Big Data Wrangling With Google Books Ngrams

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Class: Data Science Bootcamp

Institution: BrainStation

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Introduction

The purpose of this report is to instruct the user how to use AWS (Amazon Web Services) cloud services to process large datasets and databases. We will spin up (startup) a cluster with three primary services. The first service, Hadoop, allows for large volumes of data to be stored and retrieved at high speed. The second service, PySpark and JupyterHub allows users to perform analysis with RDD (Resilient Distributed Dataset). The third service, S3, is AWS secure cloud data storage that can be public or private. S3 allows access from the web to read or write data.

This report will refer to AWS setup pages and CLI (Command Line Interface) commands. The images of the AWS and CLI are in the appendix. The report will reference the appendix by letters.

Instructions

- **Access AWS**: Goto URL https://aws.amazon.com/ and click on "Sign in to the Console". If you need to create a new account, please do so now.
- **Access EMR**: After logging on to AWS, in the upper left is a search bar. Search for EMR and select it. See appendix A.
- **Setup Cluster**: Make sure that Clusters are selected under "EMR on EC2" on the left side panel. Then click on "Create cluster". Refer to appendix B for display.
- **Cluster Configuration**: In the "Name and Applications" field, give the cluster a name. The name can be anything suitable. Under "Amazon EMR release" select "emr-6.10.0". For the Application bundle select Custom. All of the following checkboxes must be selected, "Hue – Livy – Spark – Hadoop – Hive – JupyterHub". The "Operating system option" has "Amazon Linux release". Please, refer to appendix C.
- **Cluster CPU Core Selection**: For "Cluster configuration" select the radio button "Uniform instance groups". Under the "Primary" header and "Choose EC2 instance type" select "m5.xlarge". Under "Core" and "Choose EC2 instance type" select "m5.xlarge". Please, refer to appendix D for a visual.
- **Cluster scaling and provisioning:** Select option "Set cluster size manually". For "Provisioning configuration" type 2 under "Instance(s) size". Under header "Networking" pick options for "Virtual private cloud" and "Subnet". If no options are available, then click on the respective "Create" button on the right. Please, refer to appendix E if a visual guide is desired.

- **Cluster Security:** Under "Security configuration and EC2 key pair" look for heading "Amazon EC2 key pair for SSH to the cluster". If a key pair does not exist, then click on the "Create key pair" button to make one. Be sure to select the *.pem option when making and new key pair. NOTE: Please, be aware that the key pair will only work in the AWS region that it is created for. Store the downloaded key *.pem file in a location to be used later to connect to the cluster. Next, browse and select the key pair under "Amazon EC2 key pair for SSH to the cluster". For a visual aid please refer to appendix F.
- **Cluster Identity and Access Management (IAM) roles:** If there is an existing role select it for "Service Role" and "Instance profile", then select "Create cluster" button. Otherwise, click on "Create a service role" and follow the instructions. Once the service role has been created, select and perform the same process for "Instance profile". Now click on the "Create cluster" button. Please refer to append F for a visual aid.
- **EMR and Spark Cluster:** The cluster has now been created and the system is now installing the software and booting the system. It will take several minutes for the process to complete. Under "Status and time" on the right side of the window "Status" will change to "Waiting" when the cluster is ready to be used. Please, see appendix G for a reference.
- **Connect to Hadoop with SSH:** Once the status changes to "Waiting", under "Cluster management" click on "Connect to the Primary node using SSH" and copy the connection link. Open a CLI or terminal with ssh access and paste the connection link. The address of the key pair (*.pem file) will likely require changing. Once the address to the key pair is correct press enter. The window will appear the same as appendix H.

- **Large File Transfer to Hadoop:** On the CLI input command "hadoop distcp s3://brainstation-dsft/eng_1M_1gram/eng_1M_1gram.csv". Now the data will be downloaded and stored directly to the child nodes of Hadoop. For a visual please refer to appendix I and J.
- **Setup JupyterHub Secure Port for Localhost:** Open a new CLI or terminal. Type in command "ssh -I /Path/To/Key.pem -L 9995:localhost:9443 hadoop@xxxxxxxxxxxxx.compute.amazonaws.com". Replace the x's with the connect link portion used to connect to Hadoop via SSH. The window will be like appendix K.
- **Connect to JupyterHub in Browser:** Open a web browser and type in the following URL https://localhost:9995. A warning may appear regarding the expiration of the certificate, go to advance, and proceed to the site. At the logon page enter username "jovyan" and password "jupyter". A successful login will be like appendix N. Click new in the upper right corner, then select "PySpark".
- **PySpark:** Please refer to appendix L and M. Type spark in the first line and run to start the spark session. Follow the commands in appendix L and M to open the data file on the Hadoop server. Then perform a sanity check on the data to ensure that it's loaded. Now, check the number of rows and columns. The shape of the dataset is (261,823,225, 5). The column names are "token, year, frequency, pages, and books". To run a SQL statement on a PySpark dataframe it must be converted to a view. See appendix M In [8] for the command. A SQL statement of "SELECT * FROM eng_table WHERE token LIKE '%data%' is ran in order to get all the tokens with the work data. The data is stored in a new PySpark dataframe. The count of the new dataframe is 24,642. A sanity check is also performed on the new dataframe. The new dataframe is then written back to the

Hadoop child nodes with command " newdf.write.csv(path, header=True). See appendix M for the path of how to store the data to Hadoop. PySpark is then stopped with command spark.stop().

- **Retrieve the Data from Hadoop to the local machine:** In the CLI that is connected to Hadoop type the command "hadoop fs -getmerge /user/hadoop/eng_1M_1gram/ eng_token_data.csv". This will combine all the files into a single file and store it on the cluster Linux file system. To gain access to the file for the local machine, it is stored in an S3 bucket. Setup IAM with a user and setup the user with a key ID and secret. The key ID and secret must be used to access the S3 bucket from the local machine. Search the internet on how to setup the IAM account. Store the dataset on the S3 bucket with command "s3-dist-cp eng_token_data.csv – dest s3://bucketname.
- **Local Jupyter Notebook:** To access the dataset with python verify that the boto3 package is installed. If not, you can use the command "! pip install boto3" in python to install the package. To use the boto3 package "import boto3" and then set up the connection to the S3 bucket. The access key, secret key, and the name of the region the S3 bucket is hosted is required for the next command. "s3 = boto3.client('s3', aws_access_key_id='', aws_secret_access_key='', region_name=''). The following commands will load the dataset into a pandas dataframe. Import pandas first with command "import pandas as pd". Access the dataset with command "obj = s3.get_object(Bucket='S3BucketName', Key='eng_token_data.csv)". Store the dataset in a pandas dataframe with "df = pd.read_csv(obj['Body'])".

- **Store the data locally:** Perform a sanity check on the data with ‘df.head(10)” and “df.shape”. If the data is present, then store the data with “df.to_csv(‘path/to/store/file/filename.csv’).
- **Terminate the Cluster:** Go to the browser with the cluster console. Click on “Clusters” on the left-hand panel. View appendix B to verify the correct page. Click on the active cluster. On the next page click “terminate”. This will stop any additional charges now that the cluster is no longer required. The account can now be logged off and all the related windows closed.

Findings

The dataset with tokens of 'data' is a subset of eng_1M_1gram. Hadoop and PySpark were used to analyze and filter the eng_1M_1gram dataset. Once the dataset was filtered, it was saved to Hadoop. The file on the Hadoop file system was split into 40 files, one for each partition of PySpark's RDDs. To consolidate the files into a single file and store it on the file system of the server "hadoop fs -getmerge" command was used. Then the file was transferred to an S3 bucket so it could be accessed by a local machine. The file was downloaded in a jupyter notebook using the boto3 package. The cleaning of the data revealed that there were years missing information amounting to 0.47%. Because of the small number of missing values, the rows were removed instead of imputed. The final data shape of the subset was (24,642, 5). The bar graph shows exponential growth in the token 'data' from the 1500's to current times. A logged scale was used to make the graph readable. The number of tokens with 'data' was very sparse from 1500 to 1700 and then the token took off with exponential growth. The likely reason for the initial growth is that the number of published books grew at the same rate. An analysis of the original dataset would have to be conducted to test this hypothesis. After 1970 the growth is likely due to the rise of computers in the mainstream.

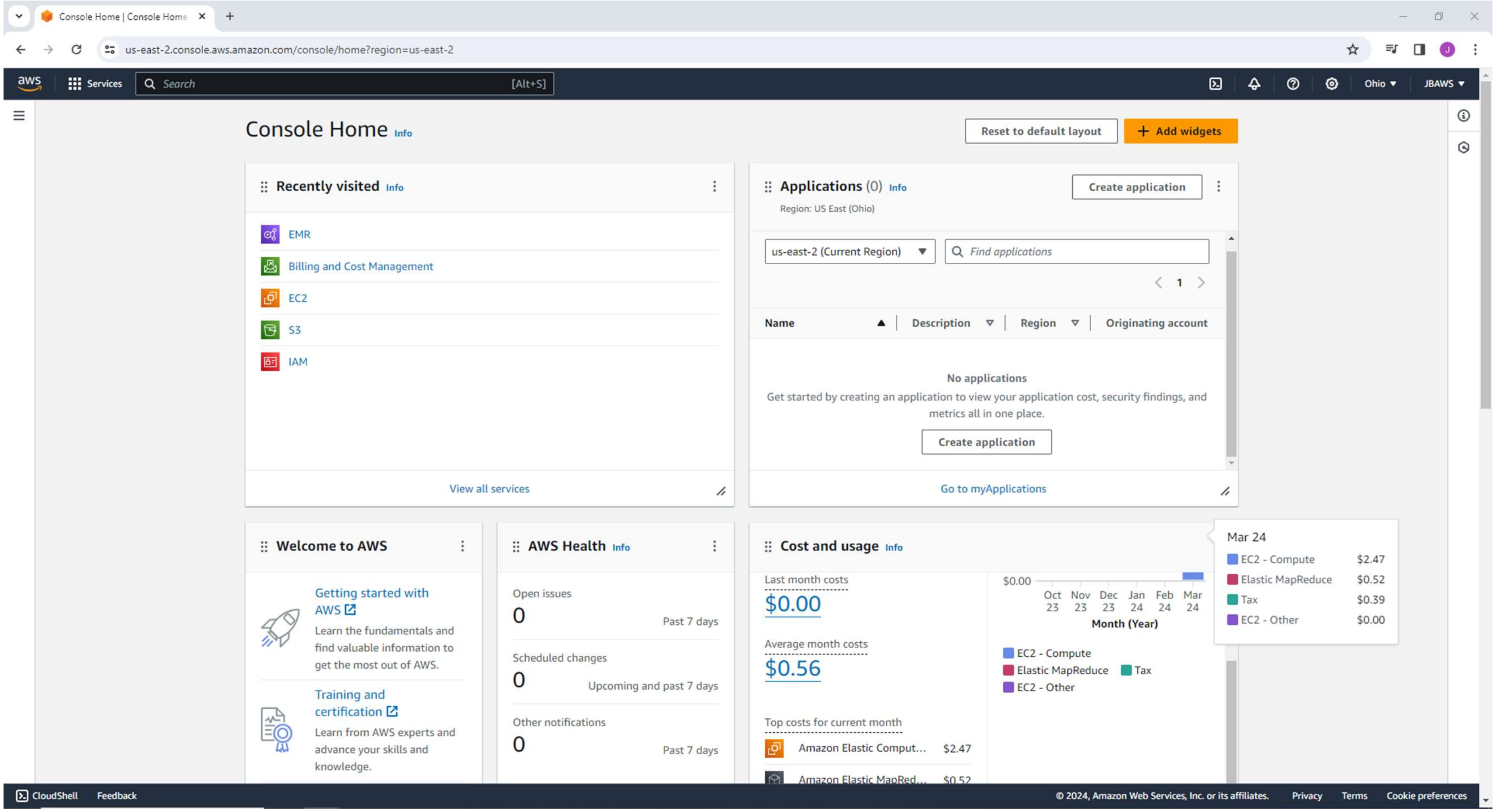
Summary

The Hadoop HDFS stores data through distribution to many Child Nodes. The Head Node breaks up an incoming file up into equal size pieces. The size of the pieces of the file are such that it requires a low amount of memory in both the Head Node and the Child Nodes. Then, the Head Node assigns each piece of data to multiple Child Nodes and transfers the data to those Child Nodes. There are multiple copies of each piece of data that are stored on different Child Nodes. In case of the event that a Child Node fails other Child Nodes have a copy of the same data.

