Sistemas Paralelos y Distribuidos

Máster en Ciencia y Tecnología Informática

Diseño de Sistemas Distribuidos

Máster en Ingeniería Informática

Curso 2021-2022

Sistemas escalables en entornos distribuidos. Introducción a Spark

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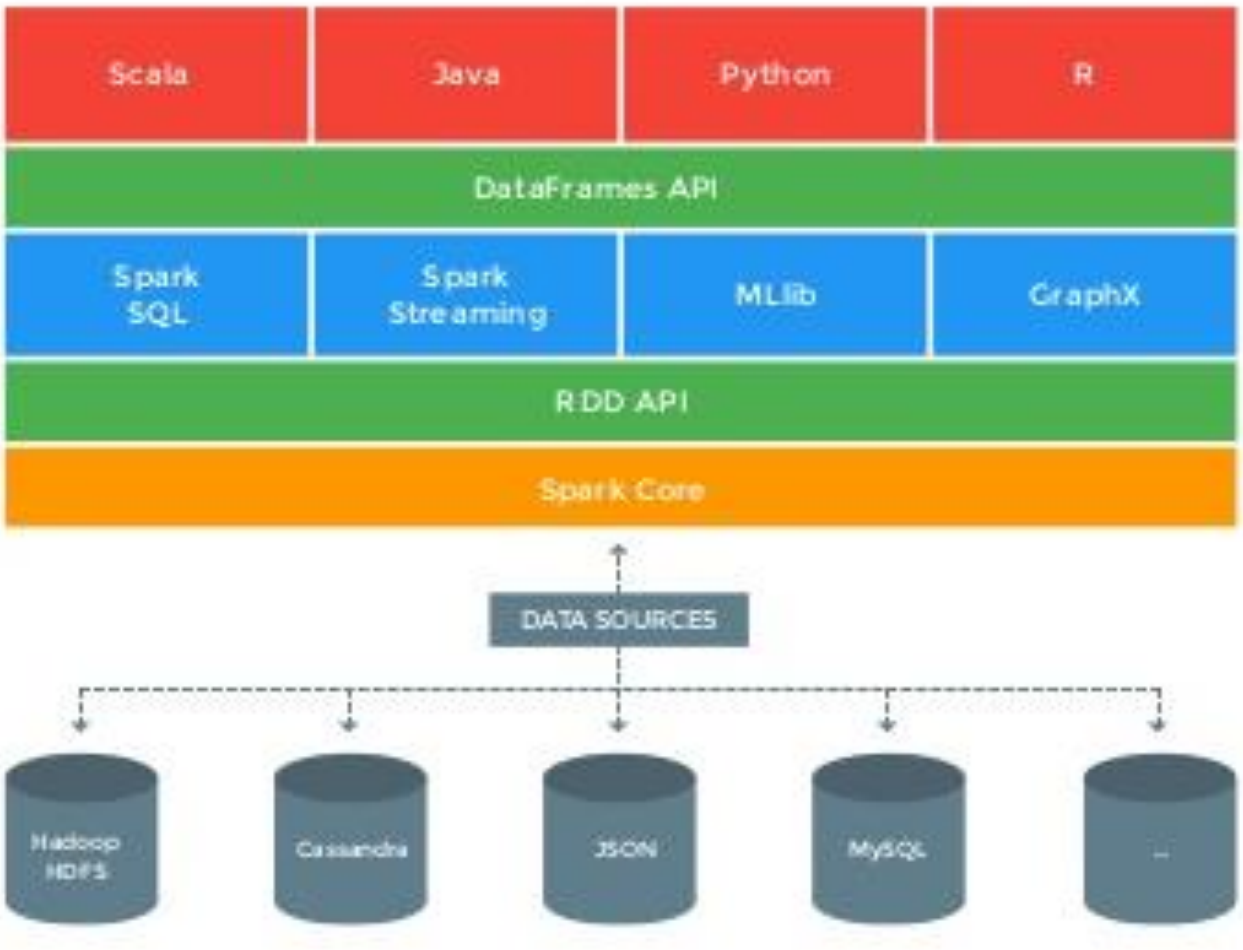
Contenidos

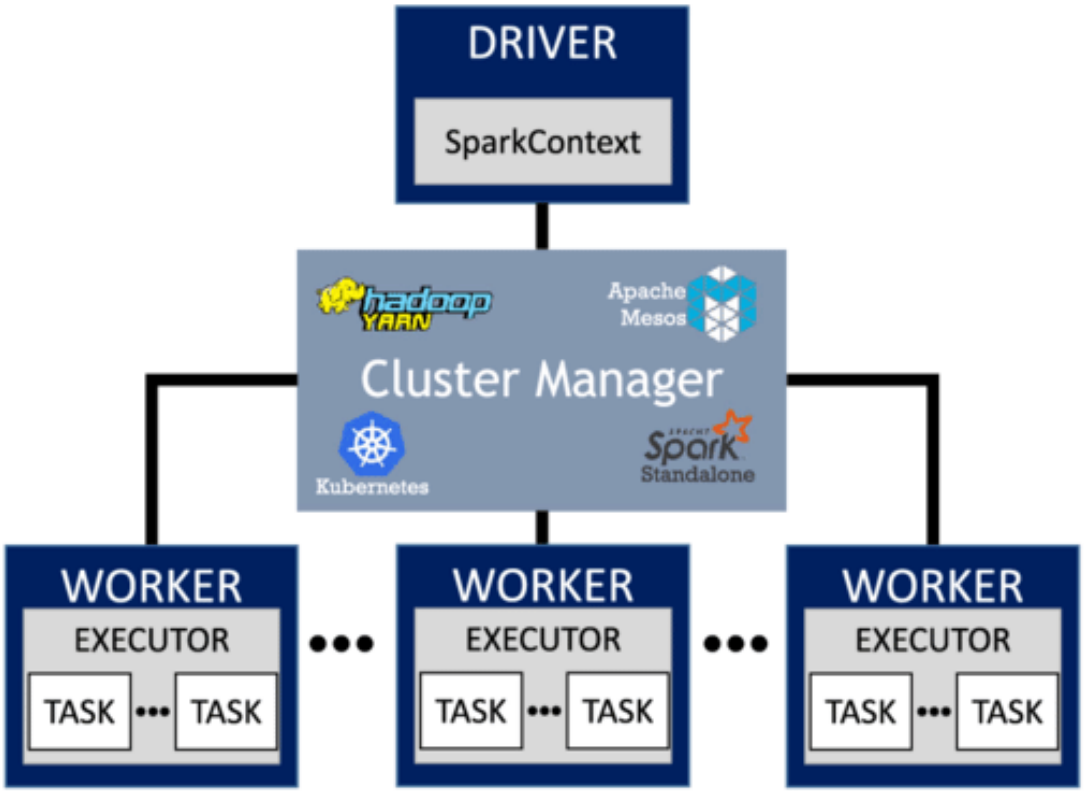
- **Introducción**
- *Hand-on*
  - Pre-requisitos e instalación
  - Nodo autónomo
  - Cluster
- *Benchmarking*

Arquitectura: capas



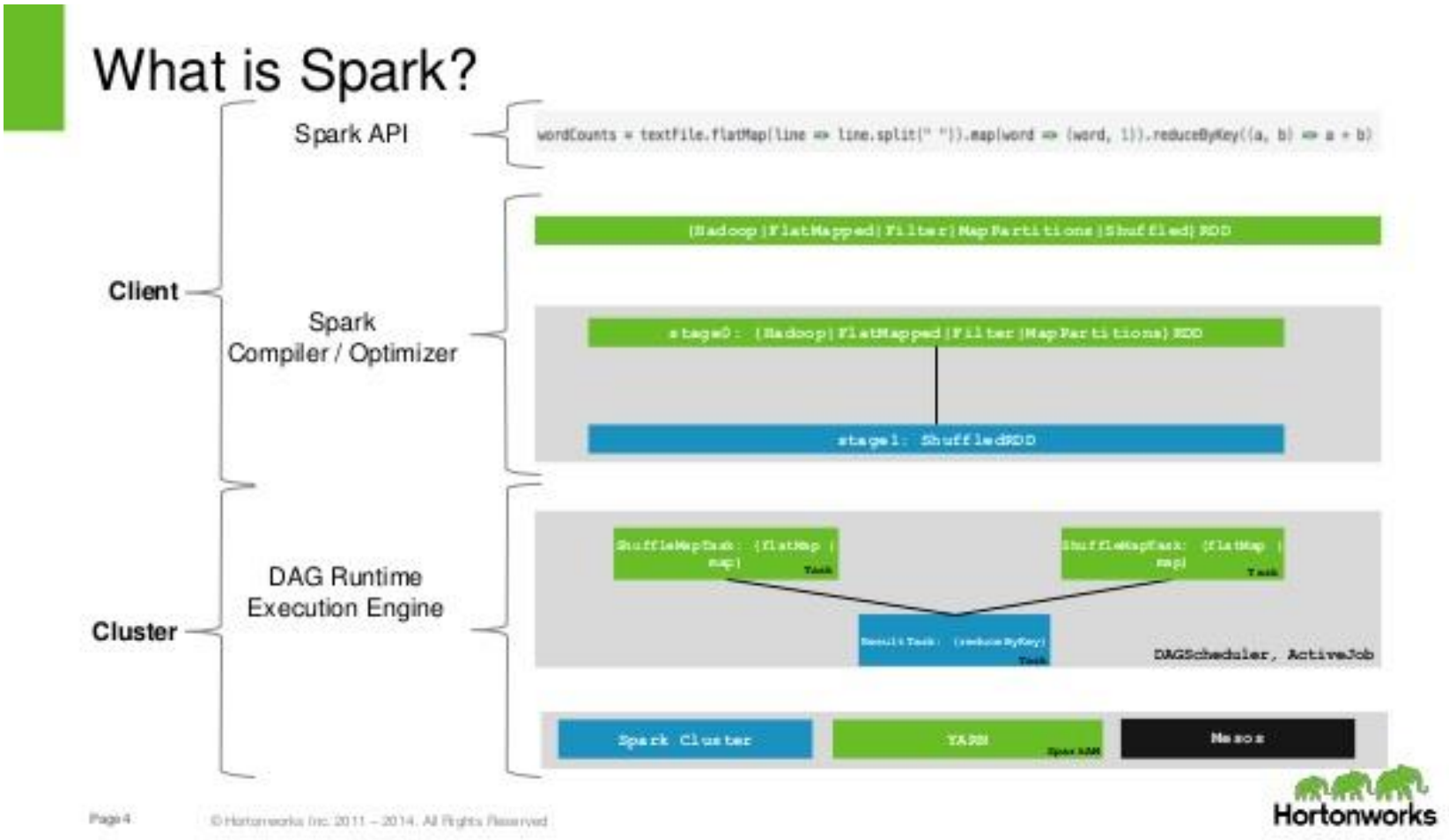
https://my-learnings-about-hadoop.blogspot.com/2017/09/1about-apache-spark.html

