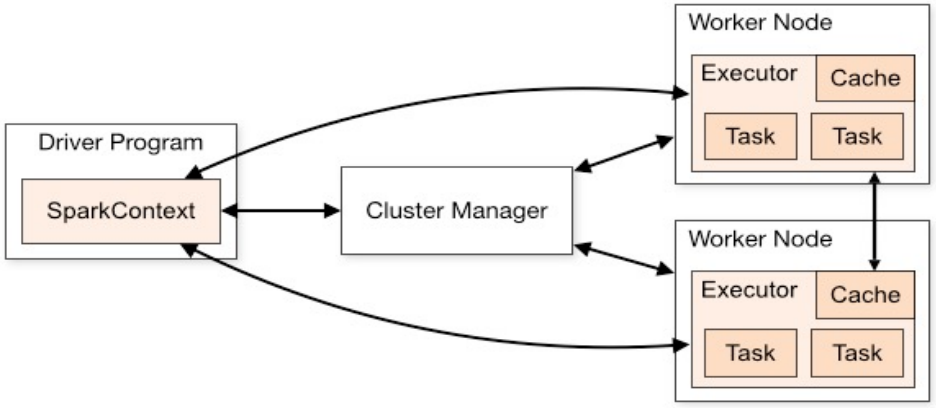
SPARK CLUSTER OVERVIEW

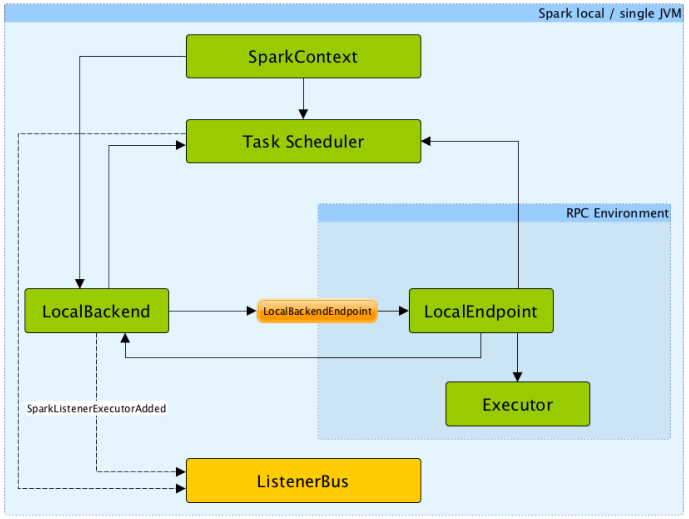
Spark Execution modes

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

Cluster mode

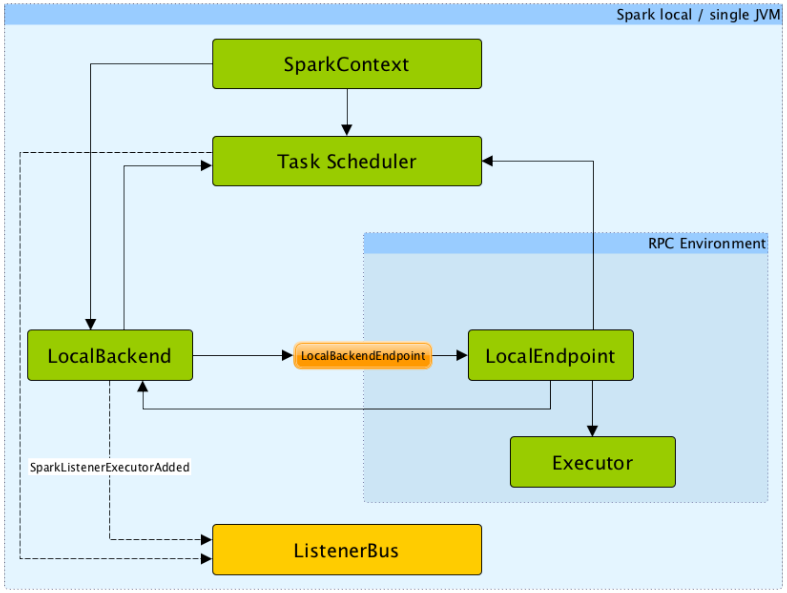


Local mode



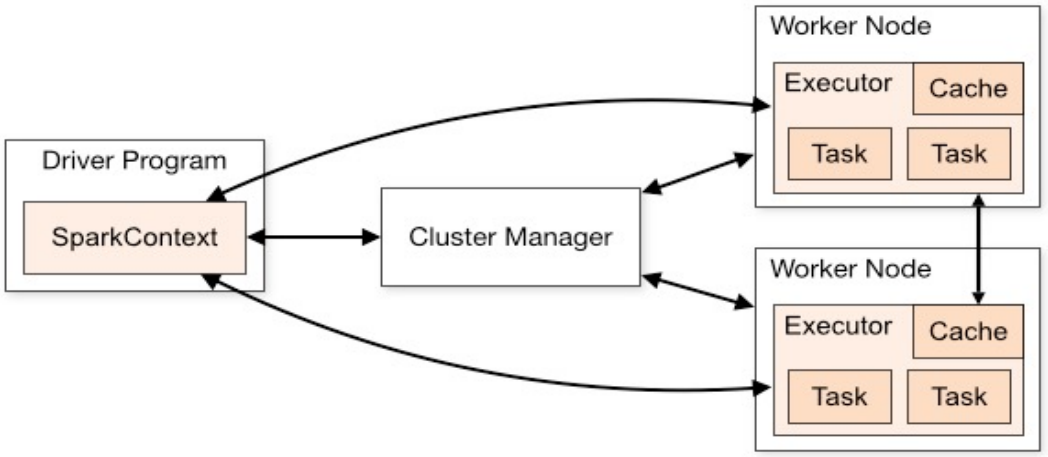
Spark Execution – Local mode

- 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.