Hadoop and Spark are different systems with different purposes. Hadoop is made to store and retrieve large volumes of data at high speed. It has redundancies (duplicated data) on separate nodes so if a small number of nodes fail the system is still functional. Hadoop was designed for commodity hardware to keep the cost of hardware and maintenance down. It was also designed so that it scales horizontally requiring minimal setup to expand the system. Spark is pandas for very large datasets. Spark runs on clusters allowing it to divide the amount of work and use the servers in the cluster. It accomplishes this by splitting the data into separate groups for each CPU core to process. The system that does this in Spark is called RDD (Resilient Distributed Dataset). Spark also allows users to run SQL queries directly on Spark dataframes. This removes the need to learn all the differences between Spark and pandas commands. Together, Hadoop and Spark are a very powerful combination for Data Scientist working on large dataset. They offer scalable storage and computational power.

Appendix

Appendix A



Console Home | Console Home

us-east-2.console.aws.amazon.com/console/home?region=us-east-2

Console Home Info

Reset to default layout | + Add widgets

Recently visited Info

- EMR
- Billing and Cost Management
- EC2
- S3
- IAM

View all services

Applications (0) Info

Region: US East (Ohio)

Create application

us-east-2 (Current Region) | Find applications

Name	Description	Region	Originating account

No applications

Get started by creating an application to view your application cost, security findings, and metrics all in one place.

Create application

Go to myApplications

Welcome to AWS

Getting started with AWS

Learn the fundamentals and find valuable information to get the most out of AWS.

Training and certification

Learn from AWS experts and advance your skills and knowledge.

AWS Health Info

Open issues
0
Past 7 days

Scheduled changes
0
Upcoming and past 7 days

Other notifications
0
Past 7 days

Cost and usage Info

Last month costs
$0.00

Average month costs
$0.56

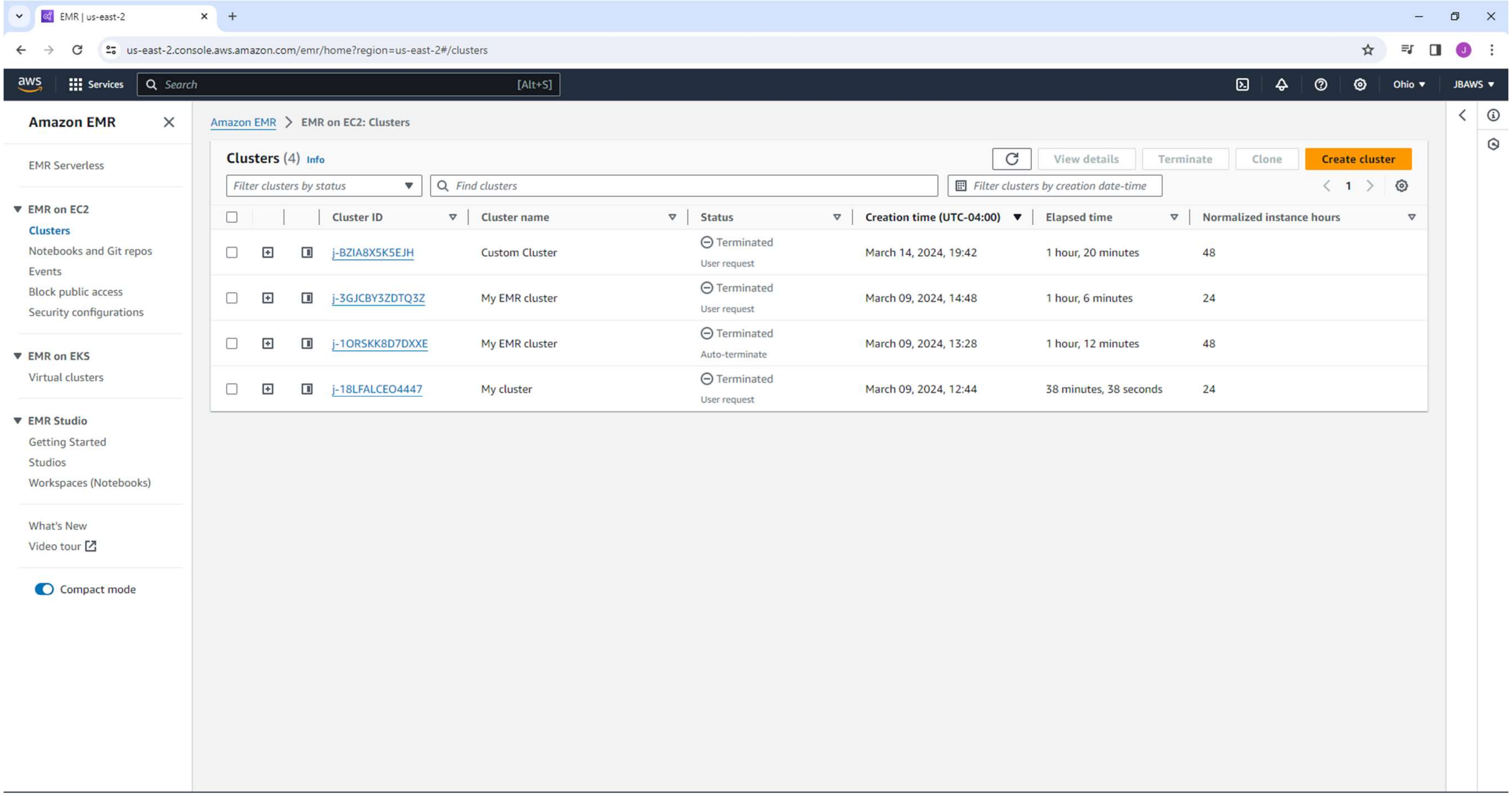
Top costs for current month

Amazon Elastic Comput...	$2.47
Amazon Elastic MapRed...	$0.52

Mar 24

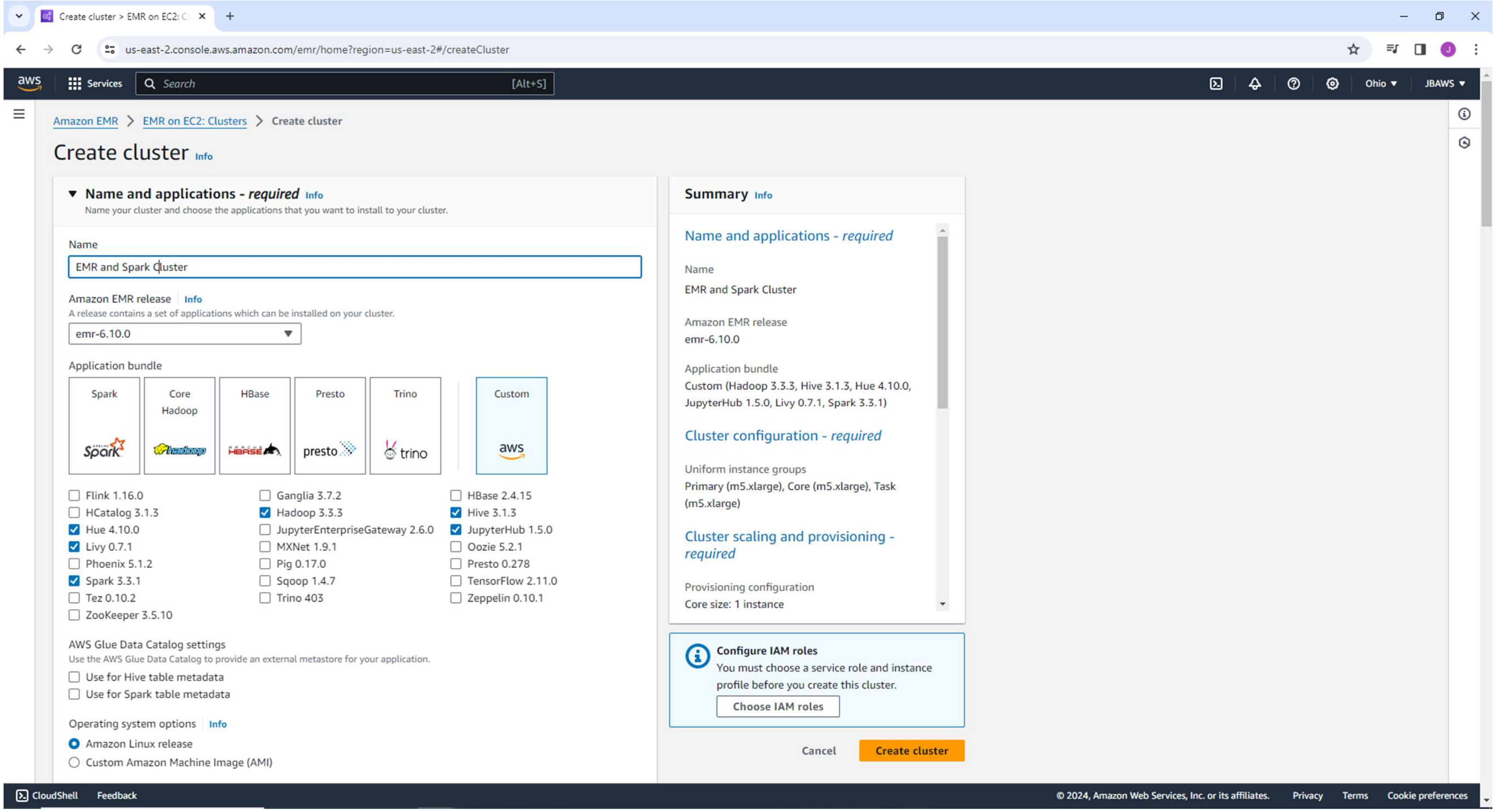
EC2 - Compute	$2.47
Elastic MapReduce	$0.52
Tax	$0.39
EC2 - Other	$0.00

Appendix B



□	Cluster ID	Cluster name	Status	Creation time (UTC-04:00)	Elapsed time	Normalized instance hours
□	j-BZIA8X5K5EJH	Custom Cluster	Terminated User request	March 14, 2024, 19:42	1 hour, 20 minutes	48
□	j-3GJCBY3ZDTQ3Z	My EMR cluster	Terminated User request	March 09, 2024, 14:48	1 hour, 6 minutes	24
□	j-1ORSKK8D7DXXE	My EMR cluster	Terminated Auto-terminate	March 09, 2024, 13:28	1 hour, 12 minutes	48
□	j-18LFALCEO4447	My cluster	Terminated User request	March 09, 2024, 12:44	38 minutes, 38 seconds	24

Appendix C


Create cluster > EMR on EC2: C
us-east-2.console.aws.amazon.com/emr/home?region=us-east-2#/createCluster
aws
Services
Search
[Alt+S]
Ohio
JBAWS

Amazon EMR > EMR on EC2: Clusters > Create cluster

Create cluster Info

Name and applications - *required* Info

Name your cluster and choose the applications that you want to install to your cluster.