Arquitectura: despliegue



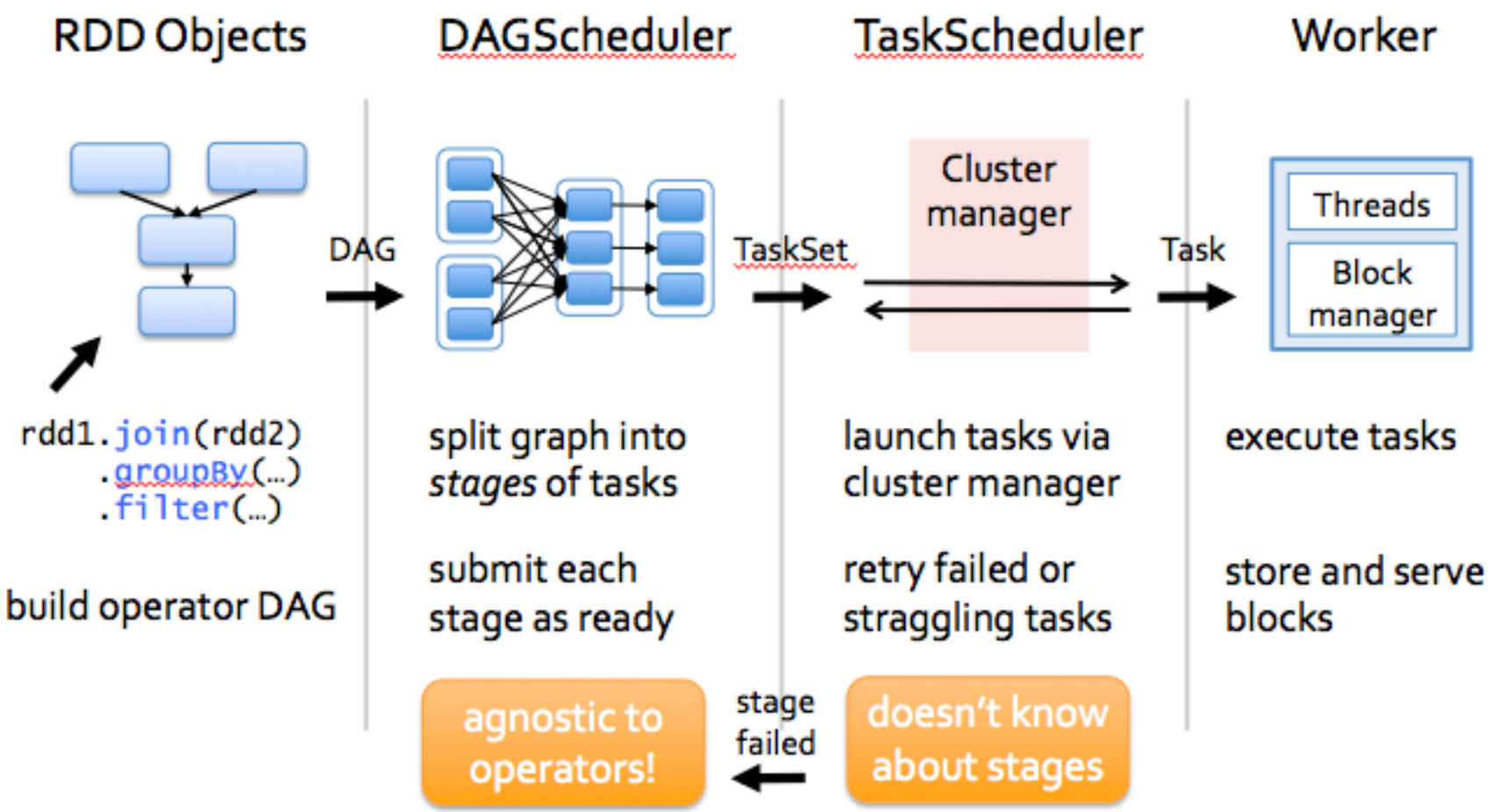
https://www.researchgate.net/figure/Apache-Spark-architecture_fig2_330614514

Arquitectura



http://image.slidesharecdn.com/sparkwebinaroctober-141002152140-phpapp02/95/yarn-ready-apache-spark-4-638.jpg?cb=1412263553

Arquitectura



https://sigmoid.com/wp-content/uploads/2015/03/Apache_Spark1.png

Contenidos

- Introducción
- ***Hand-on***
  - **Pre-requisitos e instalación**
  - Nodo autónomo
  - Cluster
- *Benchmarking*

Spark, Anaconda y Jupyter

```
acaldero@h1:~$ du -mh -s .
3,9G   .
```

Spark

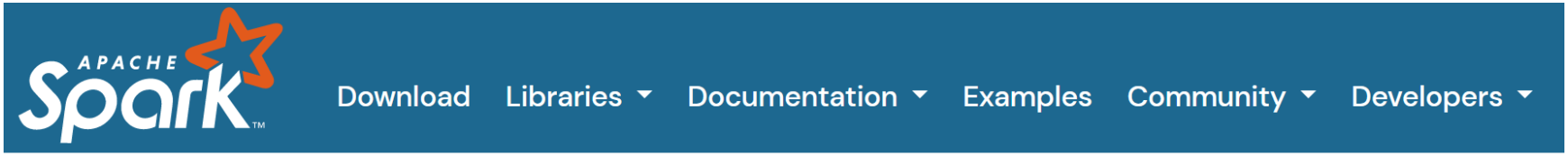
Prerequisitos Instalación Prueba básica

```
acaldero@h1:~$ sudo apt-get install ssh rsync
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  rsync ssh
…
```

```
acaldero@h1:~$ sudo apt-get install default-jdk
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  libice-dev libpthread-stubs0-dev libsm-dev libx11-dev libx11-doc
  libxau-dev libxcb1-dev libxdmcp-dev libxt-dev openjdk-7-jdk
…
```

Spark

Prerequisitos **Instalación** Prueba básica



Download Apache Spark™

1. Choose a Spark release: 3.2.0 (Oct 13 2021)
2. Choose a package type: Pre-built for Apache Hadoop 3.3 and later
3. Download Spark: spark-3.2.0-bin-hadoop3.2.tgz
4. Verify this release using the 3.2.0 signatures, checksums and project release KEYS.

Note that, Spark 2.x is pre-built with Scala 2.11 except version 2.4.2, which is pre-built with Scala 2.12. Spark 3.0+ is pre-built with Scala 2.12.

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

Spark

Prerequisitos **Instalación** Prueba básica

```
acaldero@h1:~$ wget https://dlcdn.apache.org/spark/spark-3.2.0/spark-3.2.0-bin-hadoop3.2.tgz
…
2021-11-12 12:40:44 (6,02 MB/s) - “spark-3.2.0-bin-hadoop3.2.tgz” guardado [...]
```

```
acaldero@h1:~$ tar zxf spark-3.2.0-bin-hadoop3.2.tgz
acaldero@h1:~$ ls -las spark-3.2.0-bin-hadoop3.2
total 164
 4 drwxr-xr-x 14 dsd dsd  4096 nov 10 15:06 .
 4 drwxr-xr-x 22 dsd dsd  4096 nov 14 03:34 ..
 4 drwxr-xr-x  2 dsd dsd  4096 oct  6 15:18 bin
 4 drwxr-xr-x  2 dsd dsd  4096 oct  6 15:18 conf
 4 drwxr-xr-x  5 dsd dsd  4096 oct  6 15:18 data
 4 drwxr-xr-x  4 dsd dsd  4096 oct  6 15:18 examples
16 drwxr-xr-x  2 dsd dsd 16384 oct  6 15:18 jars
 4 drwxr-xr-x  4 dsd dsd  4096 oct  6 15:18 kubernetes
24 -rw-r--r--  1 dsd dsd 22878 oct  6 15:18 LICENSE
 4 drwxr-xr-x  2 dsd dsd  4096 oct  6 15:18 licenses
 4 drwxrwxr-x  2 dsd dsd  4096 nov 10 15:07 logs
60 -rw-r--r--  1 dsd dsd 57677 oct  6 15:18 NOTICE
 4 drwxr-xr-x  9 dsd dsd  4096 oct  6 15:18 python
 4 drwxr-xr-x  3 dsd dsd  4096 oct  6 15:18 R
 8 -rw-r--r--  1 dsd dsd  4512 oct  6 15:18 README.md
 4 -rw-r--r--  1 dsd dsd   167 oct  6 15:18 RELEASE
 4 drwxr-xr-x  2 dsd dsd  4096 oct  6 15:18 sbin
 4 drwxr-xr-x  2 dsd dsd  4096 oct  6 15:18 yarn
```

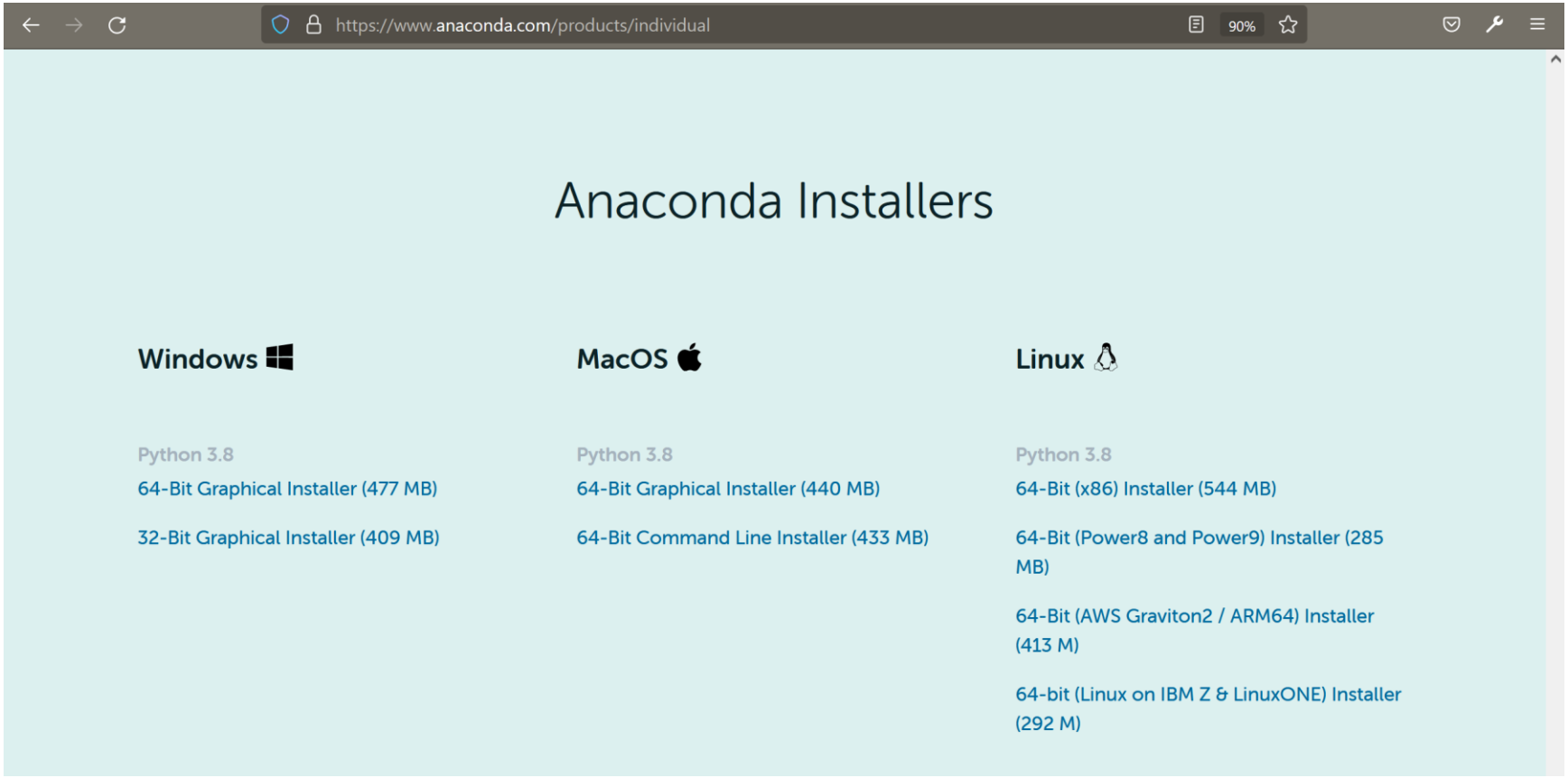
Spark

Prerequisitos Instalación **Prueba básica**

```
acaldero@h1:~/spark-3.2.0-bin-hadoop3.2$ ./bin/run-example SparkPi 5
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
17/10/17 01:02:41 INFO SparkContext: Running Spark version 3.2.0
17/10/17 01:02:42 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using
     builtin-java classes where applicable
17/10/17 01:02:42 INFO SparkContext: Submitted application: Spark Pi
17/10/17 01:02:42 INFO SecurityManager: Changing view acls to: acaldero
17/10/17 01:02:42 INFO SecurityManager: Changing modify acls to: acaldero
17/10/17 01:02:42 INFO SecurityManager: Changing view acls groups to:
17/10/17 01:02:42 INFO SecurityManager: Changing modify acls groups to:
17/10/17 01:02:42 INFO SecurityManager: SecurityManager: authentication disabled; ui acls disabled; users
     with view permissions: Set(acaldero); groups with view permissions: Set(); users  with modify
     permissions: Set(acaldero); groups with modify permissions: Set()
17/10/17 01:02:42 INFO Utils: Successfully started service 'sparkDriver' on port 39281.
17/10/17 01:02:42 INFO SparkEnv: Registering MapOutputTracker
17/10/17 01:02:42 INFO SparkEnv: Registering BlockManagerMaster
…
17/10/17 01:02:45 INFO DAGScheduler: Job 0 finished: reduce at SparkPi.scala:38, took 0,687226 s
Pi is roughly 3.1418622837245676
17/10/17 01:02:45 INFO SparkUI: Stopped Spark web UI at http://10.0.2.15:4040
…
```

