> Jiahui Tang

Spec:

- Cluster: AWS Hadoop EMR cluster with 2/4/8 worker instances, with instances type m4.xlarge
- Kernal:

```
[hadoop@ip-172-31-16-80 ~]$ uname -a
Linux ip-172-31-16-80 4.14.200-155.322.amzn2.x86_64 #1 SMP Thu Oct 15 20:11:12 UTC 2020 x86_64 x86_64 x86_64 GNU/Linux
[hadoop@ip-172-31-16-80 ~]$
```

- Network:

```
[hadoop@ip-172-31-16-80 ~]$ ping 172.31.25.92
PING 172.31.25.92 (172.31.25.92) 56(84) bytes of data.
64 bytes from 172.31.25.92: icmp_seq=1 ttl=255 time=0.152 ms
64 bytes from 172.31.25.92: icmp_seq=2 ttl=255 time=0.165 ms
64 bytes from 172.31.25.92: icmp_seq=3 ttl=255 time=0.184 ms
64 bytes from 172.31.25.92: icmp_seq=4 ttl=255 time=0.160 ms
64 bytes from 172.31.25.92: icmp_seq=5 ttl=255 time=0.130 ms
64 bytes from 172.31.25.92: icmp_seq=6 ttl=255 time=0.156 ms
64 bytes from 172.31.25.92: icmp_seq=7 ttl=255 time=0.173 ms
64 bytes from 172.31.25.92: icmp_seq=8 ttl=255 time=0.188 ms
64 bytes from 172.31.25.92: icmp_seq=9 ttl=255 time=0.203 ms
64 bytes from 172.31.25.92: icmp_seq=10 ttl=255 time=0.159 ms
64 bytes from 172.31.25.92: icmp_seq=11 ttl=255 time=0.155 ms
64 bytes from 172.31.25.92: icmp_seq=12 ttl=255 time=0.157 ms
^C
--- 172.31.25.92 ping statistics ---
12 packets transmitted, 12 received, 0% packet loss, time 11258ms
rtt min/avg/max/mdev = 0.130/0.165/0.203/0.019 ms
[hadoop@ip-172-31-16-80 ~]$
```

- Bandwidth: Amazon says it's 5 Gbps
- Python Version:

```
[hadoop@ip-172-31-16-80 ~]$ python --version
Python 3.7.9
[hadoop@ip-172-31-16-80 ~]$
```

- CPU Info:

```
[hadoop@ip-172-31-16-80 ~]$ cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 79
model name      : Intel(R) Xeon(R) CPU E5-2686 v4 @ 2.30GHz
stepping        : 1
microcode       : 0xb000038
cpu MHz         : 2299.982
cache size      : 46080 KB
physical id     : 0
siblings        : 4
core id         : 0
cpu cores       : 2
apicid          : 0
initial apicid  : 0
fpu             : yes
fpu_exception   : yes
cpuid level     : 13
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat
 x2apic movbe popcnt tsc_deadline_timer aes xsave avx f16c rdrand hypervisor lahf_lm
bugs            : cpu_meltdown spectre_v1 spectre_v2 spec_store_bypass l1tf mds swap
bogomips        : 4600.14
clflush size    : 64
cache_alignment : 64
address sizes   : 46 bits physical, 48 bits virtual
power management:
```

```
[hadoop@ip-172-31-16-80 ~]$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    2
Core(s) per socket:    2
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 79
Model name:            Intel(R) Xeon(R) CPU E5-2686 v4 @ 2.30GHz
Stepping:              1
CPU MHz:               2299.982
BogoMIPS:              4600.14
Hypervisor vendor:     Xen
Virtualization type:   full
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              46080K
NUMA node0 CPU(s):     0-3
Flags:                 fpu vme de pse tsc msr pae mce cx8 apic sep mtrr p
```

1.6. Parallel Execution (25 points)

Use the Distributed Grep MapReduce code developed in exercise 1.1 and the large version of the movielens data set (224MB) to show the ratings with 5.0 stars.

- Execute the MapReduce code on a cluster with 2, 4 and 8 m4.xlarge worker instances (i.e. core nodes only) and calculate the speedup. You can start with a cluster of 2 worker nodes and then dynamically resize it to include more nodes (Hardware tab).

Note - we recommend that you hard-code the input argument for AWS EMR interface/GUI in the mapper function you wrote in problem 1.1. Also if you get stuck on provisioning when working with 8 cores, you may have to request a limit increase.