Name

EMR and Spark Cluster

Amazon EMR release Info

A release contains a set of applications which can be installed on your cluster.

emr-6.10.0

Application bundle

Spark
Core Hadoop
HBase
Presto
Trino
Custom

□ Flink 1.16.0
□ HCatalog 3.1.3
☑ Hue 4.10.0
☑ Livy 0.7.1
□ Phoenix 5.1.2
☑ Spark 3.3.1
□ Tez 0.10.2
□ ZooKeeper 3.5.10
□ Ganglia 3.7.2
☑ Hadoop 3.3.3
□ JupyterEnterpriseGateway 2.6.0
□ MXNet 1.9.1
□ Pig 0.17.0
□ Sqoop 1.4.7
□ Trino 403
□ HBase 2.4.15
☑ Hive 3.1.3
☑ JupyterHub 1.5.0
□ Oozie 5.2.1
□ Presto 0.278
□ TensorFlow 2.11.0
□ Zeppelin 0.10.1

AWS Glue Data Catalog settings

Use the AWS Glue Data Catalog to provide an external metastore for your application.

□ Use for Hive table metadata
□ Use for Spark table metadata

Operating system options Info

● Amazon Linux release
○ Custom Amazon Machine Image (AMI)

Summary Info

Name and applications - *required*

Name
EMR and Spark Cluster

Amazon EMR release
emr-6.10.0

Application bundle
Custom (Hadoop 3.3.3, Hive 3.1.3, Hue 4.10.0, JupyterHub 1.5.0, Livy 0.7.1, Spark 3.3.1)

Cluster configuration - *required*

Uniform instance groups
Primary (m5.xlarge), Core (m5.xlarge), Task (m5.xlarge)

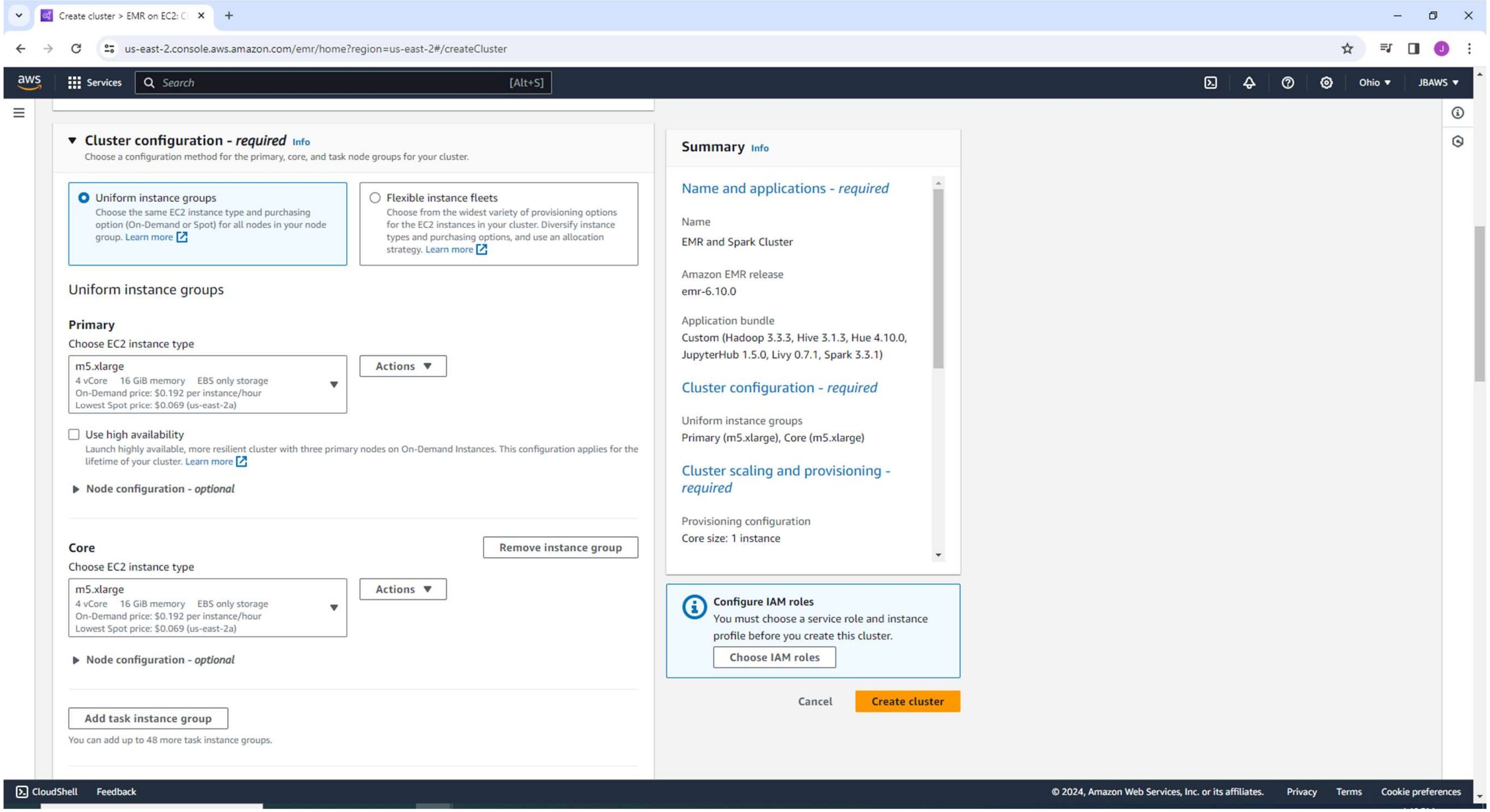
Cluster scaling and provisioning - *required*

Provisioning configuration
Core size: 1 instance

Configure IAM roles

You must choose a service role and instance profile before you create this cluster.

Appendix D



Create cluster > EMR on EC2: C
us-east-2.console.aws.amazon.com/emr/home?region=us-east-2#/createCluster
aws
Services
Search
[Alt+S]
Ohio
JBAWS

▼ **Cluster configuration - *required*** Info

Choose a configuration method for the primary, core, and task node groups for your cluster.

● Uniform instance groups
Choose the same EC2 instance type and purchasing option (On-Demand or Spot) for all nodes in your node group. Learn more

○ Flexible instance fleets
Choose from the widest variety of provisioning options for the EC2 instances in your cluster. Diversify instance types and purchasing options, and use an allocation strategy. Learn more

Uniform instance groups

Primary

Choose EC2 instance type

m5.xlarge
4 vCore 16 GiB memory EBS only storage
On-Demand price: $0.192 per instance/hour
Lowest Spot price: $0.069 (us-east-2a)

Actions ▼

□ Use high availability
Launch highly available, more resilient cluster with three primary nodes on On-Demand Instances. This configuration applies for the lifetime of your cluster. Learn more

▶ Node configuration - *optional*

Core

Remove instance group

Choose EC2 instance type

m5.xlarge
4 vCore 16 GiB memory EBS only storage
On-Demand price: $0.192 per instance/hour
Lowest Spot price: $0.069 (us-east-2a)

Actions ▼

▶ Node configuration - *optional*

Add task instance group

You can add up to 48 more task instance groups.

Summary Info

Name and applications - *required*

Name
EMR and Spark Cluster

Amazon EMR release
emr-6.10.0

Application bundle
Custom (Hadoop 3.3.3, Hive 3.1.3, Hue 4.10.0, JupyterHub 1.5.0, Livy 0.7.1, Spark 3.3.1)

Cluster configuration - *required*

Uniform instance groups
Primary (m5.xlarge), Core (m5.xlarge)

Cluster scaling and provisioning - *required*

Provisioning configuration
Core size: 1 instance

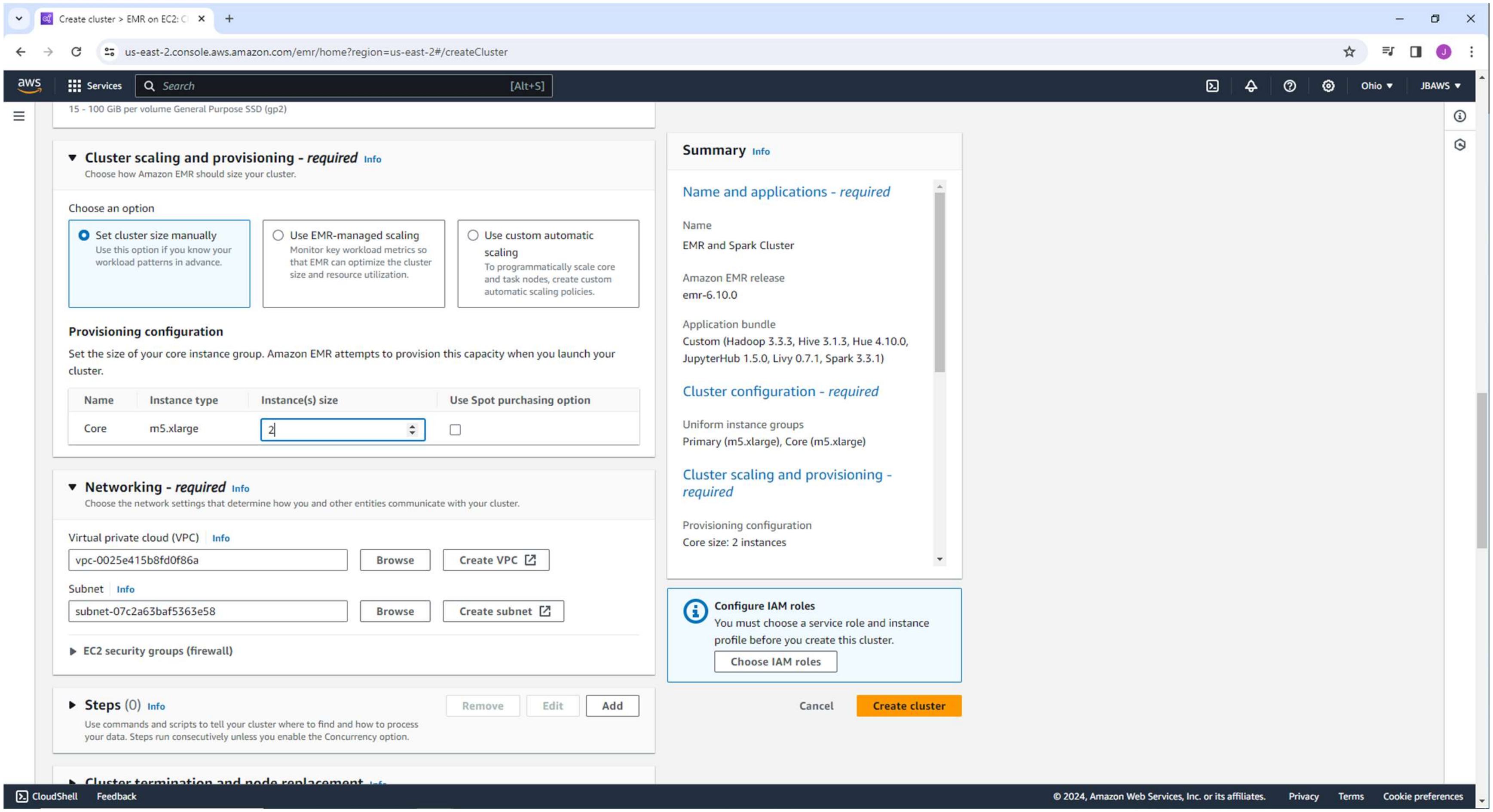
Configure IAM roles
You must choose a service role and instance profile before you create this cluster.