Anaconda

Instalación Prueba básica



https://www.anaconda.com/download/

Anaconda

Instalación Prueba básica

```
acaldero@h1:~$ wget https://repo.anaconda.com/archive/Anaconda3-2021.05-Linux-x86_64.sh

…
2018-11-18 15:12:23 (5,57 MB/s) - “Anaconda3-2021.05-Linux-x86_64.sh” guardado [...]
```

```
acaldero@h1:~$ chmod a+x Anaconda3-2021.05-Linux-x86_64.sh
acaldero@h1:~$ ./Anaconda3-2021.05-Linux-x86_64.sh
Welcome to Anaconda3 2021.05 (by Continuum Analytics, Inc.)

In order to continue the installation process, please review the license
agreement.
Please, press ENTER to continue
>>>
…
```

```
acaldero@h1:~$ bash
acaldero@h1:~$ conda update --all
Fetching package metadata .......
Solving package specifications: ..........
…
```

http://jupyter.readthedocs.io/en/latest/install.html#existing-python-new-jupyter

Jupyter

Instalación Prueba básica

```
acaldero@h1:~$ conda install jupyter
Fetching package metadata .......
Solving package specifications: ..........

# All requested packages already installed.
# packages in environment at /home/acaldero/anaconda2:
#
jupyter                   1.0.0                    py27h9d2e098_2 …
```

```
acaldero@h1:~$ jupyter notebook
[I 18:32:31.686 NotebookApp] [nb_conda_kernels] enabled, 2 kernels found
[I 18:32:31.792 NotebookApp] ✓ nbpresent HTML export ENABLED
[W 18:32:31.792 NotebookApp] ✗ nbpresent PDF export DISABLED: No module named nbbrowserpdf.exporters.pdf
[I 18:32:31.796 NotebookApp] [nb_conda] enabled
[I 18:32:32.336 NotebookApp] [nb_anacondacloud] enabled
[I 18:32:32.338 NotebookApp] Serving notebooks from local directory: /home/acaldero
[I 18:32:32.338 NotebookApp] 0 active kernels
[I 18:32:32.338 NotebookApp] The Jupyter Notebook is running at: http://localhost:8888/
[I 18:32:32.338 NotebookApp] Use Control-C to stop this server and shut down all kernels (twice to skip
     confirmation).
…
```

http://www.ithinkcloud.com/tutorials/tutorial-on-how-to-install-apache-spark-on-windows/

Spark, Anaconda y Jupyter

Configuración

```
acaldero@h1:~$ ln -s spark-3.2.0-bin-hadoop3.2 spark
acaldero@h1:~$ echo "export PATH=$PATH:/home/acaldero/spark/bin"          >> .profile
acaldero@h1:~$ echo "export PYSPARK_DRIVER_PYTHON=ipython"                >> .profile
acaldero@h1:~$ echo "export PYSPARK_DRIVER_PYTHON_OPTS='notebook' pyspark">> .profile
acaldero@h1:~$ source .profile

…
```

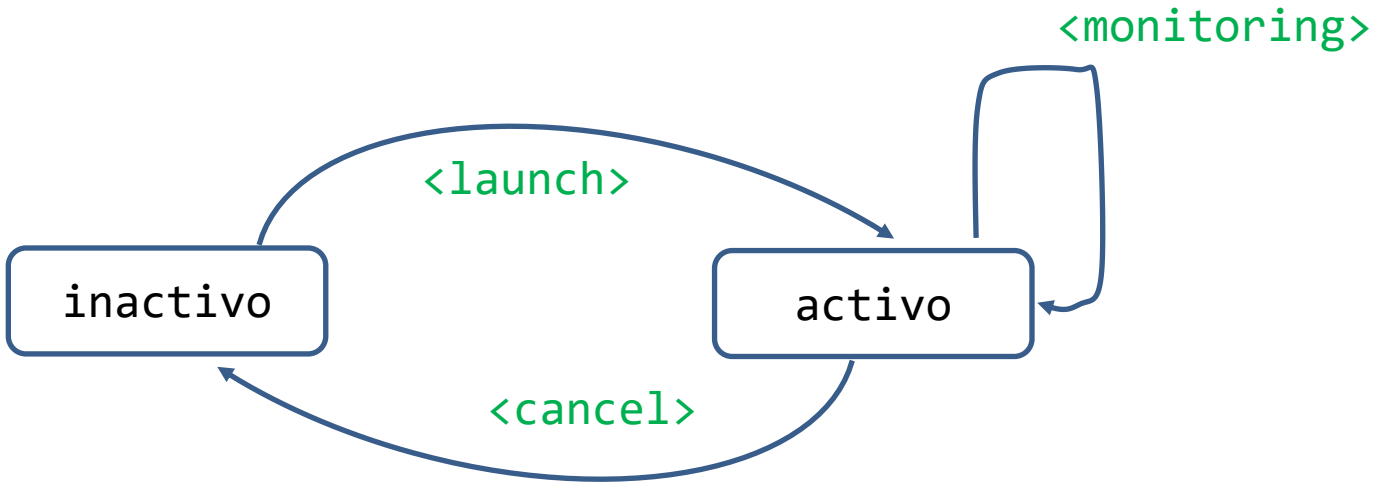
https://gist.github.com/tommycarpi/f5a67c66a8f2170e263c

Contenidos

- Introducción
- ***Hand-on***
  - Pre-requisitos e instalación
  - **Nodo autónomo**
  - Cluster
- *Benchmarking*

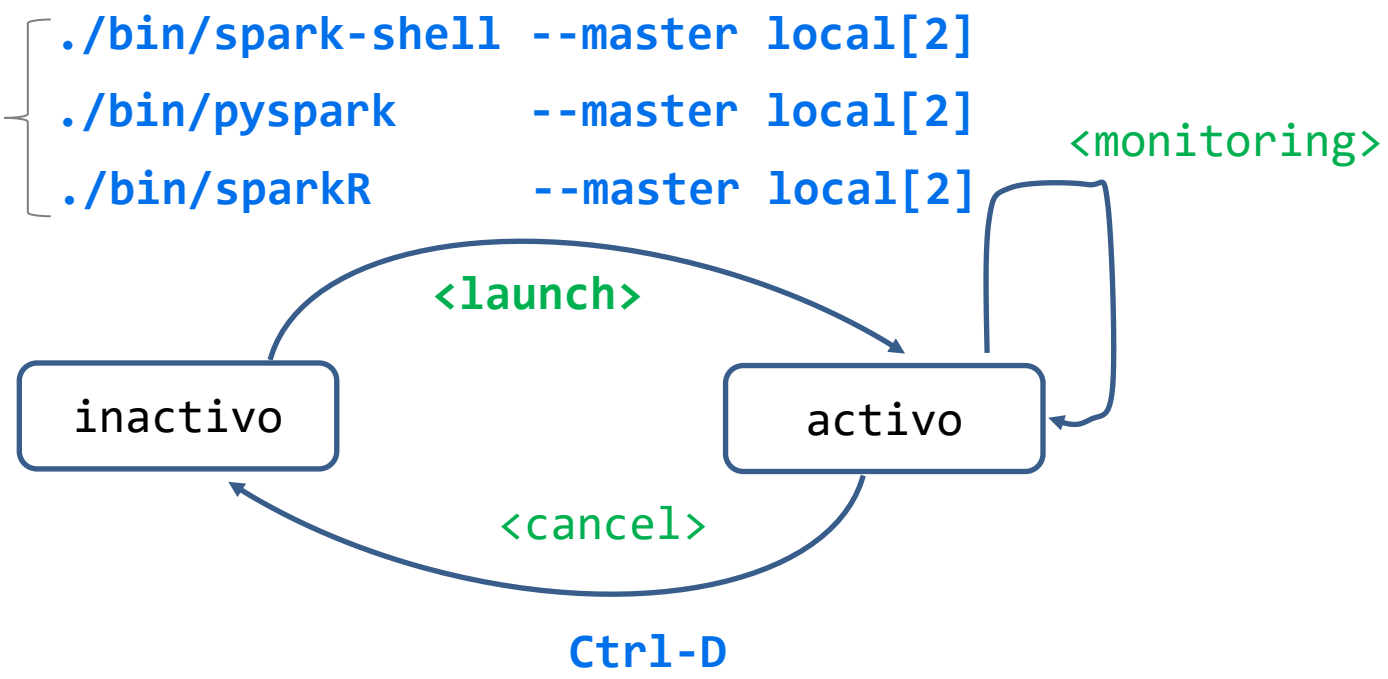
Spark

Funcionamiento General



Spark: nodo autónomo

shell-interactivo submit libro-interactivo

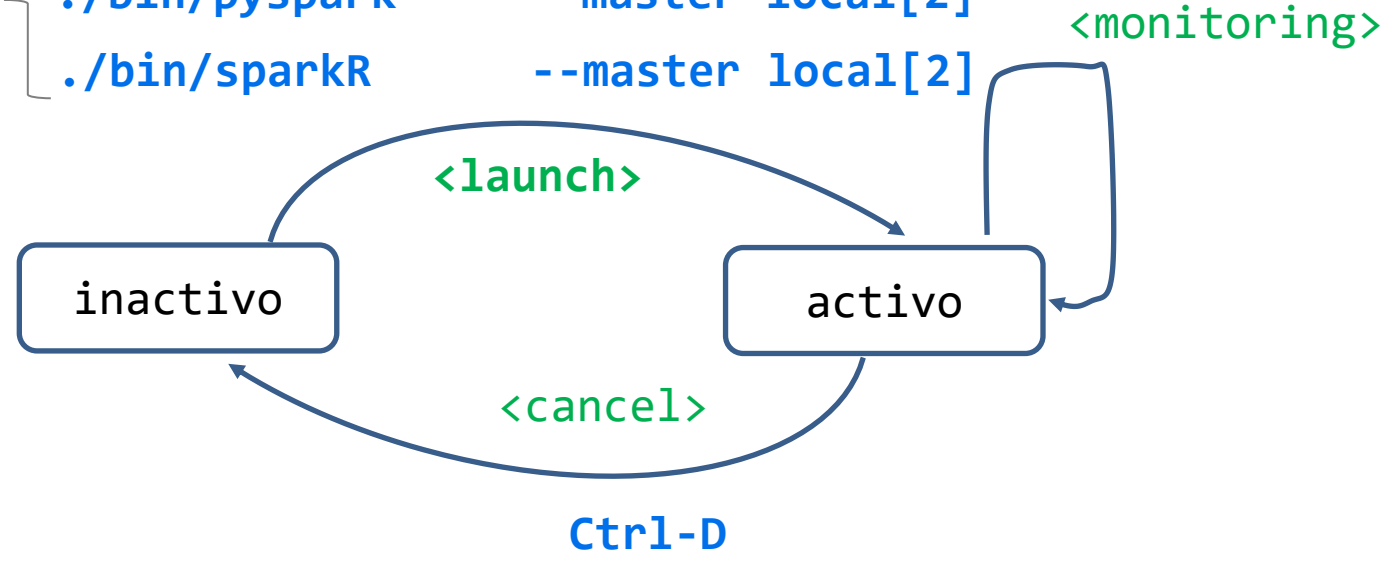


Spark: nodo autónomo

shell-interactivo submit libro-interactivo

local -> 1 thread
local[N] -> N threads
local[*] -> as many threads as cores are

```
./bin/spark-shell --master local[2]
./bin/pyspark     --master local[2]
./bin/sparkR      --master local[2]
```