Spark Execution – Cluster mode

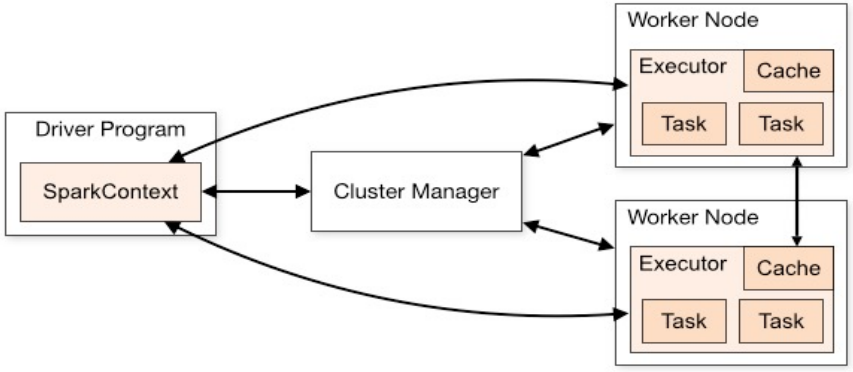
- **Spark Driver**:
  - Separate process to execute user applications
  - Creates SparkContext to schedule jobs execution and negotiate with cluster manager



- **Executors**:
  - Executors run tasks scheduled by the driver
  - Store computation results in memory, on disk or off-heap
  - Interact with storage systems
  - Executors manage computation as well as storage and caching

Spark Execution – Cluster mode

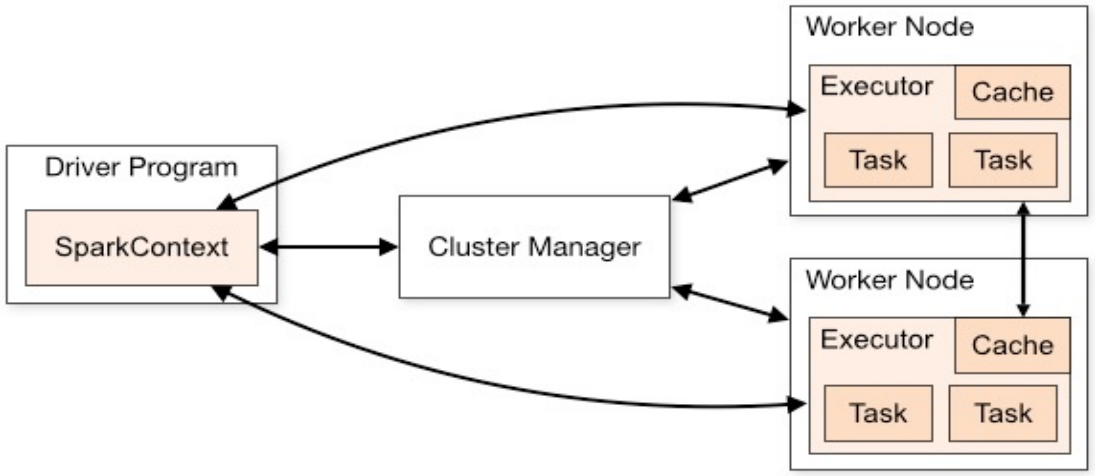
- **Spark Cluster**:
  - Mesos
  - YARN
  - Kubernetes
  - Spark Standalone –simplest way to deploy Spark on a private cluster



Spark is agnostic to the underlying cluster manager

Spark Execution – Cluster Mode

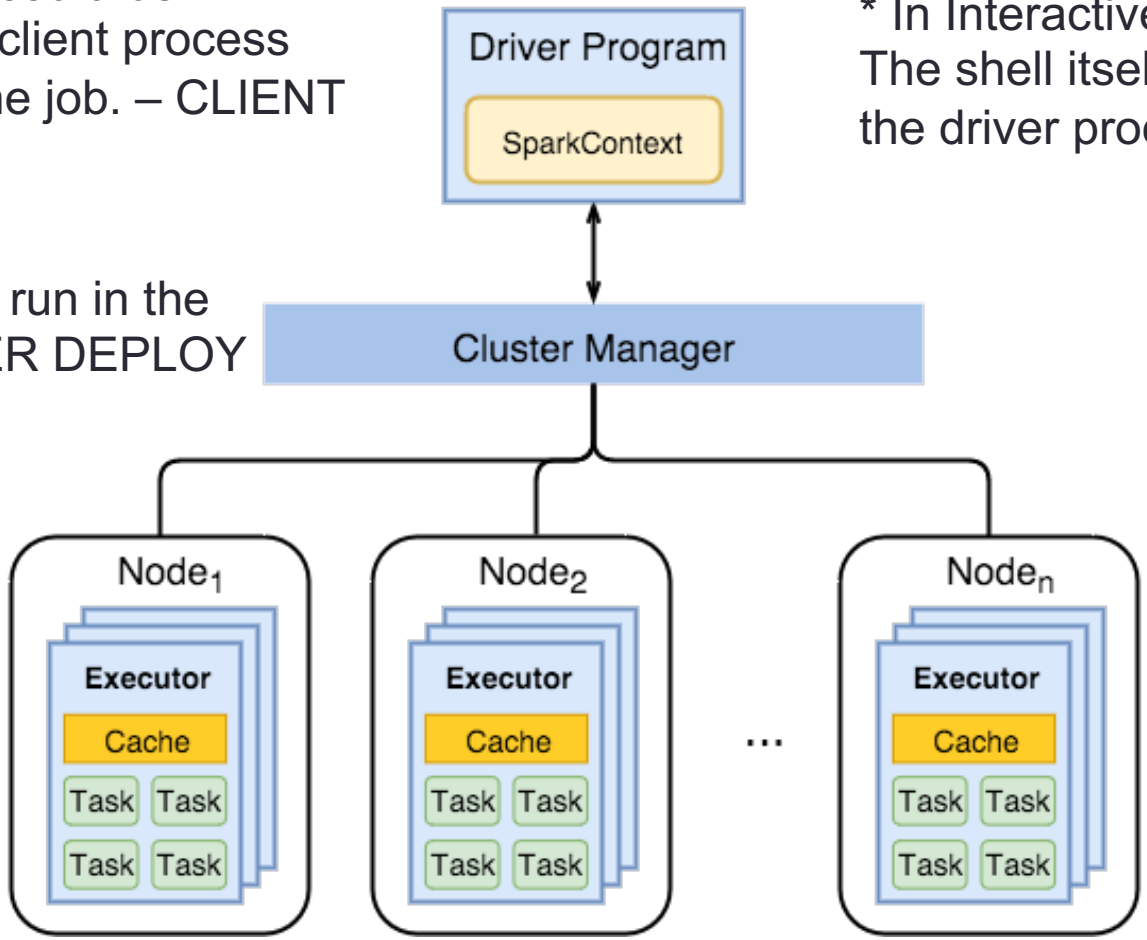
- The application code is sent from the *driver* to the *executors*, and the executors specify the context and the various *tasks* to be run.
- The *driver* program must listen for and accept incoming connections from its executors throughout its lifetime.



