CS 696 Intro to Big Data: Tools and Methods
Fall Semester, 2020
Doc 19 Spark on AWS
Mar 24, 2020

Virus infection Simulation

Assumptions

Infect 10% of people you meet

Contact 20 people per day

New Cases Each Day

0% Immune	50% Immune	80% Immune
1	1	1
2	1	0
6	2	1
18	4	1
54	8	1
162	16	2
486	32	2
1,458	64	3
4,374	128	4
13,122	256	6
39,366	512	8
118,098	1,024	12
354,294	2,048	16

Assumptions

Infect 10% of people you meet

0% Immune

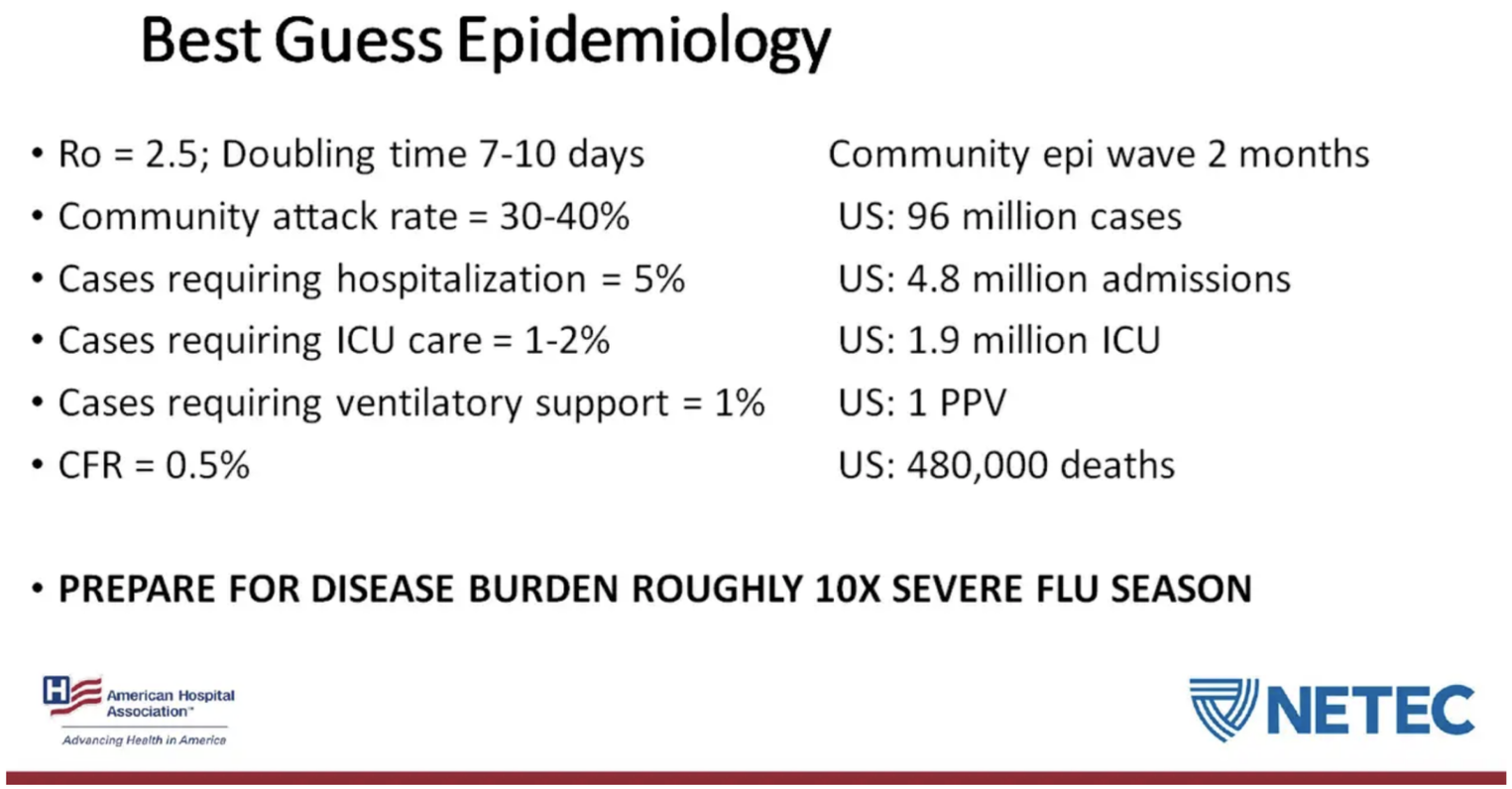
New Cases Each Day

Contact 5 People	Contact 10 People	Contact 20 People	Contact 25 People
1	1	1	1
1	1	2	3
1	2	6	9
1	4	18	31
2	8	54	107
3	16	162	375
4	32	486	1,313
6	64	1,458	4,596
9	128	4,374	16,085
13	256	13,122	56,297
19	512	39,366	197,039
29	1,024	118,098	689,637
43	2,048	354,294	2,413,729

https://medium.com/@tomaspueyo/coronavirus-act-today-or-people-will-die-f4d3d9cd99ca

https://tinyurl.com/w49ms3s

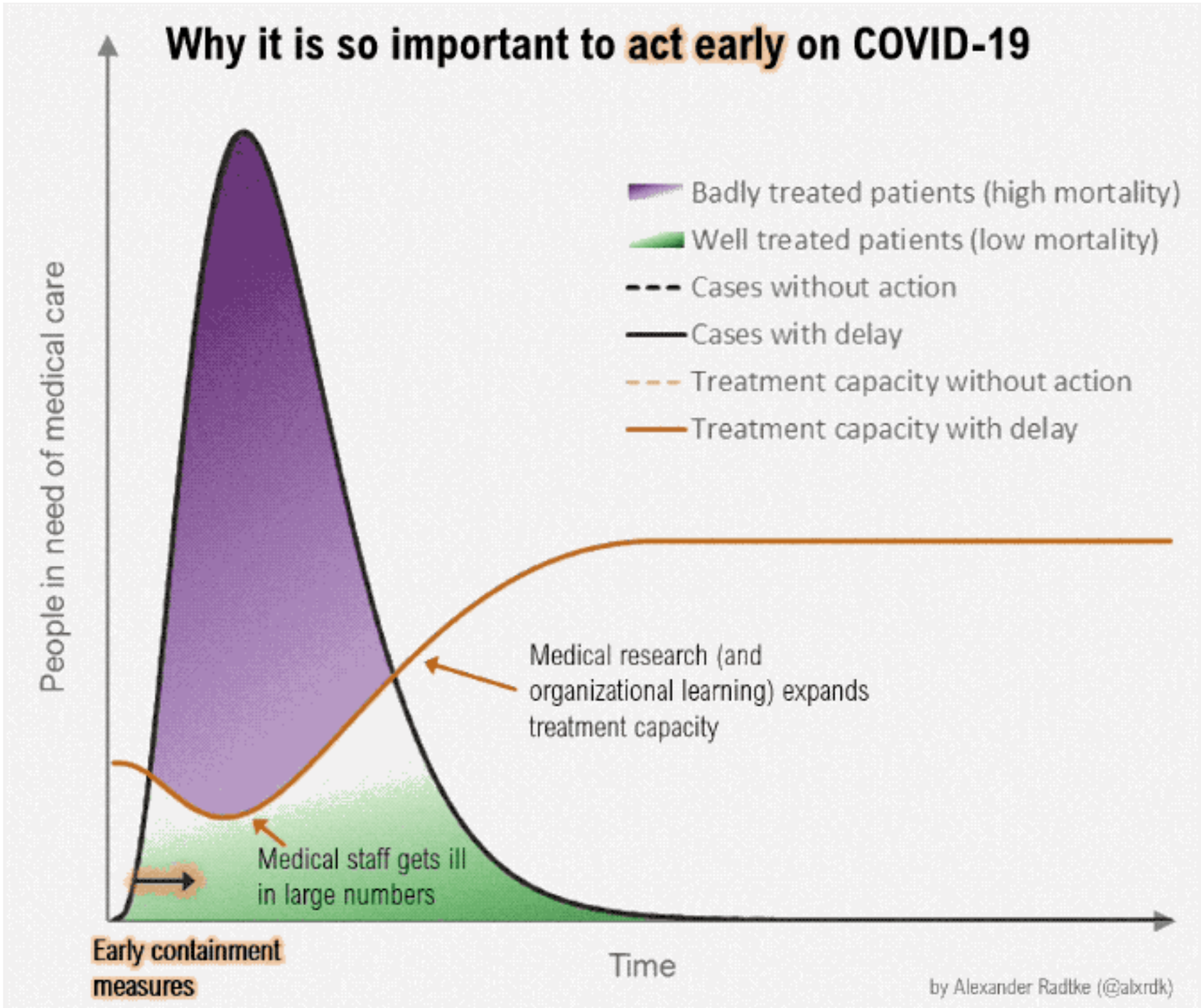
Chart 18: Slide from a Webinar of the American Hospital Association, communicating best guesses on the impact of the Coronavirus in the US healthcare system in 2020



AHA webinar

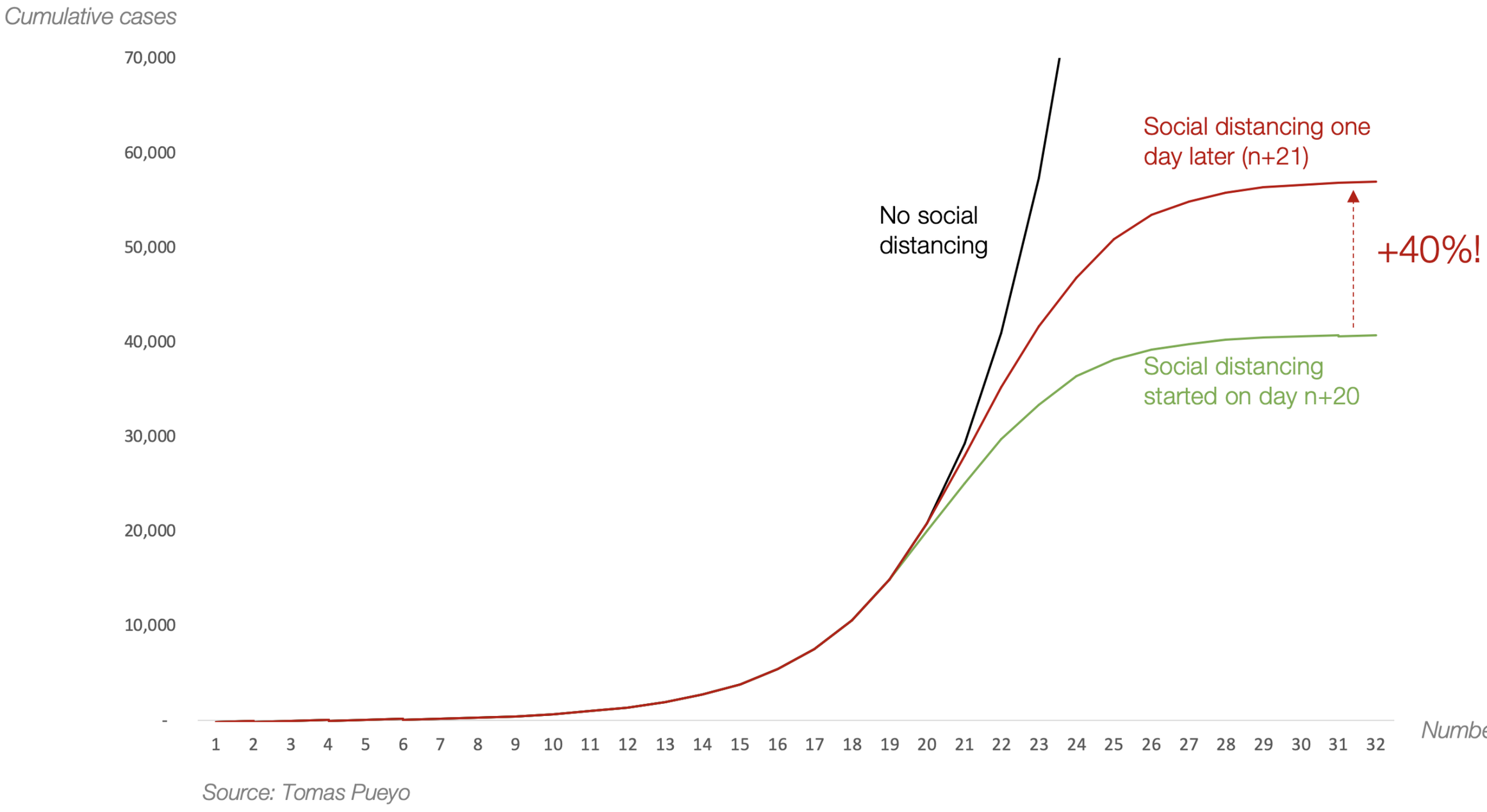
Source: *Dr. James Lawler, professor at the University of Nebraska Medical Center, for the American Hospital Association, via Business Insider, https://www.businessinsider.com/presentation-us-hospitals-preparing-for-millions-of-hospitalizations-2020-3*