Spark: nodo autónomo

shell-interactivo submit libro-interactivo

```
acaldero@h1:~/spark$ ./bin/pyspark
Python 3.8.12 (default, Oct 12 2021, 13:49:34)
[GCC 7.5.0] :: Anaconda, Inc. on linux
Type "help", "copyright", "credits" or "license" for more information.
…
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).
21/11/14 04:04:48 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform... using
     builtin-java classes where applicable
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /__ / .__/\_,_/_/ /_/\_\   version 3.2.0
      /_/

Using Python version 3.8.12 (default, Oct 12 2021 13:49:34)
Spark context Web UI available at http://10.0.2.15:4040
Spark context available as 'sc' (master = local[*], app id = local-1636859089934).
SparkSession available as 'spark'.
>>>
```

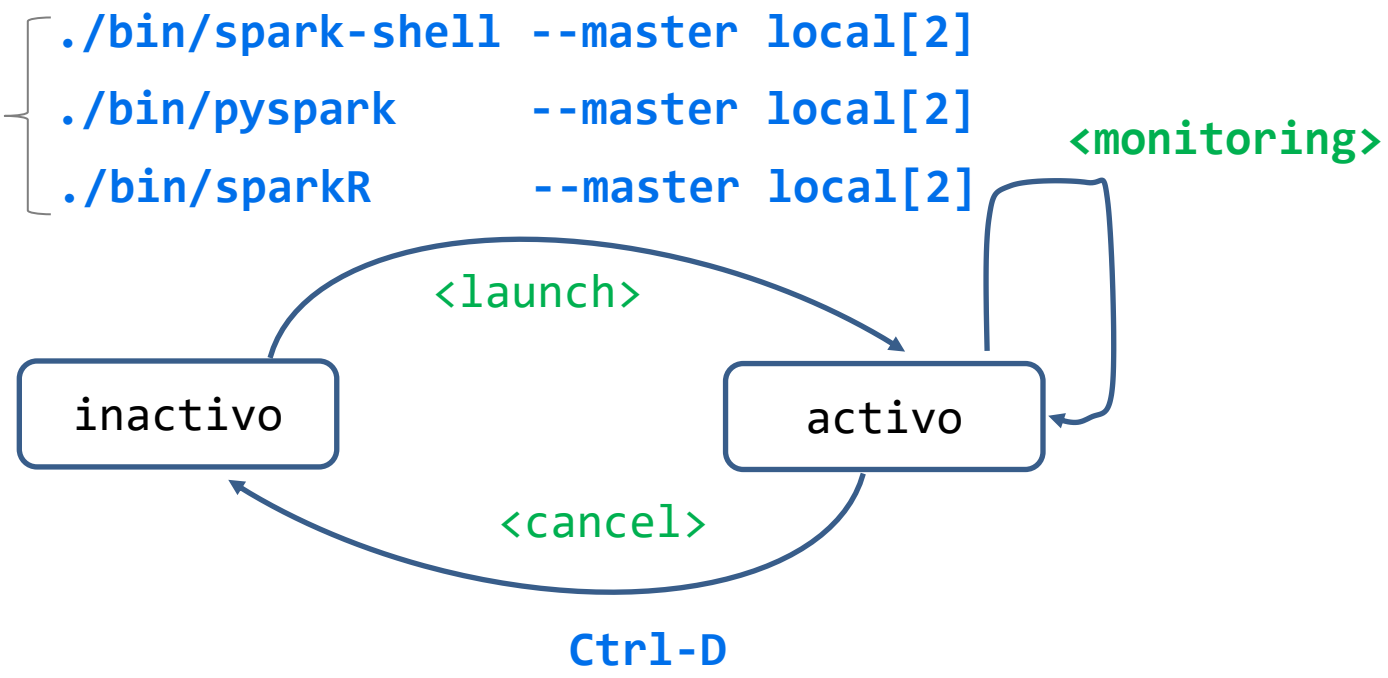
Spark: nodo autónomo

shell-interactivo submit libro-interactivo

```
SparkSession available as 'spark'.
>>> import sys
>>> from random import random
>>> from operator import add
>>> from pyspark.sql import SparkSession
>>>
>>> partitions = 2
>>> n = 100000 * partitions
>>> def f(_):
...     x = random() * 2 - 1
...     y = random() * 2 - 1
...     return 1 if x ** 2 + y ** 2 < 1 else 0
...
>>> spark = SparkSession.builder.appName("PythonPi").getOrCreate()
>>> count = spark.sparkContext.parallelize(range(1, n + 1), partitions).map(f).reduce(add)
16/11/27 14:08:13 WARN TaskSetManager: Stage 0 contains a task of very large size (368 KB). The maximum
     recommended task size is 100 KB.
>>> print("Pi is roughly %f" % (4.0 * count / n))
Pi is roughly 3.139500
>>> spark.stop()
>>>
```

Spark: nodo autónomo

shell-interactivo submit libro-interactivo



Spark: nodo autónomo

shell-interactivo submit libro-interactivo

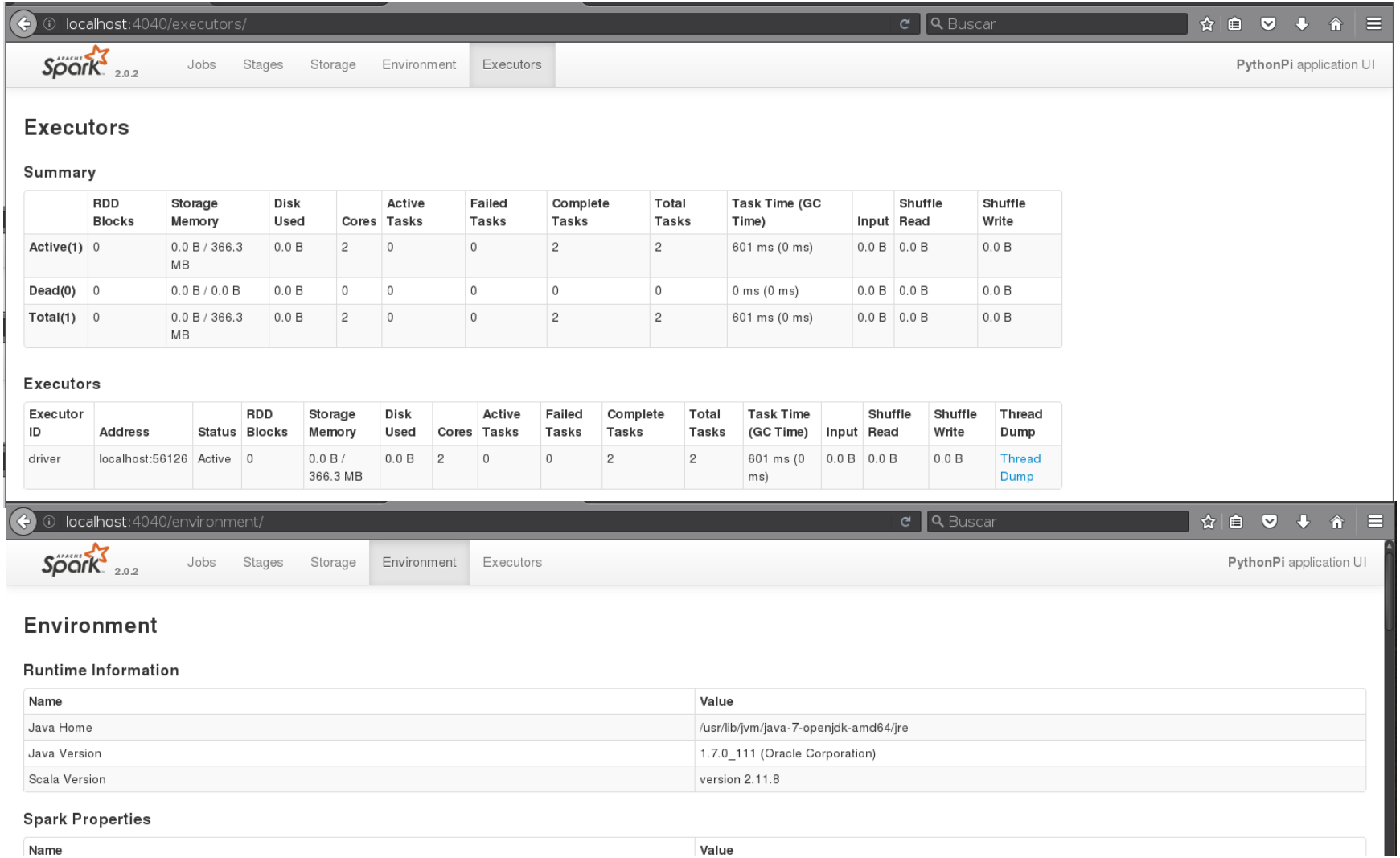
```
SparkSession available as 'spark'.
>>> import sys
>>> from random import random
>>> from operator import add
>>> from pyspark.sql import SparkSession
>>>
>>> partitions = 2
>>> n = 100000 * partitions
>>> def f(_):
...     x = random() * 2 - 1
...     y = random() * 2 - 1
...     return 1 if x ** 2 + y ** 2 < 1 else 0
...
>>> spark = SparkSession.builder.appName("PythonPi").getOrCreate()
>>> count = spark.sparkContext.parallelize(range(1, n + 1), partitions).map(f).reduce(add)
16/11/27 14:08:13 WARN TaskSetManager: Stage 0 contains a task of very large size (368 KB).
    The maximum recommended task size is 100 KB.
>>> print("Pi is roughly %f" % (4.0 * count / n))
Pi is roughly 3.139500
>>> spark.stop()
>>>
```

http://<ip>:4040
http://<ip>:4041
...

