Course: C553
Cloud Computing
PA 2
TeraSort on Hadoop/Spark
Design Document and Performance

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Shared-Memory Terasort

- Implemented the Shared-Memory TeraSort application in your favorite language (without using Hadoop or Spark).
- Generated the 128GB and 1TB dataset and measure the time to sort it.
- It is multi-threaded to take advantage of multiple cores and SSD storage

Specification:

	Instance	VCPUs	Memory(Gib)	Instance Storage(GB)	Node	Region
Part 1	i3.large	2	15.25	1*0.475 NVMe SSD	1	us-east-1 (N. Virginia)
Part 2	i3.4xlarge	16	122	2*1.9 NVMe SSD	1	us-east-1 (N. Virginia)

Installation:

1. sudo apt-get install default-jdk
2. sudo apt-get update

Execution:

We have generated a a 128GB file using a tool call Gensort. Now the generated Input File is divided into chunks of small sizes.Small chunks are read from disk And Quick sort is performed on these small chunks and written back to disk. All the sorted small chunks are then merged and sorted together using Merge Sort and the Final Output File is generated which is validated using val Sort.

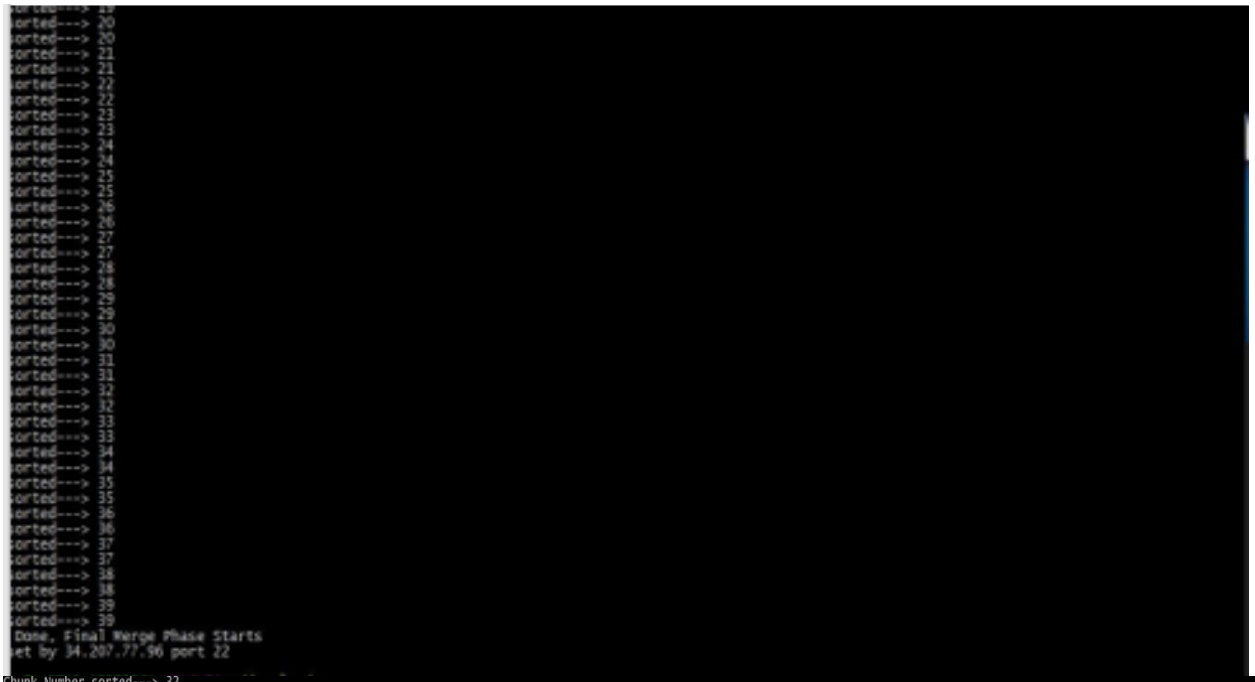
1. Virtual Cluster (1-node i3.large):

128 GB with 1 Thread (Sorting done totally with 772 chunks)

```
chunk-058.txt  chunk-119.txt  chunk-180.txt  chunk-241.txt  c
chunk-059.txt  chunk-120.txt  chunk-181.txt  chunk-242.txt  c
chunk-060.txt  chunk-121.txt  chunk-182.txt  chunk-243.txt  c
root@ip-172-31-33-187:/data/64# vi SharedMem.java
root@ip-172-31-33-187:/data/64# javac SharedMem.java
root@ip-172-31-33-187:/data/64# java -Xmx12g SharedMem 1
Time Taken in millis: 1.4261591E7
root@ip-172-31-33-187:/data/64# ls
```

```
chunk-035.txt  chunk-096.txt  chunk-157.txt  chunk-218.txt  chunk-279.txt  chunk-340.txt  chunk-401.txt  chunk-462.txt  chunk-523.txt  chunk-584.txt  chunk-645.txt  chunk-706.txt  chunk-767.txt
chunk-036.txt  chunk-097.txt  chunk-158.txt  chunk-219.txt  chunk-280.txt  chunk-341.txt  chunk-402.txt  chunk-463.txt  chunk-524.txt  chunk-585.txt  chunk-646.txt  chunk-707.txt  chunk-768.txt
chunk-037.txt  chunk-098.txt  chunk-159.txt  chunk-220.txt  chunk-281.txt  chunk-342.txt  chunk-403.txt  chunk-464.txt  chunk-525.txt  chunk-586.txt  chunk-647.txt  chunk-708.txt  chunk-769.txt
chunk-038.txt  chunk-099.txt  chunk-160.txt  chunk-221.txt  chunk-282.txt  chunk-343.txt  chunk-404.txt  chunk-465.txt  chunk-526.txt  chunk-587.txt  chunk-648.txt  chunk-709.txt  chunk-770.txt
chunk-039.txt  chunk-100.txt  chunk-161.txt  chunk-222.txt  chunk-283.txt  chunk-344.txt  chunk-405.txt  chunk-466.txt  chunk-527.txt  chunk-588.txt  chunk-649.txt  chunk-710.txt  chunk-771.txt
chunk-040.txt  chunk-101.txt  chunk-162.txt  chunk-223.txt  chunk-284.txt  chunk-345.txt  chunk-406.txt  chunk-467.txt  chunk-528.txt  chunk-589.txt  chunk-650.txt  chunk-711.txt  FinalOutput.txt
chunk-041.txt  chunk-102.txt  chunk-163.txt  chunk-224.txt  chunk-285.txt  chunk-346.txt  chunk-407.txt  chunk-468.txt  chunk-529.txt  chunk-590.txt  chunk-651.txt  chunk-712.txt  gensort
chunk-042.txt  chunk-103.txt  chunk-164.txt  chunk-225.txt  chunk-286.txt  chunk-347.txt  chunk-408.txt  chunk-469.txt  chunk-530.txt  chunk-591.txt  chunk-652.txt  chunk-713.txt  MergedOutput.txt
chunk-043.txt  chunk-104.txt  chunk-165.txt  chunk-226.txt  chunk-287.txt  chunk-348.txt  chunk-409.txt  chunk-470.txt  chunk-531.txt  chunk-592.txt  chunk-653.txt  chunk-714.txt  SharedMem$1.class
chunk-044.txt  chunk-105.txt  chunk-166.txt  chunk-227.txt  chunk-288.txt  chunk-349.txt  chunk-410.txt  chunk-471.txt  chunk-532.txt  chunk-593.txt  chunk-654.txt  chunk-715.txt  SharedMem.class
chunk-045.txt  chunk-106.txt  chunk-167.txt  chunk-228.txt  chunk-289.txt  chunk-350.txt  chunk-411.txt  chunk-472.txt  chunk-533.txt  chunk-594.txt  chunk-655.txt  chunk-716.txt  SharedMem.java
chunk-046.txt  chunk-107.txt  chunk-168.txt  chunk-229.txt  chunk-290.txt  chunk-351.txt  chunk-412.txt  chunk-473.txt  chunk-534.txt  chunk-595.txt  chunk-656.txt  chunk-717.txt  Test$1.class
chunk-047.txt  chunk-108.txt  chunk-169.txt  chunk-230.txt  chunk-291.txt  chunk-352.txt  chunk-413.txt  chunk-474.txt  chunk-535.txt  chunk-596.txt  chunk-657.txt  chunk-718.txt  Test.class
chunk-048.txt  chunk-109.txt  chunk-170.txt  chunk-231.txt  chunk-292.txt  chunk-353.txt  chunk-414.txt  chunk-475.txt  chunk-536.txt  chunk-597.txt  chunk-658.txt  chunk-719.txt  Test.java
chunk-049.txt  chunk-110.txt  chunk-171.txt  chunk-232.txt  chunk-293.txt  chunk-354.txt  chunk-415.txt  chunk-476.txt  chunk-537.txt  chunk-598.txt  chunk-659.txt  chunk-720.txt  valsort
chunk-050.txt  chunk-111.txt  chunk-172.txt  chunk-233.txt  chunk-294.txt  chunk-355.txt  chunk-416.txt  chunk-477.txt  chunk-538.txt  chunk-599.txt  chunk-660.txt  chunk-721.txt
chunk-051.txt  chunk-112.txt  chunk-173.txt  chunk-234.txt  chunk-295.txt  chunk-356.txt  chunk-417.txt  chunk-478.txt  chunk-539.txt  chunk-600.txt  chunk-661.txt  chunk-722.txt
chunk-052.txt  chunk-113.txt  chunk-174.txt  chunk-235.txt  chunk-296.txt  chunk-357.txt  chunk-418.txt  chunk-479.txt  chunk-540.txt  chunk-601.txt  chunk-662.txt  chunk-723.txt
chunk-053.txt  chunk-114.txt  chunk-175.txt  chunk-236.txt  chunk-297.txt  chunk-358.txt  chunk-419.txt  chunk-480.txt  chunk-541.txt  chunk-602.txt  chunk-663.txt  chunk-724.txt
chunk-054.txt  chunk-115.txt  chunk-176.txt  chunk-237.txt  chunk-298.txt  chunk-359.txt  chunk-420.txt  chunk-481.txt  chunk-542.txt  chunk-603.txt  chunk-664.txt  chunk-725.txt
chunk-055.txt  chunk-116.txt  chunk-177.txt  chunk-238.txt  chunk-299.txt  chunk-360.txt  chunk-421.txt  chunk-482.txt  chunk-543.txt  chunk-604.txt  chunk-665.txt  chunk-726.txt
chunk-056.txt  chunk-117.txt  chunk-178.txt  chunk-239.txt  chunk-300.txt  chunk-361.txt  chunk-422.txt  chunk-483.txt  chunk-544.txt  chunk-605.txt  chunk-666.txt  chunk-727.txt
chunk-057.txt  chunk-118.txt  chunk-179.txt  chunk-240.txt  chunk-301.txt  chunk-362.txt  chunk-423.txt  chunk-484.txt  chunk-545.txt  chunk-606.txt  chunk-667.txt  chunk-728.txt
chunk-058.txt  chunk-119.txt  chunk-180.txt  chunk-241.txt  chunk-302.txt  chunk-363.txt  chunk-424.txt  chunk-485.txt  chunk-546.txt  chunk-607.txt  chunk-668.txt  chunk-729.txt
chunk-059.txt  chunk-120.txt  chunk-181.txt  chunk-242.txt  chunk-303.txt  chunk-364.txt  chunk-425.txt  chunk-486.txt  chunk-547.txt  chunk-608.txt  chunk-669.txt  chunk-730.txt
chunk-060.txt  chunk-121.txt  chunk-182.txt  chunk-243.txt  chunk-304.txt  chunk-365.txt  chunk-426.txt  chunk-487.txt  chunk-548.txt  chunk-609.txt  chunk-670.txt  chunk-731.txt
root@ip-172-31-33-187:/data/64# du -sh FinalOutput.txt
128G    FinalOutput.txt
root@ip-172-31-33-187:/data/64# ./valsort FinalOutput.txt
Records: 1367122448
Checksum: 28be4709e85645cb
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-33-187:/data/64#
```