Choose IAM roles

Cancel

Create cluster

Appendix E


Create cluster > EMR on EC2: C
us-east-2.console.aws.amazon.com/emr/home?region=us-east-2#/createCluster
aws
Services
Search
[Alt+S]
Ohio ▾
JBAWS ▾
CloudShell
Feedback
© 2024, Amazon Web Services, Inc. or its affiliates.
Privacy
Terms
Cookie preferences

15 - 100 GiB per volume General Purpose SSD (gp2)

Cluster scaling and provisioning - *required* Info

Choose how Amazon EMR should size your cluster.

Choose an option

● Set cluster size manually
Use this option if you know your workload patterns in advance.

○ Use EMR-managed scaling
Monitor key workload metrics so that EMR can optimize the cluster size and resource utilization.

○ Use custom automatic scaling
To programmatically scale core and task nodes, create custom automatic scaling policies.

Provisioning configuration

Set the size of your core instance group. Amazon EMR attempts to provision this capacity when you launch your cluster.

Name	Instance type	Instance(s) size	Use Spot purchasing option
Core	m5.xlarge	2	□

Networking - *required* Info

Choose the network settings that determine how you and other entities communicate with your cluster.

Virtual private cloud (VPC) Info

vpc-0025e415b8fd0f86a | Browse | Create VPC

Subnet Info

subnet-07c2a63baf5363e58 | Browse | Create subnet

▸ EC2 security groups (firewall)

Steps (0) Info | Remove | Edit | Add

Use commands and scripts to tell your cluster where to find and how to process your data. Steps run consecutively unless you enable the Concurrency option.

▸ Cluster termination and node replacement Info

Summary Info

Name and applications - *required*

Name
EMR and Spark Cluster

Amazon EMR release
emr-6.10.0

Application bundle
Custom (Hadoop 3.3.3, Hive 3.1.3, Hue 4.10.0, JupyterHub 1.5.0, Livy 0.7.1, Spark 3.3.1)

Cluster configuration - *required*

Uniform instance groups
Primary (m5.xlarge), Core (m5.xlarge)

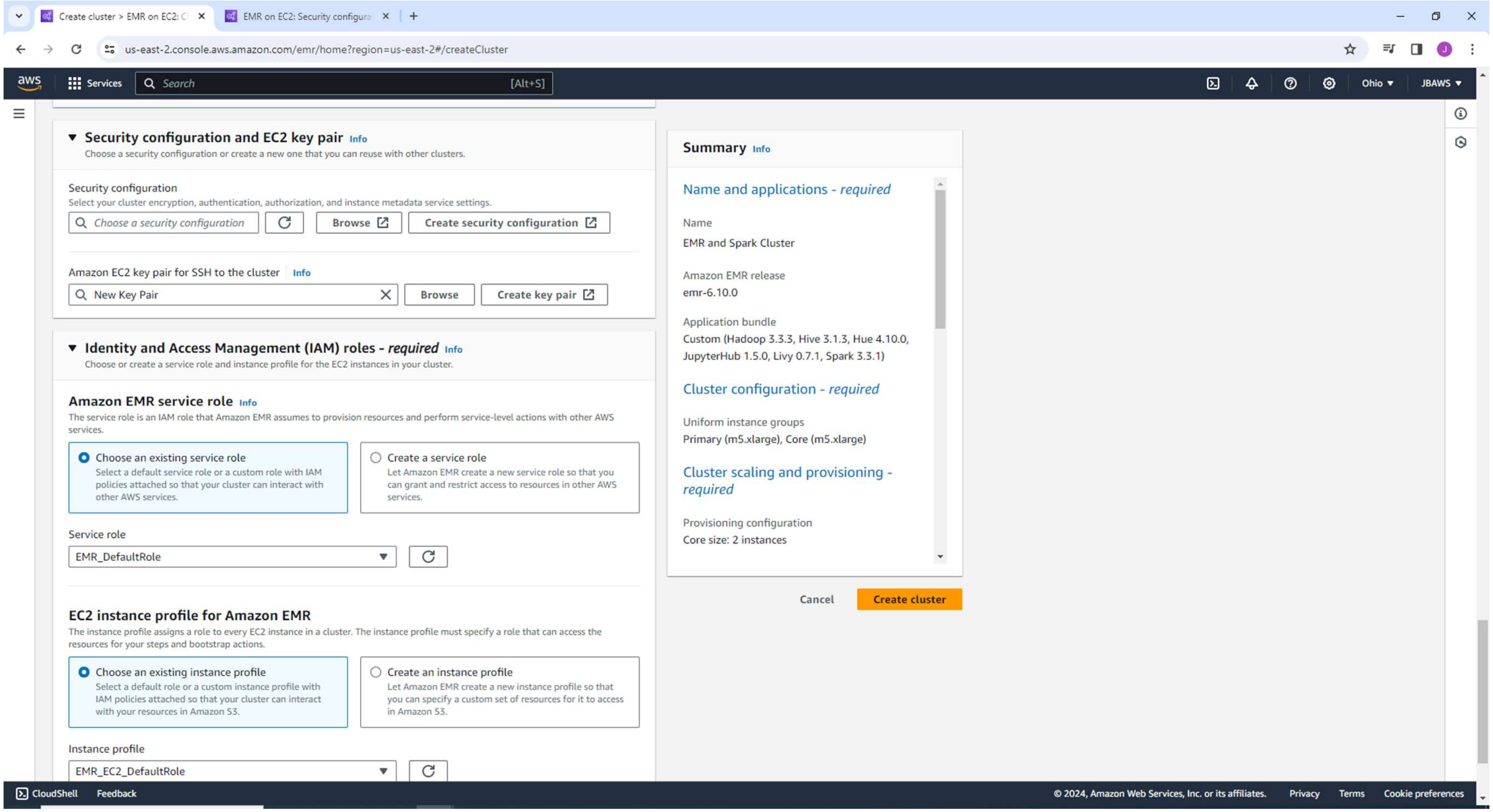
Cluster scaling and provisioning - *required*

Provisioning configuration
Core size: 2 instances

Configure IAM roles
You must choose a service role and instance profile before you create this cluster.
Choose IAM roles

Cancel | Create cluster

Appendix F



Create cluster > EMR on EC2: C
EMR on EC2: Security configura
us-east-2.console.aws.amazon.com/emr/home?region=us-east-2#/createCluster
aws
Services
Search
[Alt+S]
Ohio ▾
JBAWS ▾

▼ Security configuration and EC2 key pair Info

Choose a security configuration or create a new one that you can reuse with other clusters.

Security configuration

Select your cluster encryption, authentication, authorization, and instance metadata service settings.

Choose a security configuration
Browse
Create security configuration

Amazon EC2 key pair for SSH to the cluster Info

New Key Pair

▼ Identity and Access Management (IAM) roles - *required* Info

Choose or create a service role and instance profile for the EC2 instances in your cluster.

Amazon EMR service role Info

The service role is an IAM role that Amazon EMR assumes to provision resources and perform service-level actions with other AWS services.

● Choose an existing service role
Select a default service role or a custom role with IAM policies attached so that your cluster can interact with other AWS services.

○ Create a service role
Let Amazon EMR create a new service role so that you can grant and restrict access to resources in other AWS services.

Service role: EMR_DefaultRole

EC2 instance profile for Amazon EMR

The instance profile assigns a role to every EC2 instance in a cluster. The instance profile must specify a role that can access the resources for your steps and bootstrap actions.

● Choose an existing instance profile
Select a default role or a custom instance profile with IAM policies attached so that your cluster can interact with your resources in Amazon S3.

○ Create an instance profile
Let Amazon EMR create a new instance profile so that you can specify a custom set of resources for it to access in Amazon S3.

Instance profile: EMR_EC2_DefaultRole

Summary Info

Name and applications - *required*

Name: EMR and Spark Cluster

Amazon EMR release: emr-6.10.0

Application bundle: Custom (Hadoop 3.3.3, Hive 3.1.3, Hue 4.10.0, JupyterHub 1.5.0, Livy 0.7.1, Spark 3.3.1)

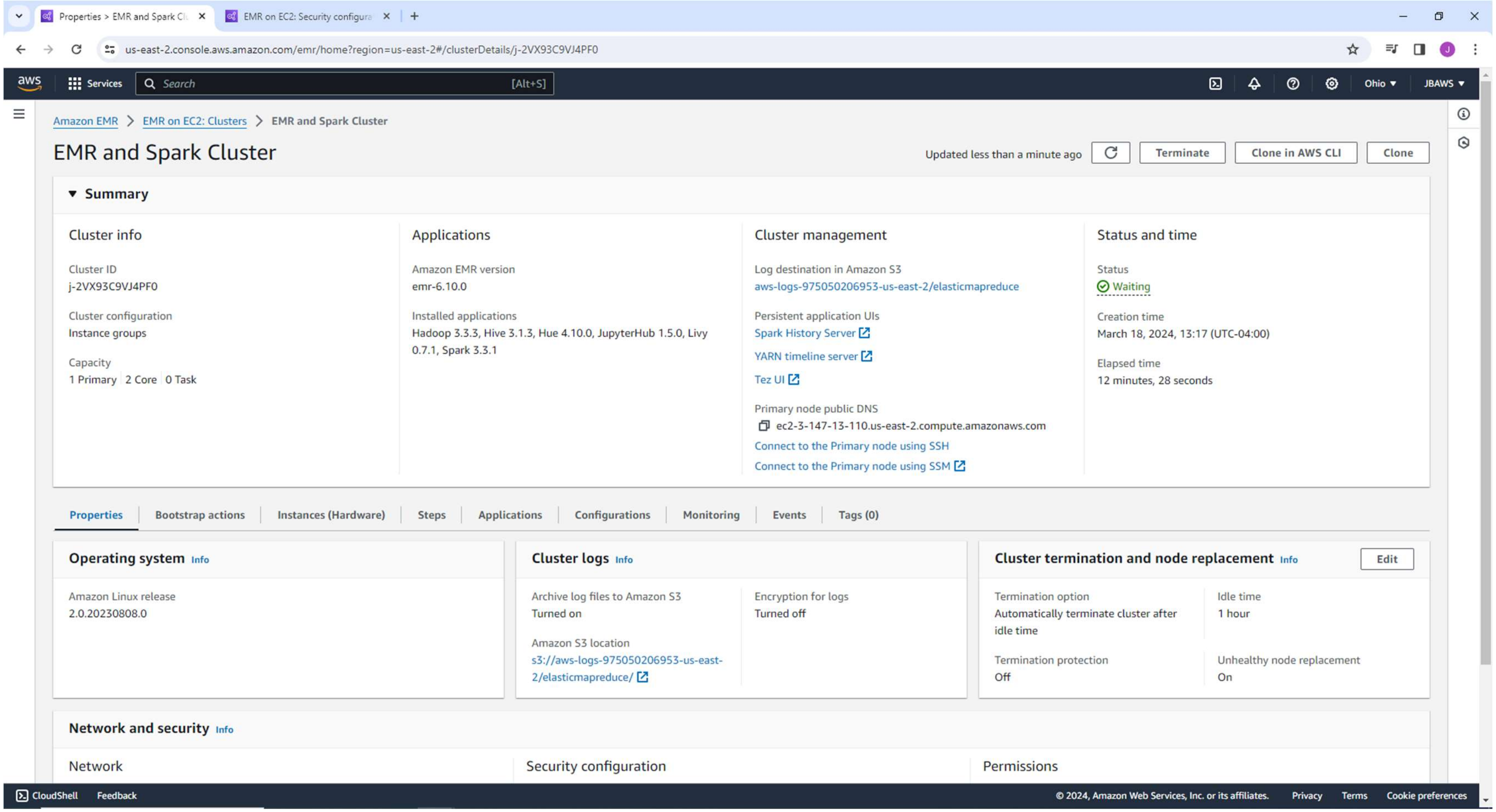
Cluster configuration - *required*

Uniform instance groups: Primary (m5.xlarge), Core (m5.xlarge)