http://spark.apache.org/docs/latest/monitoring.html

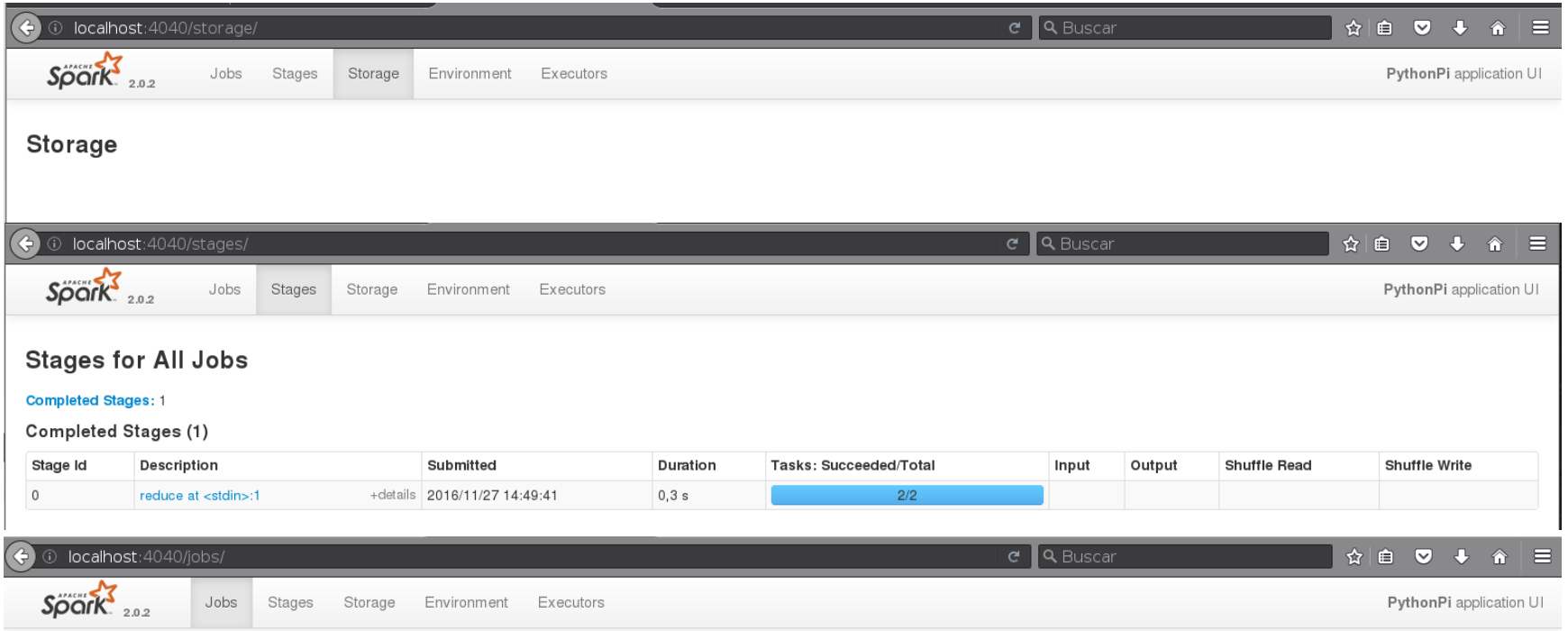
Spark: nodo autónomo

shell-interactivo submit libro-interactivo



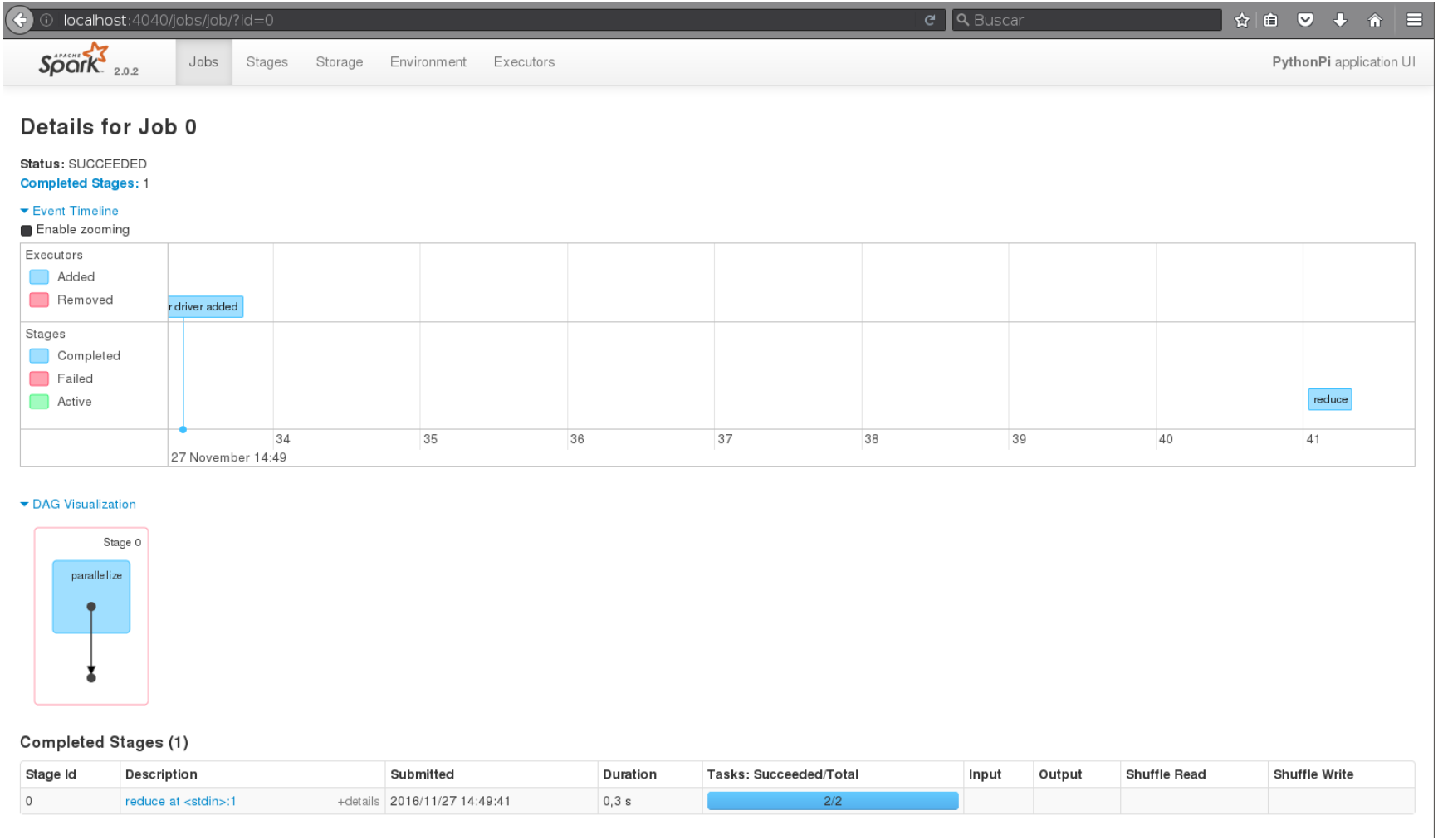
Spark: nodo autónomo

shell-interactivo submit libro-interactivo



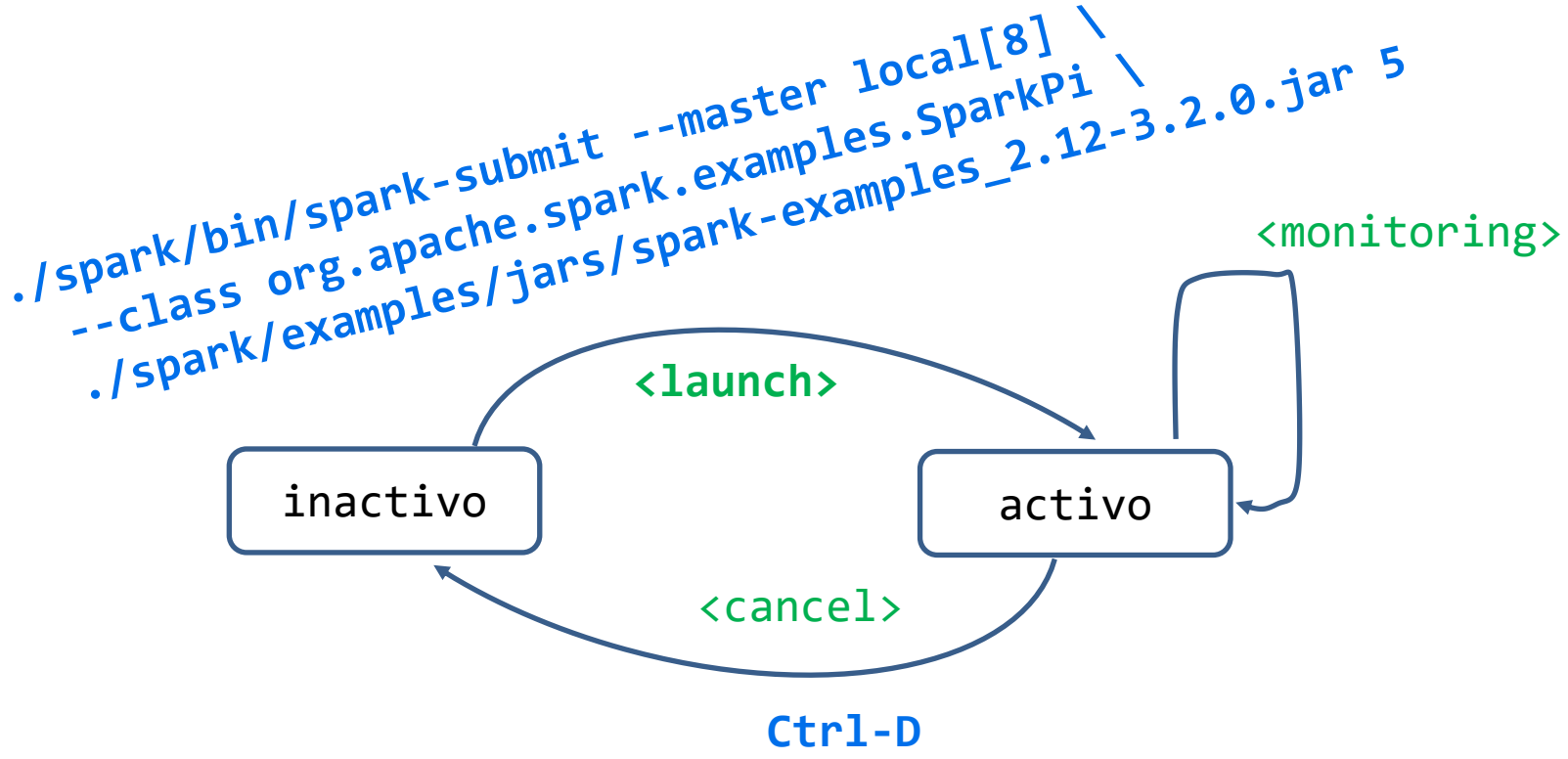
Spark: nodo autónomo

shell-interactivo submit libro-interactivo



Spark: nodo autónomo

shell-interactivo **submit** libro-interactivo



Spark: nodo autónomo

shell-interactivo submit **libro-interactivo**

```
acaldero@h1:~$ mkdir work
acaldero@h1:~$ cd work
acaldero@h1:~$ wget http://www.gutenberg.org/cache/epub/2000/pg2000.txt
```

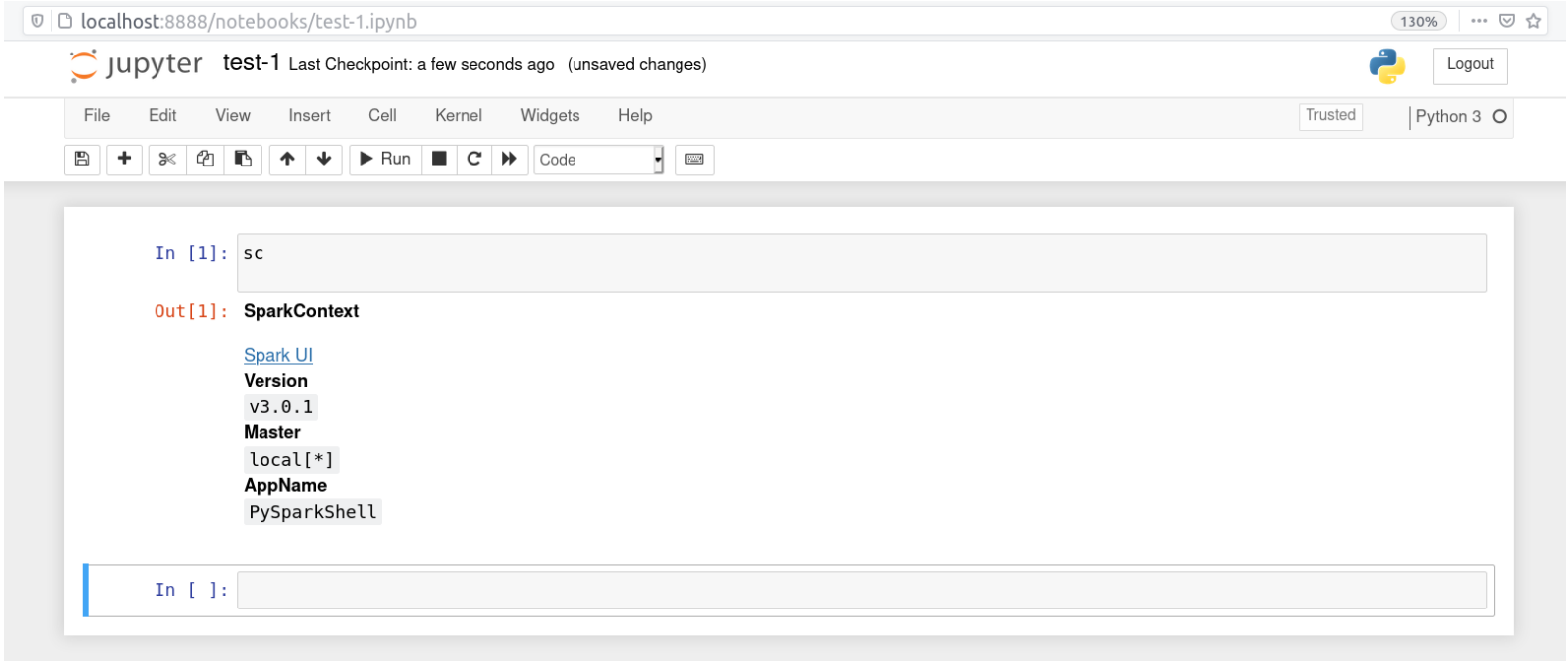
```
acaldero@h1:~$ pyspark
[TerminalIPythonApp] WARNING | Subcommand `ipython notebook` is deprecated and will be removed in future versions.
[TerminalIPythonApp] WARNING | You likely want to use `jupyter notebook` in the future
[I 18:48:14.980 NotebookApp] [nb_conda_kernels] enabled, 2 kernels found
[I 18:48:15.016 NotebookApp] ✓ nbpresent HTML export ENABLED
[W 18:48:15.016 NotebookApp] ✗ nbpresent PDF export DISABLED: No module named nbbrowserpdf.exporters.pdf
[I 18:48:15.018 NotebookApp] [nb_conda] enabled
…
```