Submission
- `P16.pdf`: Description of the experiment and discussion about the performance and speed-up,

Result

Workder Instances/Core Nodes	Log Time	Speedup
2 nodes	86 sec	1
4 nodes	66 sec	1.3030
8 nodes	52 sec	1.6538

Discussion of Performance

`grep` is a command-line utility for searching plain-text data sets for lines that match a regular expression. Its name comes from the ed command g/re/p (globally search for a regular expression and print matching lines), which has the same effect.

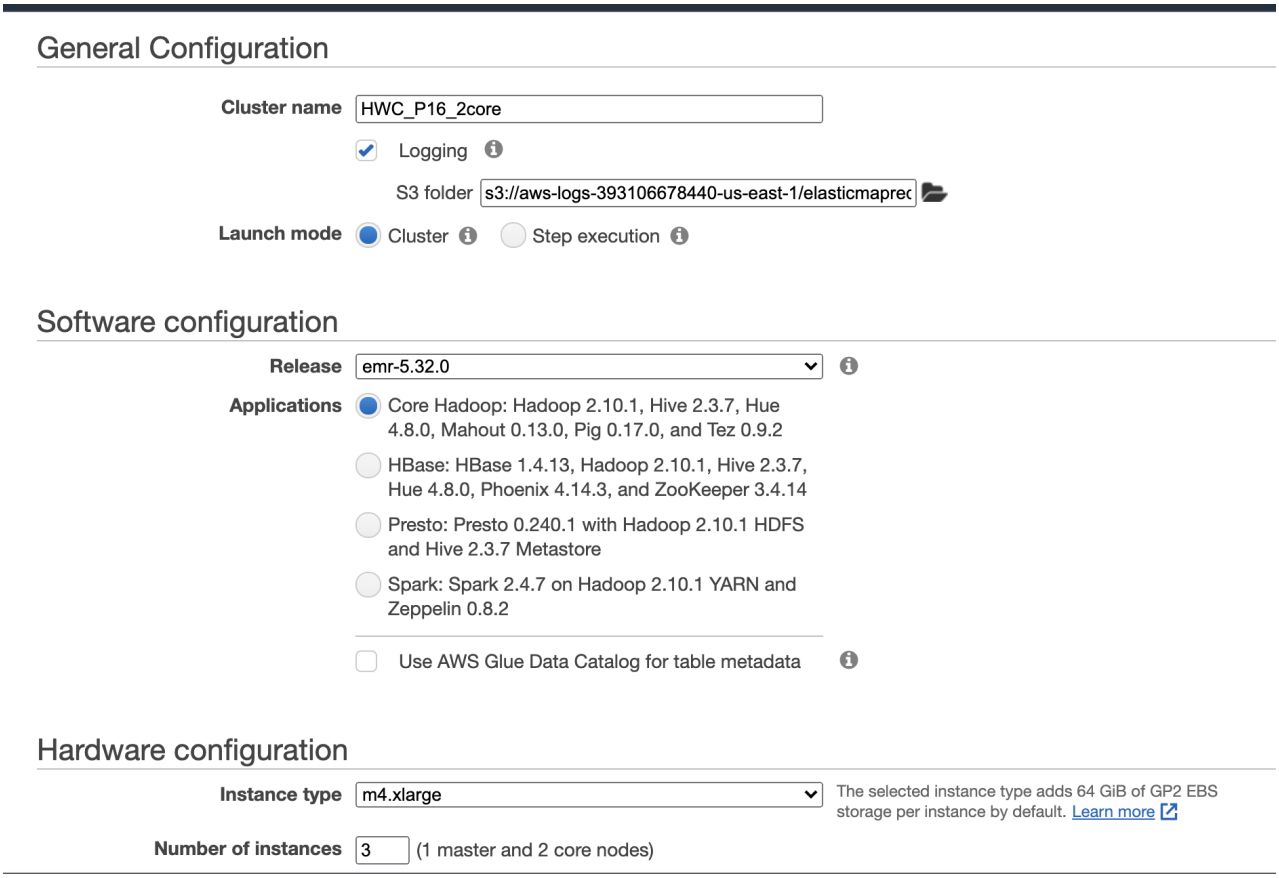
From the result table, we could see that after we increase the node, the log time didn't decrease a lot, and speedup also only increase from `1` to `1.3` and `1.6`, for node increases from `2` to `4` and `8` respectively.

