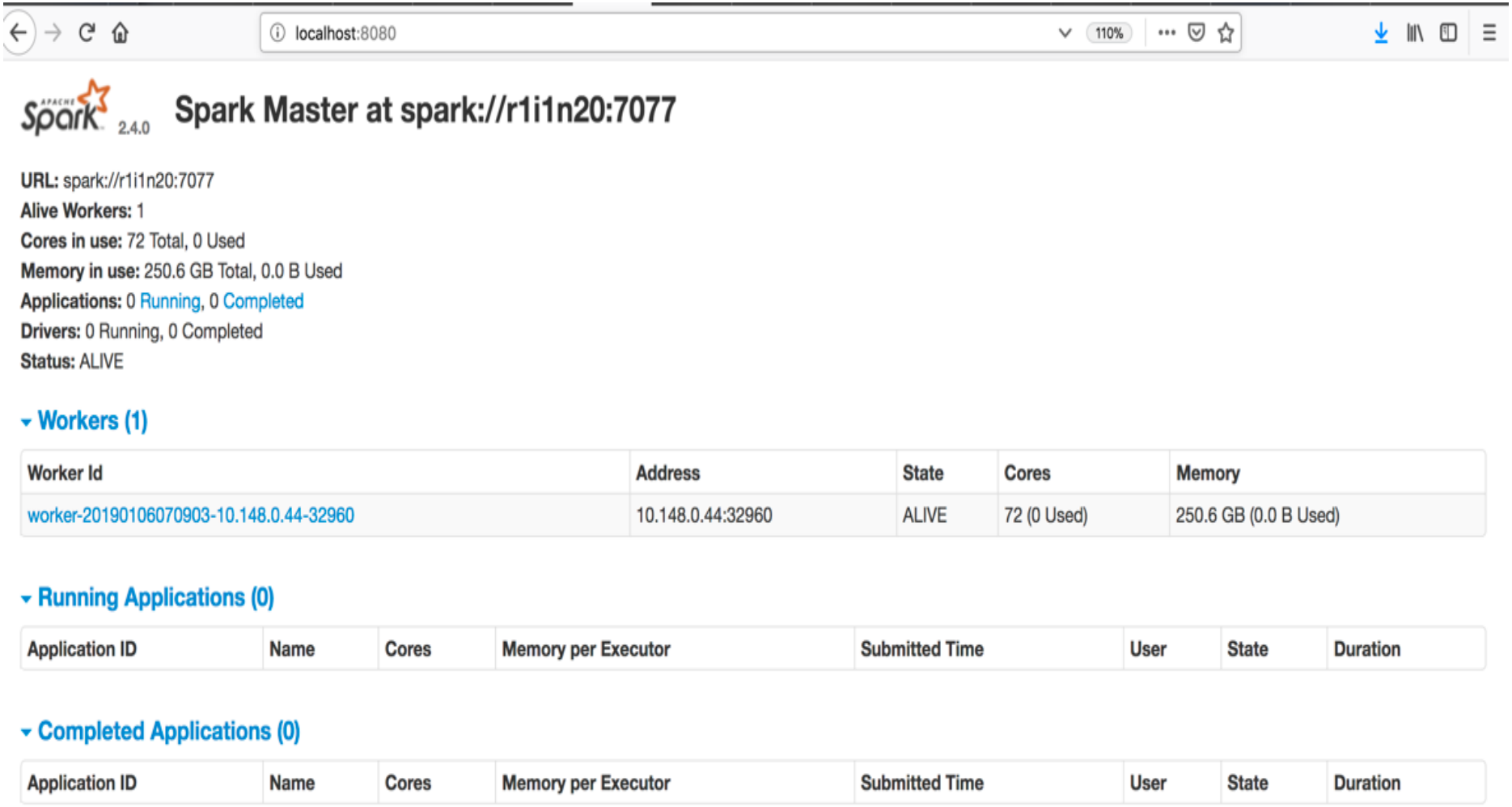
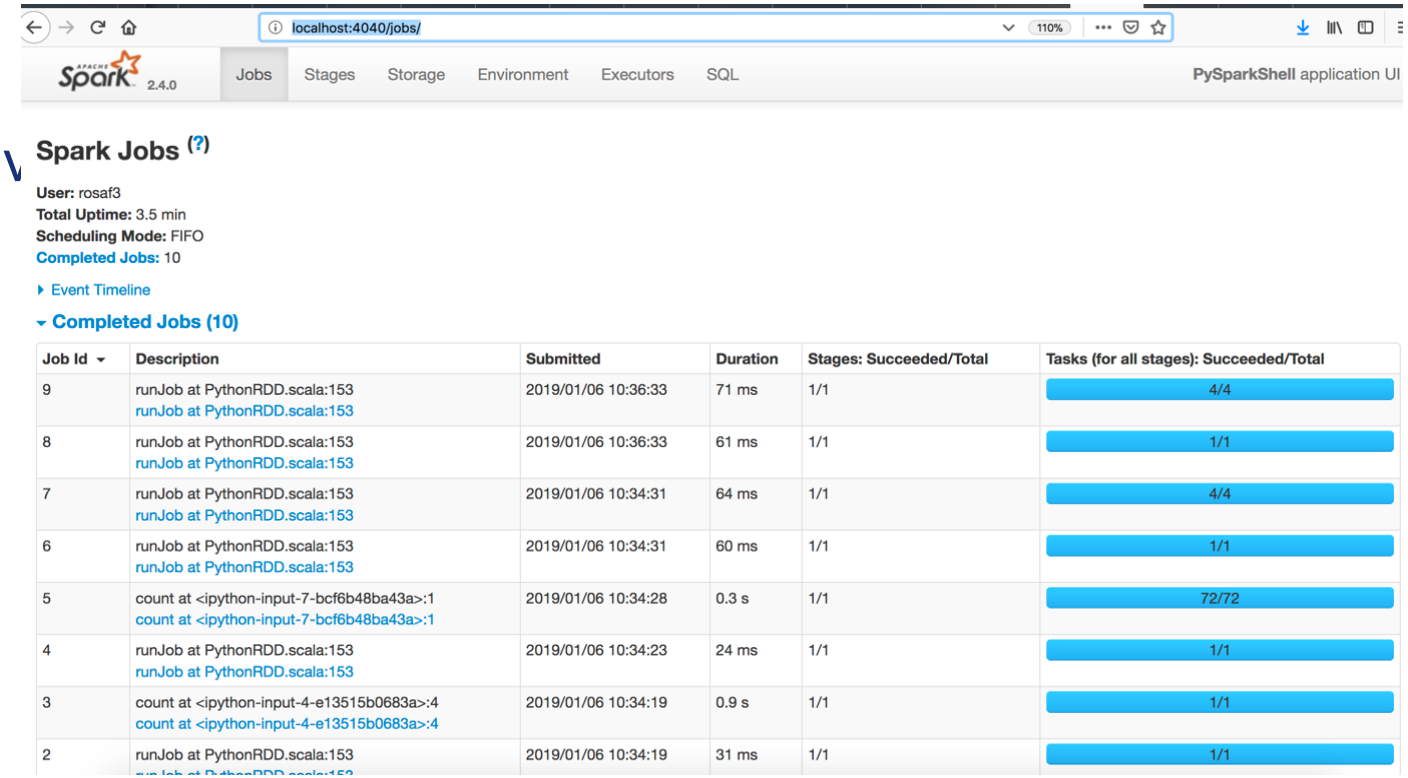
Master Spark UI