https://gist.github.com/tommycarpi/f5a67c66a8f2170e263c

Spark: nodo autónomo

shell-interactivo submit **libro-interactivo**

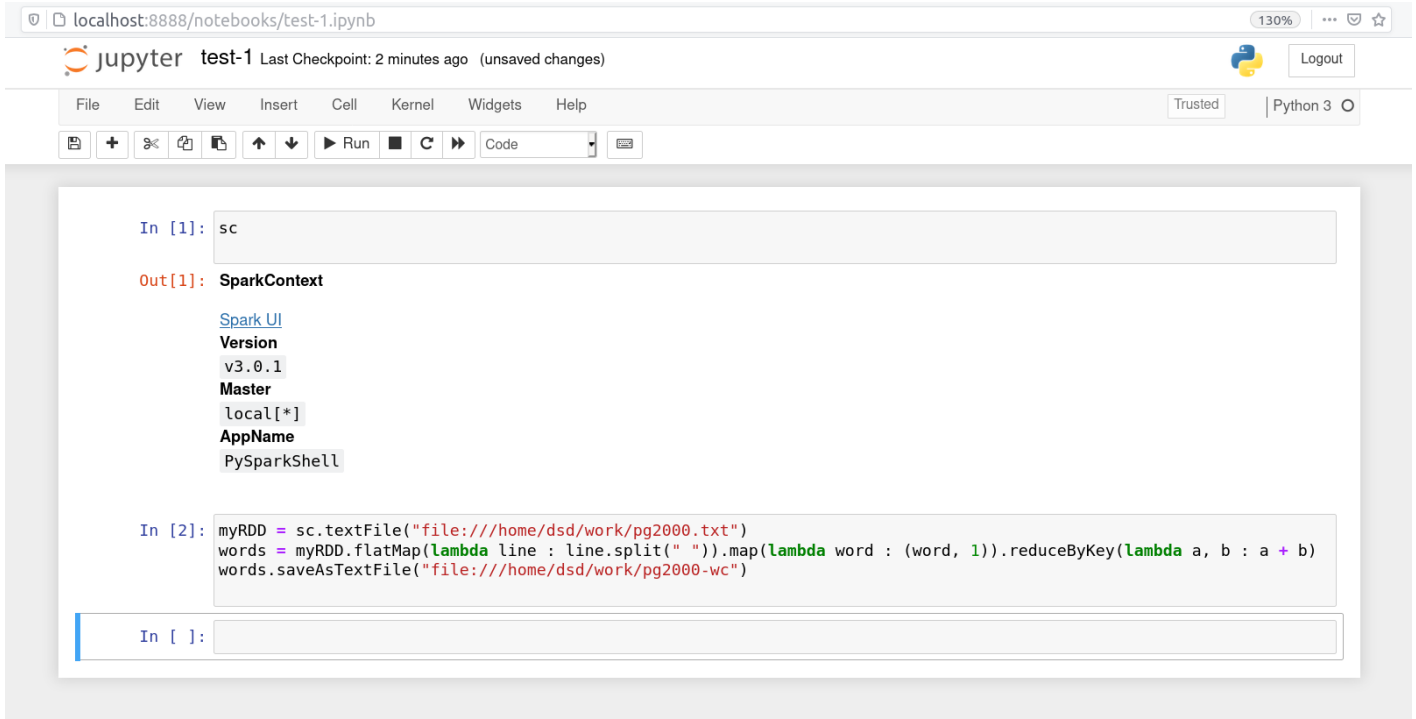
```
acaldero@h1:~$ firefox http://localhost:8888/
ps# sc + <shift + enter>
```



Spark: nodo autónomo

shell-interactivo submit **libro-interactivo**

```
myRDD = sc.textFile("file:///home/acaldero/work/pg2000.txt")
words = myRDD.flatMap(lambda line : line.split(" ")).map(lambda word : (word,
    1)).reduceByKey(lambda a, b : a + b)
words.saveAsTextFile("file:///home/acaldero/work/pg2000-wc")
```

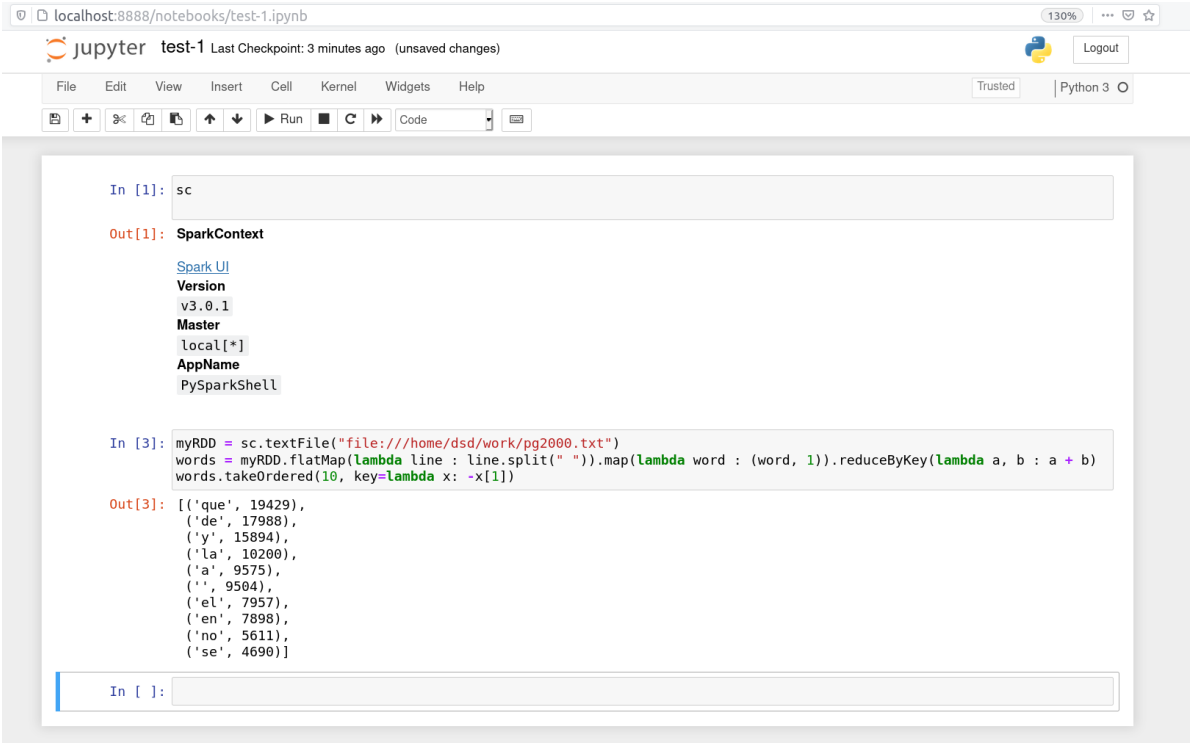


https://geekytheory.com/apache-spark-que-es-y-como-funciona/

Spark: nodo autónomo

shell-interactivo submit **libro-interactivo**

```
myRDD = sc.textFile("file:///home/acaldero/work/pg2000.txt")
words = myRDD.flatMap(lambda line : line.split(" ")).map(lambda word : (word,
    1)).reduceByKey(lambda a, b : a + b)
words.takeOrdered(10, key=lambda x: -x[1])
```

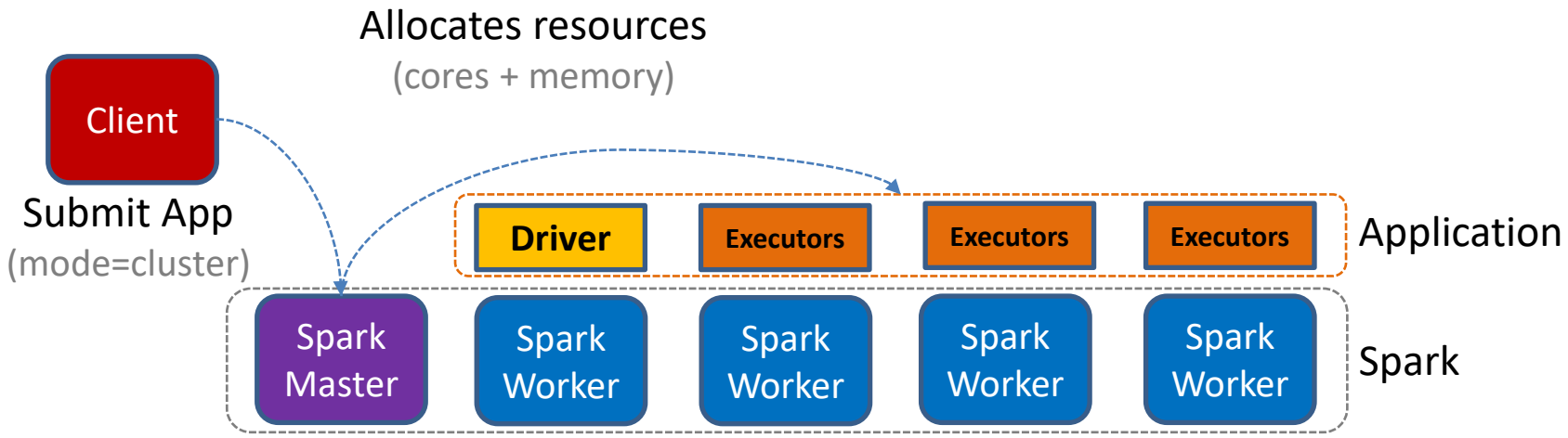


http://stackoverflow.com/questions/24656696/spark-get-collection-sorted-by-value

Contenidos

- Introducción
- ***Hand-on***
  - Pre-requisitos e instalación
  - Nodo autónomo
  - **Cluster**
- *Benchmarking*

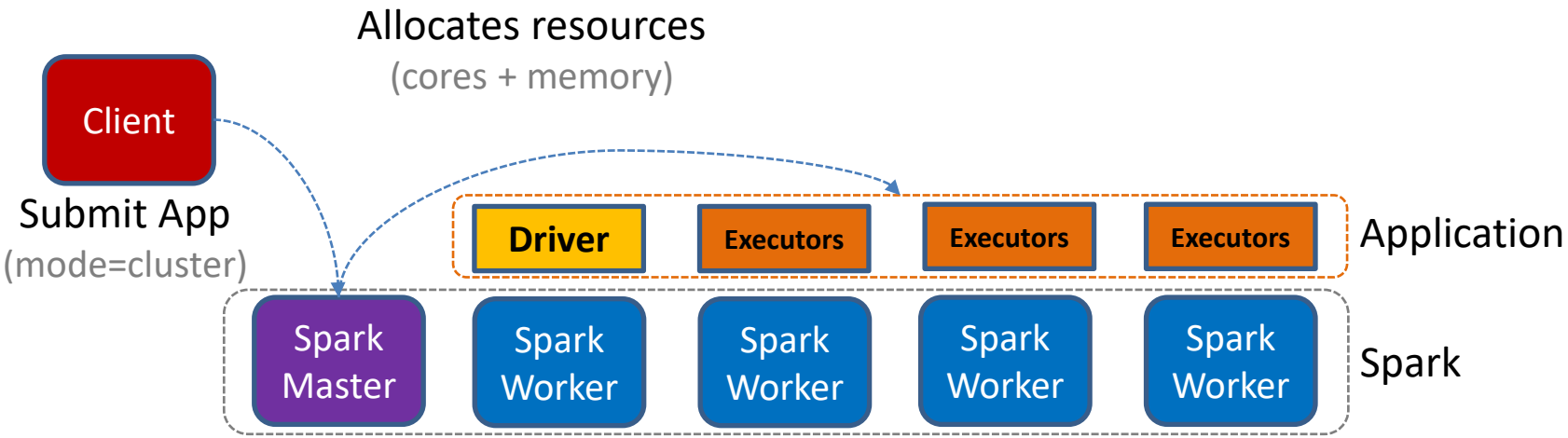
Spark: cluster privado



https://trongkhoanguyenblog.wordpress.com/2014/11/23/a-gentle-introduction-to-apache-spark/