It is mainly because of `grep` has a I/O bound, rather than CPU bound (In CPU we only check for `5.0 in line`).

As the `EXECUTION_TIME = CPU_TIME + I/O_TIME + SYSTEM_TIME`, when we increase the node, we could decrease `CPU_TIME`, as it is being parallelized. However, as we are doing grep and search for the same pattern, the read and write data part takes a large amount of total execution time, which also keeps unchanged even when the nodes are increased. Thus, as `I/O_TIME` keeps unchanged, while provisioning and shuffle data into more nodes may take more time in Hadoop job, `SYSTEM_TIME` may also be increase, which shows overhead overall is proportional to the number of workers. The total speedup would thus be way less than theortical speed up when number of nodes increases.

Steps/Experiment

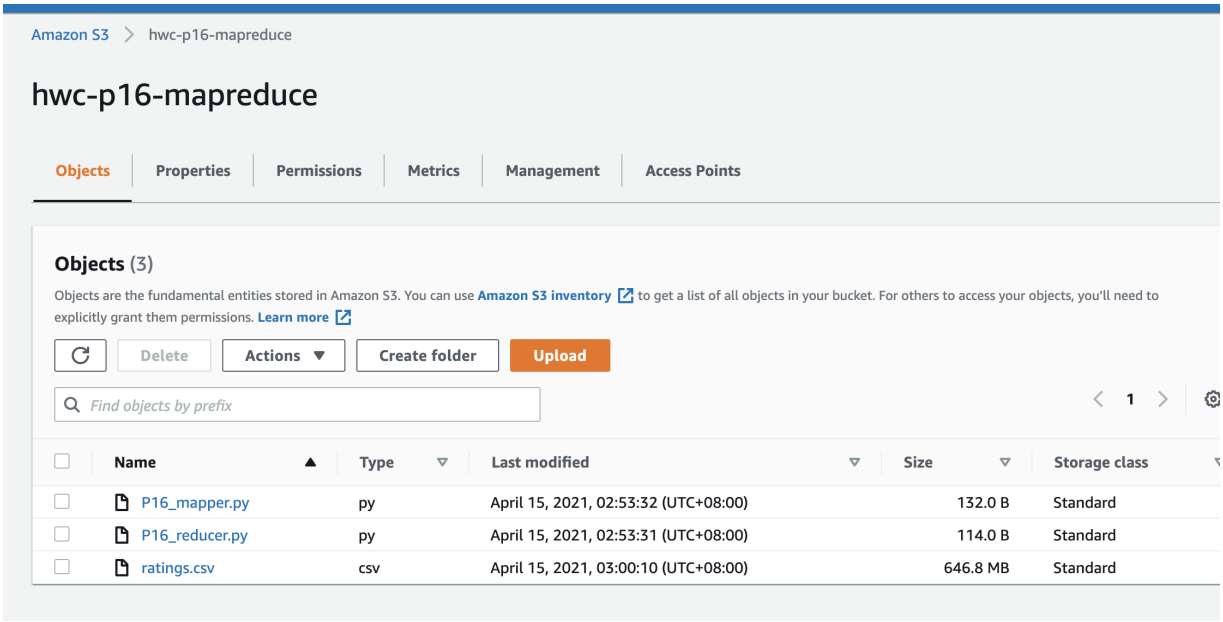
1. Start Hadoop EMR Cluster with 3 instances (1 master + 2 core nodes)