Cluster scaling and provisioning - *required*

Provisioning configuration: Core size: 2 instances

Appendix G


Properties > EMR and Spark Cl
EMR on EC2: Security configura
us-east-2.console.aws.amazon.com/emr/home?region=us-east-2#/clusterDetails/j-2VX93C9VJ4PF0
aws
Services
Search
[Alt+S]
Ohio ▾
JBAWS ▾
Amazon EMR > EMR on EC2: Clusters > EMR and Spark Cluster
Updated less than a minute ago
Terminate
Clone in AWS CLI
Clone
Properties
Bootstrap actions
Instances (Hardware)
Steps
Applications
Configurations
Monitoring
Events
Tags (0)
Edit
CloudShell
Feedback
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EMR and Spark Cluster

▼ Summary

Cluster info

Cluster ID
j-2VX93C9VJ4PF0

Cluster configuration
Instance groups

Capacity
1 Primary | 2 Core | 0 Task

Applications

Amazon EMR version
emr-6.10.0

Installed applications
Hadoop 3.3.3, Hive 3.1.3, Hue 4.10.0, JupyterHub 1.5.0, Livy 0.7.1, Spark 3.3.1

Cluster management

Log destination in Amazon S3
aws-logs-975050206953-us-east-2/elasticmapreduce

Persistent application UIs
Spark History Server
YARN timeline server
Tez UI

Primary node public DNS
ec2-3-147-13-110.us-east-2.compute.amazonaws.com
Connect to the Primary node using SSH
Connect to the Primary node using SSM

Status and time

Status
Waiting

Creation time
March 18, 2024, 13:17 (UTC-04:00)