https://tinyurl.com/w49ms3s



https://tinyurl.com/w49ms3s

Chart 23: Model of Cumulative Cases of Coronavirus with Social Distancing Measures Taken One Day Apart



Source: Tomas Pueyo

Why We Sleep

By Mathew Walker

Professor of neuroscience and psychology

Director of the Center for Human Sleep Science at the University of California, Berkeley

Effect of lack of sleep

Immune system

Learning

Amazon Elastic Map-Reduce (EMR)

Hadoop, Hive, Spark, etc on Cluster

Predefined set of languages/tools available

Can create cluster of machines

https://aws.amazon.com

- Create new account
- Get 12 months free access

AWS Free Tier

I and students were charged last year

12 months free

EC2 - compute instances
- 740 hours per month
- Billed in hour increments
- Billed per instance

S3 - storage
- 5 GB
- 20,000 Get requests

RDS - MySQL, PostgresSQL, SQL Sever
- 20 GB
- 750 hours

EC2 Container - Docker images
- 500 MB

AWS Educate

https://aws.amazon.com/education/awseducate/

SDSU is an institutional member

Students get $100 credit

EC2 Pricing

	Price Per Hour	
	On Demand	Spot
a1.medium	$0.0255	$0.0050
t3.nano	$0.0058	$0.0016
m5.large	$0.0960	$0.0202
c5.large	$0.0850	$0.0200
p3.2xlarge (GPU)	$3.0600	$0.9413

Basic Outline

Develop & test Spark locally

Upload program file & data to S3

Configure & launch cluster
- AWS Management Console
- AWS CLI
- SDKs

Monitor cluster

Make sure you terminate cluster when done

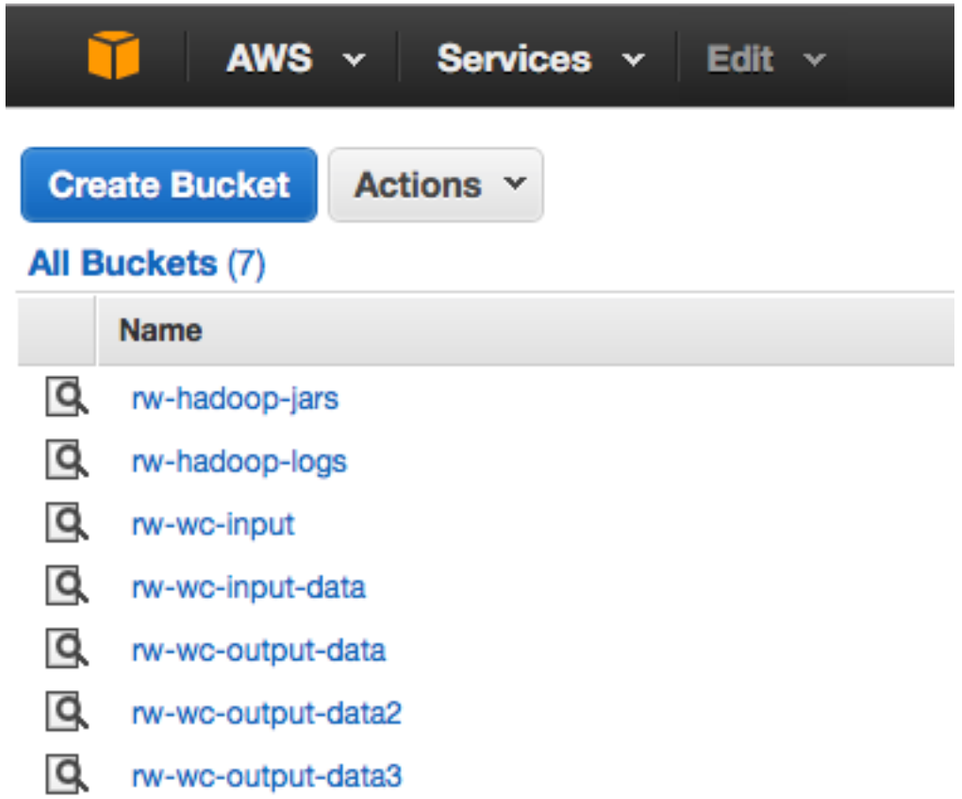
Simple Storage System - S3

Files are stored in buckets

Bucket names are global

Supports
- s3 - files divided in to block
- s3n

Accessing files
- S3 console
- Third party
- REST
- Java, C#, etc



Amazon S3

Amazon S3

Discover the new console Quick tips

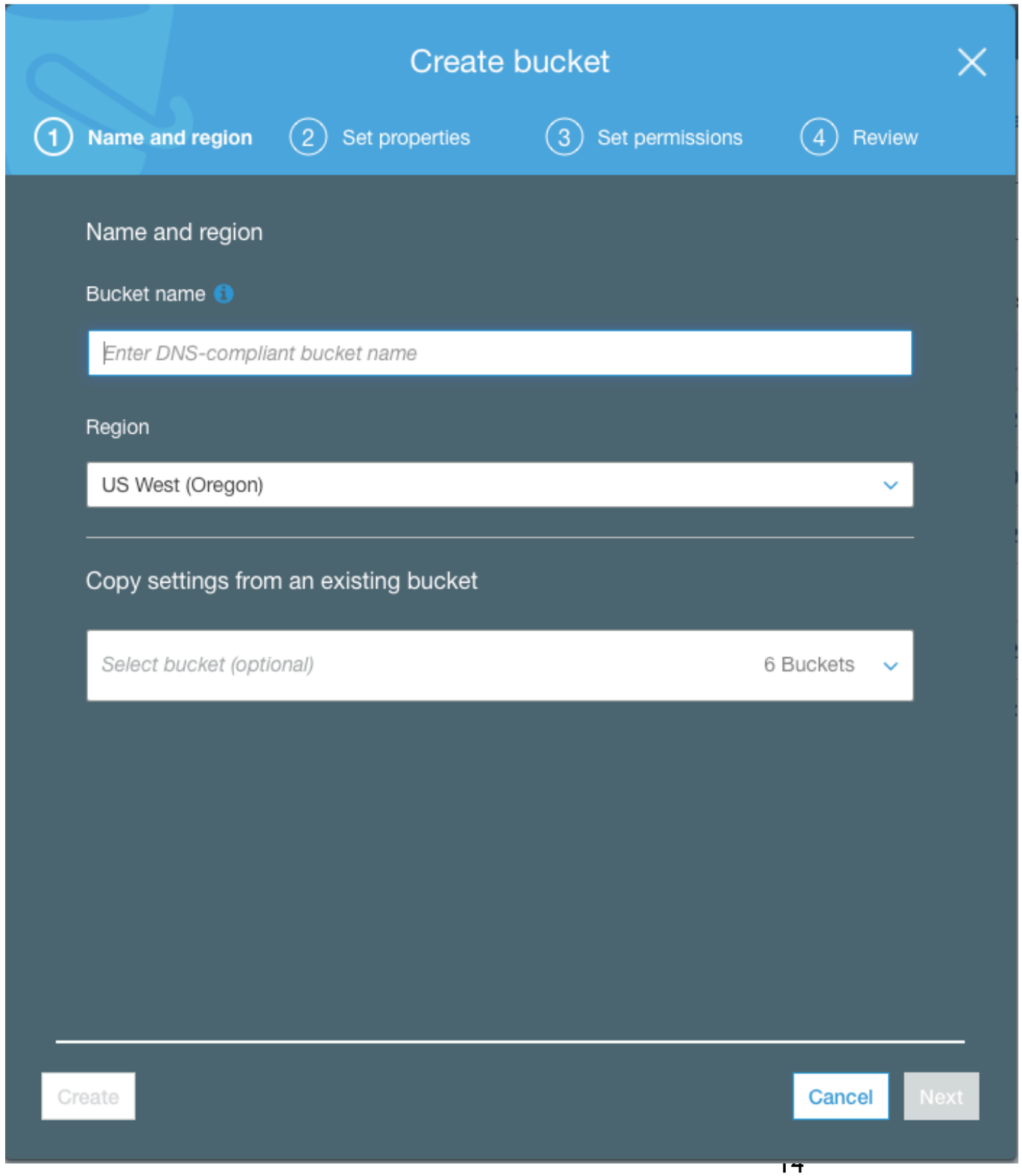
Search for buckets

+ Create bucket | Delete bucket | Empty bucket

6 Buckets 1 Regions

Bucket name	Region	Date created
aws-logs-834365227482-us-west-2	US West (Oregon)	Dec 8, 2016 3:27:27 PM
rw-hadoop-jars	US West (Oregon)	Nov 7, 2016 6:39:03 PM
rw-hadoop-logs	US West (Oregon)	Nov 7, 2016 6:51:29 PM
rw-output-data	US West (Oregon)	Nov 5, 2017 7:29:12 PM
rw-wc-input-data	US West (Oregon)	Nov 7, 2016 6:32:22 PM
rw-wc-output-data	US West (Oregon)	Nov 16, 2016 8:35:53 PM

S3 Creating a Bucket



S3 Costs

AWS Free Usage Tier

New AWS customers receive each month for one year
- 5 GB of Amazon S3 storage in the Standard Storage class,
- 20,000 Get Requests,
- 2,000 Put Requests, and
- 15 GB of data transfer out

	Standard Storage	Standard - Infrequent Access Storage	Glacier Storage
First 50 TB / month	$0.023 per GB	$0.0125 per GB	$0.004 per GB
Next 450 TB / month	$0.022 per GB	$0.0125 per GB	$0.004 per GB
Over 500 TB / month	$0.021 per GB	$0.0125 per GB	$0.004 per GB

S3 Objects

Objects contain
- Object data
- Metadata

Size
- 1 byte to 5 gigabytes per object

Object data
- Just bytes
- No meaning associated with bytes

Metadata
- Name-value pairs to describe the object
- Some http headers used
  - Content-Type