2. Uploading ratings.csv and mapper and reducer python files to S3 buckets (either use cmd line as below or GUI)

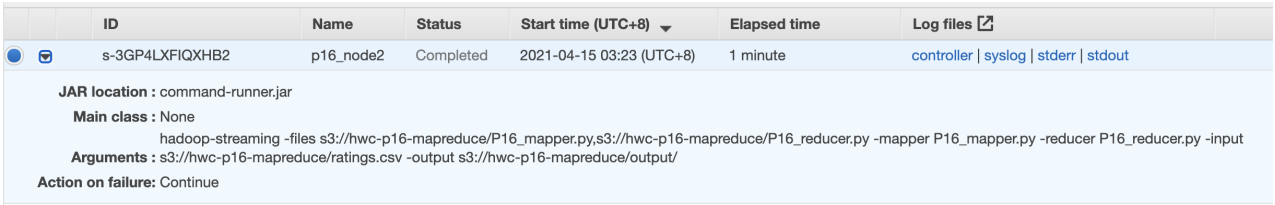
```
[hadoop@ip-172-31-21-150 ml-25m]$ ls -lh
total 1.1G
-rw-rw-r-- 1 hadoop hadoop 416M Nov 21  2019 genome-scores.csv
-rw-rw-r-- 1 hadoop hadoop  18K Nov 21  2019 genome-tags.csv
-rw-rw-r-- 1 hadoop hadoop 1.4M Nov 21  2019 links.csv
-rw-rw-r-- 1 hadoop hadoop 2.9M Nov 21  2019 movies.csv
-rw-rw-r-- 1 hadoop hadoop 647M Nov 21  2019 ratings.csv
-rw-rw-r-- 1 hadoop hadoop  11K Nov 21  2019 README.txt
-rw-rw-r-- 1 hadoop hadoop  38M Nov 21  2019 tags.csv
[hadoop@ip-172-31-21-150 ml-25m]$ aws s3 ls
2021-03-24 11:39:24 aws-logs-393106678440-us-east-1
2021-03-24 12:00:24 emr-example-python-lab8
2021-04-14 18:52:22 hwc-p16-mapreduce
[hadoop@ip-172-31-21-150 ml-25m]$ aws s3 cp ratings.csv s3://hwc-p16-mapreduce
upload: ./ratings.csv to s3://hwc-p16-mapreduce/ratings.csv
[hadoop@ip-172-31-21-150 ml-25m]$
```

3. Uploaded files used for MapReduce Job in S3 bucket



4. A screenshot for mapper and reducer (with hardcoded input argue for 5.0 ratings)

5. Go to the Hadoop cluster dashboard's Steps tab and click on "Add Step" to create hadoop job with files in S3 bucket.



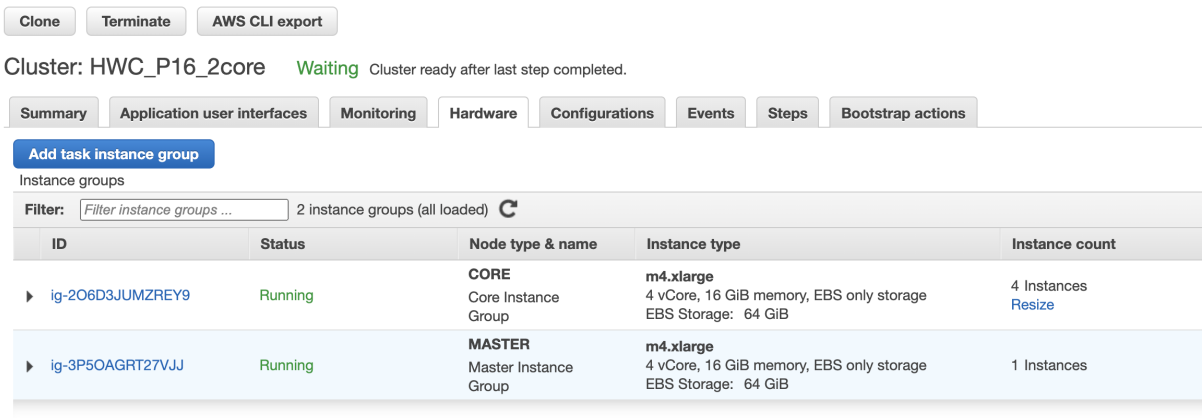
6. Controller Log for 2 core nodes (86 seconds)