Elapsed time
12 minutes, 28 seconds

Operating system Info

Amazon Linux release
2.0.20230808.0

Cluster logs Info

Archive log files to Amazon S3
Turned on

Amazon S3 location
s3://aws-logs-975050206953-us-east-2/elasticmapreduce/

Encryption for logs
Turned off

Cluster termination and node replacement Info

Termination option
Automatically terminate cluster after idle time

Idle time
1 hour

Termination protection
Off

Unhealthy node replacement
On

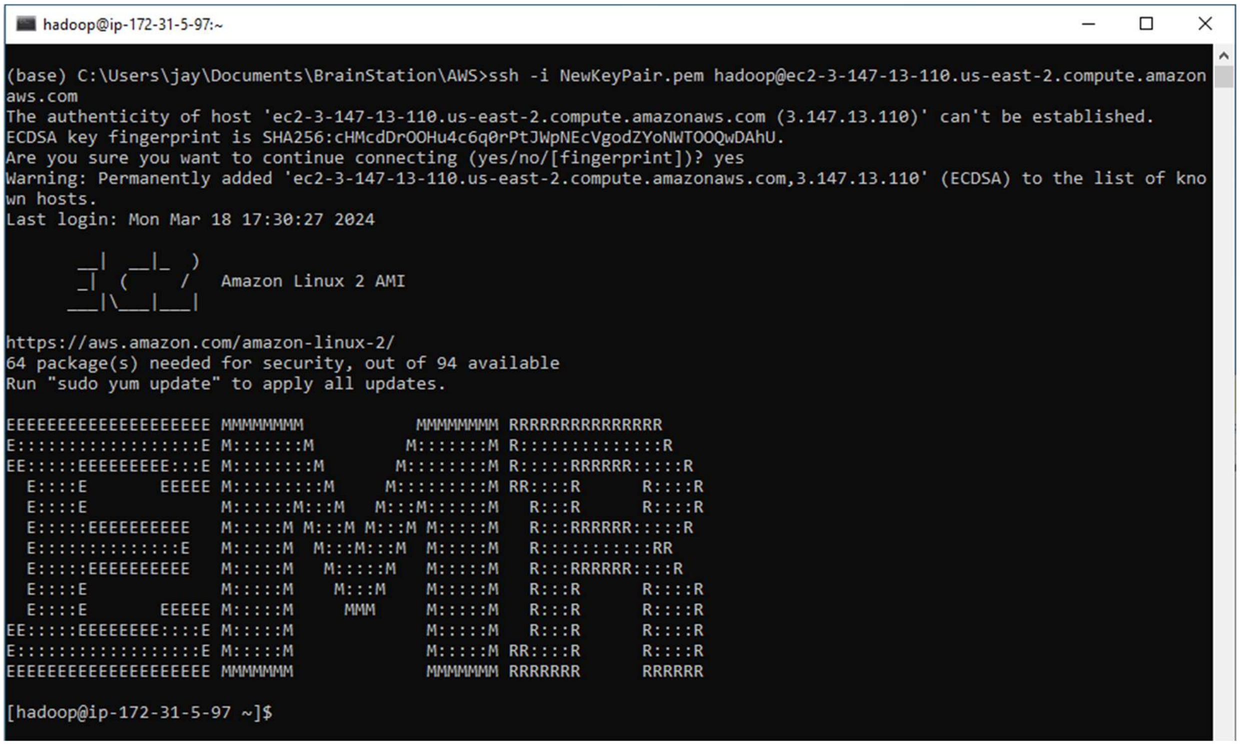
Network and security Info

Network

Security configuration

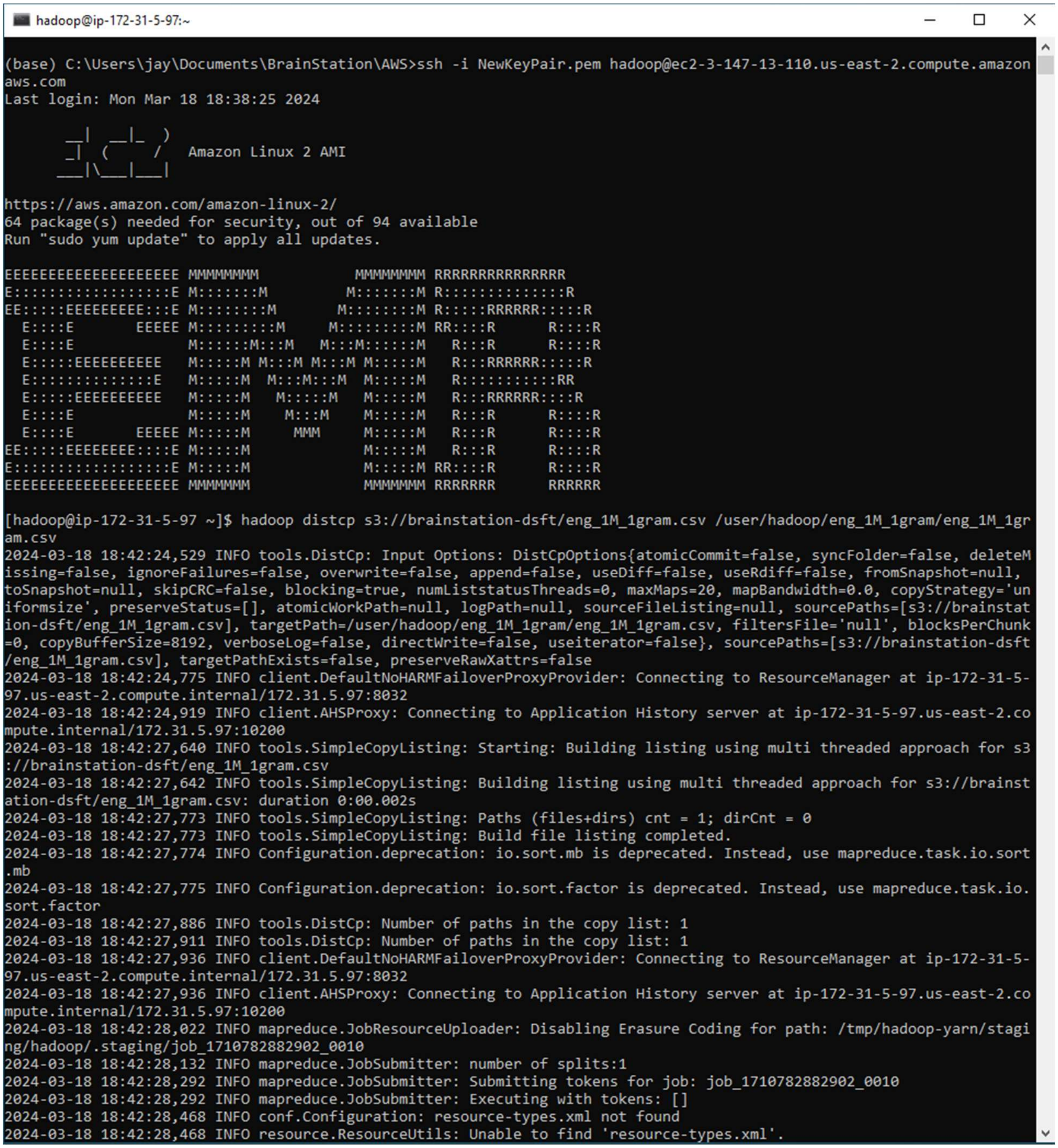
Permissions

Appendix H



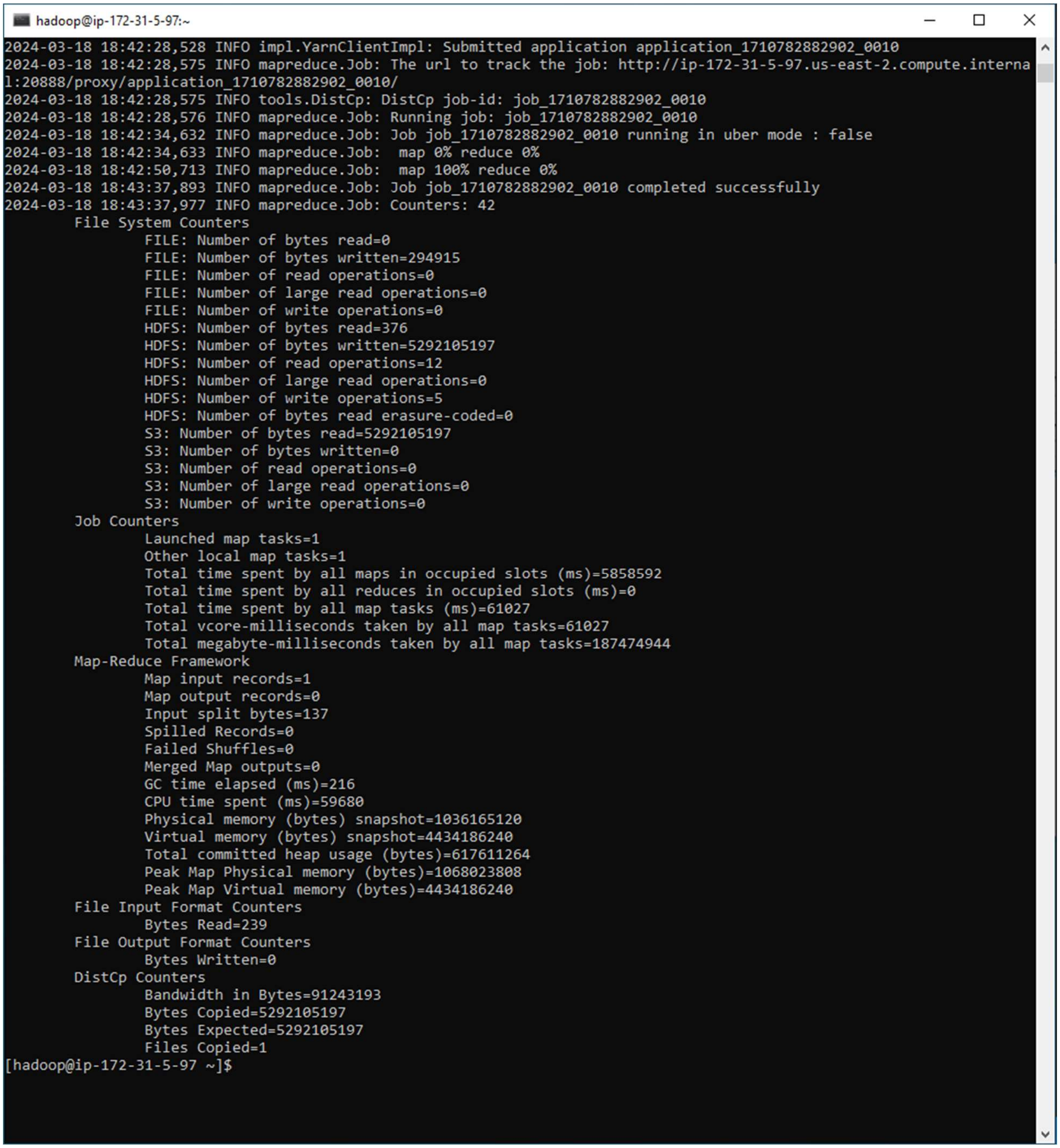
```
(base) C:\Users\jay\Documents\BrainStation\AWS>ssh -i NewKeyPair.pem hadoop@ec2-3-147-13-110.us-east-2.compute.amazon
aws.com
The authenticity of host 'ec2-3-147-13-110.us-east-2.compute.amazonaws.com (3.147.13.110)' can't be established.
ECDSA key fingerprint is SHA256:cHMcdDrOOHu4c6q0rPtJWpNEcVgodZYoNWTOOQwDAhU.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'ec2-3-147-13-110.us-east-2.compute.amazonaws.com,3.147.13.110' (ECDSA) to the list of kno
wn hosts.
Last login: Mon Mar 18 17:30:27 2024

       __|  __|_  )
       _|  (     /   Amazon Linux 2 AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-2/
64 package(s) needed for security, out of 94 available
Run "sudo yum update" to apply all updates.

EEEEEEEEEEEEEEEEEEEE MMMMMMMM           MMMMMMMM RRRRRRRRRRRRRRR
E::::::::::::::::::E M:::::::M         M:::::::M R::::::::::::::R
EE:::::EEEEEEEEE:::E M::::::::M       M::::::::M R:::::RRRRRR:::::R
  E::::E       EEEEE M:::::::::M     M:::::::::M RR::::R      R::::R
  E::::E             M::::::M:::M   M:::M::::::M   R:::R      R::::R
  E:::::EEEEEEEEEE   M:::::M M:::M M:::M M:::::M   R:::RRRRRR:::::R
  E::::::::::::::E   M:::::M  M:::M:::M  M:::::M   R:::::::::::RR
  E:::::EEEEEEEEEE   M:::::M   M:::::M   M:::::M   R:::RRRRRR::::R
  E::::E             M:::::M    M:::M    M:::::M   R:::R      R::::R
  E::::E       EEEEE M:::::M     MMM     M:::::M   R:::R      R::::R
EE:::::EEEEEEEE::::E M:::::M             M:::::M   R:::R      R::::R
E::::::::::::::::::E M:::::M             M:::::M RR::::R      R::::R
EEEEEEEEEEEEEEEEEEEE MMMMMMM             MMMMMMM RRRRRRR      RRRRRR

[hadoop@ip-172-31-5-97 ~]$
```

Appendix I



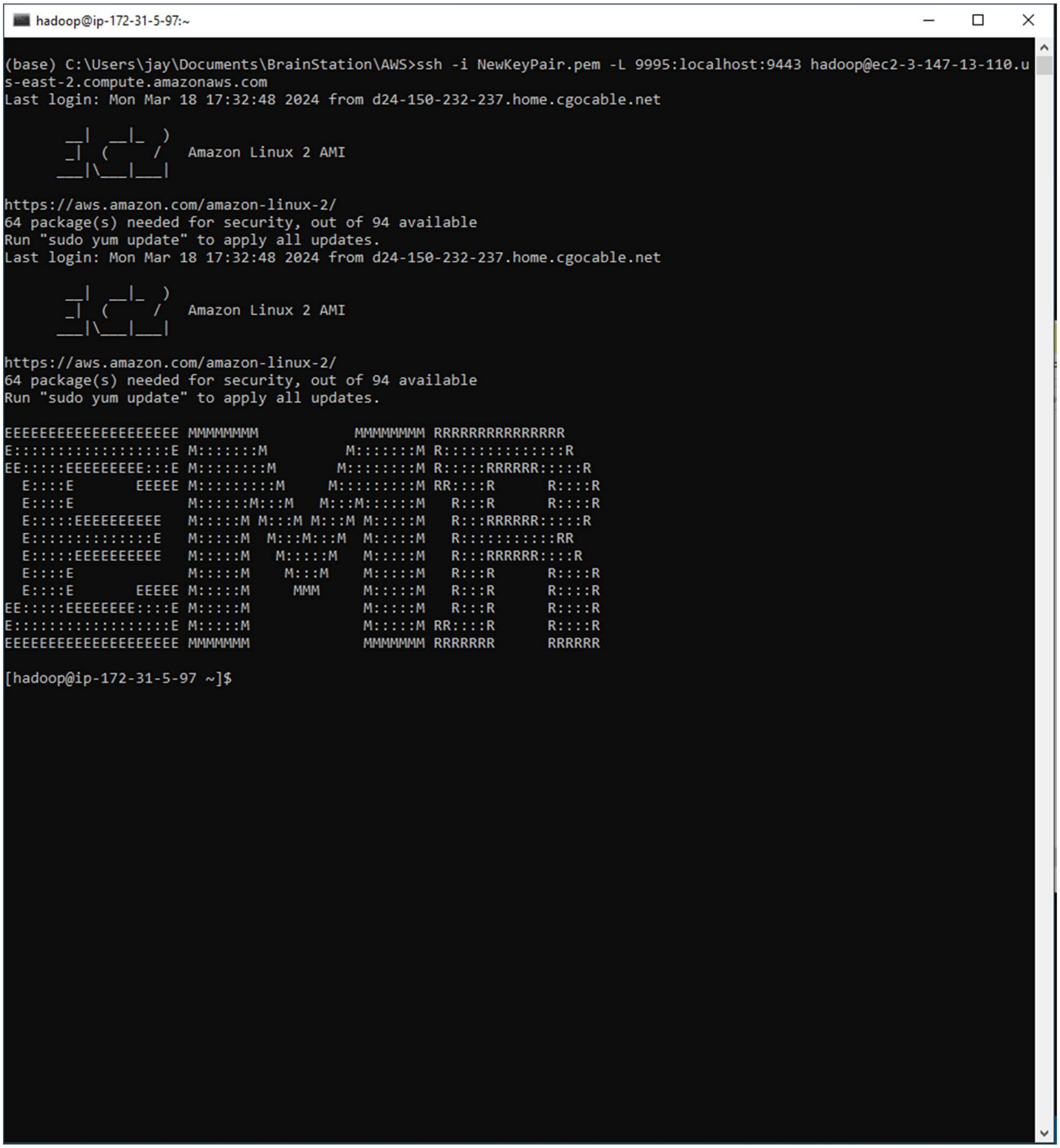
```
(base) C:\Users\jay\Documents\BrainStation\AWS>ssh -i NewKeyPair.pem hadoop@ec2-3-147-13-110.us-east-2.compute.amazon
aws.com
Last login: Mon Mar 18 18:38:25 2024

       __|  __|_  )
       _|  (     /   Amazon Linux 2 AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-2/
64 package(s) needed for security, out of 94 available
Run "sudo yum update" to apply all updates.

EEEEEEEEEEEEEEEEEEEE MMMMMMMM           MMMMMMMM RRRRRRRRRRRRRRR
E::::::::::::::::::E M:::::::M         M:::::::M R::::::::::::::R
EE:::::EEEEEEEEE:::E M::::::::M       M::::::::M R:::::RRRRRR:::::R
  E::::E       EEEEE M:::::::::M     M:::::::::M RR::::R      R::::R
  E::::E             M::::::M:::M   M:::M::::::M   R:::R      R::::R
  E:::::EEEEEEEEEE   M:::::M M:::M M:::M M:::::M   R:::RRRRRR:::::R
  E::::::::::::::E   M:::::M  M:::M:::M  M:::::M   R:::::::::::RR
  E:::::EEEEEEEEEE   M:::::M   M:::::M   M:::::M   R:::RRRRRR::::R
  E::::E             M:::::M    M:::M    M:::::M   R:::R      R::::R
  E::::E       EEEEE M:::::M     MMM     M:::::M   R:::R      R::::R
EE:::::EEEEEEEE::::E M:::::M             M:::::M   R:::R      R::::R
E::::::::::::::::::E M:::::M             M:::::M RR::::R      R::::R
EEEEEEEEEEEEEEEEEEEE MMMMMMM             MMMMMMM RRRRRRR      RRRRRR

[hadoop@ip-172-31-5-97 ~]$ hadoop distcp s3://brainstation-dsft/eng_1M_1gram.csv /user/hadoop/eng_1M_1gram/eng_1M_1gr
am.csv
2024-03-18 18:42:24,529 INFO tools.DistCp: Input Options: DistCpOptions{atomicCommit=false, syncFolder=false, deleteM
issing=false, ignoreFailures=false, overwrite=false, append=false, useDiff=false, useRdiff=false, fromSnapshot=null,
toSnapshot=null, skipCRC=false, blocking=true, numListstatusThreads=0, maxMaps=20, mapBandwidth=0.0, copyStrategy='un
iformsize', preserveStatus=[], atomicWorkPath=null, logPath=null, sourceFileListing=null, sourcePaths=[s3://brainstat
ion-dsft/eng_1M_1gram.csv], targetPath=/user/hadoop/eng_1M_1gram/eng_1M_1gram.csv, filtersFile='null', blocksPerChunk
=0, copyBufferSize=8192, verboseLog=false, directWrite=false, useiterator=false}, sourcePaths=[s3://brainstation-dsft
/eng_1M_1gram.csv], targetPathExists=false, preserveRawXattrs=false
2024-03-18 18:42:24,775 INFO client.DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at ip-172-31-5-
97.us-east-2.compute.internal/172.31.5.97:8032
2024-03-18 18:42:24,919 INFO client.AHSProxy: Connecting to Application History server at ip-172-31-5-97.us-east-2.co
mpute.internal/172.31.5.97:10200
2024-03-18 18:42:27,640 INFO tools.SimpleCopyListing: Starting: Building listing using multi threaded approach for s3
://brainstation-dsft/eng_1M_1gram.csv
2024-03-18 18:42:27,642 INFO tools.SimpleCopyListing: Building listing using multi threaded approach for s3://brainst
ation-dsft/eng_1M_1gram.csv: duration 0:00.002s
2024-03-18 18:42:27,773 INFO tools.SimpleCopyListing: Paths (files+dirs) cnt = 1; dirCnt = 0
2024-03-18 18:42:27,773 INFO tools.SimpleCopyListing: Build file listing completed.
2024-03-18 18:42:27,774 INFO Configuration.deprecation: io.sort.mb is deprecated. Instead, use mapreduce.task.io.sort
.mb
2024-03-18 18:42:27,775 INFO Configuration.deprecation: io.sort.factor is deprecated. Instead, use mapreduce.task.io.
sort.factor
2024-03-18 18:42:27,886 INFO tools.DistCp: Number of paths in the copy list: 1
2024-03-18 18:42:27,911 INFO tools.DistCp: Number of paths in the copy list: 1
2024-03-18 18:42:27,936 INFO client.DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at ip-172-31-5-
97.us-east-2.compute.internal/172.31.5.97:8032
2024-03-18 18:42:27,936 INFO client.AHSProxy: Connecting to Application History server at ip-172-31-5-97.us-east-2.co
mpute.internal/172.31.5.97:10200
2024-03-18 18:42:28,022 INFO mapreduce.JobResourceUploader: Disabling Erasure Coding for path: /tmp/hadoop-yarn/stagi
ng/hadoop/.staging/job_1710782882902_0010
2024-03-18 18:42:28,132 INFO mapreduce.JobSubmitter: number of splits:1
2024-03-18 18:42:28,292 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1710782882902_0010
2024-03-18 18:42:28,292 INFO mapreduce.JobSubmitter: Executing with tokens: []
2024-03-18 18:42:28,468 INFO conf.Configuration: resource-types.xml not found
2024-03-18 18:42:28,468 INFO resource.ResourceUtils: Unable to find 'resource-types.xml'.
```