Spark: cluster privado

Prerequisitos **Instalación** Uso básico

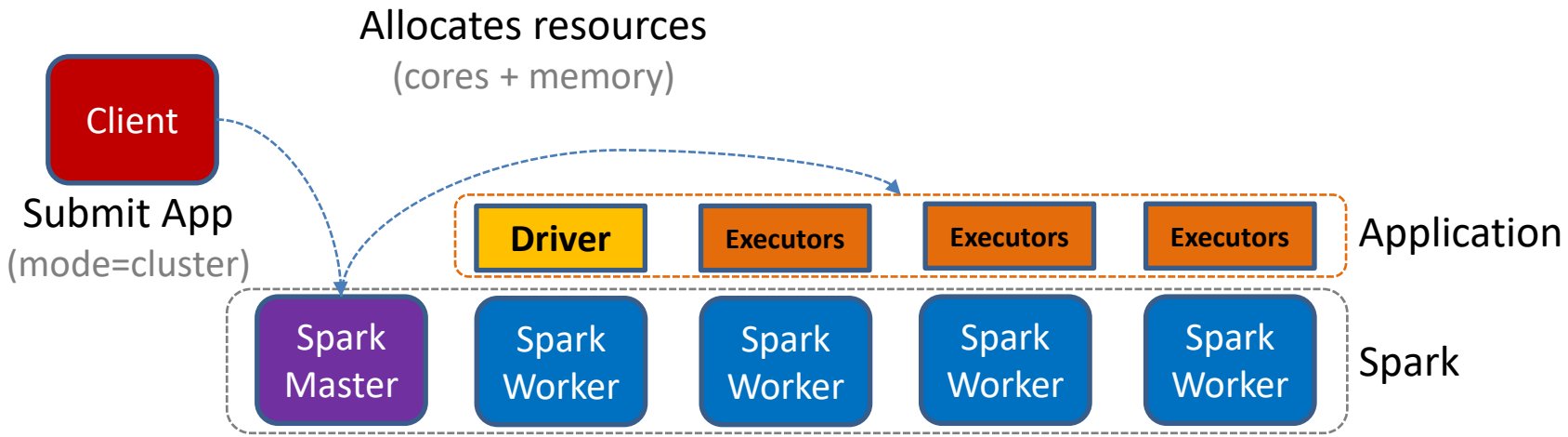


```
acaldero@h1:~$ echo "127.0.0.1  master1"  >> /etc/hosts
acaldero@h1:~$ echo "127.0.0.1  worker1"  >> /etc/hosts
acaldero@h1:~$ echo "127.0.0.1  worker2"  >> /etc/hosts
```

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

Spark: cluster privado

Prerequisitos **Instalación** Uso básico



```
acaldero@h1:~$ echo "worker1" >> spark/conf/workers
acaldero@h1:~$ echo "worker2" >> spark/conf/workers
```

```
acaldero@h1:~$ : Spark en todos los nodos (si fuera necesario)
acaldero@h1:~$ scp -r spark acaldero@worker[1-2]:~/
…
```

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

Spark: cluster privado

```
acaldero@h1:/home/acaldero$ ssh-keygen -t rsa -P ""
Generating public/private rsa key pair.
Enter file in which to save the key (/home/acaldero/.ssh/id_rsa):
Created directory '/home/acaldero/.ssh'.
Your identification has been saved in /home/acaldero/.ssh/id_rsa.
Your public key has been saved in /home/acaldero/.ssh/id_rsa.pub.
The key fingerprint is:
f0:14:95:a1:0b:78:57:0b:c7:65:47:43:39:b2:2f:8a acaldero@ws1
The key's randomart image is:
+---[RSA 2048]----+
|        oo=+oo=. |
|     .   *oo..o. |
…
```

Spark: cluster privado

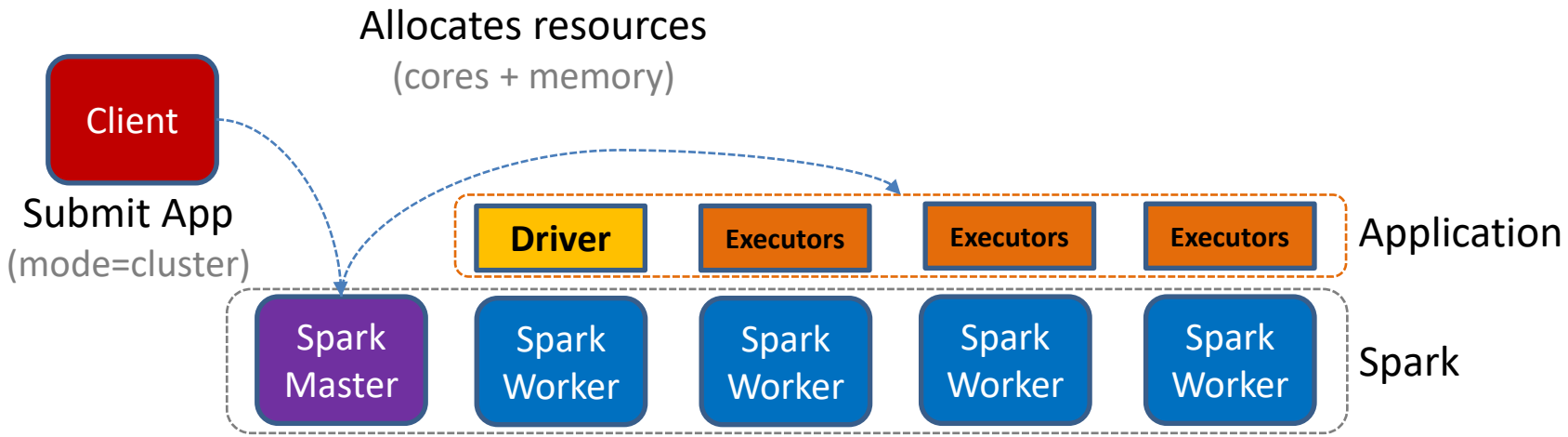
```
acaldero@h1:/home/acaldero$ scp .ssh/id_rsa.pub acaldero@worker2:~/.ssh/authorized_keys
Password:
…
```

```
acaldero@h1:/home/acaldero$ ssh worker2
The authenticity of host 'localhost (::1)' can't be established.
ECDSA key fingerprint is bb:85:4c:6a:ff:e4:34:f8:ac:82:bf:56:a6:79:d8:80.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added 'localhost' (ECDSA) to the list of known hosts.
…
```

```
acaldero@worker2:~$ exit
logout
```

Spark: cluster privado

Prerequisitos Instalación **Uso básico**

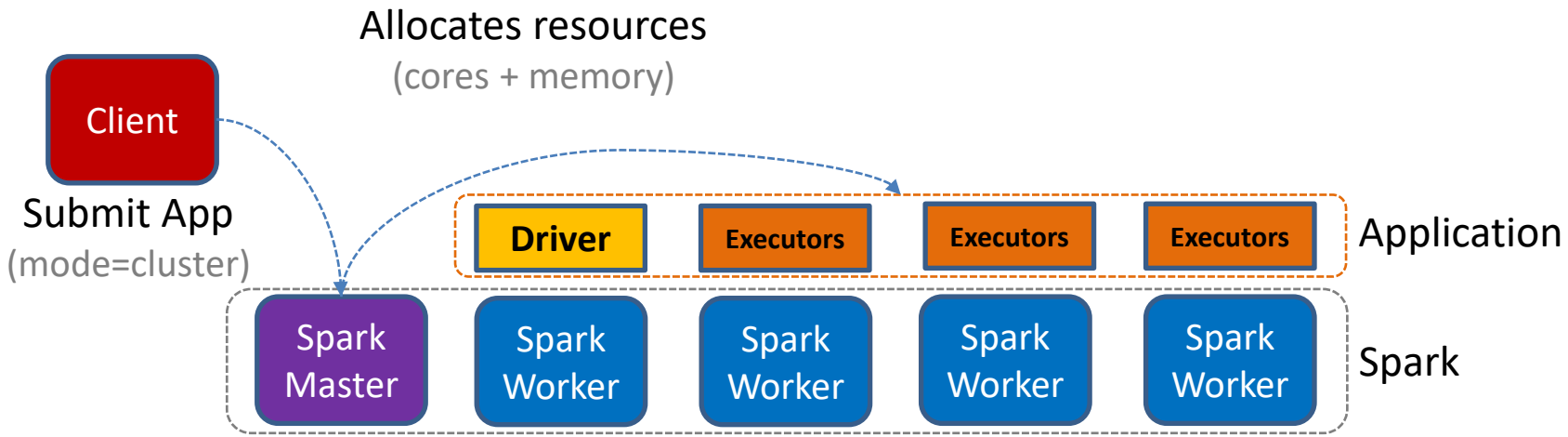


```
acaldero@h1:~$ : Ir al nodo master
acaldero@h1:~$ ssh acaldero@master1
acaldero@master1:~$ ./spark/sbin/start-all.sh
localhost: starting org.apache.spark.deploy.worker.Worker, logging to /home/acaldero/spark/logs/spark-acaldero-org.apache.spark.deploy.worker.Worker-1-ws1.out
localhost: starting org.apache.spark.deploy.worker.Worker, logging to /home/acaldero/spark/logs/spark-acaldero-org.apache.spark.deploy.worker.Worker-1-ws1.out
localhost: starting org.apache.spark.deploy.worker.Worker, logging to /home/acaldero/spark/logs/spark-acaldero-org.apache.spark.deploy.worker.Worker-1-ws1.out
...
```

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

Spark: cluster privado

Prerequisitos Instalación **Uso básico**

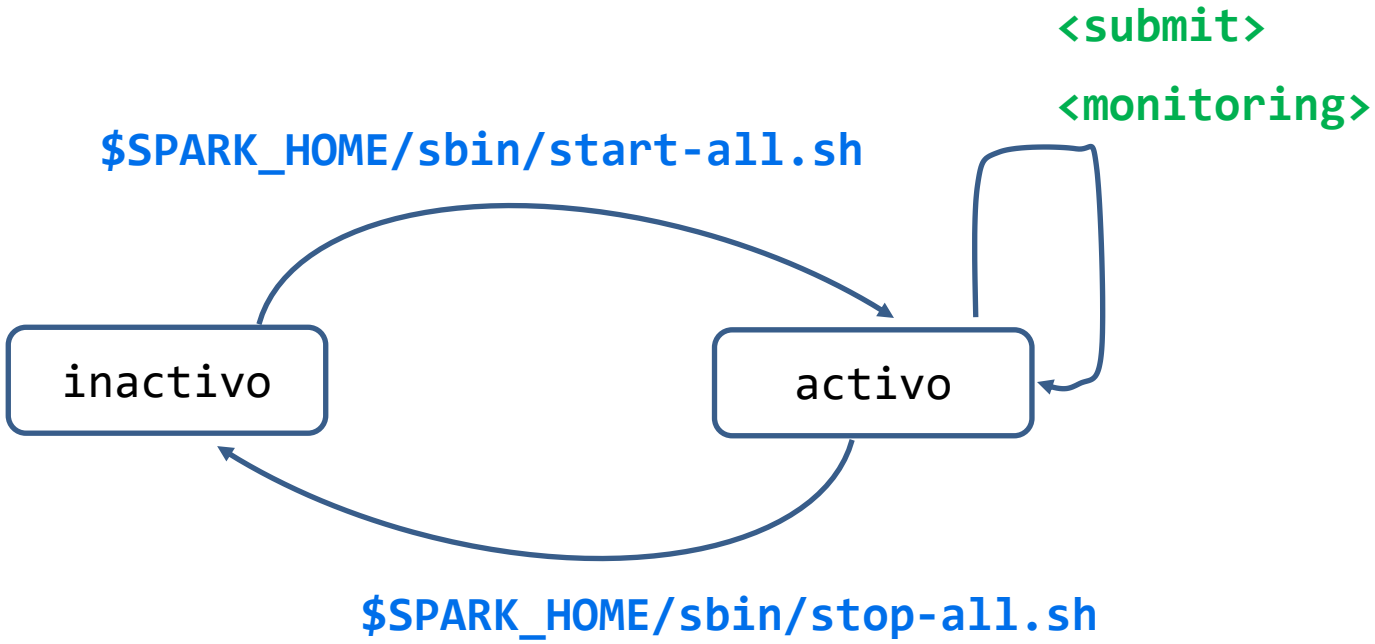


```
acaldero@master1:~$ ./spark/sbin/stop-all.sh
acaldero@master1:~$ exit
acaldero@h1:~$ : Regresar al cliente
localhost: stopping org.apache.spark.deploy.worker.Worker
localhost: stopping org.apache.spark.deploy.worker.Worker
localhost: stopping org.apache.spark.deploy.worker.Worker
stopping org.apache.spark.deploy.master.Master
```