S3 Buckets

Namespace for objects

No limitation on number of object per bucket

Only 100 buckets per account

Each bucket has a name

Up to 255 bytes long

Cannot be same as existing bucket name by any S3 user

Bucket Names

Bucket names must

- Contain lowercase letters, numbers, periods (.), underscores (_), and dashes (-)
- Start with a number or letter
- Be between 3 and 255 characters long
- Not be in an IP address style (e.g., "192.168.5.4")

To conform with DNS requirements, Amazon recommends

- Bucket names should not contain underscores (_)
- Bucket names should be between 3 and 63 characters long
- Bucket names should not end with a dash
- Bucket names cannot contain dashes next to periods (e.g., "my-.bucket.com" and "my.-bucket" are invalid

Key

Unique identifier for an object within a bucket

Object Url

http://buckerName.s3.amazonaws.com/Key

http://doc.s3.amazonaws.com/2006-03-01/AmazonS3.wsdl

Bucket = doc

Key = 2006-03-01/AmazonS3.wsdl

Access Control Lists (ACL)

Each Bucket has an ACL
  Determines who has read/write access

Each Object can have an ACL
  Determines who has read/write access

ACL consists of a list of grants

Grant contains
  One grantee
  One permission

S3 Data Consistency Model

Updates to a single object at a key in a bucket are atomic

But a read after a write may return the old value
  Changes may take time to progate

No object locking
  If two writes to same object occur at the same time
  The one with later timestamp wins

CAP Theorem

CAP theorem says in a distributed system you can not have all three

- Consistency
- Availability
- Tolerance to network Partitions

Consistency

	Machine 1	Machine 2
	A = 2	A = 2
Not Consistent	A = 2	A = 3

Partition

Machine 1

A = 2

Machine 2

A = 2

Partitioned

Machine 1 cannot

talk to machine 2

A = 2

A = 2

But how does machine 1 tell the difference between no connection and a very slow connection or busy machine 2?

Latency

Latency

Time between making a request and getting a response

Distributed systems always have latency

In practice detect a partition by latency

When no response in a given time frame assume we are partitioned

Available

	Machine 1	Machine 2	
Client	A = 2	A = 2	
Client	A = 2	A = 2	Client can not access value of A

What does not available mean?

- No connection
- Slow connection
- What is the difference?

Some say high available - meaning low latency

In practice available and latency are related

Consistency over Latency

Machine 1 Machine 2

Set A to 3 A = 2 A = 2

Set A to 3 A = 2 Lock A A = 2

Write requests queued until unlocked

Set A to 3 A = 2 Set A to 3 A = 2

Increased latency
System still available

Set A to 3 A = 3 Unlock A A = 3

A = 3 A = 3

Latency over Consistency

Machine 1

Machine 2

Set A to 3

A = 2

A = 2

A = 3

A = 2

Write requests accepted

Set A to 3

Low latency

System inconsistent

A = 3

A = 2

A = 3

A = 3

Latency over Consistency - Write Conflicts

Machine 1

Machine 2

Set A to 3

A = 2

A = 2

Subtract 1 from A

A = 3

A = 2

Set A to 3

A = 3

A = 1

Subtract 1 from A

A = ?

A = ?

Need policy to make system consistent

Partition

Machine 1	Machine 2
A = 2	A = 2
A = 2	A = 2
Set A to 3	Subtract 1 from A
A = 3	A = 1
A = ?	A = ?

Need policy to make system consistent

CAP Theorem

Not a theorem

Too simplistic
- What is availability
- What is a partition of the network

Misleading

Intent of CAP was to focus designers attention on the tradeoffs in distributed systems

- How to handle partitions in the network
- Consistency
- Latency
- Availability

CAP & S3

S3 favors latency over consistency

Running Program on AWS EMR

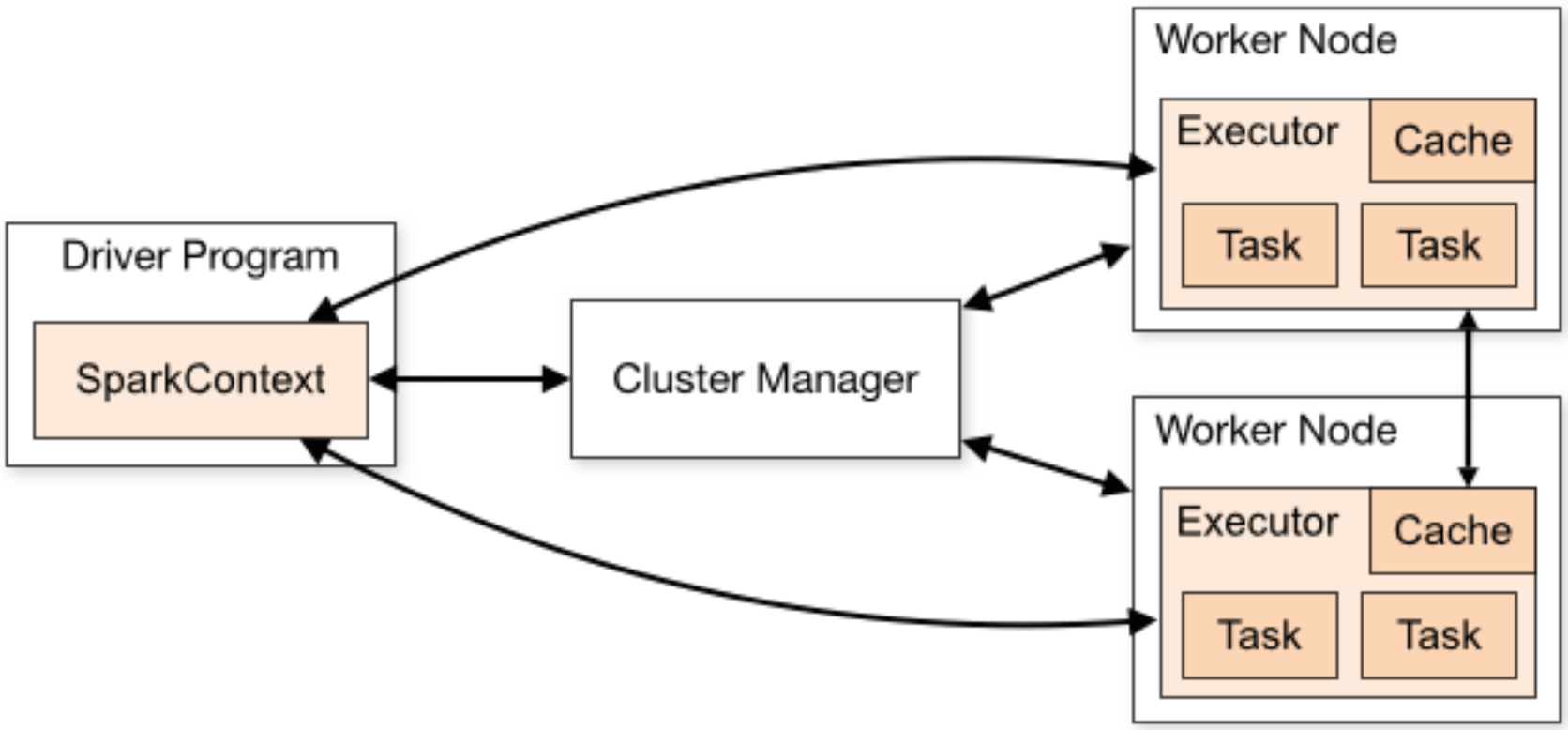
Make sure program runs locally

Create program file containing code

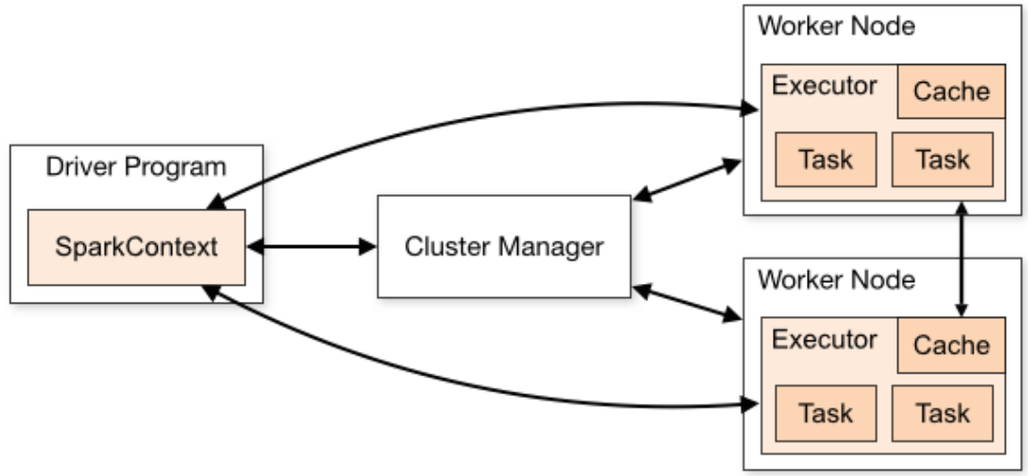
Create s3 bucket(s) for
- program file file
- logs
- input
- output

Upload program & data files to s3

Spark Components



Terms



Application

User program built on Spark

Driver program + executors

Driver program

The process running the main() function of the application and creating the SparkContext

Cluster manager

External service for acquiring resources on the cluster

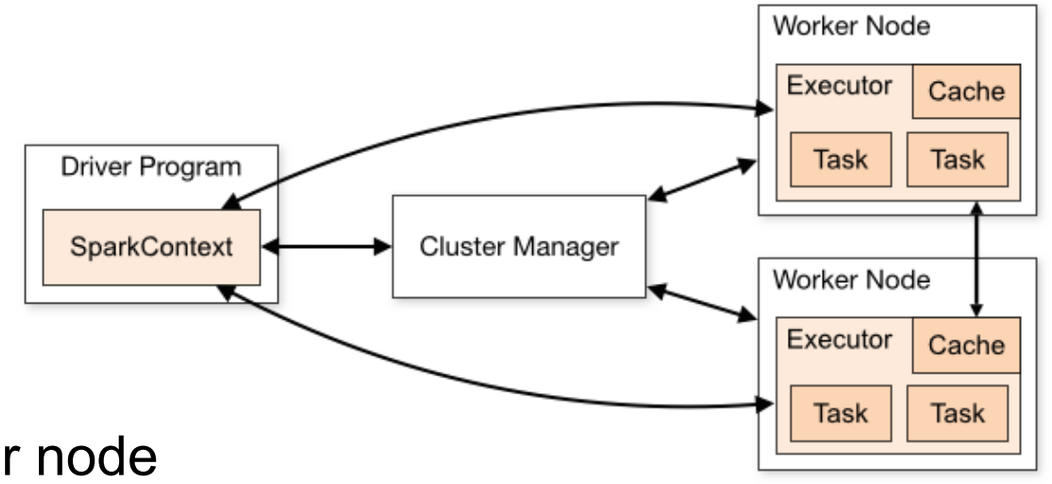
Deploy mode

Where the driver process runs

"cluster" - the driver inside of the cluster

"client" - the driver outside of the cluster

Terms



Executor

A process launched for an application on a worker node

Runs tasks and keeps data in memory or disk storage across them.