Appendix J



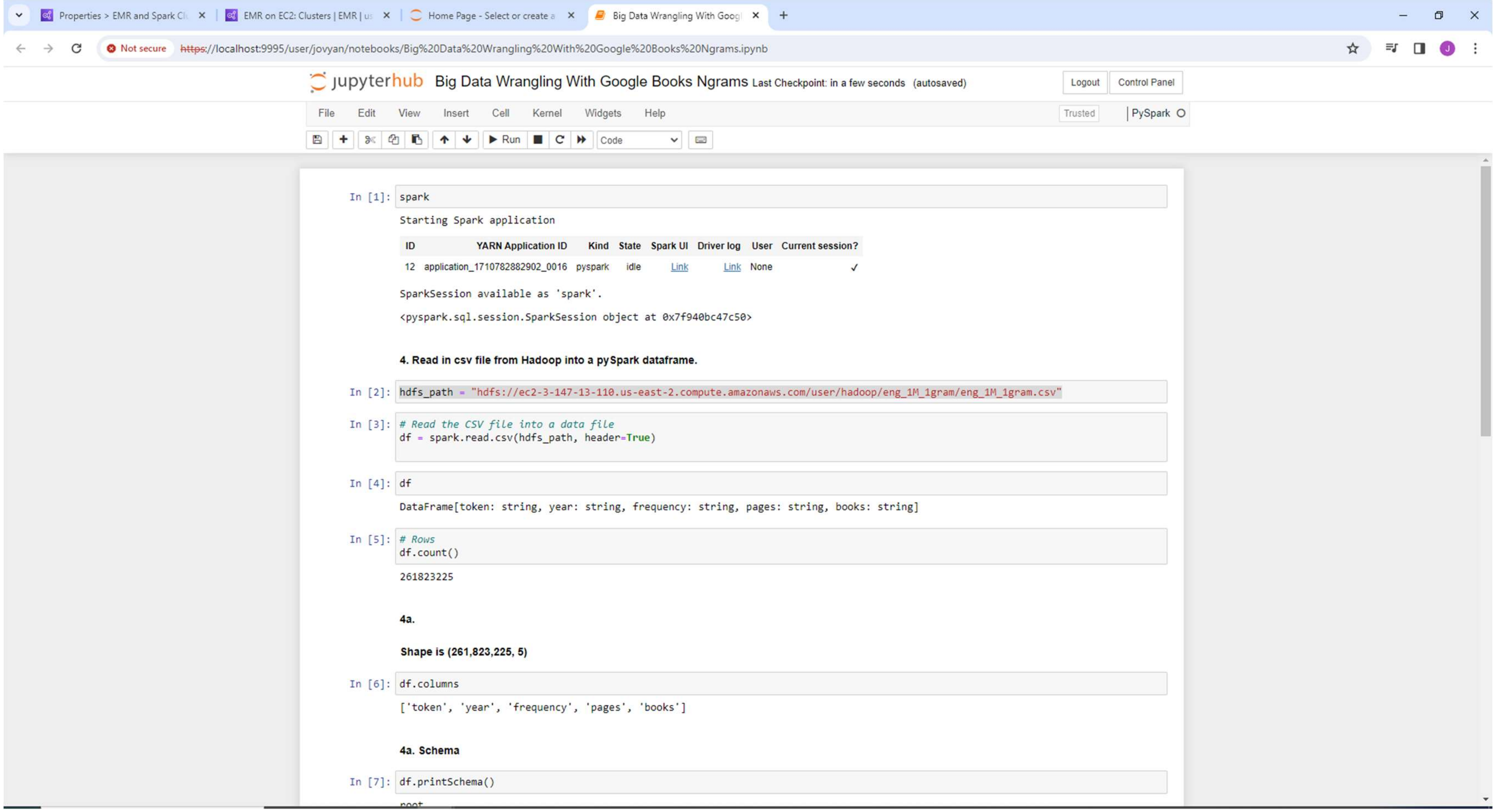
```
2024-03-18 18:42:28,528 INFO impl.YarnClientImpl: Submitted application application_1710782882902_0010
2024-03-18 18:42:28,575 INFO mapreduce.Job: The url to track the job: http://ip-172-31-5-97.us-east-2.compute.interna
l:20888/proxy/application_1710782882902_0010/
2024-03-18 18:42:28,575 INFO tools.DistCp: DistCp job-id: job_1710782882902_0010
2024-03-18 18:42:28,576 INFO mapreduce.Job: Running job: job_1710782882902_0010
2024-03-18 18:42:34,632 INFO mapreduce.Job: Job job_1710782882902_0010 running in uber mode : false
2024-03-18 18:42:34,633 INFO mapreduce.Job:  map 0% reduce 0%
2024-03-18 18:42:50,713 INFO mapreduce.Job:  map 100% reduce 0%
2024-03-18 18:43:37,893 INFO mapreduce.Job: Job job_1710782882902_0010 completed successfully
2024-03-18 18:43:37,977 INFO mapreduce.Job: Counters: 42
        File System Counters
                FILE: Number of bytes read=0
                FILE: Number of bytes written=294915
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=376
                HDFS: Number of bytes written=5292105197
                HDFS: Number of read operations=12
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=5
                HDFS: Number of bytes read erasure-coded=0
                S3: Number of bytes read=5292105197
                S3: Number of bytes written=0
                S3: Number of read operations=0
                S3: Number of large read operations=0
                S3: Number of write operations=0
        Job Counters
                Launched map tasks=1
                Other local map tasks=1
                Total time spent by all maps in occupied slots (ms)=5858592
                Total time spent by all reduces in occupied slots (ms)=0
                Total time spent by all map tasks (ms)=61027
                Total vcore-milliseconds taken by all map tasks=61027
                Total megabyte-milliseconds taken by all map tasks=187474944
        Map-Reduce Framework
                Map input records=1
                Map output records=0
                Input split bytes=137
                Spilled Records=0
                Failed Shuffles=0
                Merged Map outputs=0
                GC time elapsed (ms)=216
                CPU time spent (ms)=59680
                Physical memory (bytes) snapshot=1036165120
                Virtual memory (bytes) snapshot=4434186240
                Total committed heap usage (bytes)=617611264
                Peak Map Physical memory (bytes)=1068023808
                Peak Map Virtual memory (bytes)=4434186240
        File Input Format Counters
                Bytes Read=239
        File Output Format Counters
                Bytes Written=0
        DistCp Counters
                Bandwidth in Bytes=91243193
                Bytes Copied=5292105197
                Bytes Expected=5292105197
                Files Copied=1
[hadoop@ip-172-31-5-97 ~]$
```

Appendix K



```
(base) C:\Users\jay\Documents\BrainStation\AWS>ssh -i NewKeyPair.pem -L 9995:localhost:9443 hadoop@ec2-3-147-13-110.u
s-east-2.compute.amazonaws.com
Last login: Mon Mar 18 17:32:48 2024 from d24-150-232-237.home.cgocable.net

       __|  __|_  )
       _|  (     /   Amazon Linux 2 AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-2/
64 package(s) needed for security, out of 94 available
Run "sudo yum update" to apply all updates.
Last login: Mon Mar 18 17:32:48 2024 from d24-150-232-237.home.cgocable.net

       __|  __|_  )
       _|  (     /   Amazon Linux 2 AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-2/
64 package(s) needed for security, out of 94 available
Run "sudo yum update" to apply all updates.

EEEEEEEEEEEEEEEEEEEE MMMMMMMM           MMMMMMMM RRRRRRRRRRRRRRR
E::::::::::::::::::E M:::::::M         M:::::::M R::::::::::::::R
EE:::::EEEEEEEEE:::E M::::::::M       M::::::::M R:::::RRRRRR:::::R
  E::::E       EEEEE M:::::::::M     M:::::::::M RR::::R      R::::R
  E::::E             M::::::M:::M   M:::M::::::M   R:::R      R::::R
  E:::::EEEEEEEEEE   M:::::M M:::M M:::M M:::::M   R:::RRRRRR:::::R
  E::::::::::::::E   M:::::M  M:::M:::M  M:::::M   R:::::::::::RR
  E:::::EEEEEEEEEE   M:::::M   M:::::M   M:::::M   R:::RRRRRR::::R
  E::::E             M:::::M    M:::M    M:::::M   R:::R      R::::R
  E::::E       EEEEE M:::::M     MMM     M:::::M   R:::R      R::::R
EE:::::EEEEEEEE::::E M:::::M             M:::::M   R:::R      R::::R
E::::::::::::::::::E M:::::M             M:::::M RR::::R      R::::R
EEEEEEEEEEEEEEEEEEEE MMMMMMM             MMMMMMM RRRRRRR      RRRRRR

[hadoop@ip-172-31-5-97 ~]$
```

Appendix L


Properties > EMR and Spark Cl
EMR on EC2: Clusters | EMR | us
Home Page - Select or create a
Big Data Wrangling With Googl
Not secure
https://localhost:9995/user/jovyan/notebooks/Big%20Data%20Wrangling%20With%20Google%20Books%20Ngrams.ipynb
jupyterhub
Big Data Wrangling With Google Books Ngrams Last Checkpoint: in a few seconds (autosaved)
Logout
Control Panel
File
Edit
View
Insert
Cell
Kernel
Widgets
Help
Trusted
PySpark
Run
Code

```
In [1]: spark
```

Starting Spark application

ID	YARN Application ID	Kind	State	Spark UI	Driver log	User	Current session?
12	application_1710782882902_0016	pyspark	idle	Link	Link	None	✓

```
SparkSession available as 'spark'.

<pyspark.sql.session.SparkSession object at 0x7f940bc47c50>
```

4. Read in csv file from Hadoop into a pySpark dataframe.

```
In [2]: hdfs_path = "hdfs://ec2-3-147-13-110.us-east-2.compute.amazonaws.com/user/hadoop/eng_1M_1gram/eng_1M_1gram.csv"

In [3]: # Read the CSV file into a data file
        df = spark.read.csv(hdfs_path, header=True)

In [4]: df

        DataFrame[token: string, year: string, frequency: string, pages: string, books: string]

In [5]: # Rows
        df.count()

        261823225
```

4a.