Spark Execution -- Cluster Mode

* Driver process could be the same as the client process used to initiate the job. – CLIENT DEPLOY MODE

* Driver process run in the luster - CLUSTER DEPLOY MODE



* In Interactive Mode, The shell itself is the driver process

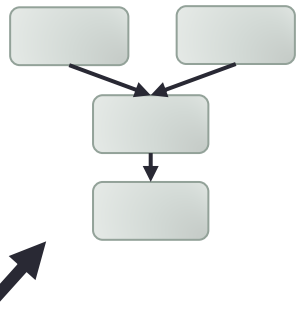
Job scheduling

RDD Objects

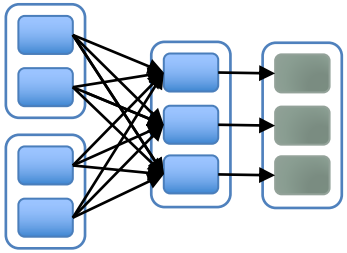
DAGScheduler

TaskScheduler

Worker

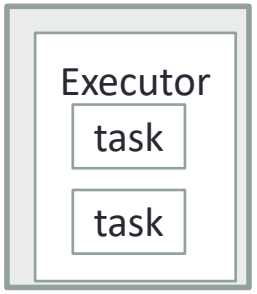


DAG



TaskSet

Tasks




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

build operator DAG

split graph into *stages* of tasks

submit each stage as ready

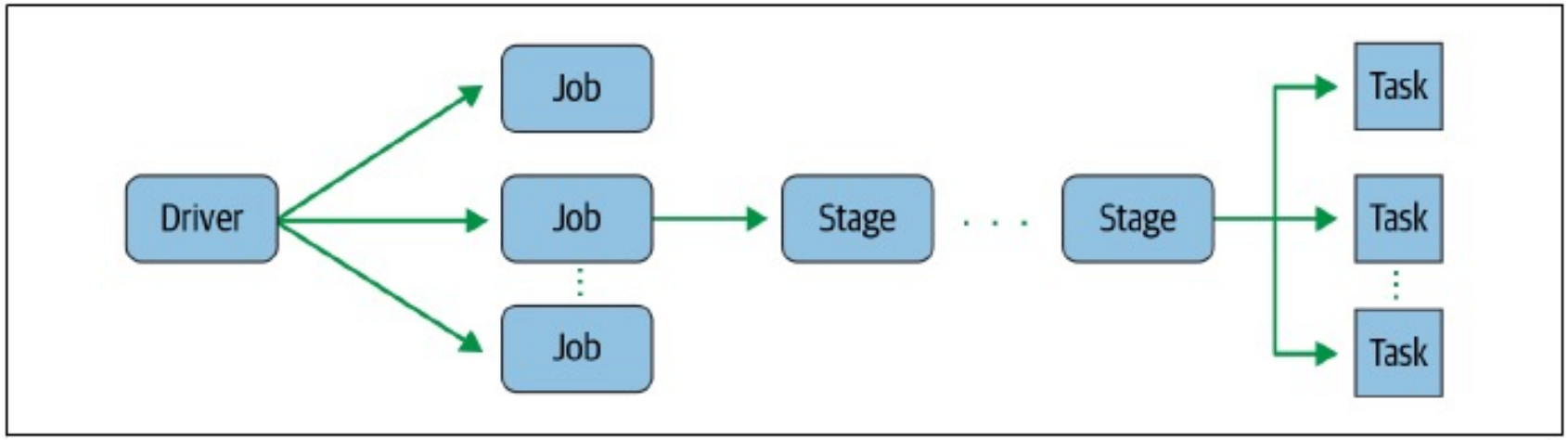
launch tasks via cluster manager

retry failed or straggling tasks

execute tasks

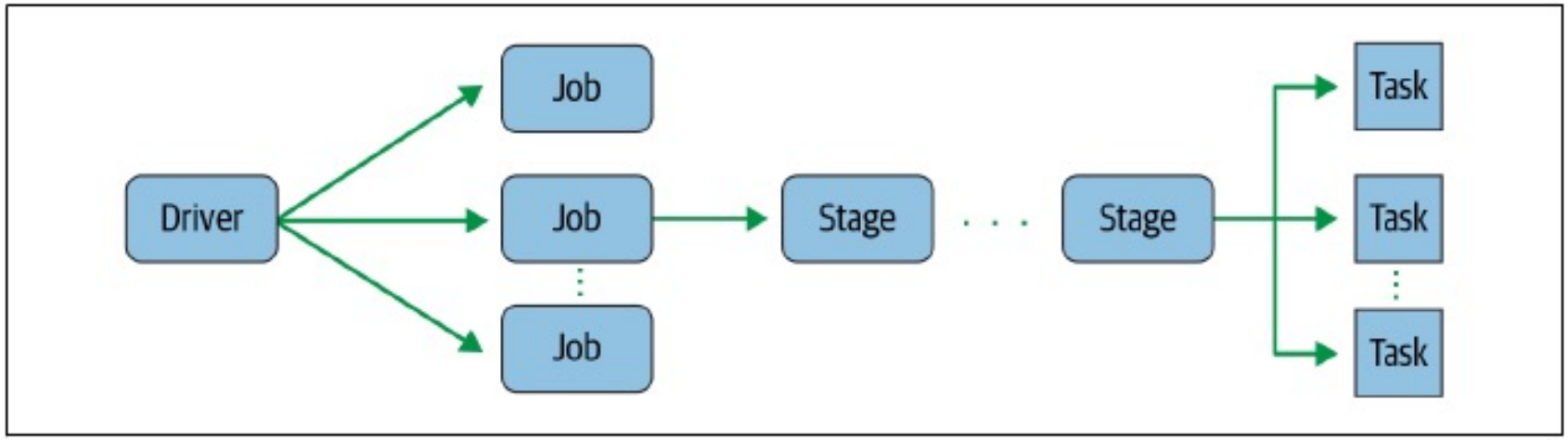
Spark Components

- Job: is work submitted to Spark**.** We have 1 job per action. Jobs are divided into **stages**
- Stage: is a sequence of **Tasks** that can all be run together, **in parallel**, without a shuffle
- Task: single unit of work that will be sent to a spark executor. A task compromise a series of instructions (.map, .filter) applied to a single partition. Every task in the stage executes the same set of instructions
- RDD: Parallel dataset with partitions



Spark Components

- A Spark application can have many jobs.
- A job can have many stages.
- A stage can have many tasks.
- A task executes a series of instructions



Partition

- **Partition** is a logical chunk of your RDD/Dataset.
- RDD is split into **Partitions** so that each **Executor core** can operate on a single part, enabling parallelization.
- A partition can be processed by a single **Executor core**.
- Example: If you have 4 partitions and you have 4 executor cores, you can process the tasks of a **Stage** in parallel, in a single pass.