128GB with 2 threads :
Below is the progress shown in 128GB 2 thread run. We have printed the increment value to check the progress of the program. We created 80 chunks and each thread performed sorting on 40 chunks. Sorting was performed properly and Merging was done and Mergedoutput file was also generated, But the connection was reset at the End. We tracked the time though(around 5.15 hrs). We were very sure the program ran fully as we connected to the instance again and saw the output file with the 128GB size and we also performed valsort on the file and the result was success with the exact same amount of records. Those screenshots are shown below:




```
Chunk Number sorted---> 32
Chunk Number sorted---> 32
Chunk Number sorted---> 33
Chunk Number sorted---> 33
Chunk Number sorted---> 34
Chunk Number sorted---> 34
Chunk Number sorted---> 35
Chunk Number sorted---> 35
Chunk Number sorted---> 36
Chunk Number sorted---> 36
Chunk Number sorted---> 37
Chunk Number sorted---> 37
Chunk Number sorted---> 38
Chunk Number sorted---> 38
Chunk Number sorted---> 39
Chunk Number sorted---> 39
Sorted Chunks Done, Final Merge Phase Starts
Connection reset by 34.207.77.96 port 22

pshanmuganathan@LAPTOP-OI131IGQ MINGW64 ~/downloads
$ ssh -i "test8.pem" ubuntu@ec2-34-207-77-96.compute-1.amazonaws.com
Welcome to Ubuntu 16.04.3 LTS (GNU/Linux 4.4.0-1041-aws x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

  Get cloud support with Ubuntu Advantage Cloud Guest:
    http://www.ubuntu.com/business/services/cloud

5 packages can be updated.
0 updates are security updates.


Last login: Mon Dec  4 00:47:14 2017 from 207.237.205.216
ubuntu@ip-172-31-34-60:~$ sudo -i
root@ip-172-31-34-60:~# cd data/64
-bash: cd: data/64: No such file or directory
root@ip-172-31-34-60:~# cd /data/64
root@ip-172-31-34-60:/data/64# ls
chunk-00.txt  chunk-07.txt  chunk-14.txt  chunk-21.txt  chunk-28.txt  chunk-35.txt  chunk-42.txt  chunk-49.txt  chunk-56.txt  chunk-63.txt  chunk-70.txt  chunk-77.txt       SharedMem.java
chunk-01.txt  chunk-08.txt  chunk-15.txt  chunk-22.txt  chunk-29.txt  chunk-36.txt  chunk-43.txt  chunk-50.txt  chunk-57.txt  chunk-64.txt  chunk-71.txt  chunk-78.txt       valsort
chunk-02.txt  chunk-09.txt  chunk-16.txt  chunk-23.txt  chunk-30.txt  chunk-37.txt  chunk-44.txt  chunk-51.txt  chunk-58.txt  chunk-65.txt  chunk-72.txt  chunk-79.txt
chunk-03.txt  chunk-10.txt  chunk-17.txt  chunk-24.txt  chunk-31.txt  chunk-38.txt  chunk-45.txt  chunk-52.txt  chunk-59.txt  chunk-66.txt  chunk-73.txt  gensort
chunk-04.txt  chunk-11.txt  chunk-18.txt  chunk-25.txt  chunk-32.txt  chunk-39.txt  chunk-46.txt  chunk-53.txt  chunk-60.txt  chunk-67.txt  chunk-74.txt  MergedOutput.txt
chunk-05.txt  chunk-12.txt  chunk-19.txt  chunk-26.txt  chunk-33.txt  chunk-40.txt  chunk-47.txt  chunk-54.txt  chunk-61.txt  chunk-68.txt  chunk-75.txt  SharedMem$1.class
chunk-06.txt  chunk-13.txt  chunk-20.txt  chunk-27.txt  chunk-34.txt  chunk-41.txt  chunk-48.txt  chunk-55.txt  chunk-62.txt  chunk-69.txt  chunk-76.txt  SharedMem.class
root@ip-172-31-34-60:/data/64# ./valsort MergedOutput.txt
Records: 1280000000
Checksum: 26258da068f32569
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-34-60:/data/64# rm chunk*
root@ip-172-31-34-60:/data/64# la
gensort  MergedOutput.txt  SharedMem$1.class  SharedMem.class  SharedMem.java  valsort
root@ip-172-31-34-60:/data/64# ls
gensort  MergedOutput.txt  SharedMem$1.class  SharedMem.class  SharedMem.java  valsort
root@ip-172-31-34-60:/data/64# rm M*
root@ip-172-31-34-60:/data/64# ls
gensort  SharedMem$1.class  SharedMem.class  SharedMem.java  valsort
root@ip-172-31-34-60:/data/64# ./gensort -a 1280000000 InputFile.txt
```

2.Virtual Cluster (1-node i3.4xlarge):

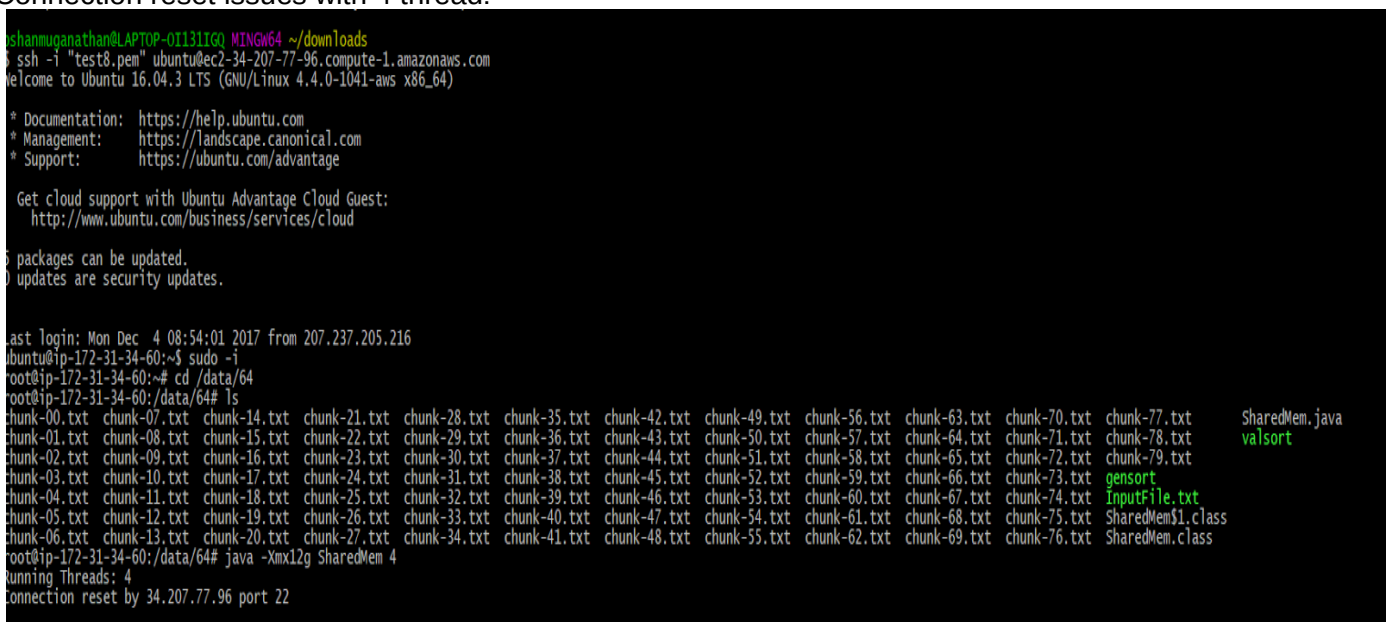
Final Metrics :

	Compute Time	Throughput
(128 GB) 1 Thread	3.96hrs	8.97 MB/sec
(128 GB) 2 Thread	4.3hrs	7.90 MB/sec
(1 TB) 1 Thread	9.5hrs	29MB/sec

And our finding is that the throughput will go down for 8 threads , as there will be issue with JVM increasing the Heap size.

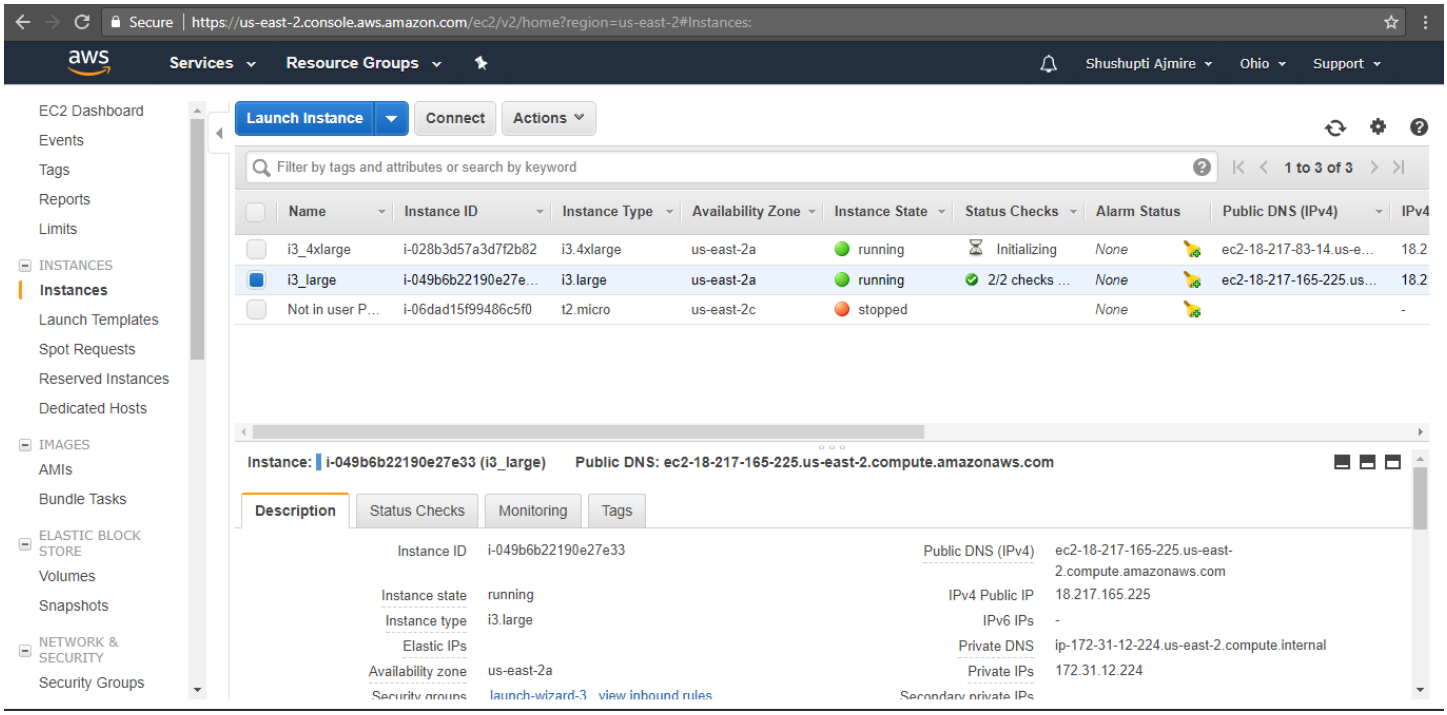
Issues:

Connection reset issues with 4 thread:



Hadoop Terasort

- We used Hadoop's Map-Reduce based implementation to sort large datasets.
- We Install Hadoop (including the HDFS distributed file system); all Hadoop components should be configured on this 1 node; load the 128GB dataset into HDFS; implement the Hadoop TeraSort application.
- Hadoop has a Sort and Shuffle phase, which does the Sorting of data internally, without writing any code particularly for sort.
- I have tested the performance of hadoop on 1-Node (128GB, 1TB) and 8-Node (1TB).