Each application has its own executors

Task

A unit of work that will be sent to one executor

Job

A parallel computation consisting of multiple tasks

Gets spawned in response to a Spark action (e.g. save, collect)

Stage

Job divided into smaller tasks called stages

Depend on each other

Test Program 1 - Pi

Designed to have no
- Command line dependancies
- No input or output files

```
from random import random
from operator import add

from pyspark import SparkContext

if __name__ == "__main__":
    sc = SparkContext(appName="PythonPi")
    partitions =  3
    n = 100000 * partitions

    def f(_):
        x = random() * 2 - 1
        y = random() * 2 - 1
        return 1 if x ** 2 + y ** 2 < 1 else 0

    count = sc.parallelize(range(1, n + 1), partitions).map(f).reduce(add)
    print("Pi is roughly %f" % (4.0 * count / n))

    sc.stop()
```

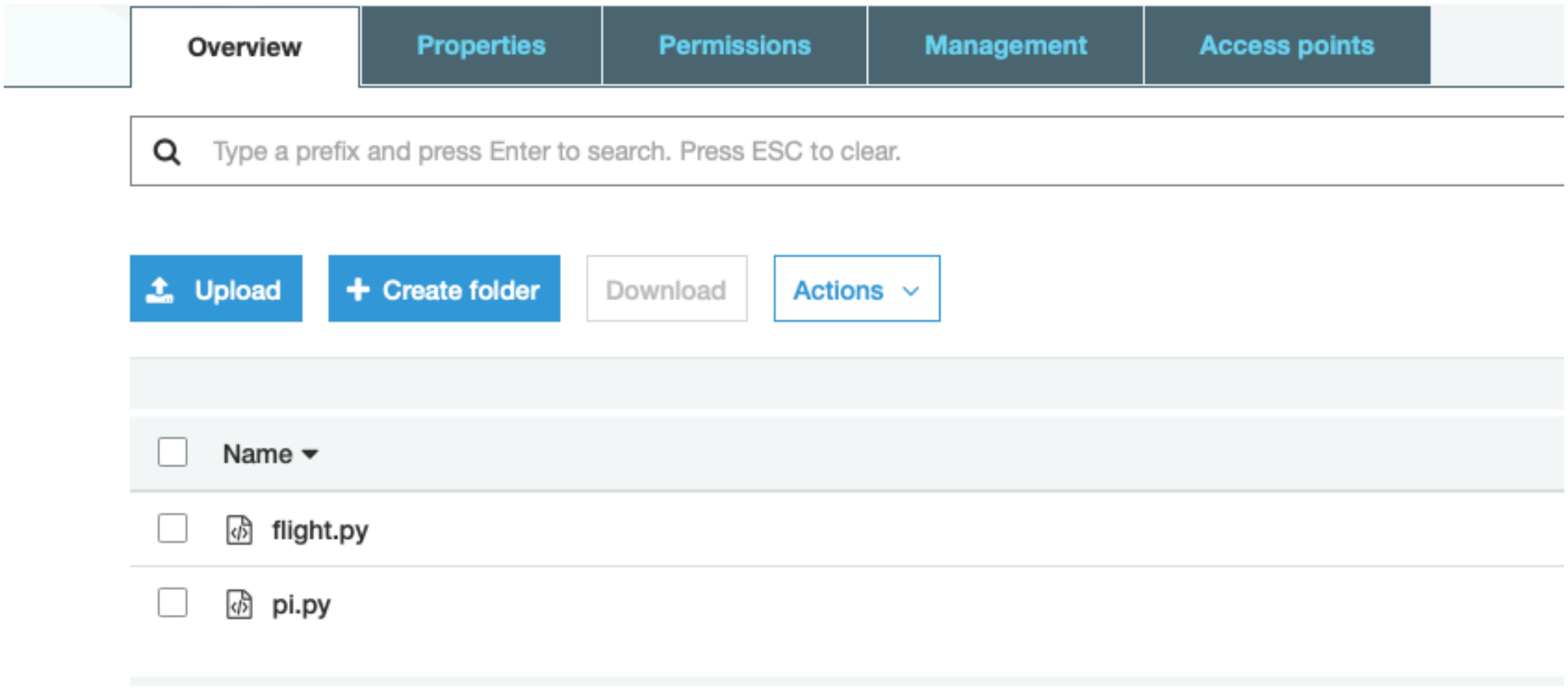
My S3 Buckets

Buckets (9)

Find bucket by name

Name	Region
aws-emr-resources-834365227482-us-west-2	US West (Oregon) us-west-2
aws-logs-834365227482-us-west-2	US West (Oregon) us-west-2
rw-696-flight	US West (Oregon) us-west-2
rw-cs696-data	US West (Oregon) us-west-2
rw-hadoop-jars	US West (Oregon) us-west-2
rw-hadoop-logs	US West (Oregon) us-west-2
rw-output-data	US West (Oregon) us-west-2
rw-ws-input-data	US West (Oregon) us-west-2

My S3 Buckets



My S3 Buckets

pi.py Latest version

Overview | Properties | Permissions | Select from

Open | Download | Download as | Make public | Copy path

Owner
rwhitney

Last modified
Mar 27, 2019 8:58:15 PM GMT-0700

Etag
2a37d19cc32e1a51c0472473e26f72d1

Storage class
Standard

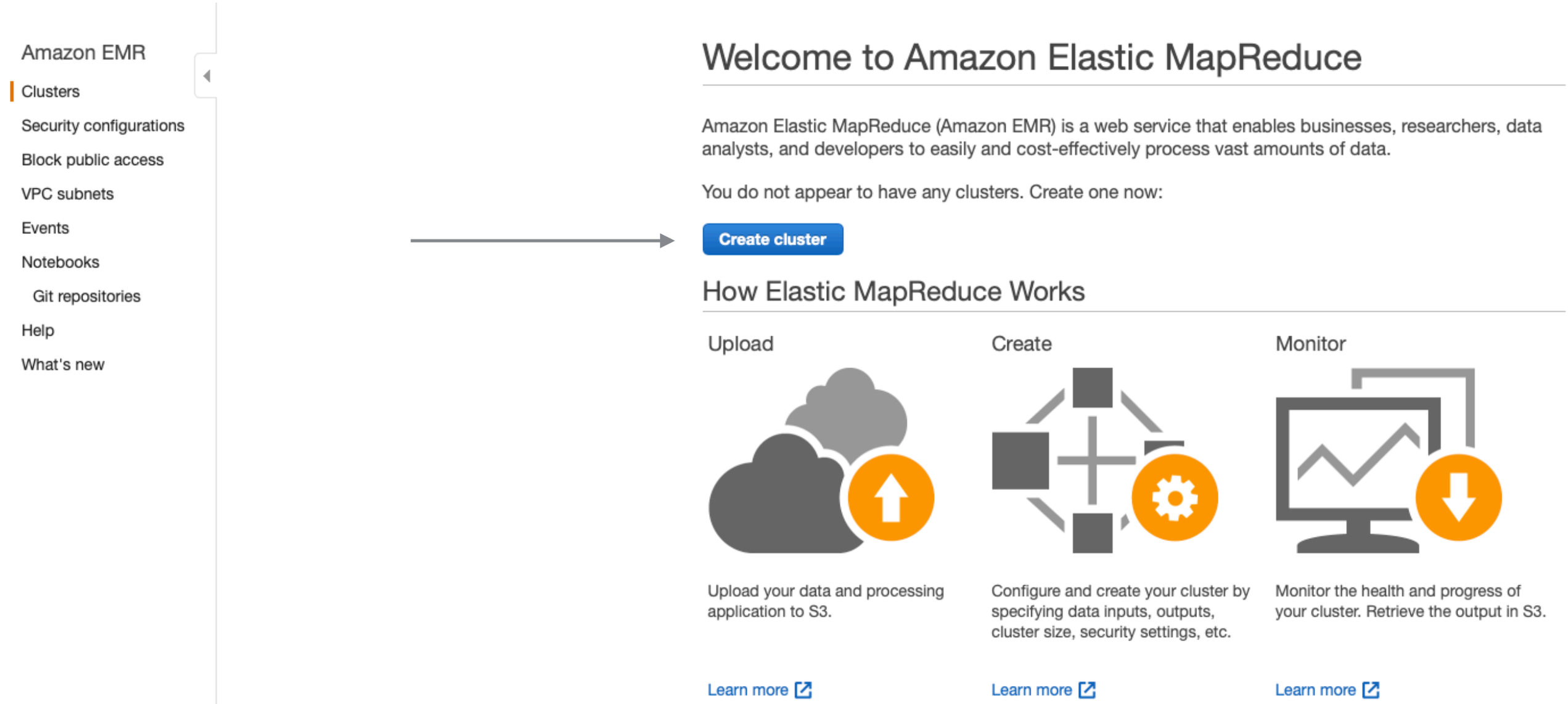
Server-side encryption
None

Size
498.0 B

Key
pi.py

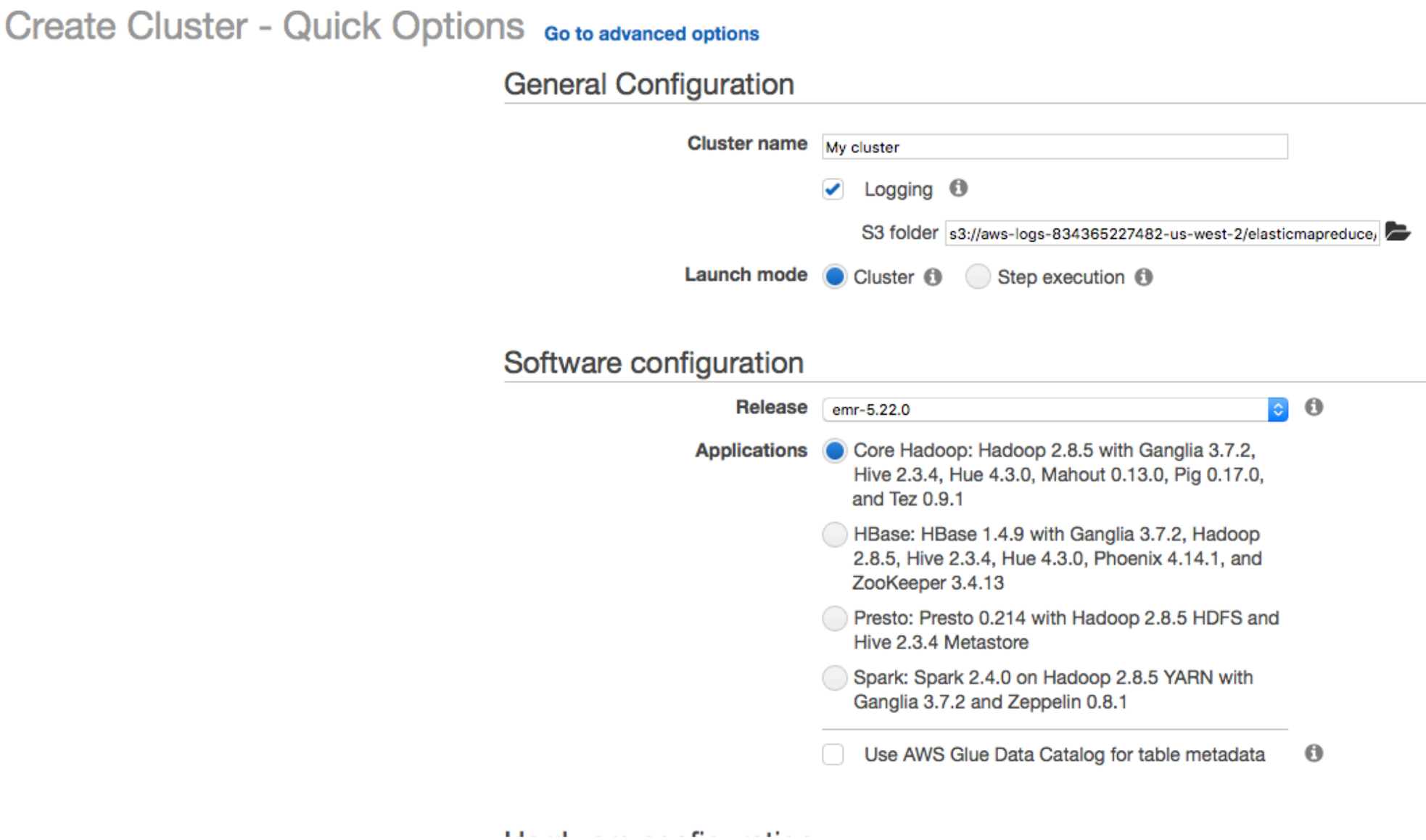
Object URL
https://rw-696-flight.s3-us-west-2.amazonaws.com/pi.py