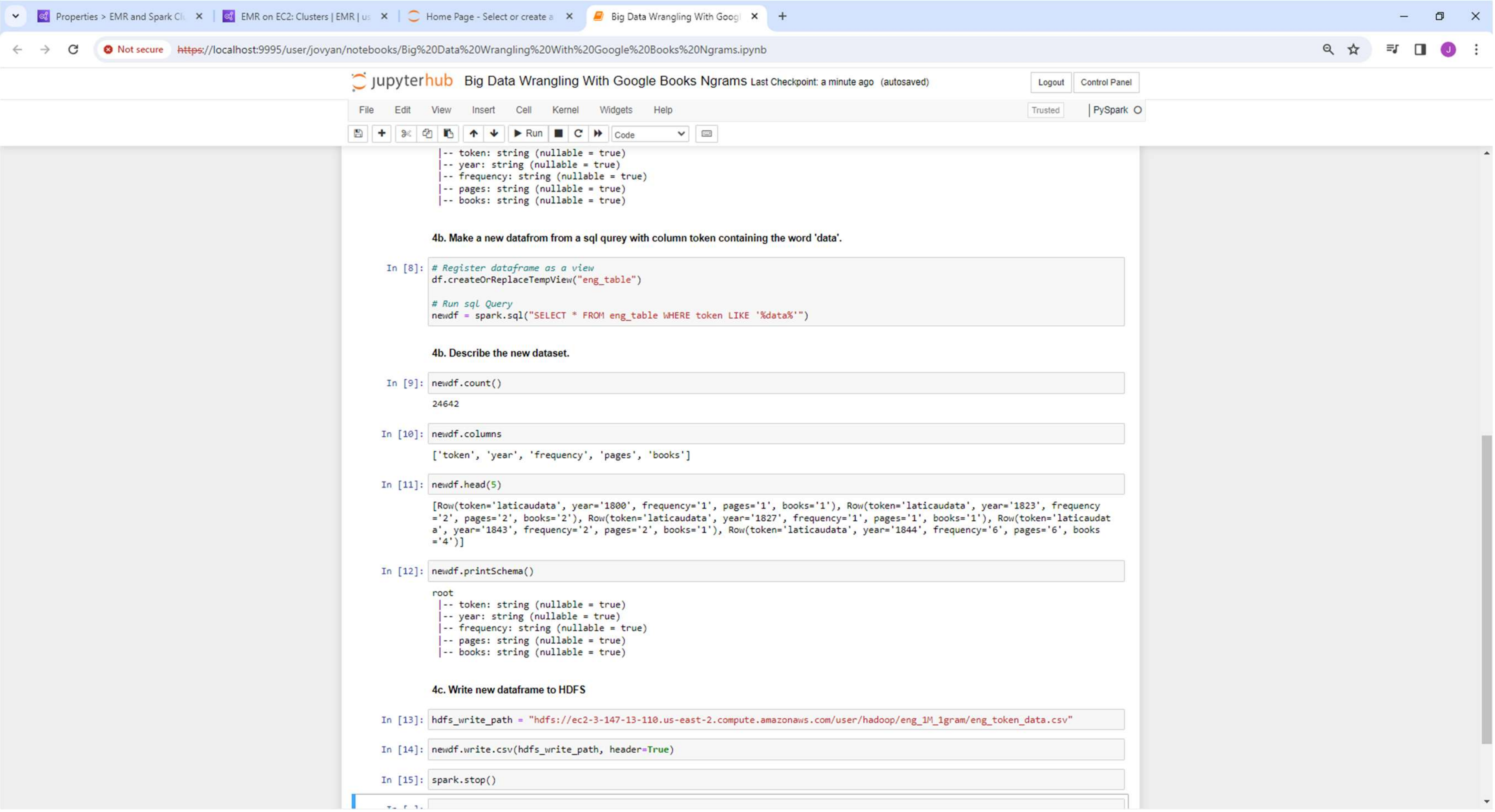
Shape is (261,823,225, 5)

```
In [6]: df.columns

        ['token', 'year', 'frequency', 'pages', 'books']
```

4a. Schema

```
In [7]: df.printSchema()

        root
```

Appendix M


Properties > EMR and Spark Cl
EMR on EC2: Clusters | EMR | us
Home Page - Select or create a
Big Data Wrangling With Googl
Not secure
https://localhost:9995/user/jovyan/notebooks/Big%20Data%20Wrangling%20With%20Google%20Books%20Ngrams.ipynb
jupyterhub
Big Data Wrangling With Google Books Ngrams Last Checkpoint: a minute ago (autosaved)
Logout
Control Panel
File
Edit
View
Insert
Cell
Kernel
Widgets
Help
Trusted
PySpark
Run
Code

```
 |-- token: string (nullable = true)
 |-- year: string (nullable = true)
 |-- frequency: string (nullable = true)
 |-- pages: string (nullable = true)
 |-- books: string (nullable = true)
```

4b. Make a new datafrom from a sql qurey with column token containing the word 'data'.

```
In [8]: # Register dataframe as a view
        df.createOrReplaceTempView("eng_table")

        # Run sql Query
        newdf = spark.sql("SELECT * FROM eng_table WHERE token LIKE '%data%'")
```

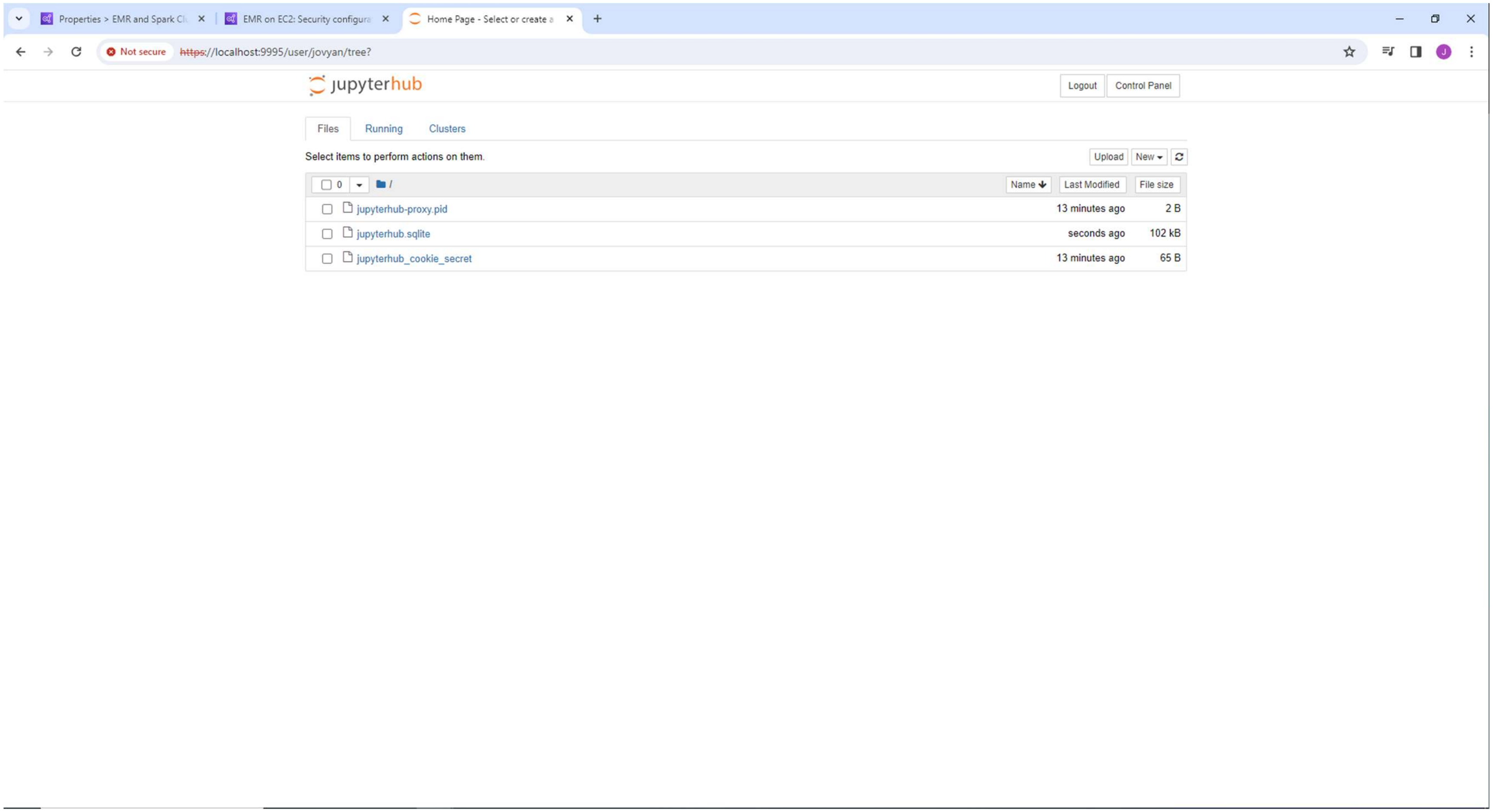
4b. Describe the new dataset.

```
In [9]: newdf.count()

        24642

In [10]: newdf.columns

         ['token', 'year', 'frequency', 'pages', 'books']

In [11]: newdf.head(5)

         [Row(token='laticaudata', year='1800', frequency='1', pages='1', books='1'), Row(token='laticaudata', year='1823', frequency
         ='2', pages='2', books='2'), Row(token='laticaudata', year='1827', frequency='1', pages='1', books='1'), Row(token='laticaudat
         a', year='1843', frequency='2', pages='2', books='1'), Row(token='laticaudata', year='1844', frequency='6', pages='6', books
         ='4')]

In [12]: newdf.printSchema()

         root
          |-- token: string (nullable = true)
          |-- year: string (nullable = true)
          |-- frequency: string (nullable = true)
          |-- pages: string (nullable = true)
          |-- books: string (nullable = true)
```

4c. Write new dataframe to HDFS

```
In [13]: hdfs_write_path = "hdfs://ec2-3-147-13-110.us-east-2.compute.amazonaws.com/user/hadoop/eng_1M_1gram/eng_token_data.csv"

In [14]: newdf.write.csv(hdfs_write_path, header=True)

In [15]: spark.stop()
```

Appendix N


Properties > EMR and Spark Cl
EMR on EC2: Security configura
Home Page - Select or create a
Not secure
https://localhost:9995/user/jovyan/tree?
jupyterhub
Logout
Control Panel
Files
Running
Clusters
Upload
New
Name
Last Modified
File size

Select items to perform actions on them.

□ 0 /

Name	Last Modified	File size
□ jupyterhub-proxy.pid	13 minutes ago	2 B
□ jupyterhub.sqlite	seconds ago	102 kB
□ jupyterhub_cookie_secret	13 minutes ago	65 B