Specifications:

	Instance	VCPUs	Memory(Gib)	Instance Storage(GB)	Node	Region
Part 1	i3.large	2	15.25	1*0.475 NVMe SSD	1	us-east-2 (Ohio)
Part 2	i3.4xlarge	16	122	2*1.9 NVMe SSD	1	us-east-2 (Ohio)
Part 3	i3.large	2	15.25	1*0.475 NVMe SSD	8	us-east-2 (Ohio)

Installation:

1. Install EC2 instance for i3.large and i3.4xlarge.
2. Launch 1 instance of i3.large, and then we will make AMI of it and launch 8 slaves from the same AMI.
3. Sudo -i
4. Download wget http://www.apache.org/dyn/closer.cgi/hadoop/common/hadoop-2.8.2/hadoop-2.8.2.tar.gz
5. tar -xvzf hadoop-2.8.2.tar.gz mv hadoop-2.8.2.tar.gz hadoop
6. ssh root@localhost
   ssh-keygen -t rsa
   cd .ssh
   cat id_rsa.pub

```
root@ip-172-31-14-106:~# ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/root/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /root/.ssh/id_rsa.
Your public key has been saved in /root/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:1kdOLQIfwBPHo87Cq+D58DF5KguJFMKG9OmYHDEyJv4 root@ip-172-31-14-106
The key's randomart image is:
+---[RSA 2048]----+
|+.+.     .+=+ .. |
|*+ =      o++o. .|
|o== .      ooo . |
|o.oo .   ...     |
| . Eo  .So. .    |
|.. .   oo o.     |
|. o o + .o       |
|   o.= =.        |
|    ++=.         |
+----[SHA256]-----+
root@ip-172-31-14-106:~# cd .ssh
root@ip-172-31-14-106:~/.ssh# cat id_rsa.pub
ssh-rsa AAAAB3NzaC1yc2EAAAADAQABAAABAQC7xNHzsx2oxfUN9qwGJ61Kb92WeAMIpreEFol44aov70UyttKdQpbK1kYDceFQ10bf/MxVg7t2xDuFPpwrFlP4HFqqq5vkxY6RvL4QR6wxL6OfXl9+hPHN91OGHqhLxOicWl4LlemcPyOlYdggfXgOmnCw
PYAEXSUV91P1IvEOP9OLrNA/NHdQOdGkLkoFdPuaoahSjDgyDEfsgRhyaic5NOGbWhAJyzttUsi++8MgoGb5G3R9o9tuTzCQGTm/l9fr6tMPhLv5p4qQyvlKAzkBAZgXBViIB3hH1lxP742pfcYal6efZQS++RahQybl7GXINJZrb+ByWmApMkMPvS1B roo
t@ip-172-31-14-106
root@ip-172-31-14-106:~/.ssh# ls
authorized_keys  id_rsa  id_rsa.pub  known_hosts
root@ip-172-31-14-106:~/.ssh# vi authorized_keys
root@ip-172-31-14-106:~/.ssh# cd ~
```

7. mount the file to get more space
   sudo apt-get install mdadm
   lsblk
   sudo file -s /dev/nvme0n1
   sudo mkfs -t ext4 /dev/nvme0n1
   sudo mkdir /data
   sudo mount /dev/nvme0n1 /data
8. mv Hadoop /data
9. Make changes in below configuration file and their properties
   cd /data/Hadoop/etc/hadoop
   core-site.xml
   fs.default.name
   hadoop.tmp.dir

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<!--
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  Unless required by applicable law or agreed to in writing, software
  distributed under the License is distributed on an "AS IS" BASIS,
  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
        <property>
                <name>fs.default.name</name>
                <value>hdfs://ec2-18-217-165-225.us-east-2.compute.amazonaws.com:9000</value>
        </property>
        <property>
                <name>hadoop.tmp.dir</name>
                <value>/data/tmp/</value>
        </property>
</configuration>
```

10. **yarn-site.xml**

yarn.resourcemanage.hostname
yarn.nodemanager.aux-services
yarn.nodemanager.aux-services.mapreduce.shuffle.class
yarn.resourcemanager.scheduler.address
yarn.resourcemanager.address
yarn.resourcemanager.webapp.address
yarn.resourcemanager.resource-tracker.address
yarn.resourcemanager.admin.address

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->
<configuration>

<!-- Site specific YARN configuration properties -->
        <property>
                <name>yarn.resourcemanage.hostname</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com</value>
        </property>
        <property>
                <name>yarn.nodemanager.aux-services</name>
                <value>mapreduce_shuffle</value>
        </property>
        <property>
                <name>yarn.nodemanager.aux-services.mapreduce.shuffle.class</name>
                <value>org.apache.hadoop.mapred.ShuffleHandler</value>
        </property>
        <property>
                <name>yarn.resourcemanager.scheduler.address</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8030</value>
        </property>
        <property>
                <name>yarn.resourcemanager.address</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8032</value>
        </property>
        <property>
                <name>yarn.resourcemanager.webapp.address</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8088</value>
        </property>
        <property>
                <name>yarn.resourcemanager.resource-tracker.address</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8031</value>
        </property>
        <property>
                <name>yarn.resourcemanager.admin.address</name>
                <value>ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8033</value>
        </property>
        <property>
                <name>yarn.nodemanager.vmem-pmem-ratio</name>
                <value>2.1</value>
        </property>
        <property>
                <name>yarn.nodemanager.disk-health-checker.max-disk-utilization-per-disk-percentage</name>
                <value>99</value>
        </property>

</configuration>
```

hdfs-site.xml

dfs.replication
dfs.namenode.name.dir
datanode.data.dir

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<!--
  Licensed under the Apache License, Version 2.0 (the "License");
  you may not use this file except in compliance with the License.
  You may obtain a copy of the License at

    http://www.apache.org/licenses/LICENSE-2.0

  Unless required by applicable law or agreed to in writing, software
  distributed under the License is distributed on an "AS IS" BASIS,
  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
        <property>
                <name>dfs.replication</name>
                <value>1</value>
        </property>
        <property>
                <name>dfs.permissions</name>
                <value>false</value>
        </property>
        <property>
                <name>dfs.namenode.name.dir</name>
                <value>file:/data/hadoop/hadoop_data/hdfs/namenode</value>
        </property>
        <property>
                <name>dfs.datanode.data.dir</name>
                <value>file:/data/hadoop/hadoop_data/hdfs/datanode</value>
        </property>

</configuration>
```

mapred-site.xml

mapreduce.framework.name
mapreduce.jobtracker.address
mapred.tasktracker.map.tasks
mapred.tasktracker.reduce.tasks

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<!--
  Licensed under the Apache License, Version 2.0 (the "License");
  you may not use this file except in compliance with the License.
  You may obtain a copy of the License at

    http://www.apache.org/licenses/LICENSE-2.0

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  distributed under the License is distributed on an "AS IS" BASIS,
  WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
  See the License for the specific language governing permissions and
  limitations under the License. See accompanying LICENSE file.
-->

<!-- Put site-specific property overrides in this file. -->

<configuration>
        <property>
                <name>mapreduce.jobtracker.address</name>
                <value>hdfs://ec2-18-217-165-225.us-east-2.compute.amazonaws.com:9001</value>
        </property>
        <property>
                <name>mapreduce.framework.name</name>
                <value>yarn</value>
        </property>
        <property>
                <name>mapred.tasktracker.map.tasks</name>
                <value>2</value>
        </property>
        <property>
                <name>mapred.tasktracker.reduce.tasks</name>
                <value>2</value>
        </property>
        <property>
                <name>mapred.job.shuffle.input.buffer.percent</name>
                <value>0.20</value>
        </property>
</configuration>
```

11. Slaves

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
localhost
ec2-18-217-165-225.us-east-2.compute.amazonaws.com
~
~
~
~
~
```

12. hadoop-env.sh

root@ip-172-31-12-224: /data/hadoop/etc/hadoop

```
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# distributed with this work for additional information
# regarding copyright ownership.  The ASF licenses this file
# to you under the Apache License, Version 2.0 (the
# "License"); you may not use this file except in compliance
# with the License.  You may obtain a copy of the License at
#
#     http://www.apache.org/licenses/LICENSE-2.0
#
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# distributed under the License is distributed on an "AS IS" BASIS,
# WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
# See the License for the specific language governing permissions and
# limitations under the License.

# Set Hadoop-specific environment variables here.

# The only required environment variable is JAVA_HOME.  All others are
# optional.  When running a distributed configuration it is best to
# set JAVA_HOME in this file, so that it is correctly defined on
# remote nodes.

# The java implementation to use.
export JAVA_HOME="/usr/lib/jvm/java-8-openjdk-amd64"
```

13. ~/.bashrc
14. hdfs namenode -format
    start-dfs.sh
    start-yarn.sh (to stop stop-yarn.sh)
    jps

```
localhost: starting nodemanager, logging to /data/hadoop/logs/yarn-root-nodemanager-ip-172-31-14-106.out
root@ip-172-31-14-106:/data# jps
10393 ResourceManager
10602 NodeManager
10890 Jps
9946 DataNode
10172 SecondaryNameNode
9775 NameNode
```

Execution:

Download wget http://www.ordinal.com/try.cgi/gensort-linux-1.5.tar.gz

Tar -xvzf gensort-linux-1.5.tar.gz

./gensort -a 1280000000 /data/input128.txt

hdfs dfs -mkdir /input

hdfs dfs -mkdir /output

hdfs dfs -put /data/input128.txt /input

hadoop com.sun.tools.javac.Main TeraSort.java

jar cf.jar TeraSort*.class

Hadoop jar cf.jar TeraSort /input /output

hdfs dfs -get /output /data

./valsort /data/output/part-r-00000

1.Virtual Cluster (1-node i3.large):

```
root@ip-172-31-14-106: /data/hadoop/bin
root@ip-172-31-14-106:/data# hdfs dfs -ls /input
17/12/04 06:30:34 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Found 1 items
-rw-r--r--   1 root supergroup 100000000000 2017-12-04 06:29 /input/inputTB.txt
root@ip-172-31-14-106:/data# ls
hadoop  inputTB.txt  lost+found  tmp
root@ip-172-31-14-106:/data# ce hadoop
ce: command not found
root@ip-172-31-14-106:/data# cd hadoop
root@ip-172-31-14-106:/data/hadoop# ls
bin  etc  hadoop_data  include  lib  libexec  LICENSE.txt  logs  NOTICE.txt  README.txt  sbin  share
root@ip-172-31-14-106:/data/hadoop# cd bin
root@ip-172-31-14-106:/data/hadoop/bin# ls
container-executor  hadoop  hadoop.cmd  hdfs  hdfs.cmd  mapred  mapred.cmd  rcc  test-container-executor  yarn  yarn.cmd
root@ip-172-31-14-106:/data/hadoop/bin# vi TeraSOrt.java
root@ip-172-31-14-106:/data/hadoop/bin# hadoop com.sun.tools.javac.Main TeraSOrt.java
TeraSOrt.java:15: error: class TeraSort is public, should be declared in a file named TeraSort.java
public class TeraSort {
       ^
Note: TeraSOrt.java uses or overrides a deprecated API.
Note: Recompile with -Xlint:deprecation for details.
1 error
root@ip-172-31-14-106:/data/hadoop/bin# vi mv TeraSOrt.java TeraSort.java
3 files to edit
root@ip-172-31-14-106:/data/hadoop/bin# ls
container-executor  hadoop  hadoop.cmd  hdfs  hdfs.cmd  mapred  mapred.cmd  rcc  TeraSOrt.java  test-container-executor  yarn  yarn.cmd
root@ip-172-31-14-106:/data/hadoop/bin# mv TeraSOrt.java TeraSort.java
root@ip-172-31-14-106:/data/hadoop/bin# ls
container-executor  hadoop  hadoop.cmd  hdfs  hdfs.cmd  mapred  mapred.cmd  rcc  TeraSort.java  test-container-executor  yarn  yarn.cmd
root@ip-172-31-14-106:/data/hadoop/bin# hadoop com.sun.tools.javac.Main TeraSOrt.java
javac: file not found: TeraSOrt.java
Usage: javac <options> <source files>
use -help for a list of possible options
root@ip-172-31-14-106:/data/hadoop/bin# hadoop com.sun.tools.javac.Main TeraSort.java
Note: TeraSort.java uses or overrides a deprecated API.
Note: Recompile with -Xlint:deprecation for details.
root@ip-172-31-14-106:/data/hadoop/bin# ls
container-executor  hadoop.cmd  hdfs.cmd            mapred      rcc             TeraSort.java           TokenizerMapper.class  yarn.cmd
hadoop              hdfs        IntSumReducer.class  mapred.cmd  TeraSort.class  test-container-executor  yarn
root@ip-172-31-14-106:/data/hadoop/bin# jar cf ts.jar TeraSort.class IntSumReducer.class TokenizerMapper.class
root@ip-172-31-14-106:/data/hadoop/bin# ls
container-executor  hadoop.cmd  hdfs.cmd            mapred      rcc             TeraSort.java           TokenizerMapper.class  yarn
hadoop              hdfs        IntSumReducer.class  mapred.cmd  TeraSort.class  test-container-executor  ts.jar                 yarn.cmd
root@ip-172-31-14-106:/data/hadoop/bin# hadoop jar ts.jar TeraSort /input /output
17/12/04 06:39:25 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Dec 04, 2017 6:39:25 AM TeraSort main
INFO: Total Time for Execution of MapReduce is :0 Seconds
```