Spark on AWS - EMR Console



Using Quick Options

Use Advanced Options



Advanced Options

Software Configuration

Release emr-5.29.0

☑ Hadoop 2.8.5	☐ Zeppelin 0.8.2	☐ Livy 0.6.0
☐ JupyterHub 1.0.0	☐ Tez 0.9.2	☐ Flink 1.9.1
☐ Ganglia 3.7.2	☐ HBase 1.4.10	☐ Pig 0.17.0
☐ Hive 2.3.6	☐ Presto 0.227	☐ ZooKeeper 3.4.14
☐ MXNet 1.5.1	☐ Sqoop 1.4.7	☐ Mahout 0.13.0
☐ Hue 4.4.0	☐ Phoenix 4.14.3	☐ Oozie 5.1.0
☑ Spark 2.4.4	☐ HCatalog 2.3.6	☐ TensorFlow 1.14.0

Multiple master nodes (optional)

☐ Use multiple master nodes to improve cluster availability. Learn more

AWS Glue Data Catalog settings (optional)

☐ Use for Spark table metadata

Edit software settings

◉ Enter configuration ○ Load JSON from S3

classification=config-file-name,properties=[myKey1=myValue1,myKey2=myValue2]

Steps (optional)

A step is a unit of work you submit to the cluster. For instance, a step might contain one or more Hadoop or Spark jobs. You can also submit additional steps to a cluster after it is running. Learn more

Concurrency: ☐ Run multiple steps at the same time to improve cluster utilization

After last step completes: ◉ Clusters enters waiting state

○ Cluster auto-terminates

Step type Spark application **Add step**

Cancel **Next**

Advanced Options

Hardware Configuration

If you need more than 20 EC2 instances, see this topic.

Instance group configuration

- **Uniform instance groups**
  Specify a single instance type and purchasing option for each node type.
- **Instance fleets**
  Specify target capacity and how Amazon EMR fulfills it for each node type. Mix instance types and purchasing options. Learn more

Launch the cluster into a VPC with a public, private, or shared subnet. Subnets may be associated with an AWS Outpost or AWS Local Zone.

Network vpc-9a87d8fe (172.31.0.0/16) (default) Create a VPC

EC2 Subnet subnet-0f55196b | Default in us-west-2a

Root device EBS volume size 10 GiB

Choose the instance type, number of instances, and a purchasing option. You can choose to use On-Demand Instances, Spot Instances, or both. The instance type and purchasing option apply to all EC2 instances in each instance group, and you can only specify these options for an instance group when you create it. Learn more about instance purchasing options

Node type	Instance type	Instance count	Purchasing option
Master Master - 1	**m5.xlarge** 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB Add configuration settings	1 Instances	**On-demand** **Spot** Use on-demand as max price
Core Core - 2	**m5.xlarge** 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB Add configuration settings	2 Instances	**On-demand** **Spot** Use on-demand as max price
Task Task - 3	**m5.xlarge** 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB Add configuration settings	0 Instances	**On-demand** **Spot** Use on-demand as max price

+ Add task instance group

Advanced Options

General Options

Cluster name CourseSlidesExample

Logging

S3 folder s3://aws-logs-834365227482-us-west-2/elastic

Debugging

Termination protection

Tags

Key	Value (optional)	
Add a key to create a tag		

Additional Options

EMRFS consistent view

Custom AMI ID None

▸ Bootstrap Actions

Cancel Previous Next

Advanced Options

Security Options

EC2 key pair Proceed without an EC2 key pair

Cluster visible to all IAM users in account

Permissions

Default Custom

Use default IAM roles. If roles are not present, they will be automatically created for you with managed policies for automatic policy updates.

EMR role EMR_DefaultRole

EC2 instance profile EMR_EC2_DefaultRole

Auto Scaling role EMR_AutoScaling_DefaultRole

▸ Security Configuration

▸ EC2 security groups

No EC2 key pair has been selected, so you will not be able to SSH to this cluster. Learn how to create an EC2 Key Pair.

Cancel Previous Create cluster

Cluster Created - Either Quick or Advanced

Clone | Terminate | AWS CLI export

Cluster: CourseSlidesExample Starting

Summary | Application history | Monitoring | Hardware | Configurations | Events | Steps | Bootstrap actions

Connections: --

Master public DNS: --

History service: --

Tags: -- View All / Edit

Summary

ID: j-173L2X4KKU7HX
Creation date: 2020-03-24 12:05 (UTC-7)
Elapsed time: 30 seconds
After last step completes: Cluster waits
Termination protection: On Change

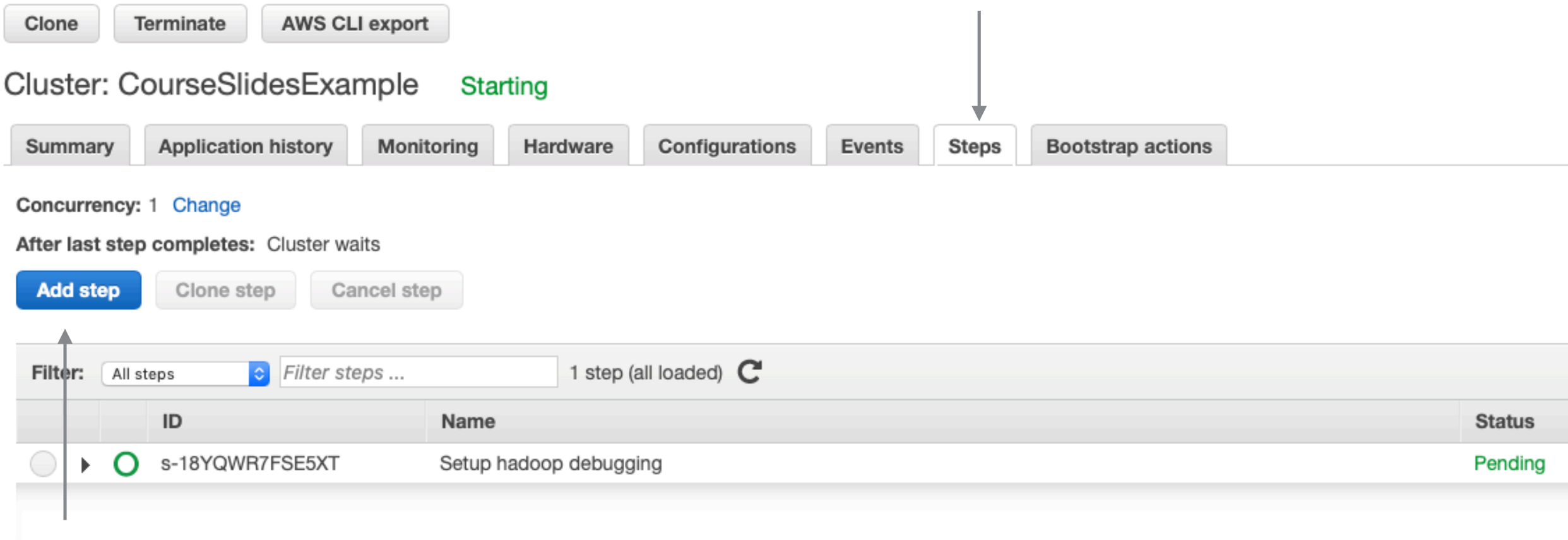
Configuration details

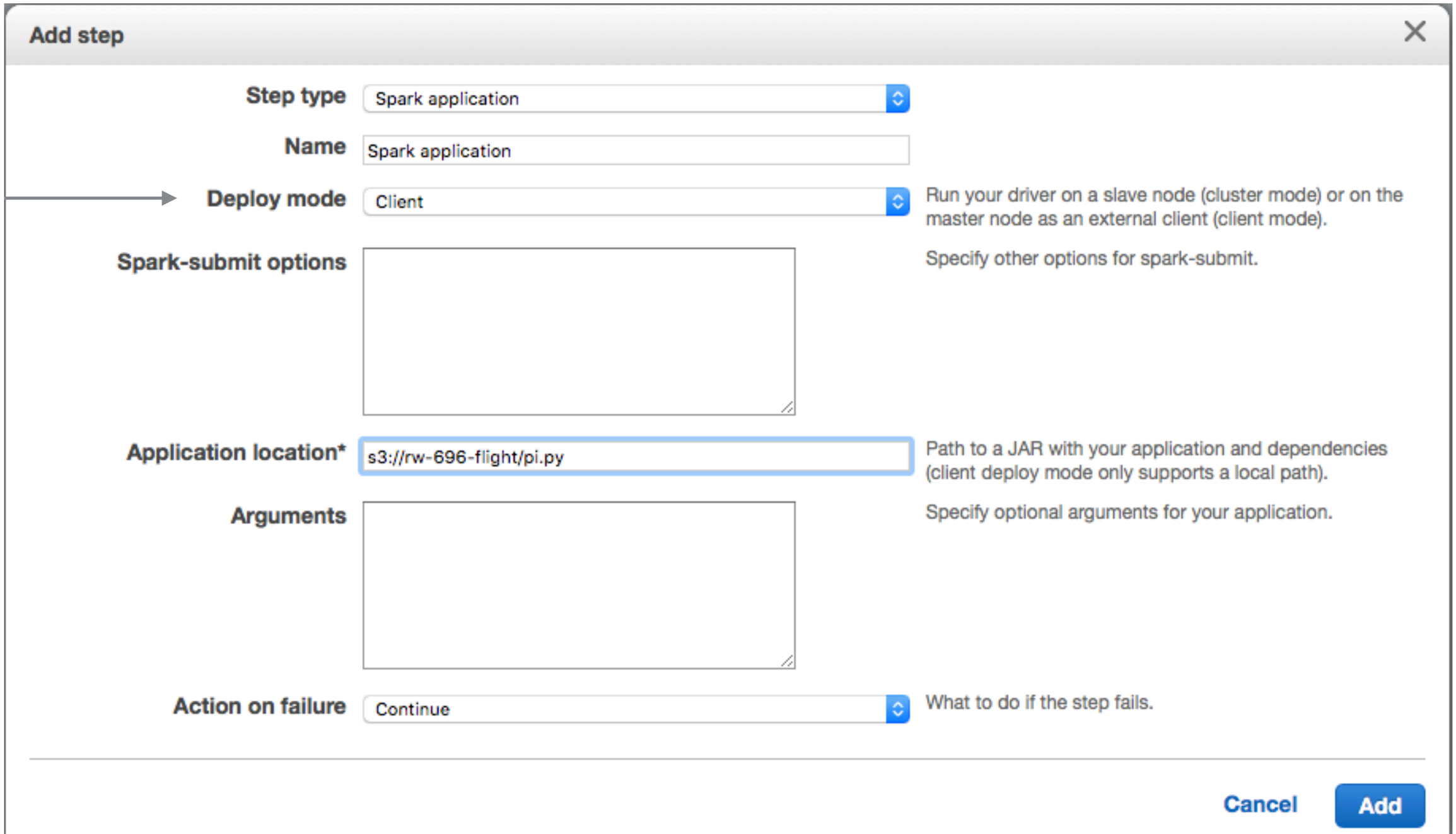
Release label: emr-5.29.0
Hadoop distribution: Amazon 2.8.5
Applications: Spark 2.4.4
Log URI: s3://aws-logs-834365227482-us-west-2/elasticmapreduce/
EMRFS consistent view: Disabled
Custom AMI ID: --

Network and hardware

Availability zone: us-west-2a
Subnet ID: subnet-0f55196b
Master: Provisioning 1 m5.xlarge
Core: Provisioning 2 m5.xlarge
Task: --

Adding a Step





Modes - client or cluster

Either works

client mode gives access to standard out

Clone | Terminate | AWS CLI export

Cluster: CourseSlidesExample Starting Configuring cluster software

Summary | Application history | Monitoring | Hardware | Configurations | Events | Steps | Bootstrap actions

Concurrency: 1 Change

After last step completes: Cluster waits

Add step | Clone step | Cancel step

Filter: All steps | Filter steps ... | 2 steps (all loaded)

	ID	Name	Status	Start time (UTC-7)	Elapsed time	Log files
▸	s-3E10OBDAULFO	Spark application	Pending		--	View logs
▸	s-18YQWR7FSE5XT	Setup hadoop debugging	Pending		--	View logs

Cluster: CourseSlidesExample Waiting Cluster ready after last step completed.