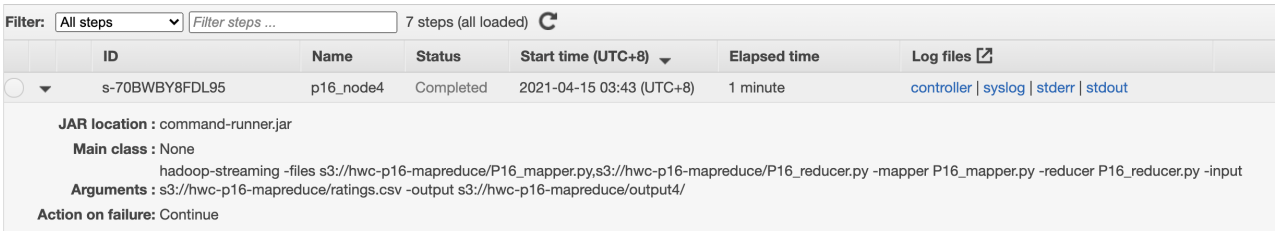
```
2021-04-14T19:23:01.096Z INFO Ensure step 6 jar file command-runner.jar
2021-04-14T19:23:01.097Z INFO StepRunner: Created Runner for step 6
INFO startExec 'hadoop jar /var/lib/aws/emr/step-runner/hadoop-jars/command-runner.jar hadoop-streaming -files s3://hwc-p16-mapreduce/P16_mapper.py,s3://hwc-p16-mapreduce/P16_reduc
mapper P16_mapper.py -reducer P16_reducer.py -input s3://hwc-p16-mapreduce/ratings.csv -output s3://hwc-p16-mapreduce/output/'
INFO Environment:
  PATH=/usr/lib64/qt-3.3/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin
  SECURITY_PROPERTIES=/emr/instance-controller/lib/security.properties
  HISTCONTROL=ignoredups
  HISTSIZE=1000
  HADOOP_ROOT_LOGGER=INFO,DRFA
  JAVA_HOME=/etc/alternatives/jre
  AWS_DEFAULT_REGION=us-east-1
  LANG=en_US.UTF-8
  MAIL=/var/spool/mail/hadoop
  LOGNAME=hadoop
  PWD=/
  HADOOP_CLIENT_OPTS=-Djava.io.tmpdir=/mnt/var/lib/hadoop/steps/s-3GP4LXFIQXHB2/tmp
  _=/etc/alternatives/jre/bin/java
  LESSOPEN=||/usr/bin/lesspipe.sh %s
  SHELL=/bin/bash
  QTINC=/usr/lib64/qt-3.3/include
  USER=hadoop
  HADOOP_LOGFILE=syslog
  HOSTNAME=ip-172-31-21-150
  QTDIR=/usr/lib64/qt-3.3
  HADOOP_LOG_DIR=/mnt/var/log/hadoop/steps/s-3GP4LXFIQXHB2
  EMR_STEP_ID=s-3GP4LXFIQXHB2
  QTLIB=/usr/lib64/qt-3.3/lib
  HOME=/home/hadoop
  SHLVL=1
  HADOOP_IDENT_STRING=hadoop
INFO redirectOutput to /mnt/var/log/hadoop/steps/s-3GP4LXFIQXHB2/stdout
INFO redirectError to /mnt/var/log/hadoop/steps/s-3GP4LXFIQXHB2/stderr
INFO Working dir /mnt/var/lib/hadoop/steps/s-3GP4LXFIQXHB2
INFO ProcessRunner started child process 32400
2021-04-14T19:23:01.098Z INFO HadoopJarStepRunner.Runner: startRun() called for s-3GP4LXFIQXHB2 Child Pid: 32400
INFO Synchronously wait child process to complete : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO waitProcessCompletion ended with exit code 0 : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO total process run time: 86 seconds
2021-04-14T19:24:27.349Z INFO Step created jobs: job_1618425734177_0001
2021-04-14T19:24:27.349Z INFO Step succeeded with exitCode 0 and took 86 seconds
```

7. Taking a peek into output files in S3 bucket to confirm the output is as expected.

```
[hadoop@ip-172-31-21-150 ml-25m]$ aws s3 cp s3://hwc-p16-mapreduce/output/part-00001 output.txt
download: s3://hwc-p16-mapreduce/output/part-00001 to ./output.txt
[hadoop@ip-172-31-21-150 ml-25m]$ cat output.txt
41426,59315,5.0,1545097716
41426,58559,5.0,1548552560
41426,53996,5.0,1547391387
41426,48780,5.0,1574088036
41426,7569,5.0,1569884286
41426,7454,5.0,1545509602
41426,7153,5.0,1569367654
41426,5952,5.0,1568069330
41426,5833,5.0,1572391935
41426,5459,5.0,1553128705
41426,4993,5.0,1566178320
41426,4638,5.0,1557446014
41426,4270,5.0,1572187794
41426,3702,5.0,1573691665
41426,3697,5.0,1554338401
41426,2993,5.0,1567425106
41426,2949,5.0,1566151127
41426,2947,5.0,1567000600
41426,2617,5.0,1569639005
41426,2571,5.0,1546217171
41426,1562,5.0,1567903683
41426,1527,5.0,1554765682
41426,1240,5.0,1564098890
41426,1198,5.0,1568479236
41426,1129,5.0,1559259144
41426,589,5.0,1564367880
41426,480,5.0,1556976627
41426,153,5.0,1567626869
41426,110,5.0,1544308149
41424,589,5.0,835365458
41424,548,5.0,835365285
```