```
17/12/03 18:38:19 INFO input.FileInputFormat: Total input files to process : 1
17/12/03 18:38:19 INFO mapreduce.JobSubmitter: number of splits:954
17/12/03 18:38:20 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1512325297242_0001
17/12/03 18:38:20 INFO impl.YarnClientImpl: Submitted application application_1512325297242_0001
17/12/03 18:38:20 INFO mapreduce.Job: The url to track the job: http://ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8088/proxy/application_1512325297242_0001/
17/12/03 18:38:20 INFO mapreduce.Job: Running job: job_1512325297242_0001
17/12/03 18:38:28 INFO mapreduce.Job: Job job_1512325297242_0001 running in uber mode : false
17/12/03 18:38:28 INFO mapreduce.Job:  map 0% reduce 0%
17/12/03 18:39:28 INFO mapreduce.Job:  map 1% reduce 0%
17/12/03 18:40:55 INFO mapreduce.Job:  map 2% reduce 0%
17/12/03 18:42:19 INFO mapreduce.Job:  map 3% reduce 0%
17/12/03 18:43:54 INFO mapreduce.Job:  map 4% reduce 0%
17/12/03 18:45:30 INFO mapreduce.Job:  map 5% reduce 0%
17/12/03 18:46:50 INFO mapreduce.Job:  map 6% reduce 0%
17/12/03 18:48:16 INFO mapreduce.Job:  map 7% reduce 0%
17/12/03 18:49:37 INFO mapreduce.Job:  map 8% reduce 0%
17/12/03 18:51:10 INFO mapreduce.Job:  map 9% reduce 0%
17/12/03 18:52:45 INFO mapreduce.Job:  map 10% reduce 0%
17/12/03 18:54:06 INFO mapreduce.Job:  map 11% reduce 0%
17/12/03 18:55:32 INFO mapreduce.Job:  map 12% reduce 0%
17/12/03 18:56:51 INFO mapreduce.Job:  map 13% reduce 0%
17/12/03 18:58:25 INFO mapreduce.Job:  map 14% reduce 0%
17/12/03 19:00:02 INFO mapreduce.Job:  map 15% reduce 0%
17/12/03 19:01:19 INFO mapreduce.Job:  map 16% reduce 0%
17/12/03 19:02:48 INFO mapreduce.Job:  map 17% reduce 0%
17/12/03 19:03:54 INFO mapreduce.Job:  map 17% reduce 1%
17/12/03 19:04:10 INFO mapreduce.Job:  map 18% reduce 1%
17/12/03 19:04:43 INFO mapreduce.Job:  map 18% reduce 2%
17/12/03 19:05:25 INFO mapreduce.Job:  map 18% reduce 3%
17/12/03 19:06:09 INFO mapreduce.Job:  map 19% reduce 3%
17/12/03 19:06:13 INFO mapreduce.Job:  map 19% reduce 4%
17/12/03 19:06:55 INFO mapreduce.Job:  map 19% reduce 5%
17/12/03 19:07:39 INFO mapreduce.Job:  map 19% reduce 6%
17/12/03 19:08:07 INFO mapreduce.Job:  map 20% reduce 6%
17/12/03 19:08:15 INFO mapreduce.Job:  map 20% reduce 7%
17/12/03 19:09:43 INFO mapreduce.Job:  map 21% reduce 7%
17/12/03 19:11:28 INFO mapreduce.Job:  map 22% reduce 7%
17/12/03 19:13:09 INFO mapreduce.Job:  map 23% reduce 7%
17/12/03 19:13:29 INFO mapreduce.Job:  map 23% reduce 8%
17/12/03 19:14:48 INFO mapreduce.Job:  map 24% reduce 8%
17/12/03 19:16:37 INFO mapreduce.Job:  map 25% reduce 8%
17/12/03 19:18:09 INFO mapreduce.Job:  map 26% reduce 8%
17/12/03 19:18:30 INFO mapreduce.Job:  map 26% reduce 9%
17/12/03 19:19:44 INFO mapreduce.Job:  map 27% reduce 9%
17/12/03 19:21:31 INFO mapreduce.Job:  map 28% reduce 9%
17/12/03 19:23:12 INFO mapreduce.Job:  map 29% reduce 9%
17/12/03 19:23:26 INFO mapreduce.Job:  map 29% reduce 10%
```

root@ip-172-31-12-224: ~/64

```
17/12/03 22:36:30 INFO mapreduce.Job:  map 100% reduce 98%
17/12/03 22:37:30 INFO mapreduce.Job:  map 100% reduce 99%
17/12/03 22:38:30 INFO mapreduce.Job:  map 100% reduce 100%
17/12/03 22:39:03 INFO mapreduce.Job: Job job_1512325297242_0001 completed successfully
17/12/03 22:39:03 INFO mapreduce.Job: Counters: 50
        File System Counters
                FILE: Number of bytes read=597946868556
                FILE: Number of bytes written=728639725118
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=128004042772
                HDFS: Number of bytes written=128000000000
                HDFS: Number of read operations=2865
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
        Job Counters
                Killed map tasks=1
                Launched map tasks=955
                Launched reduce tasks=1
                Data-local map tasks=955
                Total time spent by all maps in occupied slots (ms)=50243638
                Total time spent by all reduces in occupied slots (ms)=12941949
                Total time spent by all map tasks (ms)=50243638
                Total time spent by all reduce tasks (ms)=12941949
                Total vcore-milliseconds taken by all map tasks=50243638
                Total vcore-milliseconds taken by all reduce tasks=12941949
                Total megabyte-milliseconds taken by all map tasks=51449485312
                Total megabyte-milliseconds taken by all reduce tasks=13252555776
        Map-Reduce Framework
                Map input records=1280000000
                Map output records=1280000000
                Map output bytes=128000000000
                Map output materialized bytes=130560005724
                Input split bytes=139284
                Combine input records=1280000000
                Combine output records=1280000000
                Reduce input groups=1280000000
                Reduce shuffle bytes=130560005724
                Reduce input records=1280000000
                Reduce output records=1280000000
                Spilled Records=7142224027
                Shuffled Maps =954
                Failed Shuffles=0
                Merged Map outputs=954
                GC time elapsed (ms)=447839
                CPU time spent (ms)=17806780
                Physical memory (bytes) snapshot=261063811072
                Virtual memory (bytes) snapshot=1875665178624
                Total committed heap usage (bytes)=197708480512
```

root@ip-172-31-12-224: ~/64

```
17/12/03 22:38:30 INFO mapreduce.Job:  map 100% reduce 100%
17/12/03 22:39:03 INFO mapreduce.Job: Job job_1512325297242_0001 completed successfully
17/12/03 22:39:03 INFO mapreduce.Job: Counters: 50
        File System Counters
                FILE: Number of bytes read=597946868556
                FILE: Number of bytes written=728639725118
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=128004042772
                HDFS: Number of bytes written=128000000000
                HDFS: Number of read operations=2865
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
        Job Counters
                Killed map tasks=1
                Launched map tasks=955
                Launched reduce tasks=1
                Data-local map tasks=955
                Total time spent by all maps in occupied slots (ms)=50243638
                Total time spent by all reduces in occupied slots (ms)=12941949
                Total time spent by all map tasks (ms)=50243638
                Total time spent by all reduce tasks (ms)=12941949
                Total vcore-milliseconds taken by all map tasks=50243638
                Total vcore-milliseconds taken by all reduce tasks=12941949
                Total megabyte-milliseconds taken by all map tasks=51449485312
                Total megabyte-milliseconds taken by all reduce tasks=13252555776
        Map-Reduce Framework
                Map input records=1280000000
                Map output records=1280000000
                Map output bytes=128000000000
                Map output materialized bytes=130560005724
                Input split bytes=139284
                Combine input records=1280000000
                Combine output records=1280000000
                Reduce input groups=1280000000
                Reduce shuffle bytes=130560005724
                Reduce input records=1280000000
                Reduce output records=1280000000
                Spilled Records=7142224027
                Shuffled Maps =954
                Failed Shuffles=0
                Merged Map outputs=954
                GC time elapsed (ms)=447839
                CPU time spent (ms)=17806780
                Physical memory (bytes) snapshot=261063811072
                Virtual memory (bytes) snapshot=1875665178624
                Total committed heap usage (bytes)=197708480512
        Shuffle Errors
                BAD_ID=0
                CONNECTION=0
                IO_ERROR=0
                WRONG_LENGTH=0
                WRONG_MAP=0
                WRONG_REDUCE=0
        File Input Format Counters
                Bytes Read=128003903488
        File Output Format Counters
                Bytes Written=128000000000
root@ip-172-31-12-224:/data/hadoop/bin# hdfs dfs -ls /output
17/12/04 02:21:10 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Found 2 items
-rw-r--r--   1 root supergroup          0 2017-12-03 22:39 /output/_SUCCESS
```

Get the data from file system and compute the Valsort Phase on Sorted Data:

```
^C
root@ip-172-31-12-224:/data/hadoop/bin#
root@ip-172-31-12-224:/data/hadoop/bin# hdfs dfs -get /output /data
17/12/04 02:23:18 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
root@ip-172-31-12-224:/data/hadoop/bin# cd ../..
root@ip-172-31-12-224:/data# ls
hadoop  lost+found  output  tmp
root@ip-172-31-12-224:/data# cd output
root@ip-172-31-12-224:/data/output# ls
part-r-00000  _SUCCESS
root@ip-172-31-12-224:/data/output# cd ~
root@ip-172-31-12-224:~# ls
32  64  gensort-linux-1.5.tar.gz  gpl-2.0.txt  hadoop  hadoop-2.8.2.tar.gz  output  tmp
root@ip-172-31-12-224:~# cd 64
root@ip-172-31-12-224:~/64# ls
gensort  input.txt  smallFile.txt  valsort
root@ip-172-31-12-224:~/64# ./valsort /data/output/part-r-00000
Records: 1280000000
Checksum: 26258f2f171b72ca
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-12-224:~/64#
```

Web App Cluster:

2.Virtual Cluster (1-node i3.4xlarge):

```
root@ip-172-31-14-106: /data/hadoop/bin
root@ip-172-31-14-106:/data/hadoop/bin# hadoop jar ts.jar TeraSort /input /output
17/12/04 07:38:57 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
Dec 04, 2017 7:38:58 AM TeraSort main
INFO: Total Time for Execution of MapReduce is :0 Seconds
17/12/04 07:38:58 INFO client.RMProxy: Connecting to ResourceManager at ec2-18-217-119-143.us-east-2.compute.amazonaws.com/172.31.14.106:8032
17/12/04 07:38:58 WARN mapreduce.JobResourceUploader: Hadoop command-line option parsing not performed. Implement the Tool interface and execute your application with ToolRunner to remedy this
.
17/12/04 07:38:58 INFO input.FileInputFormat: Total input files to process : 1
17/12/04 07:38:58 INFO mapreduce.JobSubmitter: number of splits:745
17/12/04 07:38:58 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1512371130663_0001
17/12/04 07:38:59 INFO impl.YarnClientImpl: Submitted application application_1512371130663_0001
17/12/04 07:38:59 INFO mapreduce.Job: The url to track the job: http://ec2-18-217-119-143.us-east-2.compute.amazonaws.com:8088/proxy/application_1512371130663_0001/
17/12/04 07:38:59 INFO mapreduce.Job: Running job: job_1512371130663_0001
17/12/04 07:39:05 INFO mapreduce.Job: Job job_1512371130663_0001 running in uber mode : false
17/12/04 07:39:05 INFO mapreduce.Job:  map 0% reduce 0%
17/12/04 07:39:18 INFO mapreduce.Job:  map 1% reduce 0%
17/12/04 07:39:29 INFO mapreduce.Job:  map 2% reduce 0%
17/12/04 07:39:49 INFO mapreduce.Job:  map 3% reduce 0%
17/12/04 07:39:59 INFO mapreduce.Job:  map 4% reduce 0%
17/12/04 07:40:09 INFO mapreduce.Job:  map 5% reduce 0%
17/12/04 07:40:20 INFO mapreduce.Job:  map 6% reduce 0%
17/12/04 07:40:38 INFO mapreduce.Job:  map 7% reduce 0%
17/12/04 07:40:50 INFO mapreduce.Job:  map 8% reduce 0%
17/12/04 07:41:00 INFO mapreduce.Job:  map 9% reduce 0%
17/12/04 07:41:11 INFO mapreduce.Job:  map 10% reduce 0%
17/12/04 07:41:28 INFO mapreduce.Job:  map 11% reduce 0%
```

root@ip-172-31-14-106: /data/hadoop/bin