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

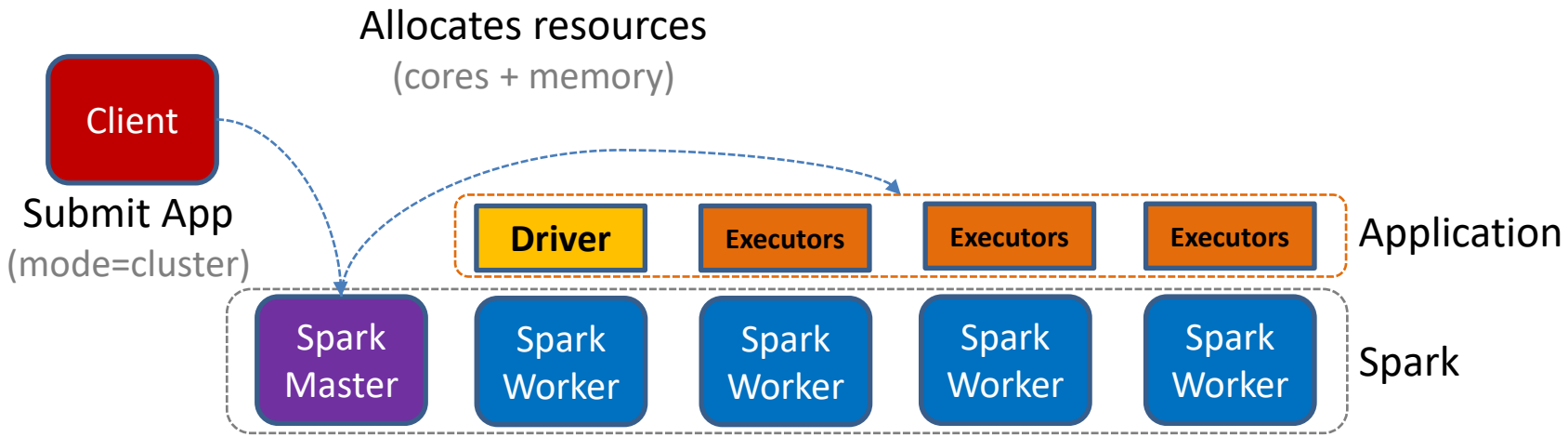
Spark: cluster privado

Prerequisitos Instalación **Uso básico**



Spark: cluster privado

Prerequisitos Instalación **Uso básico**



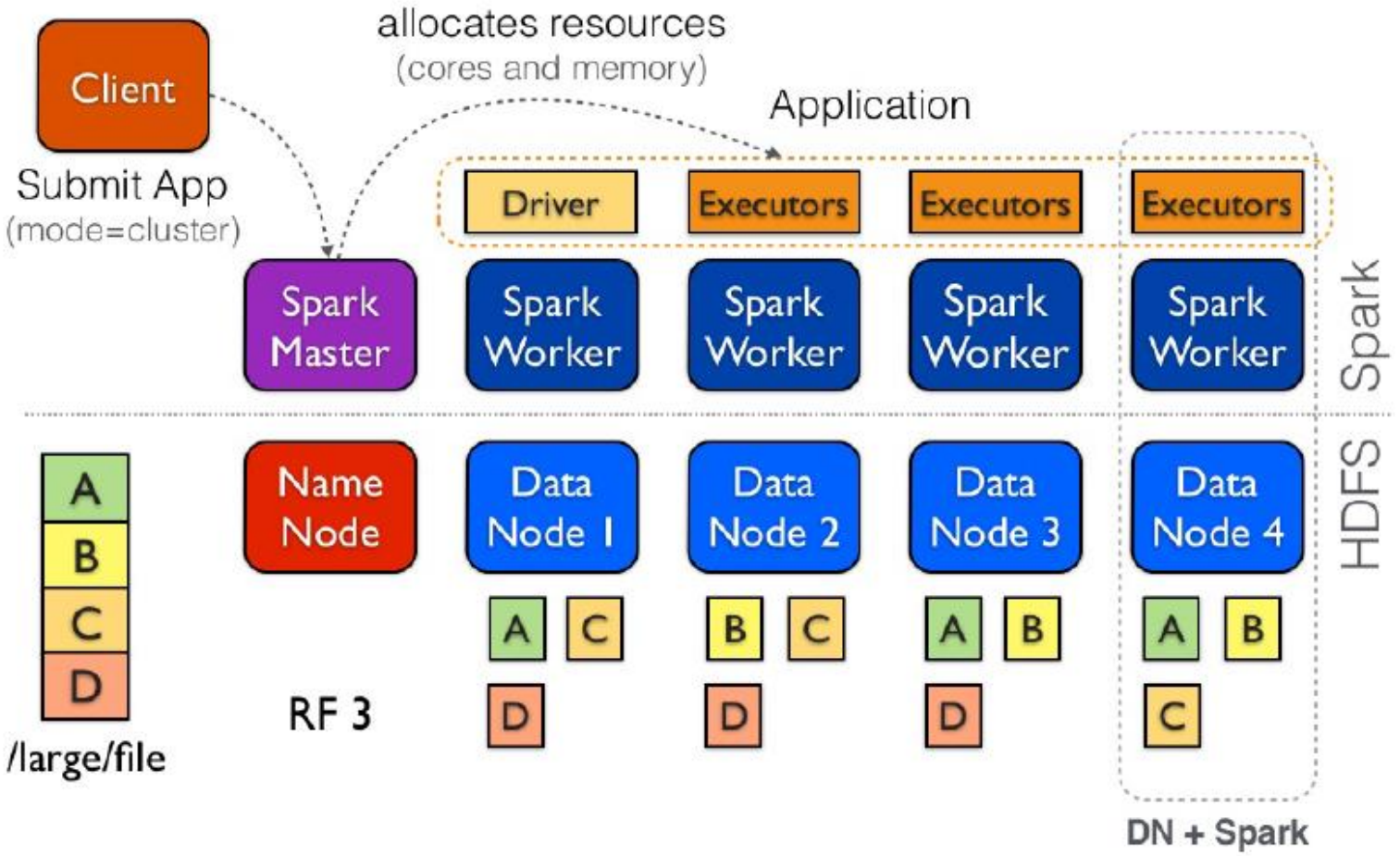
```
acaldero@h1:~$ ./spark/bin/spark-shell --master spark://master1:7077
Using Spark's default log4j profile: org/apache/spark/log4j-defaults.properties
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel).
16/11/27 23:13:55 WARN NativeCodeLoader: Unable to load native-hadoop library for your platform...

…
scala> exit
```

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

Spark: cluster privado

Prerequisitos **Instalación** Uso básico



https://trongkhoanguyenblog.wordpress.com/2014/11/23/a-gentle-introduction-to-apache-spark/

Contenidos

- Introducción
- *Hand-on*
  - Pre-requisitos e instalación
  - Nodo autónomo
  - Cluster
- ***Benchmarking***

Benchmarking

- HiBench
  - https://github.com/intel-hadoop/HiBench
- Spark-perf
  - https://github.com/databricks/spark-perf

http://01org.github.io/sparkscore/about.html

Benchmarking

- TeraSort
  - Elevada entrada y salida, y comunicación intermedia
- WordCount, PageRank
  - Contar referencias de palabras, enlaces, etc.

- SQL
  - Scan, Join, Aggregate
  - …
- Machine Learning
  - Bayesian Classification
  - K-means clustering
  - …

https://www.oreilly.com/ideas/investigating-sparks-performance

TeraSort (2014)

	Hadoop World Record	Spark 100 TB	Spark 1 PB
Data Size	102.5 TB	100 TB	1000 TB
Elapsed Time	72 mins	23 mins	234 mins
# Nodes	2100	206	190
# Cores	50400	6592	6080
# Reducers	10,000	29,000	250,000
Rate	1.42 TB/min	4.27 TB/min	4.27 TB/min
Rate/node	0.67 GB/min	20.7 GB/min	22.5 GB/min
Sort Benchmark Daytona Rules	Yes	Yes	No
Environment	dedicated data center	EC2 (i2.8xlarge)	EC2 (i2.8xlarge)

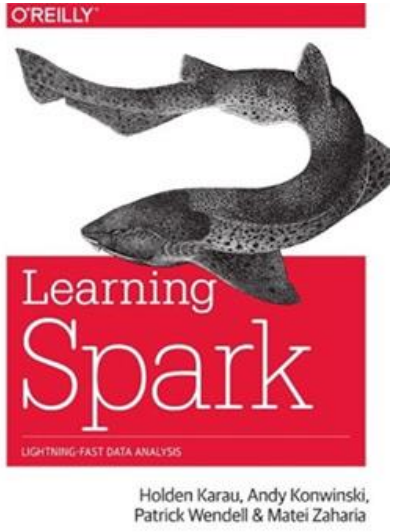
https://databricks.com/blog/2014/10/10/spark-petabyte-sort.html

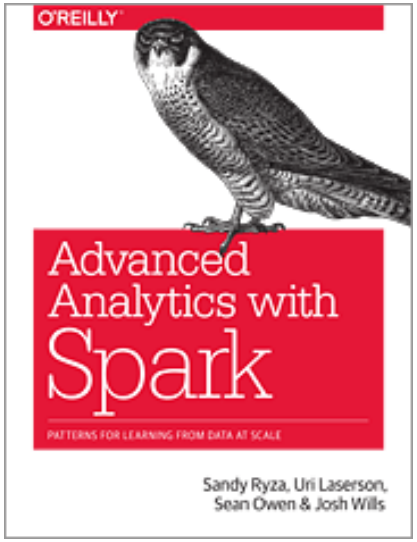
Bibliografía: tutoriales

- Página Web oficial:
  - http://spark.apache.org/
- Introducción a cómo funciona Spark:
  - http://spark.apache.org/docs/latest/quick-start.html
- Tutorial de cómo instalar y usar Spark:
  - http://spark.apache.org/docs/latest/index.html
  - http://spark.apache.org/docs/latest/configuration.html

Bibliografía: libro

- Learning Spark, Advanced Analytics with Spark:
  - http://shop.oreilly.com/product/0636920028512.do
  - http://shop.oreilly.com/product/0636920035091.do





https://github.com/databricks/learning-spark

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- Por último pero no por ello menos importante, agradecer al personal del Laboratorio del Departamento de Informática todos los comentarios y sugerencias para esta presentación.

Sistemas Paralelos y Distribuidos

Máster en Ciencia y Tecnología Informática

Diseño de Sistemas Distribuidos

Máster en Ingeniería Informática

Curso 2021-2022

Sistemas escalables en entornos distribuidos. Introducción a Spark

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