Summary | Application history | Monitoring | Hardware | Configurations | Events | Steps | Bootstrap actions

Concurrency: 1 Change

After last step completes: Cluster waits

Add step | Clone step | Cancel step

Filter: All steps | Filter steps ... | 2 steps (all loaded)

	ID	Name	Status	Start time (UTC-7)	Elapsed time	Log files
○ ▸	s-3E10OBDAULFO	Spark application	Completed	2020-03-24 12:10 (UTC-7)	24 seconds	View logs
○ ▸	s-18YQWR7FSE5XT	Setup hadoop debugging	Completed	2020-03-24 12:09 (UTC-7)	2 seconds	View logs

Concurrency: 1 Change

After last step completes: Cluster waits

Add step | Clone step | Cancel step

View Jobs in the

Filter: All steps | Filter steps ... | 2 steps (all loaded)

	ID	Name	Status	Start time (UTC-7)	Elapsed time	Log files
○ ▸	s-3E10OBDAULFO	Spark application	Completed	2020-03-24 12:10 (UTC-7)	24 seconds	controller | syslog* | stderr | stdout
○ ▸	s-18YQWR7FSE5XT	Setup hadoop debugging	Completed	2020-03-24 12:09 (UTC-7)	2 seconds	View logs

```
Pi is roughly 3.138120
```

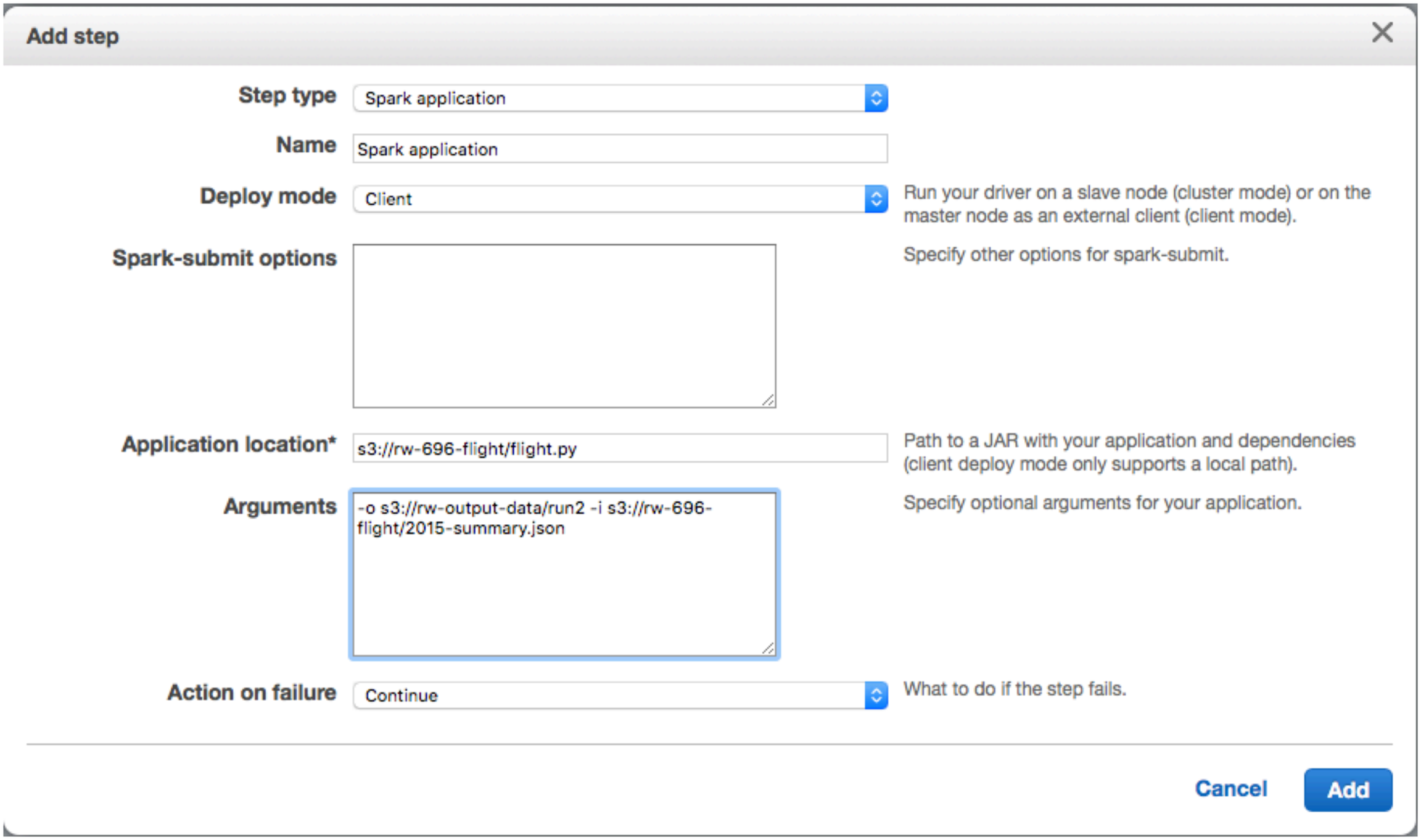
Example 2

```
def flight(input, output):
    import pyspark.sql.functions as F
    from pyspark.sql import SparkSession
    spark = SparkSession.builder \
        .appName("Fight") \
        .getOrCreate()

    flight_df = spark.read.json(input)

    grouped_df = flight_df.groupBy('DEST_COUNTRY_NAME').agg(F.sum('count'))
    grouped_df.write.format('csv').save(output)

def files_from_args():
        import argparse
        parser = argparse.ArgumentParser()
        parser.add_argument('-i', '--input', default='input')
        parser.add_argument('-o', '--output',default='output')
        args = parser.parse_args()
        return (args.input, args.output)

if __name__ == "__main__":
        inputfile, outputfile = files_from_args()
        flight(inputfile, outputfile)
```

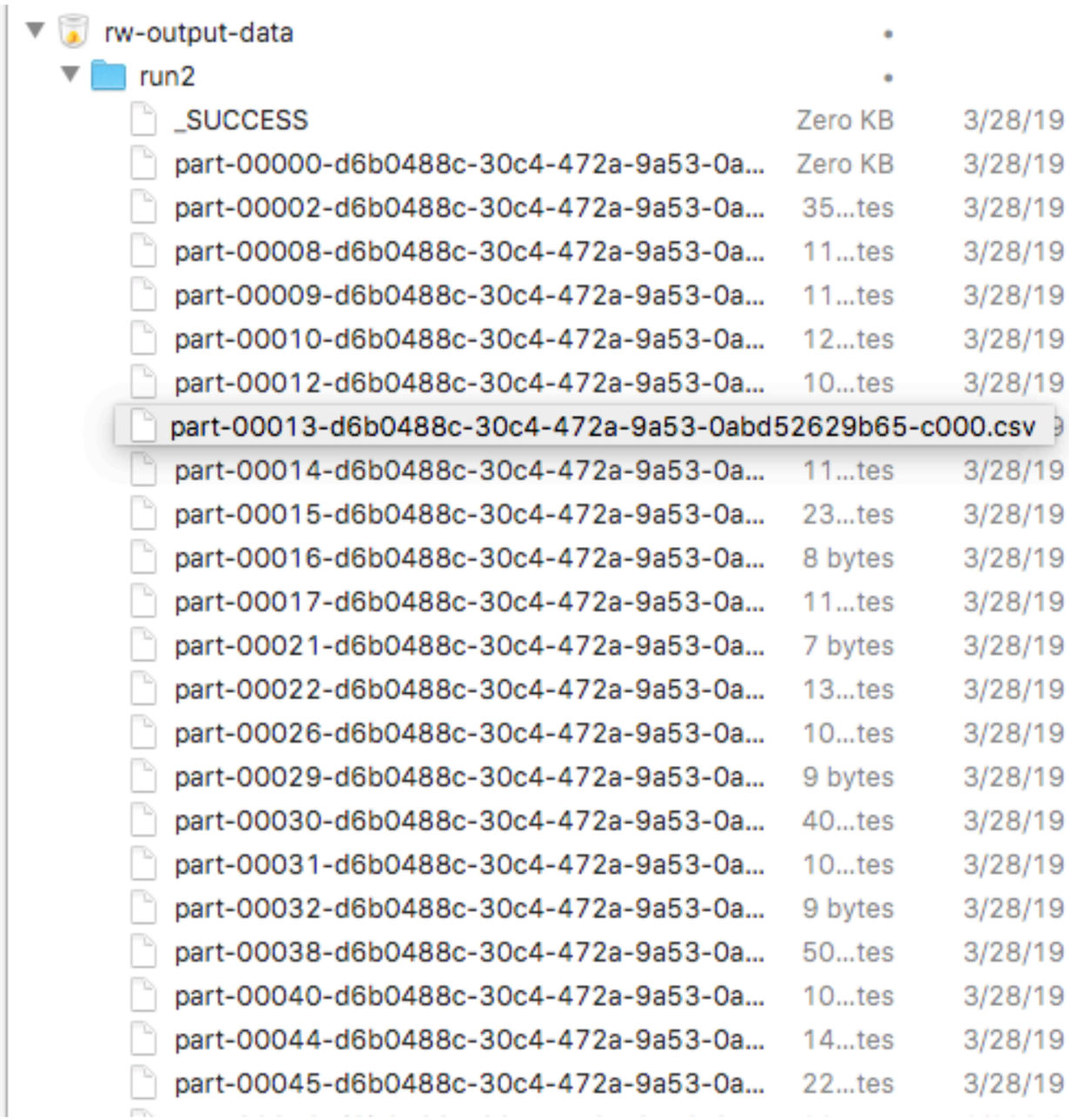
S3 Buckets


aws-emr-resources-834365227482-us-west-2
aws-logs-834365227482-us-west-2
rw-696-flight
2015-summary.json
21 KB
3/26/19
flight.py
2 KB
3/26/19
pi.py
49...tes
3/27/19
rw-cs696-data
rw-hadoop-jars