Spark Application – wordcount.py

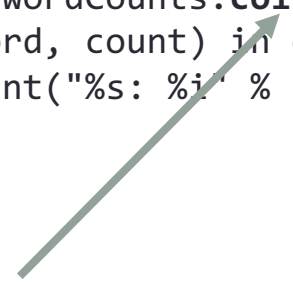
The application that we are going to create is a simple “wordcount”:

- Performs a ***textFile*** operation to read an input file
- ***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))
```



action

How many actions?

1 action → 1 Job

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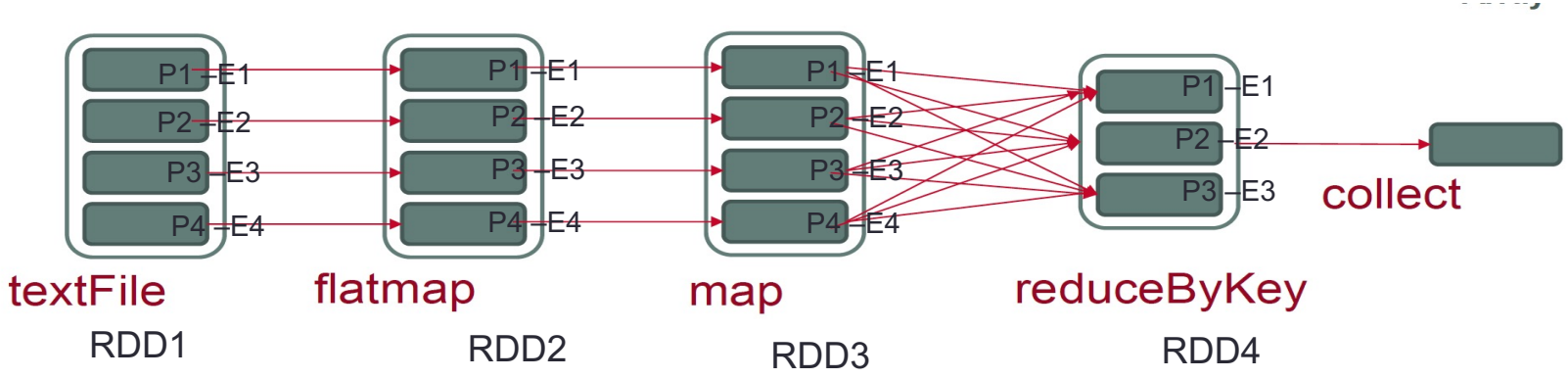
1 JOB



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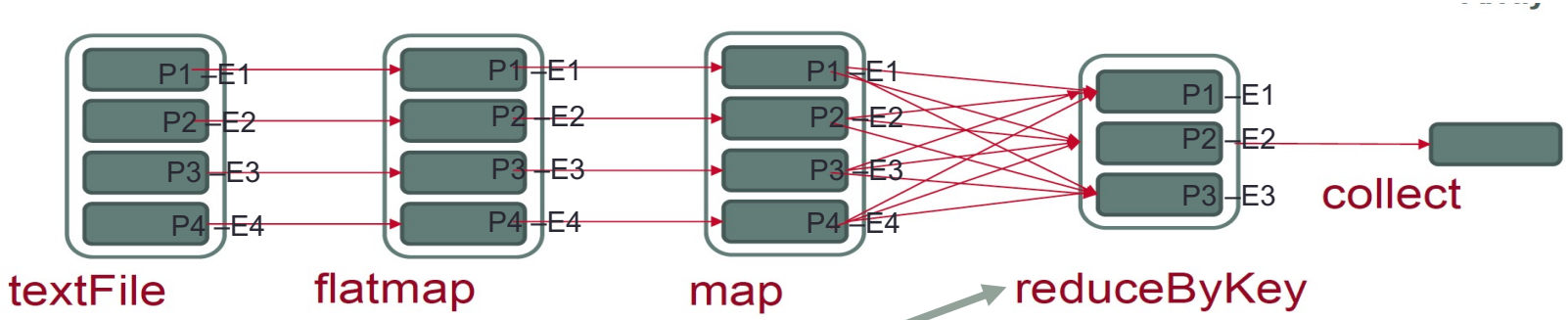


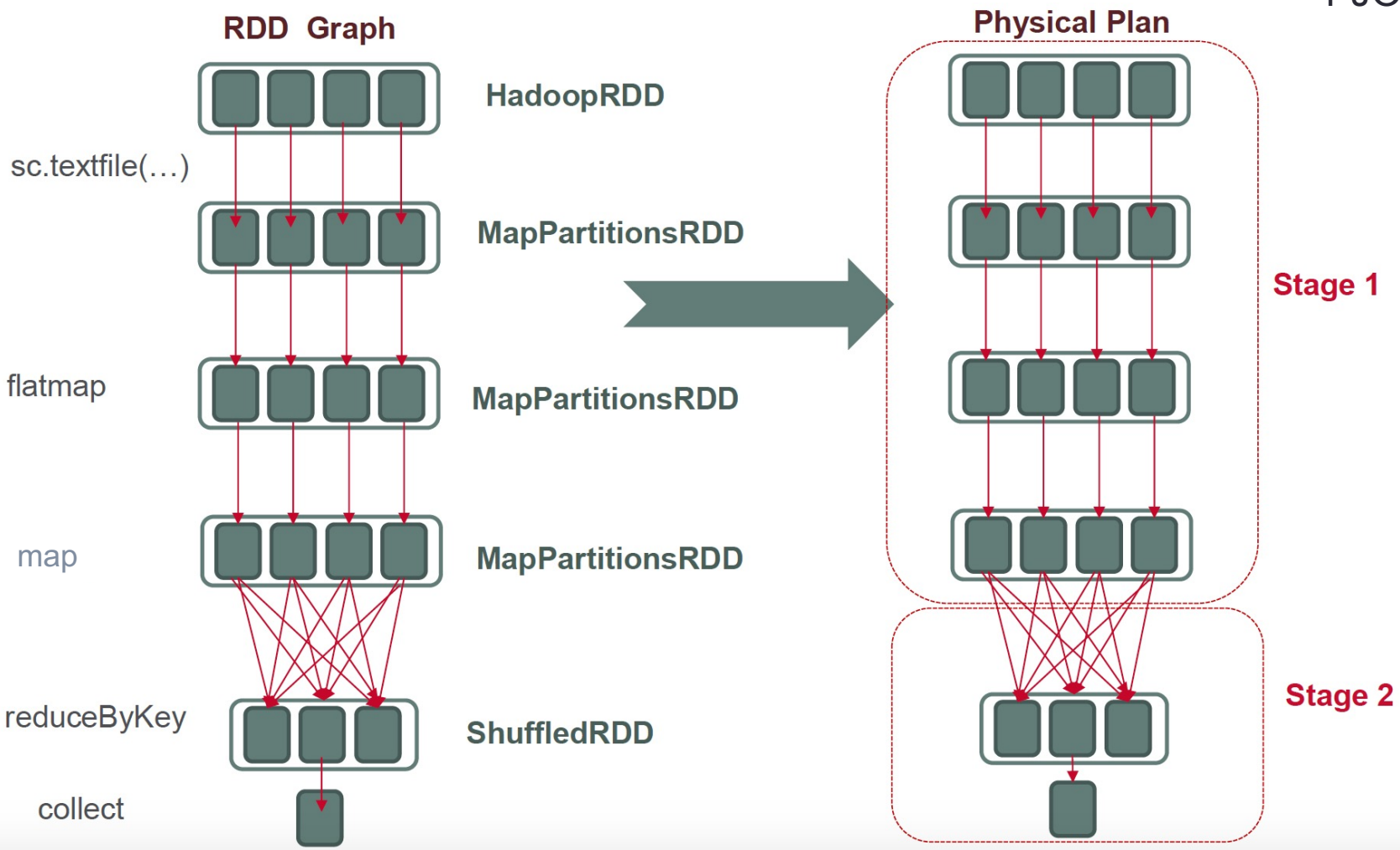
How many shuffles?

shuffle

1 shuffle → 2 stages

RDD DAG -> Physical Execution plan

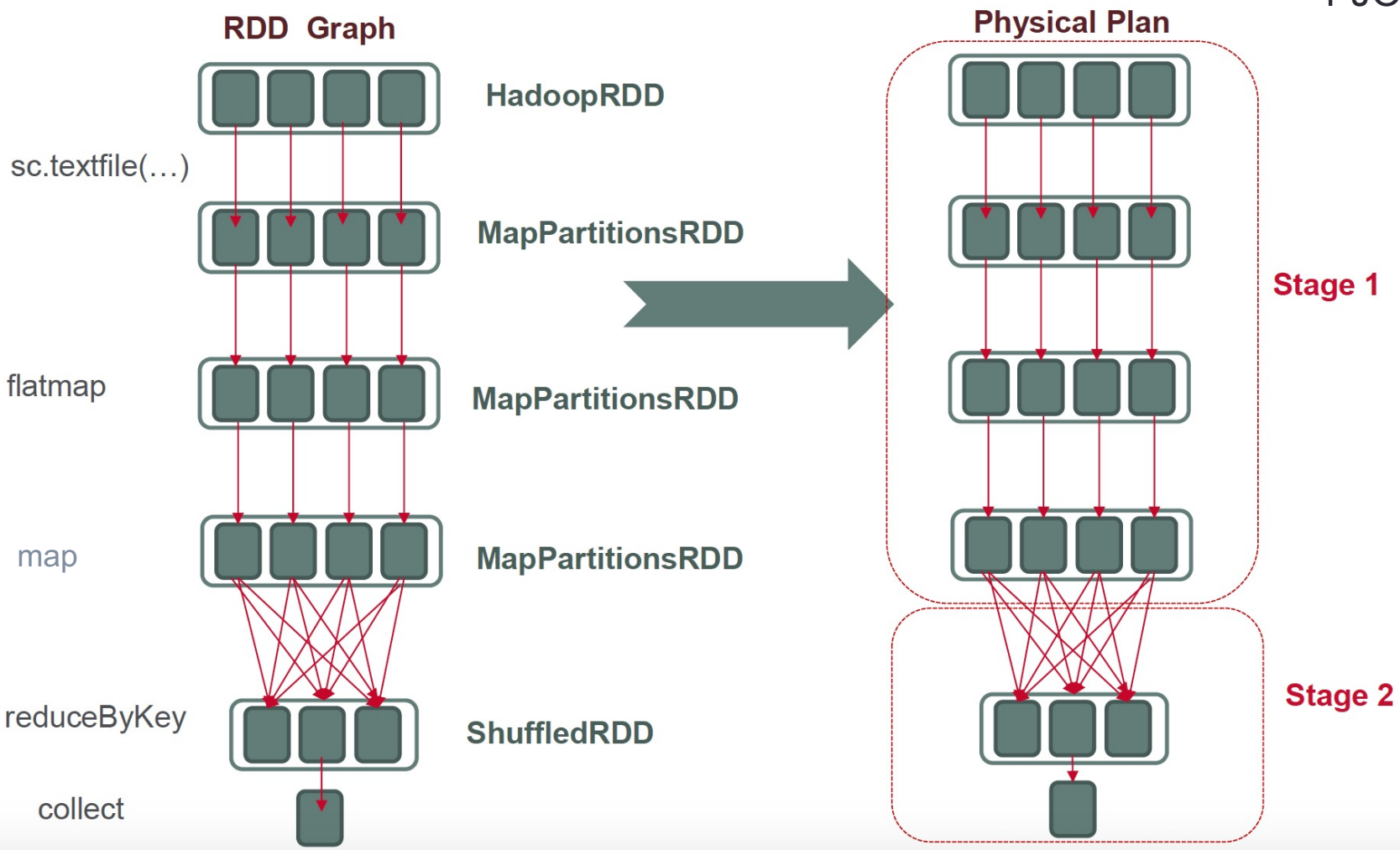
1 JOB



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

RDD DAG -> Physical Execution plan

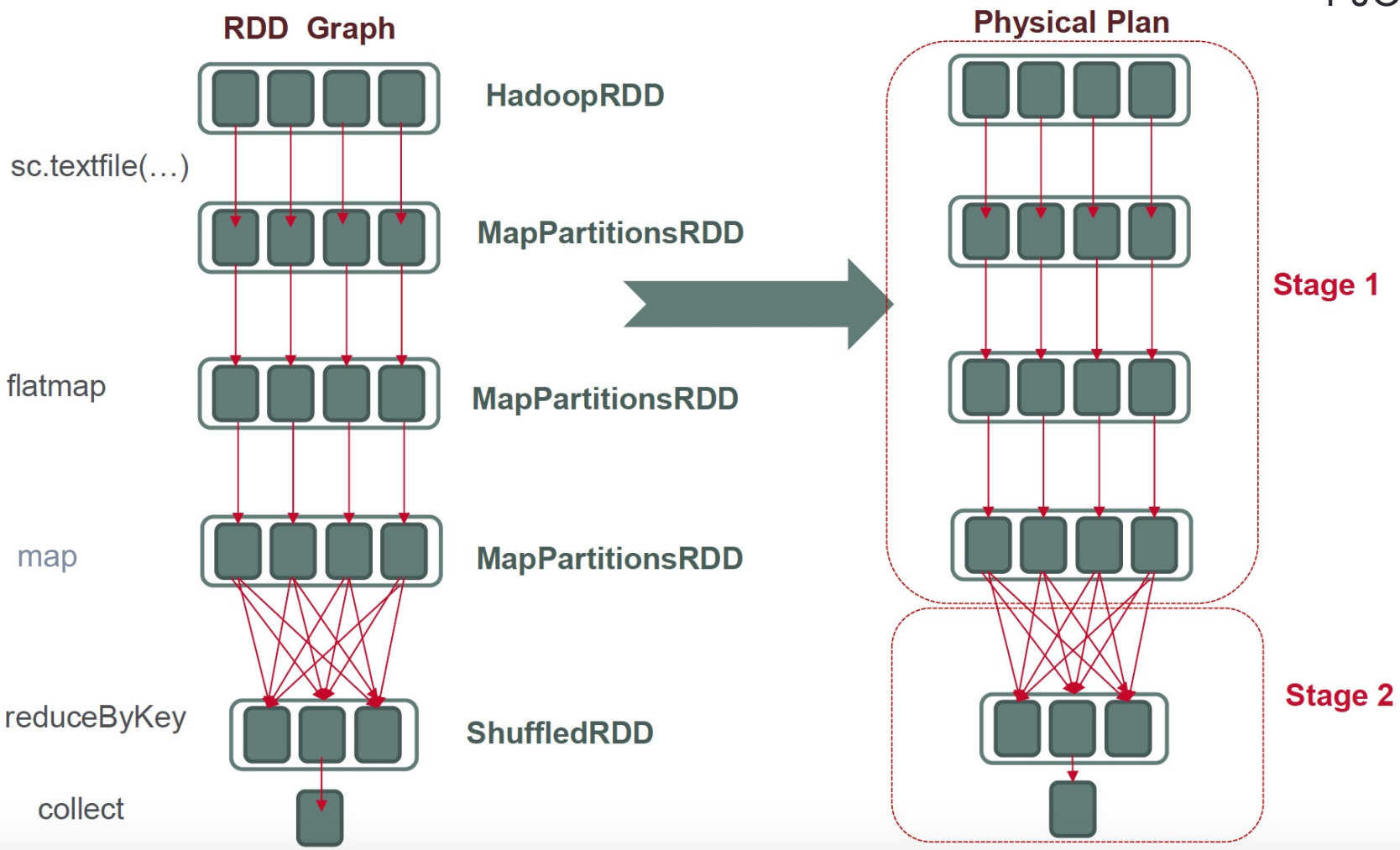
1 JOB



How many partitions in Stage 1 ? 4 Partitions 4 tasks