```
17/12/04 07:52:55 INFO mapreduce.Job:  map 53% reduce 17%
17/12/04 07:53:00 INFO mapreduce.Job:  map 53% reduce 18%
17/12/04 07:53:10 INFO mapreduce.Job:  map 54% reduce 18%
17/12/04 07:53:29 INFO mapreduce.Job:  map 55% reduce 18%
17/12/04 07:53:45 INFO mapreduce.Job:  map 56% reduce 18%
17/12/04 07:53:48 INFO mapreduce.Job:  map 56% reduce 19%
17/12/04 07:53:58 INFO mapreduce.Job:  map 57% reduce 19%
17/12/04 07:54:19 INFO mapreduce.Job:  map 58% reduce 19%
17/12/04 07:54:34 INFO mapreduce.Job:  map 59% reduce 19%
17/12/04 07:54:37 INFO mapreduce.Job:  map 59% reduce 20%
17/12/04 07:54:52 INFO mapreduce.Job:  map 60% reduce 20%
17/12/04 07:55:07 INFO mapreduce.Job:  map 61% reduce 20%
17/12/04 07:55:28 INFO mapreduce.Job:  map 62% reduce 20%
17/12/04 07:55:31 INFO mapreduce.Job:  map 62% reduce 21%
17/12/04 07:55:43 INFO mapreduce.Job:  map 63% reduce 21%
17/12/04 07:56:02 INFO mapreduce.Job:  map 64% reduce 21%
17/12/04 07:56:15 INFO mapreduce.Job:  map 65% reduce 21%
17/12/04 07:56:19 INFO mapreduce.Job:  map 65% reduce 22%
17/12/04 07:56:28 INFO mapreduce.Job:  map 66% reduce 22%
17/12/04 07:56:45 INFO mapreduce.Job:  map 67% reduce 22%
17/12/04 07:57:02 INFO mapreduce.Job:  map 68% reduce 22%
17/12/04 07:57:07 INFO mapreduce.Job:  map 68% reduce 23%
17/12/04 07:57:15 INFO mapreduce.Job:  map 69% reduce 23%
17/12/04 07:57:35 INFO mapreduce.Job:  map 70% reduce 23%
17/12/04 07:57:46 INFO mapreduce.Job:  map 71% reduce 23%
17/12/04 07:57:49 INFO mapreduce.Job:  map 71% reduce 24%
17/12/04 07:58:06 INFO mapreduce.Job:  map 72% reduce 24%
17/12/04 07:58:17 INFO mapreduce.Job:  map 73% reduce 24%
17/12/04 07:58:37 INFO mapreduce.Job:  map 74% reduce 24%
17/12/04 07:58:43 INFO mapreduce.Job:  map 74% reduce 25%
```

root@ip-172-31-14-106: /data/hadoop/bin

```
17/12/04 08:41:00 INFO mapreduce.Job:  map 100% reduce 98%
17/12/04 08:41:30 INFO mapreduce.Job:  map 100% reduce 99%
17/12/04 08:42:06 INFO mapreduce.Job:  map 100% reduce 100%
17/12/04 08:42:27 INFO mapreduce.Job: Job job_1512371130663_0001 completed successfully
17/12/04 08:42:27 INFO mapreduce.Job: Counters: 50
        File System Counters
                FILE: Number of bytes read=475645538844
                FILE: Number of bytes written=577749319953
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=100003155449
                HDFS: Number of bytes written=100000000000
                HDFS: Number of read operations=2238
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
        Job Counters
                Killed map tasks=1
                Launched map tasks=746
                Launched reduce tasks=1
                Data-local map tasks=746
                Total time spent by all maps in occupied slots (ms)=7409409
                Total time spent by all reduces in occupied slots (ms)=3581907
                Total time spent by all map tasks (ms)=7409409
                Total time spent by all reduce tasks (ms)=3581907
                Total vcore-milliseconds taken by all map tasks=7409409
                Total vcore-milliseconds taken by all reduce tasks=3581907
                Total megabyte-milliseconds taken by all map tasks=7587234816
                Total megabyte-milliseconds taken by all reduce tasks=3667872768
        Map-Reduce Framework
                Map input records=1000000000
                Map output records=1000000000
                Map output bytes=100000000000
                Map output materialized bytes=102000004470
                Input split bytes=108025
                Combine input records=1000000000
                Combine output records=1000000000
                Reduce input groups=1000000000
                Reduce shuffle bytes=102000004470
                Reduce input records=1000000000
                Reduce output records=1000000000
                Spilled Records=5663191421
                Shuffled Maps =745
                Failed Shuffles=0
                Merged Map outputs=745
                GC time elapsed (ms)=354474
                CPU time spent (ms)=41946790
                Physical memory (bytes) snapshot=220535668736
                Virtual memory (bytes) snapshot=1508811292672
                Total committed heap usage (bytes)=154228228096
```

```
root@ip-172-31-12-224:/data/hadoop/bin# hdfs dfs -get /output /data
17/12/04 02:23:18 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
root@ip-172-31-12-224:/data/hadoop/bin# cd ../..
root@ip-172-31-12-224:/data# ls
hadoop  lost+found  output  tmp
root@ip-172-31-12-224:/data# cd output
root@ip-172-31-12-224:/data/output# ls
part-r-00000  _SUCCESS
root@ip-172-31-12-224:/data/output# cd ~
root@ip-172-31-12-224:~# ls
32  64  gensort-linux-1.5.tar.gz  gpl-2.0.txt  hadoop  hadoop-2.8.2.tar.gz  output  tmp
root@ip-172-31-12-224:~# cd 64
root@ip-172-31-12-224:~/64# ls
gensort  input.txt  smallFile.txt  valsort
root@ip-172-31-12-224:~/64# ./valsort /data/output/part-r-00000
Records: 1280000000
Checksum: 26258f2f171b72ca
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-12-224:~/64#
```

Get the data from file system and compute the Valsort Phase on Sorted Data:

root@ip-172-31-14-106: ~/64

```
root@ip-172-31-14-106:/data/hadoop/bin# hdfs dfs -get /output /data
17/12/04 15:11:09 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
root@ip-172-31-14-106:/data/hadoop/bin# cd /data
root@ip-172-31-14-106:/data# ls
hadoop  inputTB.txt  lost+found  output  tmp
root@ip-172-31-14-106:/data# cd output
root@ip-172-31-14-106:/data/output# ls
part-r-00000  _SUCCESS
root@ip-172-31-14-106:/data/output# cd ..
root@ip-172-31-14-106:/data# cd 64
-bash: cd: 64: No such file or directory
root@ip-172-31-14-106:/data# cd ..
root@ip-172-31-14-106:/# ls
bin  boot  data  dev  etc  home  initrd.img  lib  lib64  lost+found  media  mnt  opt  proc  root  run  sbin  snap  srv  sys  tmp  usr  var  vmlinuz
root@ip-172-31-14-106:/# cd ~
root@ip-172-31-14-106:~# cd 64
root@ip-172-31-14-106:~/64# ls
gensort  inputTB.txt  valsort
root@ip-172-31-14-106:~/64# ./valsort /data/output/part-r-00000
Records: 1000000000
Checksum: 1dcd601caea2f059
Duplicate keys: 0
SUCCESS - all records are in order
root@ip-172-31-14-106:~/64#
```

Web App Cluster:

3.Virtual Cluster (8-nodes i3.large):

```
17/12/03 08:09:41 INFO input.FileInputFormat: Total input files to process : 1
17/12/03 08:09:41 INFO mapreduce.JobSubmitter: number of splits:954
17/12/03 08:09:42 INFO mapreduce.JobSubmitter: Submitting tokens for job: job_1512287586388_0001
17/12/03 08:09:42 INFO impl.YarnClientImpl: Submitted application application_1512287586388_0001
17/12/03 08:09:42 INFO mapreduce.Job: The url to track the job: http://ec2-18-217-165-225.us-east-2.compute.amazonaws.com:8088/proxy/application_1512287586388_0001/
17/12/03 08:09:42 INFO mapreduce.Job: Running job: job_1512287586388_0001
17/12/03 08:09:52 INFO mapreduce.Job: Job job_1512287586388_0001 running in uber mode : false
17/12/03 08:09:52 INFO mapreduce.Job:  map 0% reduce 0%
17/12/03 08:10:53 INFO mapreduce.Job:  map 1% reduce 0%
17/12/03 08:12:26 INFO mapreduce.Job:  map 2% reduce 0%
17/12/03 08:13:49 INFO mapreduce.Job:  map 3% reduce 0%
17/12/03 08:15:29 INFO mapreduce.Job:  map 4% reduce 0%
17/12/03 08:17:08 INFO mapreduce.Job:  map 5% reduce 0%
17/12/03 08:18:30 INFO mapreduce.Job:  map 6% reduce 0%
17/12/03 08:20:00 INFO mapreduce.Job:  map 7% reduce 0%
17/12/03 08:21:22 INFO mapreduce.Job:  map 8% reduce 0%
17/12/03 08:22:59 INFO mapreduce.Job:  map 9% reduce 0%
17/12/03 08:24:36 INFO mapreduce.Job:  map 10% reduce 0%
17/12/03 08:26:00 INFO mapreduce.Job:  map 11% reduce 0%
17/12/03 08:27:28 INFO mapreduce.Job:  map 12% reduce 0%
17/12/03 08:28:52 INFO mapreduce.Job:  map 13% reduce 0%
17/12/03 08:30:28 INFO mapreduce.Job:  map 14% reduce 0%
17/12/03 08:32:11 INFO mapreduce.Job:  map 15% reduce 0%
17/12/03 08:33:28 INFO mapreduce.Job:  map 16% reduce 0%
17/12/03 08:35:06 INFO mapreduce.Job:  map 17% reduce 0%
17/12/03 08:36:28 INFO mapreduce.Job:  map 18% reduce 0%
```

```
17/12/03 09:10:08 INFO mapreduce.Job:  map 37% reduce 12%
17/12/03 09:11:46 INFO mapreduce.Job:  map 38% reduce 12%
17/12/03 09:12:04 INFO mapreduce.Job:  map 38% reduce 13%
17/12/03 09:13:34 INFO mapreduce.Job:  map 39% reduce 13%
17/12/03 09:15:20 INFO mapreduce.Job:  map 40% reduce 13%
17/12/03 09:16:59 INFO mapreduce.Job:  map 41% reduce 13%
17/12/03 09:17:31 INFO mapreduce.Job:  map 41% reduce 14%
17/12/03 09:18:48 INFO mapreduce.Job:  map 42% reduce 14%
17/12/03 09:20:36 INFO mapreduce.Job:  map 43% reduce 14%
17/12/03 09:22:26 INFO mapreduce.Job:  map 44% reduce 14%
17/12/03 09:22:32 INFO mapreduce.Job:  map 44% reduce 15%
17/12/03 09:24:02 INFO mapreduce.Job:  map 45% reduce 15%
17/12/03 09:25:45 INFO mapreduce.Job:  map 46% reduce 15%
17/12/03 09:27:31 INFO mapreduce.Job:  map 47% reduce 15%
17/12/03 09:27:52 INFO mapreduce.Job:  map 47% reduce 16%
17/12/03 09:29:21 INFO mapreduce.Job:  map 48% reduce 16%
17/12/03 09:31:01 INFO mapreduce.Job:  map 49% reduce 16%
17/12/03 09:32:47 INFO mapreduce.Job:  map 50% reduce 16%
17/12/03 09:33:11 INFO mapreduce.Job:  map 50% reduce 17%
17/12/03 09:34:31 INFO mapreduce.Job:  map 51% reduce 17%
17/12/03 09:36:20 INFO mapreduce.Job:  map 52% reduce 17%
17/12/03 09:38:06 INFO mapreduce.Job:  map 53% reduce 17%
17/12/03 09:38:14 INFO mapreduce.Job:  map 53% reduce 18%
17/12/03 09:39:49 INFO mapreduce.Job:  map 54% reduce 18%
17/12/03 09:41:38 INFO mapreduce.Job:  map 55% reduce 18%
17/12/03 09:43:21 INFO mapreduce.Job:  map 56% reduce 18%
17/12/03 09:43:40 INFO mapreduce.Job:  map 56% reduce 19%
17/12/03 09:45:11 INFO mapreduce.Job:  map 57% reduce 19%
17/12/03 09:46:51 INFO mapreduce.Job:  map 58% reduce 19%
```