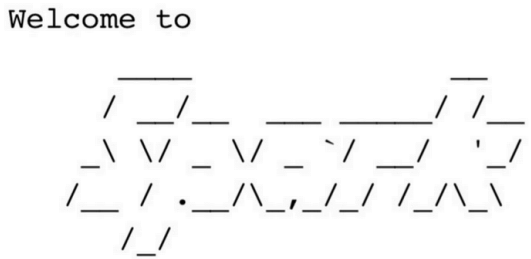
Driv



Every SparkContext launches a web UI (Spark driver's web UI),
by default on port 4040, that displays useful information about the application.

ssh USER@login.cirrus.ac.uk -L4040:DRIVER NODE:4040
web browser → localhost:4040

Running notebooks in your laptop



- **Prerequisites: Anaconda, Python3**
- Get Spark from the downloads page of the project websi
  (https://blog.sicara.com/get-started-pyspark-jupyter-guide-tutorial-ae2fe84f594f)
- Check if pyspark is properly install → type `pyspark` in a terminal

```
>> git clone https://github.com/EPCCed/prace-spark-for-data-scientists.git
>> cd walkthrough_examples
>> export SPARK_HOME=[INSTALLATION_PATH]/spark-2.4.0-bin-hadoop2.7/
>> PYSPARK_DRIVER_PYTHON=jupyter PYSPARK_DRIVER_PYTHON_OPTS='notebook' \
$SPARK_HOME/bin/pyspark
```

THANK YOU FOR YOUR ATTENTION

www.prace-ri.eu