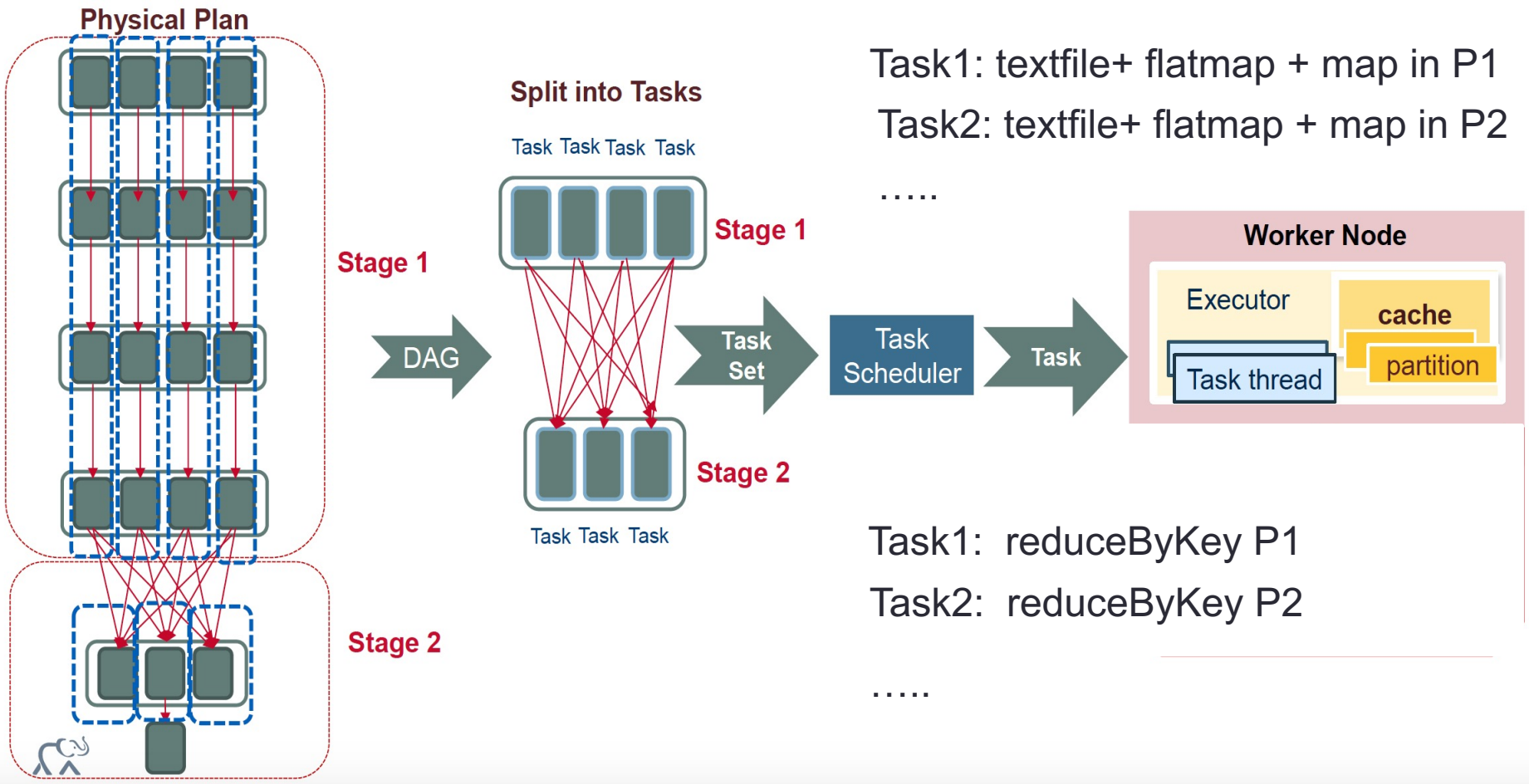
RDD DAG -> Physical Execution plan

1 JOB



How many partitions in Stage 2 ? 3 Partitions 3 tasks

Execution plan -> Stages and Tasks

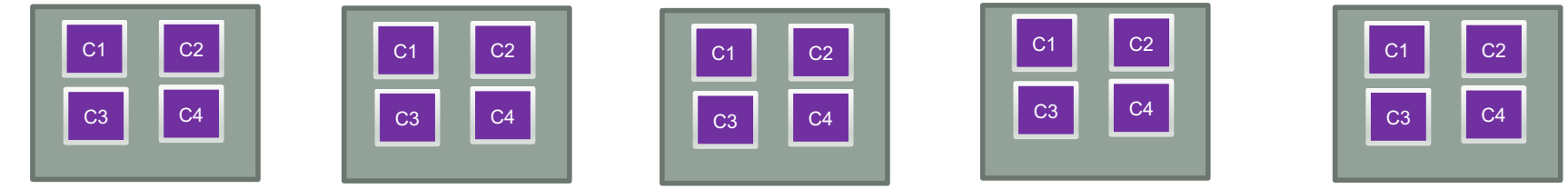


Each **Task** is executed as a single thread in an **Executor**!

Spark executors, tasks and partitions

- The number of tasks is given by the number of partitions of an RDD/DataFrame
- The number of tasks which an executor can process in parallel is given by its number of cores.
- How many task can be executed in parallel given the following example ?:

  1000 partitions and 5 executors which 4 cores each



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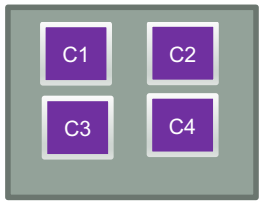
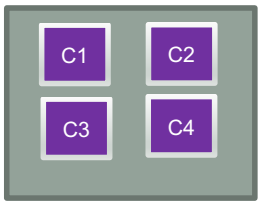
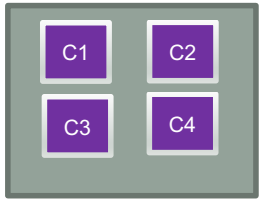


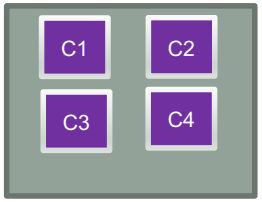
Executor 1
- 200 partitions per Ex.
- 50 partitions per Core



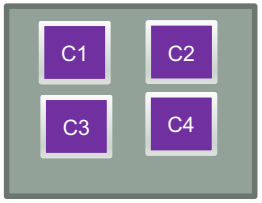
Executor 2
- 200 partitions per Ex.
- 50 partitions per Core



Executor 3
- 200 partitions per Ex.
- 50 partitions per Core



Executor 4
- 200 partitions per Ex.
- 50 partitions per Core



Executor 5
- 200 partitions per Ex.
- 50 partitions per Core

1 Executor can run 4 tasks in parallel == Num of cores.
4 task per executor x 5 executors = 20 Tasks in parallel.

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**.

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/rosafilgueira/Seminar_MUIA/blob/main/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.

Note: 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
- 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 to outside world).

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

Running jobs in 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=05:00:00,place=scatter:excl -A y15 -q
$1-j oe
```