8. Resize to 4 core nodes and redo step 5-7

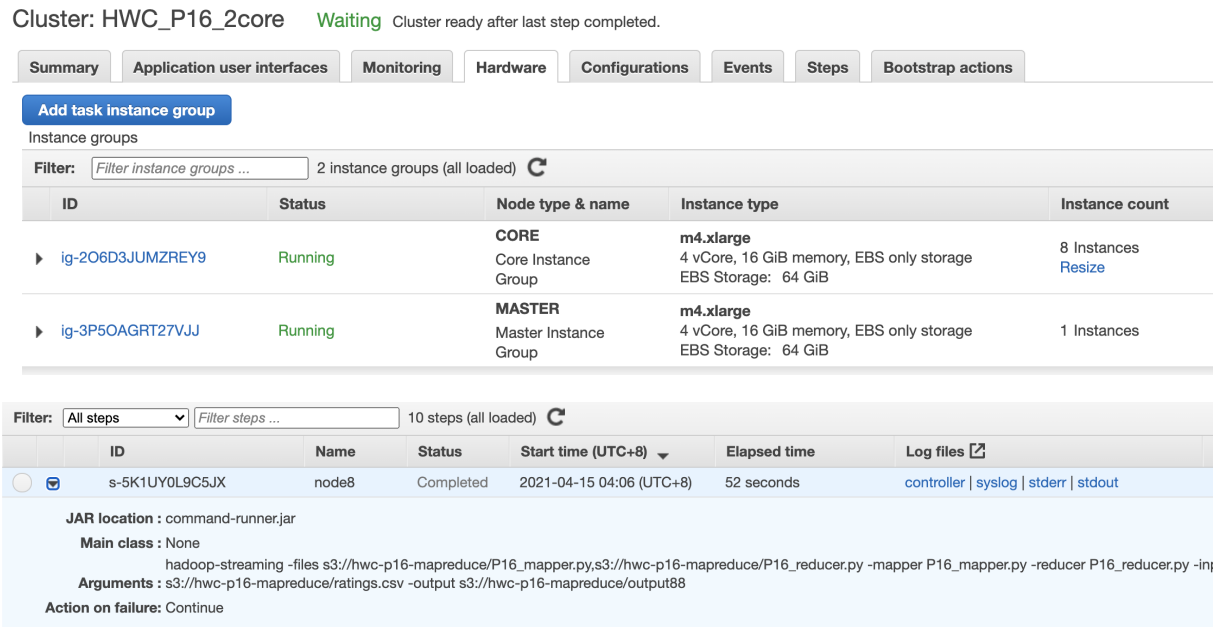




9. Controller Log for 4 core nodes (66 seconds)

```
2021-04-14T19:43:27.570Z INFO Ensure step 7 jar file command-runner.jar
2021-04-14T19:43:27.571Z INFO StepRunner: Created Runner for step 7
INFO startExec 'hadoop jar /var/lib/aws/emr/step-runner/hadoop-jars/command-runner.jar hadoop-streaming -files s3://hwc-p16-mapreduce/P16_mapper.py,s3://hwc-p16
mapper P16_mapper.py -reducer P16_reducer.py -input s3://hwc-p16-mapreduce/ratings.csv -output s3://hwc-p16-mapreduce/output4/'
INFO Environment:
  PATH=/usr/lib64/qt-3.3/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin
  SECURITY_PROPERTIES=/emr/instance-controller/lib/security.properties
  HISTCONTROL=ignoredups
  HISTSIZE=1000
  HADOOP_ROOT_LOGGER=INFO,DRFA
  JAVA_HOME=/etc/alternatives/jre
  AWS_DEFAULT_REGION=us-east-1
  LANG=en_US.UTF-8
  MAIL=/var/spool/mail/hadoop
  LOGNAME=hadoop
  PWD=/
  HADOOP_CLIENT_OPTS=-Djava.io.tmpdir=/mnt/var/lib/hadoop/steps/s-70BWBY8FDL95/tmp
  _=/etc/alternatives/jre/bin/java
  LESSOPEN=||/usr/bin/lesspipe.sh %s
  SHELL=/bin/bash
  QTINC=/usr/lib64/qt-3.3/include
  USER=hadoop
  HADOOP_LOGFILE=syslog
  HOSTNAME=ip-172-31-21-150
  QTDIR=/usr/lib64/qt-3.3
  HADOOP_LOG_DIR=/mnt/var/log/hadoop/steps/s-70BWBY8FDL95
  EMR_STEP_ID=s-70BWBY8FDL95
  QTLIB=/usr/lib64/qt-3.3/lib
  HOME=/home/hadoop
  SHLVL=1
  HADOOP_IDENT_STRING=hadoop
INFO redirectOutput to /mnt/var/log/hadoop/steps/s-70BWBY8FDL95/stdout
INFO redirectError to /mnt/var/log/hadoop/steps/s-70BWBY8FDL95/stderr
INFO Working dir /mnt/var/lib/hadoop/steps/s-70BWBY8FDL95
INFO ProcessRunner started child process 18397
2021-04-14T19:43:27.572Z INFO HadoopJarStepRunner.Runner: startRun() called for s-70BWBY8FDL95 Child Pid: 18397
INFO Synchronously wait child process to complete : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO waitProcessCompletion ended with exit code 0 : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO total process run time: 66 seconds
2021-04-14T19:44:33.678Z INFO Step created jobs: job_1618425734177_0002
2021-04-14T19:44:33.678Z INFO Step succeeded with exitCode 0 and took 66 seconds
```