```
17/12/04 08:41:00 INFO mapreduce.Job:  map 100% reduce 98%
17/12/04 08:41:30 INFO mapreduce.Job:  map 100% reduce 99%
17/12/04 08:42:06 INFO mapreduce.Job:  map 100% reduce 100%
17/12/04 08:42:27 INFO mapreduce.Job: Job job_1512371130663_0001 completed successfully
17/12/04 08:42:27 INFO mapreduce.Job: Counters: 50
        File System Counters
                FILE: Number of bytes read=475645538844
                FILE: Number of bytes written=577749319953
                FILE: Number of read operations=0
                FILE: Number of large read operations=0
                FILE: Number of write operations=0
                HDFS: Number of bytes read=100003155449
                HDFS: Number of bytes written=100000000000
                HDFS: Number of read operations=2238
                HDFS: Number of large read operations=0
                HDFS: Number of write operations=2
        Job Counters
                Killed map tasks=1
                Launched map tasks=746
                Launched reduce tasks=1
                Data-local map tasks=746
                Total time spent by all maps in occupied slots (ms)=7409409
                Total time spent by all reduces in occupied slots (ms)=3581907
                Total time spent by all map tasks (ms)=7409409
                Total time spent by all reduce tasks (ms)=3581907
                Total vcore-milliseconds taken by all map tasks=7409409
                Total vcore-milliseconds taken by all reduce tasks=3581907
                Total megabyte-milliseconds taken by all map tasks=7587234816
                Total megabyte-milliseconds taken by all reduce tasks=3667872768
        Map-Reduce Framework
                Map input records=1000000000
                Map output records=1000000000
                Map output bytes=100000000000
                Map output materialized bytes=102000004470
                Input split bytes=108025
                Combine input records=1000000000
                Combine output records=1000000000
                Reduce input groups=1000000000
                Reduce shuffle bytes=102000004470
                Reduce input records=1000000000
                Reduce output records=1000000000
                Spilled Records=5663191421
                Shuffled Maps =745
                Failed Shuffles=0
                Merged Map outputs=745
                GC time elapsed (ms)=354474
                CPU time spent (ms)=11946790
                Physical memory (bytes) snapshot=220535668736
                Virtual memory (bytes) snapshot=1508811292672
                Total committed heap usage (bytes)=154228228096
```

Get the data from file system and compute the Valsort Phase on Sorted Data:

```
root@ip-172-31-14-106:/data/hadoop/bin# hdfs dfs -get /output /data
17/12/04 15:11:09 WARN util.NativeCodeLoader: Unable to load native-hadoop library for your platform... using builtin-java classes where applicable
root@ip-172-31-14-106:/data/hadoop/bin# cd /data
root@ip-172-31-14-106:/data# ls
hadoop  inputTB.txt  lost+found  output  tmp
root@ip-172-31-14-106:/data# cd output
root@ip-172-31-14-106:/data/output# ls
part-r-00000  _SUCCESS
root@ip-172-31-14-106:/data/output# cd ..
root@ip-172-31-14-106:/data# cd 64
-bash: cd: 64: No such file or directory
root@ip-172-31-14-106:/data# cd ..
root@ip-172-31-14-106:/# ls
bin  boot  data  dev  etc  home  initrd.img  lib  lib64  lost+found  media  mnt  opt  proc  root  run  sbin  snap  srv  sys  tmp  usr  var  vmlinuz
root@ip-172-31-14-106:/# cd ~
root@ip-172-31-14-106:~# cd 64
root@ip-172-31-14-106:~/64# ls
gensort  inputTB.txt  valsort
root@ip-172-31-14-106:~/64# ./valsort /data/output/part-r-00000
Records: 1000000000
Checksum: 1dcd601caea2f059
Duplicate keys: 0
SUCCESS - all records are in order
```

Issues Faced:

- Facing memory issues.
- Mount the storage to get more data

Spark Terasort

- The code for spark is written using spark shell, which uses Scala as a programming language.
- Spark also uses the same Map-Reduce based implementation as Hadoop does.
- When installing Spark it installs various features and language packages, like Scala, R-Studio, Python, specifically for Spark.

Specification:

	Instance	VCPUs	Memory(Gib)	Instance Storage(GB)	Node	Region
Part 1	i3.large	2	15.25	1*0.475 NVMe SSD	1	us-east-1 (Ohio)
Part 2	i3.4xlarge	16	122	2*1.9 NVMe SSD	1	us-east-1 (Ohio)
Part 3	i3.large	2	15.25	1*0.475 NVMe SSD	8	us-east-1(Ohio)

Installation:

1. Install Hadoop
2. Download and untar Spark
   wget https://d3kbcqa49mib13.cloudfront.net/spark-2.2.0-bin-hadoop2.7.tgz
   sudo tar zxvf spark-2.2.0-bin-hadoop2.7.tgz /opt
3. sudo ln -fs spark-2.2.0-bin-hadoop2.7 /opt/spark
4. install python
5. Update ~/.bashrc
   export SPARK_HOME=/opt/spark
   PATH=$PATH:$SPARK_HOME/bin
   export PATH
6. source ~/.bashrc
7. export AWS_ACCESS_KEY_ID=<ACCESS_KEY>
   export AWS_SECRET_KEY=<SECRET_KEY>
8. goto folder, /spark/ec2 in your spark downloaded folder type, the command to launch master and slave instances
   ./spark-ec2 –k CloudSorting -i /home/ubuntu/CloudSorting.pem -s 8 --instance-type=i3.large –ebs-vol-size=50 -r us-east-2 -m i3.large launch sparkInstances
9. Mount the disk
10. cd ~
    cd spark-ec2/bin
    ./spark-shell

```
root@ip-172-31-41-54:/data/hadoop/bin# jps
19200 Jps
17985 NameNode
18370 SecondaryNameNode
18664 NodeManager
18139 DataNode
18523 ResourceManager
root@ip-172-31-41-54:/data/hadoop/bin# l
container-executor*  hadoop*  hadoop.cmd*  hdfs*  hdfs.cmd*  mapred*  mapred.cmd*  rcc*  test-container-executor*  yarn*  yarn.cmd*
root@ip-172-31-41-54:/data/hadoop/bin# cd
root@ip-172-31-41-54:~# vi .profile
root@ip-172-31-41-54:~# . .profile
root@ip-172-31-41-54:~# l
total 40
drwx------  6 root root 4096 Dec  3 20:30 .
drwxr-xr-x 24 root root 4096 Dec  3 18:45 ..
drwxrwxr-x  2  500  500 4096 Mar 17  2013 32
drwxrwxr-x  2  500  500 4096 Mar 17  2013 64
-rw-r--r--  1 root root 3657 Dec  3 19:31 .bashrc
drwx------  2 root root 4096 Dec  3 19:34 .cache
-rw-r--r--  1 root root  165 Dec  3 20:30 .profile
drwx------  2 root root 4096 Dec  3 19:34 .ssh
-rw-------  1 root root 4714 Dec  3 20:30 .viminfo
root@ip-172-31-41-54:~# vi .profile
root@ip-172-31-41-54:~# . .profile
root@ip-172-31-41-54:~# l
total 40
drwx------  6 root root 4096 Dec  3 20:34 .
drwxr-xr-x 24 root root 4096 Dec  3 18:45 ..
drwxrwxr-x  2  500  500 4096 Mar 17  2013 32
drwxrwxr-x  2  500  500 4096 Mar 17  2013 64
-rw-r--r--  1 root root 3657 Dec  3 19:31 .bashrc
drwx------  2 root root 4096 Dec  3 19:34 .cache
-rw-r--r--  1 root root  165 Dec  3 20:30 .profile
drwx------  2 root root 4096 Dec  3 19:34 .ssh
-rw-------  1 root root 4685 Dec  3 20:34 .viminfo
root@ip-172-31-41-54:~# jps
17985 NameNode
18370 SecondaryNameNode
18664 NodeManager
18139 DataNode
18523 ResourceManager
19275 Jps
root@ip-172-31-41-54:~# l
total 40
drwx------  6 root root 4096 Dec  3 20:34 .
drwxr-xr-x 24 root root 4096 Dec  3 18:45 ..
drwxrwxr-x  2  500  500 4096 Mar 17  2013 32
```

MINGW32:/c/Users/Shushi/downloads

```
root@ip-172-31-41-54:~# wget https://archive.apache.org/dist/spark/spark-1.6.2/spark-1.6.2-bin-hadoop2.6.tgz
--2017-12-03 20:49:01--  https://archive.apache.org/dist/spark/spark-1.6.2/spark-1.6.2-bin-hadoop2.6.tgz
Resolving archive.apache.org (archive.apache.org)... 163.172.17.199
Connecting to archive.apache.org (archive.apache.org)|163.172.17.199|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 278057117 (265M) [application/x-gzip]
Saving to: 'spark-1.6.2-bin-hadoop2.6.tgz'

spark-1.6.2-bin-hadoop2.6.tgz                 100%[=============================================================================================>] 265.18M  19.1MB/s    in 15s

2017-12-03 20:49:16 (18.1 MB/s) - 'spark-1.6.2-bin-hadoop2.6.tgz' saved [278057117/278057117]

root@ip-172-31-41-54:~# l
total 271584
drwx------  6 root root      4096 Dec  3 20:49 .
drwxr-xr-x 24 root root      4096 Dec  3 18:45 ..
drwxrwxr-x  2  500  500      4096 Mar 17  2013 32
drwxrwxr-x  2  500  500      4096 Mar 17  2013 64
-rw-r--r--  1 root root      3657 Dec  3 19:31 .bashrc
drwx------  2 root root      4096 Dec  3 19:34 .cache
-rw-r--r--  1 root root       165 Dec  3 20:30 .profile
-rw-r--r--  1 root root 278057117 Jun 25  2016 spark-1.6.2-bin-hadoop2.6.tgz
drwx------  2 root root      4096 Dec  3 19:34 .ssh
-rw-------  1 root root      4685 Dec  3 20:34 .viminfo
root@ip-172-31-41-54:~# tar -zvxf spark-1.6.2-bin-hadoop2.6.tgz
spark-1.6.2-bin-hadoop2.6/
spark-1.6.2-bin-hadoop2.6/NOTICE
spark-1.6.2-bin-hadoop2.6/CHANGES.txt
spark-1.6.2-bin-hadoop2.6/python/
spark-1.6.2-bin-hadoop2.6/python/run-tests.py
spark-1.6.2-bin-hadoop2.6/python/test_support/
spark-1.6.2-bin-hadoop2.6/python/test_support/userlibrary.py
spark-1.6.2-bin-hadoop2.6/python/test_support/userlib-0.1.zip
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/people.json
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/people1.json
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=1/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=1/c=1/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=1/c=1/part-r-00000-829af031-b970-49d6-ad39-30460a0be2c8.orc
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=1/c=1/.part-r-00000-829af031-b970-49d6-ad39-30460a0be2c8.orc.crc
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/_SUCCESS
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=0/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=0/c=0/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=0/c=0/part-r-00000-829af031-b970-49d6-ad39-30460a0be2c8.orc
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/orc_partitioned/b=0/c=0/.part-r-00000-829af031-b970-49d6-ad39-30460a0be2c8.orc.crc
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/text-test.txt
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/parquet_partitioned/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/parquet_partitioned/year=2014/
spark-1.6.2-bin-hadoop2.6/python/test_support/sql/parquet_partitioned/year=2014/month=9/
```

MINGW32:/c/Users/Shushi/downloads