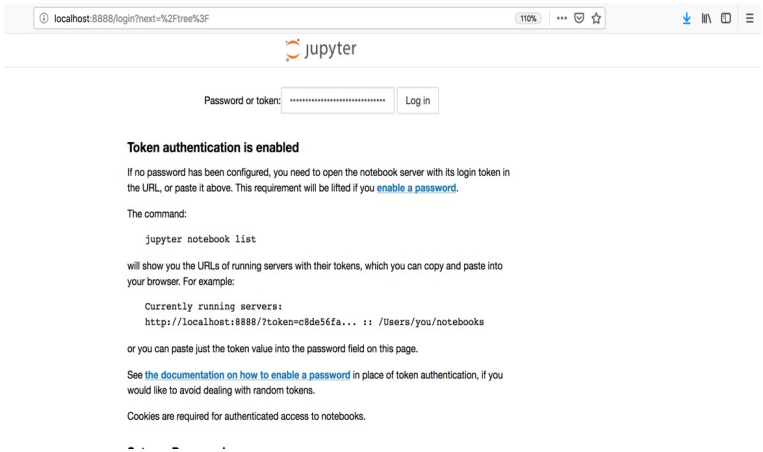
  - Your session will end:
    - It hits the requested **walltime**
    - Typing **exit command** within the session