10. Resize to 8 nodes and redo step 5-7



11. Controller Log for 8 core nodes (52 seconds)

```
2021-04-14T20:06:53.068Z INFO Ensure step 10 jar file command-runner.jar
2021-04-14T20:06:53.068Z INFO StepRunner: Created Runner for step 10
INFO startExec 'hadoop jar /var/lib/aws/emr/step-runner/hadoop-jars/command-runner.jar hadoop-streaming -files s3://hwc-p16-mapreduce/P16_mapper.py,s3://
mapper P16_mapper.py -reducer P16_reducer.py -input s3://hwc-p16-mapreduce/ratings.csv -output s3://hwc-p16-mapreduce/output88'
INFO Environment:
  PATH=/usr/lib64/qt-3.3/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin
  SECURITY_PROPERTIES=/emr/instance-controller/lib/security.properties
  HISTCONTROL=ignoredups
  HISTSIZE=1000
  HADOOP_ROOT_LOGGER=INFO,DRFA
  JAVA_HOME=/etc/alternatives/jre
  AWS_DEFAULT_REGION=us-east-1
  LANG=en_US.UTF-8
  MAIL=/var/spool/mail/hadoop
  LOGNAME=hadoop
  PWD=/
  HADOOP_CLIENT_OPTS=-Djava.io.tmpdir=/mnt/var/lib/hadoop/steps/s-5K1UY0L9C5JX/tmp
  _=/etc/alternatives/jre/bin/java
  LESSOPEN=||/usr/bin/lesspipe.sh %s
  SHELL=/bin/bash
  QTINC=/usr/lib64/qt-3.3/include
  USER=hadoop
  HADOOP_LOGFILE=syslog
  HOSTNAME=ip-172-31-21-150
  QTDIR=/usr/lib64/qt-3.3
  HADOOP_LOG_DIR=/mnt/var/log/hadoop/steps/s-5K1UY0L9C5JX
  EMR_STEP_ID=s-5K1UY0L9C5JX
  QTLIB=/usr/lib64/qt-3.3/lib
  HOME=/home/hadoop
  SHLVL=1
  HADOOP_IDENT_STRING=hadoop
INFO redirectOutput to /mnt/var/log/hadoop/steps/s-5K1UY0L9C5JX/stdout
INFO redirectError to /mnt/var/log/hadoop/steps/s-5K1UY0L9C5JX/stderr
INFO Working dir /mnt/var/lib/hadoop/steps/s-5K1UY0L9C5JX
INFO ProcessRunner started child process 27542
2021-04-14T20:06:53.069Z INFO HadoopJarStepRunner.Runner: startRun() called for s-5K1UY0L9C5JX Child Pid: 27542
INFO Synchronously wait child process to complete : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO waitProcessCompletion ended with exit code 0 : hadoop jar /var/lib/aws/emr/step-runner/hadoop-...
INFO total process run time: 52 seconds
2021-04-14T20:07:45.151Z INFO Step created jobs: job_1618425734177_0004
2021-04-14T20:07:45.151Z INFO Step succeeded with exitCode 0 and took 52 seconds
```

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