```
root@ip-172-31-41-54:~# l
total 271588
drwx------  7 root root      4096 Dec  3 20:49 .
drwxr-xr-x 24 root root      4096 Dec  3 18:45 ..
drwxrwxr-x  2  500  500      4096 Mar 17  2013 32
drwxrwxr-x  2  500  500      4096 Mar 17  2013 64
-rw-r--r--  1 root root      3657 Dec  3 19:31 .bashrc
drwx------  2 root root      4096 Dec  3 19:34 .cache
-rw-r--r--  1 root root       165 Dec  3 20:30 .profile
drwxr-xr-x 12  500  500      4096 Jun 22  2016 spark-1.6.2-bin-hadoop2.6
-rw-r--r--  1 root root 278057117 Jun 25  2016 spark-1.6.2-bin-hadoop2.6.tgz
drwx------  2 root root      4096 Dec  3 19:34 .ssh
-rw-------  1 root root      4685 Dec  3 20:34 .viminfo
root@ip-172-31-41-54:~# cd spark-1.6.2-bin-hadoop2.6/
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6# l
total 1416
drwxr-xr-x 12  500  500    4096 Jun 22  2016 .
drwx------  7 root root    4096 Dec  3 20:49 ..
drwxr-xr-x  2  500  500    4096 Jun 22  2016 bin
-rw-r--r--  1  500  500 1343562 Jun 22  2016 CHANGES.txt
drwxr-xr-x  2  500  500    4096 Jun 22  2016 conf
drwxr-xr-x  3  500  500    4096 Jun 22  2016 data
drwxr-xr-x  3  500  500    4096 Jun 22  2016 ec2
drwxr-xr-x  3  500  500    4096 Jun 22  2016 examples
drwxr-xr-x  2  500  500    4096 Jun 22  2016 lib
-rw-r--r--  1  500  500   17352 Jun 22  2016 LICENSE
drwxr-xr-x  2  500  500    4096 Jun 22  2016 licenses
-rw-r--r--  1  500  500   23529 Jun 22  2016 NOTICE
drwxr-xr-x  6  500  500    4096 Jun 22  2016 python
drwxr-xr-x  3  500  500    4096 Jun 22  2016 R
-rw-r--r--  1  500  500    3359 Jun 22  2016 README.md
-rw-r--r--  1  500  500     120 Jun 22  2016 RELEASE
drwxr-xr-x  2  500  500    4096 Jun 22  2016 sbin
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6# cd ec2
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# l
total 84
drwxr-xr-x  3 500 500  4096 Jun 22  2016 .
drwxr-xr-x 12 500 500  4096 Jun 22  2016 ..
drwxr-xr-x  3 500 500  4096 Jun 22  2016 deploy.generic
-rw-r--r--  1 500 500   184 Jun 22  2016 README
-rwxr-xr-x  1 500 500   996 Jun 22  2016 spark-ec2
-rwxr-xr-x  1 500 500 61465 Jun 22  2016 spark_ec2.py
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# vi spark_ec2.py
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# which python
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# export Access_Key_ID=AKIAIGT2BI4F4ILRC52A
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# export Secret_Access_Key=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
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# python -V
The program 'python' can be found in the following packages:
 * python-minimal
 * python3
```

MINGW32:/c/Users/Shushi/downloads

```
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# sudo apt-get install -y python3-pip
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  binutils build-essential cpp cpp-5 dpkg-dev fakeroot g++ g++-5 gcc gcc-5 libalgorithm-diff-perl libalgorithm-diff-xs-perl libalgorithm-merge-perl libasan2 libatomic1 libc-dev-bin libc6-dev
  libcc1-0 libcilkrts5 libdpkg-perl libexpat1-dev libfakeroot libfile-fcntllock-perl libgcc-5-dev libgomp1 libisl15 libitm1 liblsan0 libmpc3 libmpx0 libpython3-dev libpython3.5
  libpython3.5-dev libpython3.5-minimal libpython3.5-stdlib libquadmath0 libstdc++-5-dev libtsan0 libubsan0 linux-libc-dev make manpages-dev python-pip-whl python3-dev python3-setuptools
  python3-wheel python3.5 python3.5-dev python3.5-minimal
Suggested packages:
  binutils-doc cpp-doc gcc-5-locales debian-keyring g++-multilib g++-5-multilib gcc-5-doc libstdc++6-5-dbg gcc-multilib autoconf automake libtool flex bison gdb gcc-doc gcc-5-multilib
  libgcc1-dbg libgomp1-dbg libitm1-dbg libatomic1-dbg libasan2-dbg liblsan0-dbg libtsan0-dbg libubsan0-dbg libcilkrts5-dbg libmpx0-dbg libquadmath0-dbg glibc-doc libstdc++-5-doc make-doc
  python-setuptools-doc python3.5-venv python3.5-doc binfmt-support
The following NEW packages will be installed:
  binutils build-essential cpp cpp-5 dpkg-dev fakeroot g++ g++-5 gcc gcc-5 libalgorithm-diff-perl libalgorithm-diff-xs-perl libalgorithm-merge-perl libasan2 libatomic1 libc-dev-bin libc6-dev
  libcc1-0 libcilkrts5 libdpkg-perl libexpat1-dev libfakeroot libfile-fcntllock-perl libgcc-5-dev libgomp1 libisl15 libitm1 liblsan0 libmpc3 libmpx0 libpython3-dev libpython3.5-dev
  libquadmath0 libstdc++-5-dev libtsan0 libubsan0 linux-libc-dev make manpages-dev python-pip-whl python3-dev python3-pip python3-setuptools python3-wheel python3.5-dev
The following packages will be upgraded:
  libpython3.5 libpython3.5-minimal libpython3.5-stdlib python3.5 python3.5-minimal
5 upgraded, 45 newly installed, 0 to remove and 8 not upgraded.
Need to get 83.6 MB of archives.
After this operation, 201 MB of additional disk space will be used.
Get:1 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libpython3.5 amd64 3.5.2-2ubuntu0~16.04.4 [1,360 kB]
Get:2 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 python3.5 amd64 3.5.2-2ubuntu0~16.04.4 [165 kB]
Get:3 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libpython3.5-stdlib amd64 3.5.2-2ubuntu0~16.04.4 [2,132 kB]
Get:4 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 python3.5-minimal amd64 3.5.2-2ubuntu0~16.04.4 [1,597 kB]
Get:5 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libpython3.5-minimal amd64 3.5.2-2ubuntu0~16.04.4 [523 kB]
Get:6 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial/main amd64 libmpc3 amd64 1.0.3-1 [39.7 kB]
Get:7 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 binutils amd64 2.26.1-1ubuntu1~16.04.5 [2,311 kB]
Get:8 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libc-dev-bin amd64 2.23-0ubuntu9 [68.6 kB]
Get:9 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 linux-libc-dev amd64 4.4.0-101.124 [844 kB]
Get:10 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libc6-dev amd64 2.23-0ubuntu9 [2,082 kB]
Get:11 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial/main amd64 libisl15 amd64 0.16.1-1 [524 kB]
Get:12 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 cpp-5 amd64 5.4.0-6ubuntu1~16.04.5 [7,786 kB]
Get:13 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial/main amd64 cpp amd64 4:5.3.1-1ubuntu1 [27.7 kB]
Get:14 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libcc1-0 amd64 5.4.0-6ubuntu1~16.04.5 [38.8 kB]
Get:15 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libgomp1 amd64 5.4.0-6ubuntu1~16.04.5 [55.1 kB]
Get:16 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libitm1 amd64 5.4.0-6ubuntu1~16.04.5 [27.4 kB]
Get:17 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libatomic1 amd64 5.4.0-6ubuntu1~16.04.5 [8,920 B]
Get:18 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libasan2 amd64 5.4.0-6ubuntu1~16.04.5 [264 kB]
Get:19 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 liblsan0 amd64 5.4.0-6ubuntu1~16.04.5 [105 kB]
Get:20 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libtsan0 amd64 5.4.0-6ubuntu1~16.04.5 [244 kB]
Get:21 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libubsan0 amd64 5.4.0-6ubuntu1~16.04.5 [95.3 kB]
Get:22 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libcilkrts5 amd64 5.4.0-6ubuntu1~16.04.5 [40.1 kB]
Get:23 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libmpx0 amd64 5.4.0-6ubuntu1~16.04.5 [9,786 B]
Get:24 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libquadmath0 amd64 5.4.0-6ubuntu1~16.04.5 [131 kB]
Get:25 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libgcc-5-dev amd64 5.4.0-6ubuntu1~16.04.5 [2,226 kB]
Get:26 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 gcc-5 amd64 5.4.0-6ubuntu1~16.04.5 [8,638 kB]
Get:27 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial/main amd64 gcc amd64 4:5.3.1-1ubuntu1 [5,244 B]
Get:28 http://us-east-1.ec2.archive.ubuntu.com/ubuntu xenial-updates/main amd64 libstdc++-5-dev amd64 5.4.0-6ubuntu1~16.04.5 [1,430 kB]
```

```
MINGW32:/c/Users/Shushi/downloads
Setting up libffi-dev:amd64 (3.2.1-4) ...
Processing triggers for libc-bin (2.23-0ubuntu9) ...
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# ./spark-ec2 -k shalin_key -i /home/ubuntu/shalin_key.pem -s 1 -t i3.large --ebs-vol-size=300 -m i3.large launch sparkShu
Downloading external libraries that spark-ec2 needs from PyPI to /root/spark-1.6.2-bin-hadoop2.6/ec2/lib...
This should be a one-time operation.
 - Downloading boto...
 - Finished downloading boto.
ERROR: The environment variable AWS_ACCESS_KEY_ID must be set
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# export AWS_ACCESS_KEY_ID=AKIAIGT2BI4F4ILRC52A
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2#
: command not found
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2././spark-ec2 -k shalin_key -i /home/ubuntu/shalin_key.pem -s 1 -t i3.large --ebs-vol-size=300 -m i3.large launch sparkShu
ERROR: The environment variable AWS_SECRET_ACCESS_KEY must be set
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2./export AWS_SECRET_ACCESS_KEY=zPval4euKGAsBZUDLVqekRCEI+nfBBKVrKnxS/xG
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# ./spark-ec2 -k shalin_key -i /home/ubuntu/shalin_key.pem -s 1 -t i3.large --ebs-vol-size=300 -m i3.large launch sparkShu
ERROR: The identity file must be accessible only by you.
You can fix this with: chmod 400 "/home/ubuntu/shalin_key.pem"
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# sudo chmod -R 400 /home/ubuntu/shalin_key.pem
root@ip-172-31-41-54:~/spark-1.6.2-bin-hadoop2.6/ec2# ./spark-ec2 -k shalin_key -i /home/ubuntu/shalin_key.pem -s 1 -t i3.large --ebs-vol-size=300 -m i3.large launch sparkShu
Setting up security groups...
Creating security group sparkShu-master
Creating security group sparkShu-slaves
Searching for existing cluster sparkShu in region us-east-1...
Spark AMI: ami-35b1885c
```

```
Connection established.
To escape to local shell, press 'Ctrl+Alt+]'.

Last login: Mon Mar 28 08:36:18 2016 from ip-172-31-35-135.ec2.internal

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

https://aws.amazon.com/amazon-linux-ami/2013.03-release-notes/
Amazon Linux version 2016.03 is available.
root@ip-172-31-35-135 ~]$ df -h
Filesystem            Size  Used Avail Use% Mounted on
/dev/xvda1            7.9G  3.4G  4.5G  43% /
tmpfs                 1.9G     0  1.9G   0% /dev/shm
/dev/xvdb              16G  1.3G   14G   9% /mnt
/dev/xvdf              16G  167M   15G   2% /mnt2
/dev/xvds              30G   33M   30G   1% /vol0
root@ip-172-31-35-135 ~]$
```

Execution:

Virtual Cluster (1-node i3.large):

Submitting job to master by the spark shell stage 1