Added Step


Add step
Step type
Spark application
Name
Spark application
Deploy mode
Client
Run your driver on a slave node (cluster mode) or on the master node as an external client (client mode).
Spark-submit options
Specify other options for spark-submit.
Application location*
s3://rw-696-flight/flight.py
Path to a JAR with your application and dependencies (client deploy mode only supports a local path).
Arguments
-o s3://rw-output-data/run2 -i s3://rw-696-flight/2015-summary.json
Specify optional arguments for your application.
Action on failure
Continue
What to do if the step fails.
Cancel
Add

S3 output


rw-output-data
run2
_SUCCESS Zero KB 3/28/19
part-00000-d6b0488c-30c4-472a-9a53-0a... Zero KB 3/28/19
part-00002-d6b0488c-30c4-472a-9a53-0a... 35...tes 3/28/19
part-00008-d6b0488c-30c4-472a-9a53-0a... 11...tes 3/28/19
part-00009-d6b0488c-30c4-472a-9a53-0a... 11...tes 3/28/19
part-00010-d6b0488c-30c4-472a-9a53-0a... 12...tes 3/28/19
part-00012-d6b0488c-30c4-472a-9a53-0a... 10...tes 3/28/19
part-00013-d6b0488c-30c4-472a-9a53-0abd52629b65-c000.csv
part-00014-d6b0488c-30c4-472a-9a53-0a... 11...tes 3/28/19
part-00015-d6b0488c-30c4-472a-9a53-0a... 23...tes 3/28/19
part-00016-d6b0488c-30c4-472a-9a53-0a... 8 bytes 3/28/19
part-00017-d6b0488c-30c4-472a-9a53-0a... 11...tes 3/28/19
part-00021-d6b0488c-30c4-472a-9a53-0a... 7 bytes 3/28/19
part-00022-d6b0488c-30c4-472a-9a53-0a... 13...tes 3/28/19
part-00026-d6b0488c-30c4-472a-9a53-0a... 10...tes 3/28/19
part-00029-d6b0488c-30c4-472a-9a53-0a... 9 bytes 3/28/19
part-00030-d6b0488c-30c4-472a-9a53-0a... 40...tes 3/28/19
part-00031-d6b0488c-30c4-472a-9a53-0a... 10...tes 3/28/19
part-00032-d6b0488c-30c4-472a-9a53-0a... 9 bytes 3/28/19
part-00038-d6b0488c-30c4-472a-9a53-0a... 50...tes 3/28/19
part-00040-d6b0488c-30c4-472a-9a53-0a... 10...tes 3/28/19
part-00044-d6b0488c-30c4-472a-9a53-0a... 14...tes 3/28/19
part-00045-d6b0488c-30c4-472a-9a53-0a... 22...tes 3/28/19

Warning on AWS

It can take 5-10 minutes to start cluster

Logs do not show your logging statements

When you configure Steps incorrectly they fail
  Error messages are not very helpful

SSH to your Master Node

Create Amazon EC2 Key pair

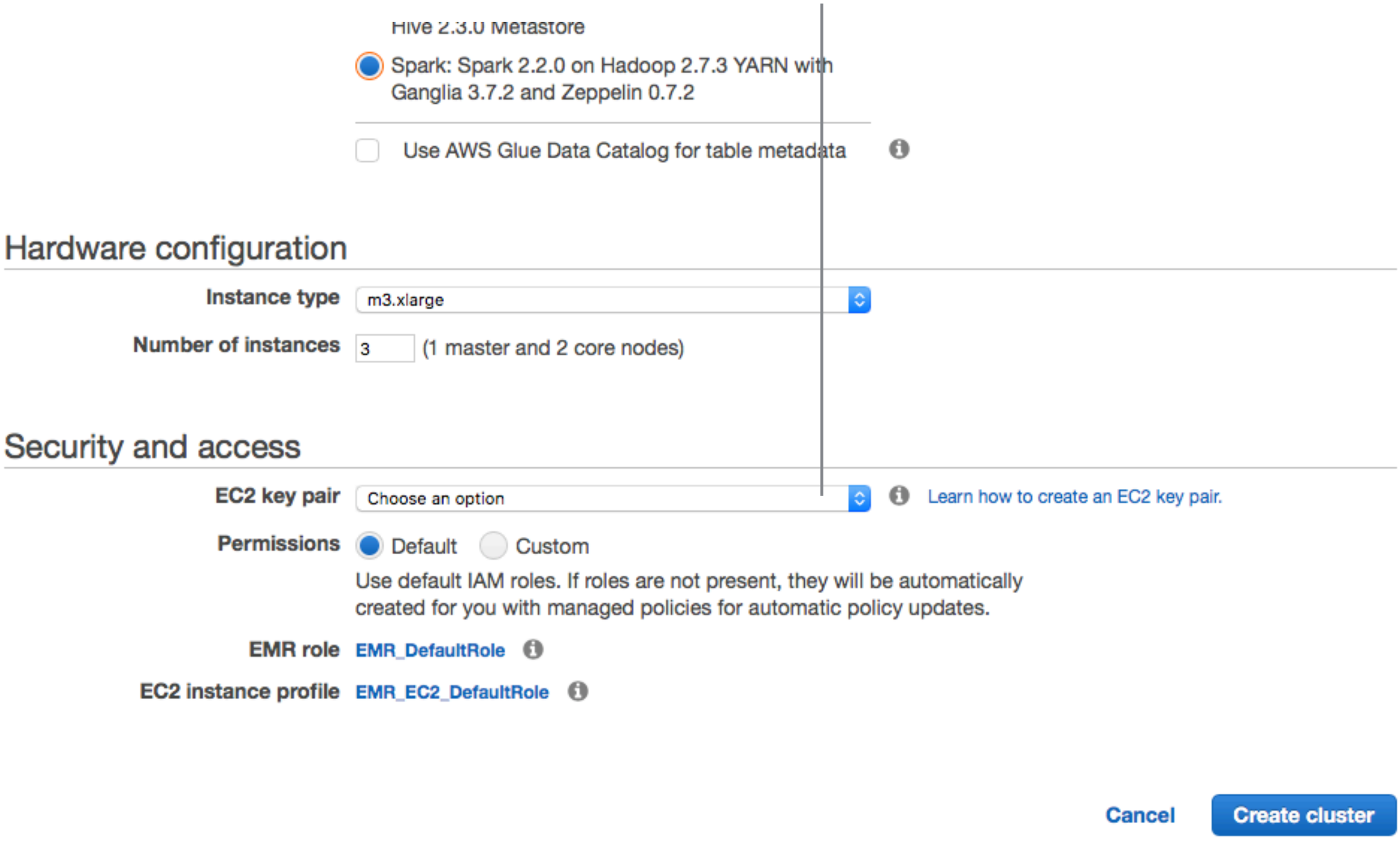
Instructions

http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/ec2-key-pairs.html#having-ec2-create-your-key-pair