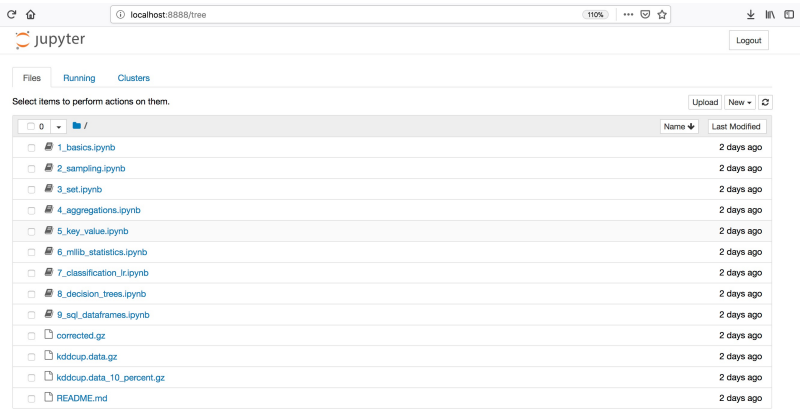
https://cirrus.readthedocs.io/en/latest/user-guide/batch.html#interactive-jobs

Jupyter notebooks

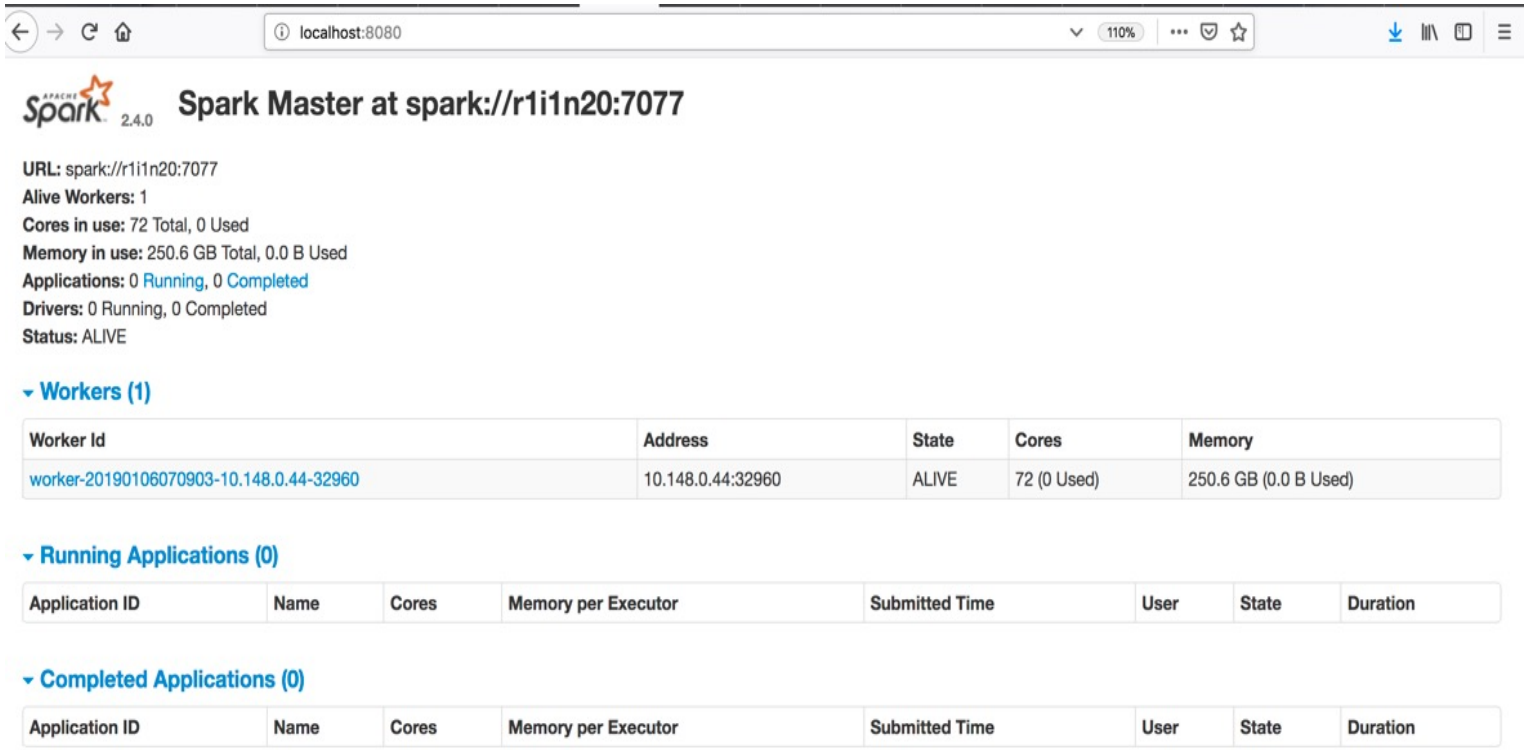
- Start the jupyter server:
  ./start_Jupyter_local.sh <master> → It will give you a token, like this one:
  http://0.0.0.0:8888/?token=2d5e554b2397355c334b8c3367503b06c4f6f95a26151795

- Open **another terminal** and type the following command
  >> ssh **USER**@login.cirrus.ac.uk -L8888:**MASTER NODE**:8888
  Got to a Web browser and type → http://localhost:8888





Master Spark UI

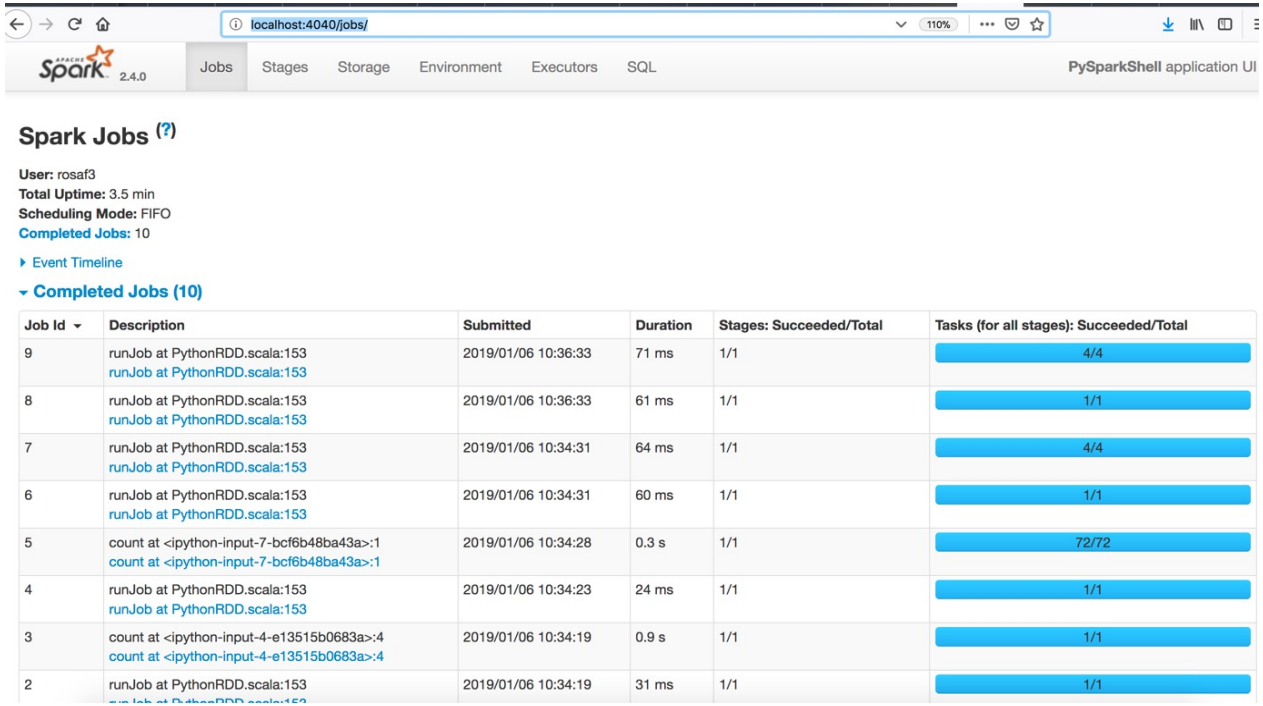


The spark setup can be monetarised via the **Master's web UI**

```
>> ssh USER@login.cirrus.ac.uk -L8080:MASTER NODE:8080
```

Got to a Web browser and type `localhost:8080`

Driver Spark UI



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, Java 10 or Java 11**
- Get Spark from the downloads page of the project website

  (https://blog.sicara.com/get-started-pyspark-jupyter-guide-tutorial-ae2fe84f594f)
- Check if pyspark is properly install → type `pyspark` in a terminal

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

- `>> git clone https://github.com/rosafilgueira/Seminar_MUIA.git`
- `>> cd walkthrough_examples`
- `>> export SPARK_HOME=[INSTALLATION_PATH]/spark-3.2.1-bin-hadoop3.2/`
- **`>> export PYSPARK_DRIVER_PYTHON=jupyter`**
- **`>> export PYSPARK_DRIVER_PYTHON_OPTS='notebook'`**
- `>> $SPARK_HOME/bin/pyspark`