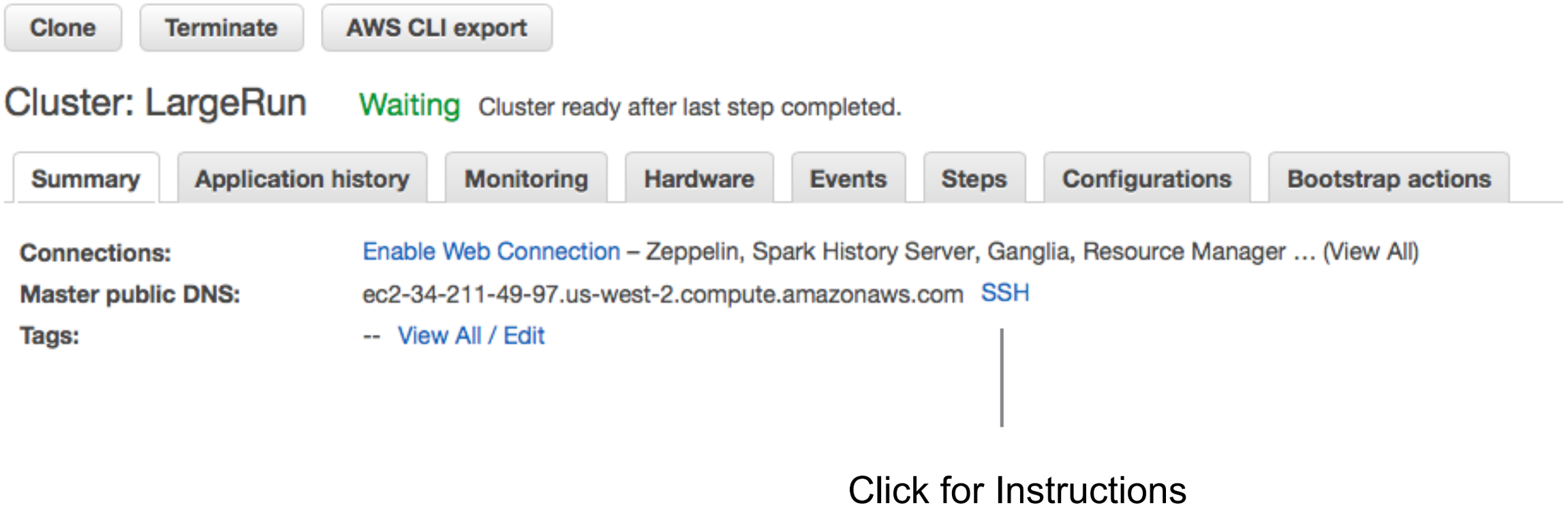
Open EC2 Dashboard - Select Key Pairs

SSH to your Master Node

In Create Cluster - Quick Options



SSH to your Master Node



Click for Instructions

Command-line Tools

Flintrock

Open-source command-line tool for launching Apache Spark clusters

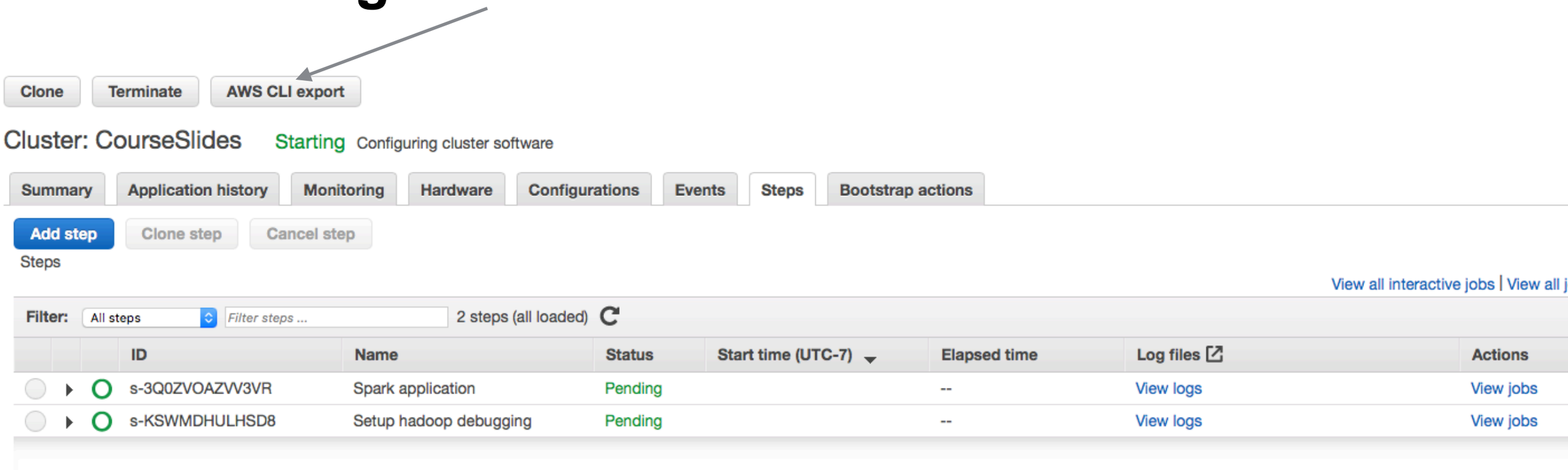
https://github.com/nchammas/flintrock

aws cli

Amazon's command line tool

https://aws.amazon.com/cli/

Generating the Command Line



AWS CLI export

```
aws emr create-cluster --termination-protected --applications Name=Hadoop Name=Spark --ec2-attributes
'{"InstanceProfile":"EMR_EC2_DefaultRole","SubnetId":"subnet-0f55196b","EmrManagedSlaveSecurityGroup":"sg-
65bffa1c","EmrManagedMasterSecurityGroup":"sg-62bffa1b"}' --release-label emr-5.22.0 --log-uri 's3n://aws-
logs-834365227482-us-west-2/elasticmapreduce/' --steps '[{"Args":["spark-submit","--deploy-
mode","client","s3://rw-696-flight/pi.py"],"Type":"CUSTOM_JAR","ActionOnFailure":"CONTINUE","Jar":"command-
runner.jar","Properties":"","Name":"Spark application"}]' --instance-groups
'[{"InstanceCount":1,"InstanceGroupType":"MASTER","InstanceType":"m3.xlarge","Name":"Master - 1"},
{"InstanceCount":2,"InstanceGroupType":"CORE","InstanceType":"m3.xlarge","Name":"Core - 2"}]' --auto-scaling-
role EMR_AutoScaling_DefaultRole --ebs-root-volume-size 10 --service-role EMR_DefaultRole --enable-
debugging --name 'CourseSlides' --scale-down-behavior TERMINATE_AT_TASK_COMPLETION --region us-west-2
```

Hadoop Ecosystem

Hadoop
- HDFS
- MapReduce
- YARN

Tez

Pig

Hive

Hbase

Sqoop

Oozie

Falcon

Spark

ZooKeeper

Mahout

Phoenix

BigTop

+ others

Apache Pig

Programming Map-Reduce can be low level

Apache Pig - high-level platform for creating programs for Hadoop

Pig Latin

```
input_lines = LOAD '/tmp/my-copy-of-all-pages-on-internet' AS (line:chararray);
words = FOREACH input_lines GENERATE FLATTEN(TOKENIZE(line)) AS word;
filtered_words = FILTER words BY word MATCHES '\\w+';
word_groups = GROUP filtered_words BY word;
word_count = FOREACH word_groups GENERATE COUNT(filtered_words) AS
                        count, group AS word;

ordered_word_count = ORDER word_count BY count DESC;
STORE ordered_word_count INTO '/tmp/number-of-words-on-internet';
```

Apache Hive

SQL is common way to interact with data

Hive provides SQL like query language for HDFS, Amazon S3 data

HiveQL - converted into MapReduce

```
DROP TABLE IF EXISTS docs;
CREATE TABLE docs (line STRING);
LOAD DATA INPATH 'input_file' OVERWRITE INTO TABLE docs;
CREATE TABLE word_counts AS
SELECT word, count(1) AS count FROM
 (SELECT explode(split(line, '\s')) AS word FROM docs) temp
GROUP BY word
ORDER BY word;
```

Apache HBase

BigTable for Hadoop

Non-relational distributed database

Fault-tolerant way of storing large quantites of sparse data

Apache Sqoop

People have data in non-hadoop databases

Sqoop

Transferring data between relational databases & Hadoop

Apache Phoenix

But SQL is common

Phoenix

- Massively parallel relational database for Hadoop
- Uses HBase to store data

Apache Spark

Hadoop has latency issues - reads data from disk
MapReduce is not conducive to solving all problems

Spark
- Uses distributed shared memory: Resilient distributed dataset (RDD)
- Iterative algorithms
- Implemented in Scala

Spark Core
Spark SQL
- Dataframes & SQL

Spark Streaming
Spark MLlib
- Machine learning

Apache Mahout

Hadoop does not have machine learning libraries

Mahout

- Environment for quickly creating scalable machine learning applications
- Samsara - R-line syntax & environment

Apache Flink, Apache Storm

Hadoop does batch jobs

Spark streaming has delays

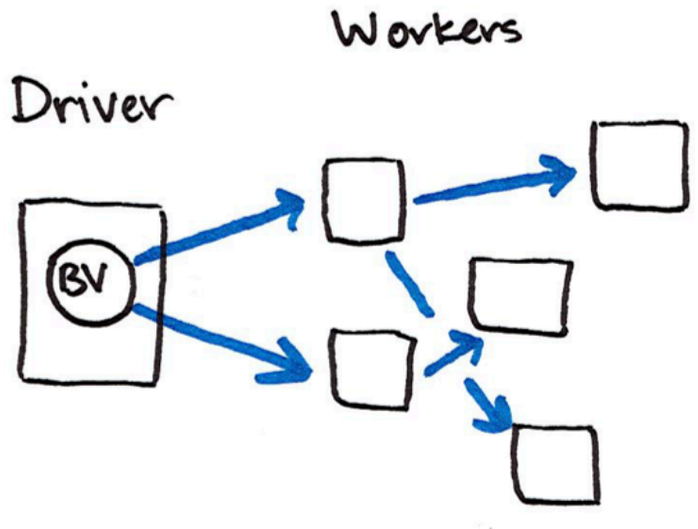
Fling & Storm

Each calin to have high throughput and low latency streaming

Distributed Variables

Broadcast

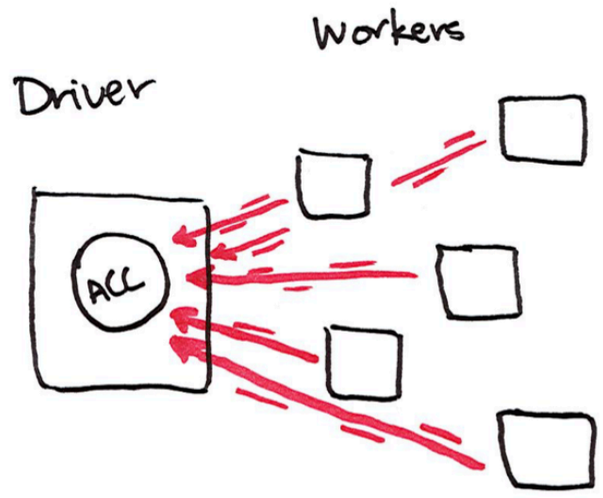
Read-only data shared among workers



Accumulator

Write only by workers

Read only on master



Broadcast Example

```
from pyspark.sql import SparkSession

spark = SparkSession\
        .builder\
        .appName("variables")\
        .getOrCreate()

courseSize = 45
courseSizeBroadcast = spark.sparkContext.broadcast(courseSize)

courseSizeBroadcast.value

data = spark.sparkContext.parallelize((1,2,3,4,5,6,7,8), 2)
data.map(lambda x: x + courseSizeBroadcast.value).collect()
```

Using ComplexType

```
sampleMap =  {'a': 10,'bat':1 }
sampleBroadCast = spark.sparkContext.broadcast(sampleMap)
sampleBroadCast.value
```

```
import org.apache.spark.sql.SparkSession
val blockSize =  "4096"
val spark = SparkSession.builder().
      appName("Broadcast Test").
      config("spark.broadcast.blockSize", blockSize).
      getOrCreate()

val sc = spark.sparkContext
val slices =  2
val num =  10000000

val arr1 = (0 until num).toArray

for (i <- 0 until 3) {
    println("Iteration " + i)
    println("===========")
    val startTime = System.nanoTime
    val barr1 = sc.broadcast(arr1)
    val observedSizes = sc.parallelize(1 to 10, slices).map(_ => barr1.value.length)
   observedSizes.collect().foreach(i => println(i))
    println("Iteration %d took %.0f milliseconds".format(i, (System.nanoTime - startTime) / 1E6))
}
```

Accumulator Example

```
from pyspark.sql import SparkSession

spark = SparkSession\
        .builder\
        .appName("variables")\
        .getOrCreate()

counter = spark.sparkContext.accumulator(0)
def count(item):
    global counter
    print("item: ", item.id)
    counter.add(1)

df = spark.range(16)
smaller = df.coalesce(4)
smaller.foreach(count)
counter.value
```

Output

16

Accumulator

add()

value

Numbers only

Can create custom accumulators

Machine Learning in Spark

MLlib

RDD-based
org.apache.spark.mllib
Maintenance mode

DataFrame based (Spark ML)
org.apache.spark.ml
Pipelines
Inspired by Python scikit-learn

Classification
Regression
Clustering
Collaborative Filtering
Dimension reduction
Linear Algebra
Statistics

http://spark.apache.org/docs/latest/ml-guide.html

MLlib: Main Guide

- Basic statistics
- Data sources
- Pipelines
- Extracting, transforming and selecting features
- Classification and Regression
- Clustering
- Collaborative filtering
- Frequent Pattern Mining
- Model selection and tuning
- Advanced topics

Machine Learning Library (MLlib) Guide

MLlib is Spark's machine learning (ML) library. Its goal is to make practical machine learning scalable provides tools such as:

- ML Algorithms: common learning algorithms such as classification, regression, clustering, and co
- Featurization: feature extraction, transformation, dimensionality reduction, and selection
- Pipelines: tools for constructing, evaluating, and tuning ML Pipelines
- Persistence: saving and load algorithms, models, and Pipelines
- Utilities: linear algebra, statistics, data handling, etc.

Announcement: DataFrame-based API is prima

The MLlib RDD-based API is now in maintenance mode.

As of Spark 2.0, the RDD-based APIs in the `spark.mllib` package have entered maintenance mode.

Python Examples

$SPARK_INSTALL_DIR/examples/src/main/python/ml

aft_survival_regression.py
als_example.py
binarizer_example.py
bisecting_k_means_example.py
bucketed_random_projection_lsh_example.py
bucketizer_example.py
chi_square_test_example.py
chisq_selector_example.py
correlation_example.py
count_vectorizer_example.py
cross_validator.py
dataframe_example.py
dct_example.py
decision_tree_classification_example.py
decision_tree_regression_example.py
elementwise_product_example.py
estimator_transformer_param_example.py
feature_hasher_example.py
fpgrowth_example.py
gaussian_mixture_example.py
generalized_linear_regression_example.py
gradient_boosted_tree_classifier_example.py
gradient_boosted_tree_regressor_example.py
imputer_example.py
index_to_string_example.py
isotonic_regression_example.py
kmeans_example.py
lda_example.py
linear_regression_with_elastic_net.py
linearsvc.py
logistic_regression_summary_example.py
logistic_regression_with_elastic_net.py
max_abs_scaler_example.py
min_hash_lsh_example.py
min_max_scaler_example.py
multiclass_logistic_regression_with_elastic_
multilayer_perceptron_classification.py
n_gram_example.py
naive_bayes_example.py
normalizer_example.py
one_vs_rest_example.py
onehot_encoder_estimator_example.py
pca_example.py
pipeline_example.py
polynomial_expansion_example.py
prefixspan_example.py
quantile_discretizer_example.py
random_forest_classifier_example.py