```
08:56:16 INFO scheduler.DAGScheduler: Parents of final stage: List()
08:56:16 INFO scheduler.DAGScheduler: Missing parents: List()
08:56:16 INFO scheduler.DAGScheduler: Submitting ResultStage 0 (MapPartitionsRDD[5] at sortByKey at <console>:29), which has no missing parents
08:56:16 INFO storage.MemoryStore: Block broadcast_1 stored as values in memory (estimated size 3.9 KB, free 36.0 KB)
08:56:16 INFO storage.MemoryStore: Block broadcast_1_piece0 stored as bytes in memory (estimated size 2.1 KB, free 38.1 KB)
08:56:16 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on 172.31.35.135:42538 (size: 2.1 KB, free: 511.5 MB)
08:56:16 INFO spark.SparkContext: Created broadcast 1 from broadcast at DAGScheduler.scala:1006
08:56:16 INFO scheduler.DAGScheduler: Submitting 8 missing tasks from ResultStage 0 (MapPartitionsRDD[5] at sortByKey at <console>:29)
08:56:16 INFO scheduler.TaskSchedulerImpl: Adding task set 0.0 with 8 tasks
08:56:16 INFO scheduler.TaskSetManager: Starting task 0.0 in stage 0.0 (TID 0, ip-172-31-43-21.ec2.internal, partition 0,NODE_LOCAL, 2162 bytes)
08:56:16 INFO scheduler.TaskSetManager: Starting task 1.0 in stage 0.0 (TID 1, ip-172-31-43-21.ec2.internal, partition 1,NODE_LOCAL, 2162 bytes)
08:56:17 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on ip-172-31-43-21.ec2.internal:58510 (size: 2.1 KB, free: 1539.0 MB)
08:56:17 INFO storage.BlockManagerInfo: Added broadcast_0_piece0 in memory on ip-172-31-43-21.ec2.internal:58510 (size: 5.6 KB, free: 1539.0 MB)
08:56:20 INFO scheduler.TaskSetManager: Starting task 2.0 in stage 0.0 (TID 2, ip-172-31-43-21.ec2.internal, partition 2,NODE_LOCAL, 2162 bytes)
08:56:20 INFO scheduler.TaskSetManager: Finished task 0.0 in stage 0.0 (TID 0) in 3876 ms on ip-172-31-43-21.ec2.internal (1/8)
08:56:20 INFO scheduler.TaskSetManager: Starting task 3.0 in stage 0.0 (TID 3, ip-172-31-43-21.ec2.internal, partition 3,NODE_LOCAL, 2162 bytes)
08:56:20 INFO scheduler.TaskSetManager: Finished task 1.0 in stage 0.0 (TID 1) in 4113 ms on ip-172-31-43-21.ec2.internal (2/8)
08:56:22 INFO scheduler.TaskSetManager: Starting task 4.0 in stage 0.0 (TID 4, ip-172-31-43-21.ec2.internal, partition 4,NODE_LOCAL, 2162 bytes)
08:56:22 INFO scheduler.TaskSetManager: Finished task 3.0 in stage 0.0 (TID 3) in 2000 ms on ip-172-31-43-21.ec2.internal (3/8)
08:56:22 INFO scheduler.TaskSetManager: Starting task 5.0 in stage 0.0 (TID 5, ip-172-31-43-21.ec2.internal, partition 5,NODE_LOCAL, 2162 bytes)
08:56:22 INFO scheduler.TaskSetManager: Finished task 2.0 in stage 0.0 (TID 2) in 2299 ms on ip-172-31-43-21.ec2.internal (4/8)
08:56:24 INFO scheduler.TaskSetManager: Starting task 6.0 in stage 0.0 (TID 6, ip-172-31-43-21.ec2.internal, partition 6,NODE_LOCAL, 2162 bytes)
08:56:24 INFO scheduler.TaskSetManager: Finished task 4.0 in stage 0.0 (TID 4) in 1803 ms on ip-172-31-43-21.ec2.internal (5/8)
08:56:24 INFO scheduler.TaskSetManager: Starting task 7.0 in stage 0.0 (TID 7, ip-172-31-43-21.ec2.internal, partition 7,NODE_LOCAL, 2162 bytes)
08:56:24 INFO scheduler.TaskSetManager: Finished task 5.0 in stage 0.0 (TID 5) in 1783 ms on ip-172-31-43-21.ec2.internal (6/8)
08:56:25 INFO scheduler.TaskSetManager: Finished task 7.0 in stage 0.0 (TID 7) in 764 ms on ip-172-31-43-21.ec2.internal (7/8)
08:56:25 INFO scheduler.TaskSetManager: Finished task 6.0 in stage 0.0 (TID 6) in 1259 ms on ip-172-31-43-21.ec2.internal (8/8)
08:56:25 INFO scheduler.DAGScheduler: ResultStage 0 (sortByKey at <console>:29) finished in 9.179 s
08:56:25 INFO scheduler.DAGScheduler: Job 0 finished: sortByKey at <console>:29, took 9.236036 s
08:56:25 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 0.0, whose tasks have all completed, from pool
```

Stage 2

```
08:59:39 INFO scheduler.DAGScheduler: waiting: Set(ResultStage 2)
08:59:39 INFO scheduler.DAGScheduler: failed: Set()
08:59:39 INFO scheduler.DAGScheduler: Submitting ResultStage 2 (MapPartitionsRDD[8] at saveAsTextFile at <console>:32), which has no missing parents
08:59:39 INFO storage.MemoryStore: Block broadcast_3 stored as values in memory (estimated size 15.5 KB, free 60.5 KB)
08:59:39 INFO storage.MemoryStore: Block broadcast_3_piece0 stored as bytes in memory (estimated size 8.1 KB, free 68.6 KB)
08:59:39 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on 172.31.35.135:42538 (size: 8.1 KB, free: 511.5 MB)
08:59:39 INFO spark.SparkContext: Created broadcast 3 from broadcast at DAGScheduler.scala:1006
08:59:39 INFO scheduler.DAGScheduler: Submitting 8 missing tasks from ResultStage 2 (MapPartitionsRDD[8] at saveAsTextFile at <console>:32)
08:59:39 INFO scheduler.TaskSchedulerImpl: Adding task set 2.0 with 8 tasks
08:59:39 INFO scheduler.TaskSetManager: Starting task 0.0 in stage 2.0 (TID 16, ip-172-31-43-21.ec2.internal, partition 0,NODE_LOCAL, 1894 bytes)
08:59:39 INFO scheduler.TaskSetManager: Starting task 1.0 in stage 2.0 (TID 17, ip-172-31-43-21.ec2.internal, partition 1,NODE_LOCAL, 1894 bytes)
08:59:39 INFO storage.BlockManagerInfo: Added broadcast_3_piece0 in memory on ip-172-31-43-21.ec2.internal:50510 (size: 8.1 KB, free: 1539.0 MB)
08:59:39 INFO spark.MapOutputTrackerMasterEndpoint: Asked to send map output locations for shuffle 0 to ip-172-31-43-21.ec2.internal:55737
08:59:39 INFO spark.MapOutputTrackerMaster: Size of output statuses for shuffle 0 is 185 bytes
08:59:49 INFO scheduler.TaskSetManager: Starting task 2.0 in stage 2.0 (TID 18, ip-172-31-43-21.ec2.internal, partition 2,NODE_LOCAL, 1894 bytes)
08:59:49 INFO scheduler.TaskSetManager: Finished task 1.0 in stage 2.0 (TID 17) in 10077 ms on ip-172-31-43-21.ec2.internal (1/8)
08:59:51 INFO scheduler.TaskSetManager: Starting task 3.0 in stage 2.0 (TID 19, ip-172-31-43-21.ec2.internal, partition 3,NODE_LOCAL, 1894 bytes)
08:59:51 INFO scheduler.TaskSetManager: Finished task 0.0 in stage 2.0 (TID 16) in 12106 ms on ip-172-31-43-21.ec2.internal (2/8)
09:00:02 INFO scheduler.TaskSetManager: Starting task 4.0 in stage 2.0 (TID 20, ip-172-31-43-21.ec2.internal, partition 4,NODE_LOCAL, 1894 bytes)
09:00:02 INFO scheduler.TaskSetManager: Finished task 2.0 in stage 2.0 (TID 18) in 12077 ms on ip-172-31-43-21.ec2.internal (3/8)
09:00:04 INFO scheduler.TaskSetManager: Starting task 5.0 in stage 2.0 (TID 21, ip-172-31-43-21.ec2.internal, partition 5,NODE_LOCAL, 1894 bytes)
09:00:04 INFO scheduler.TaskSetManager: Finished task 3.0 in stage 2.0 (TID 19) in 12798 ms on ip-172-31-43-21.ec2.internal (4/8)
09:00:12 INFO scheduler.TaskSetManager: Starting task 6.0 in stage 2.0 (TID 22, ip-172-31-43-21.ec2.internal, partition 6,NODE_LOCAL, 1894 bytes)
09:00:12 INFO scheduler.TaskSetManager: Finished task 4.0 in stage 2.0 (TID 20) in 10108 ms on ip-172-31-43-21.ec2.internal (5/8)
09:00:15 INFO scheduler.TaskSetManager: Starting task 7.0 in stage 2.0 (TID 23, ip-172-31-43-21.ec2.internal, partition 7,NODE_LOCAL, 1894 bytes)
09:00:15 INFO scheduler.TaskSetManager: Finished task 5.0 in stage 2.0 (TID 21) in 10962 ms on ip-172-31-43-21.ec2.internal (6/8)
09:00:23 INFO scheduler.TaskSetManager: Finished task 6.0 in stage 2.0 (TID 22) in 10995 ms on ip-172-31-43-21.ec2.internal (7/8)
09:00:25 INFO scheduler.TaskSetManager: Finished task 7.0 in stage 2.0 (TID 23) in 9916 ms on ip-172-31-43-21.ec2.internal (8/8)
09:00:25 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:32) finished in 45.780 s
09:00:25 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
09:00:25 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextFile at <console>:32, took 60.095390 s
```

Give input

```
val inputFile = sc.textFile("/input100B")
8 09:37:09 INFO storage.MemoryStore: Block broadcast_0 stored as values in memory (estimated size 26.5 KB, free 26.5 KB)
8 09:37:09 INFO storage.MemoryStore: Block broadcast_0_piece0 stored as bytes in memory (estimated size 5.6 KB, free 32.1 KB)
8 09:37:09 INFO storage.BlockManagerInfo: Added broadcast_0_piece0 in memory on 172.31.35.135:58635 (size: 5.6 KB, free: 511.5 MB)
8 09:37:09 INFO spark.SparkContext: Created broadcast 0 from textFile at <console>:27
le: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[1] at textFile at <console>:27
```

```
val startSort = inputFile.flatMap(line => line.split("\n")).map(line => (line.substring(0,10), line.substring(10,98))).sortByKey().map{case(k, v) => k + v + " "}
8 09:37:18 WARN snappy.LoadSnappy: Snappy native library not loaded
8 09:37:18 INFO mapred.FileInputFormat: Total input paths to process : 1
8 09:37:18 INFO spark.SparkContext: Starting job: sortByKey at <console>:29
8 09:37:18 INFO scheduler.DAGScheduler: Got job 0 (sortByKey at <console>:29) with 75 output partitions
8 09:37:18 INFO scheduler.DAGScheduler: Final stage: ResultStage 0 (sortByKey at <console>:29)
8 09:37:18 INFO scheduler.DAGScheduler: Parents of final stage: List()
8 09:37:18 INFO scheduler.DAGScheduler: Missing parents: List()
8 09:37:18 INFO scheduler.DAGScheduler: Submitting ResultStage 0 (MapPartitionsRDD[5] at sortByKey at <console>:29), which has no missing parents
8 09:37:18 INFO storage.MemoryStore: Block broadcast_1 stored as values in memory (estimated size 3.9 KB, free 36.0 KB)
8 09:37:18 INFO storage.MemoryStore: Block broadcast_1_piece0 stored as bytes in memory (estimated size 2.1 KB, free 38.1 KB)
8 09:37:18 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on 172.31.35.135:58635 (size: 2.1 KB, free: 511.5 MB)
8 09:37:18 INFO spark.SparkContext: Created broadcast 1 from broadcast at DAGScheduler.scala:1006
8 09:37:18 INFO scheduler.DAGScheduler: Submitting 75 missing tasks from ResultStage 0 (MapPartitionsRDD[5] at sortByKey at <console>:29)
8 09:37:18 INFO scheduler.TaskSchedulerImpl: Adding task set 0.0 with 75 tasks
8 09:37:18 INFO scheduler.TaskSetManager: Starting task 0.0 in stage 0.0 (TID 0, ip-172-31-43-21.ec2.internal, partition 0,NODE_LOCAL, 2166 bytes)
8 09:37:18 INFO scheduler.TaskSetManager: Starting task 1.0 in stage 0.0 (TID 1, ip-172-31-43-21.ec2.internal, partition 1,NODE_LOCAL, 2166 bytes)
8 09:37:18 INFO storage.BlockManagerInfo: Added broadcast_1_piece0 in memory on ip-172-31-43-21.ec2.internal:48750 (size: 2.1 KB, free: 1539.0 MB)
8 09:37:19 INFO storage.BlockManagerInfo: Added broadcast_0_piece0 in memory on ip-172-31-43-21.ec2.internal:48750 (size: 5.6 KB, free: 1539.0 MB)
```

Map Phase

```
09:37:46 INFO scheduler.TaskSetManager: Starting task 32.0 in stage 0.0 (TID 32, ip-172-31-43-21.ec2.internal, partition 32,NODE_LOCAL, 2166 bytes)
09:37:46 INFO scheduler.TaskSetManager: Finished task 30.0 in stage 0.0 (TID 30) in 1606 ms on ip-172-31-43-21.ec2.internal (31/75)
09:37:46 INFO scheduler.TaskSetManager: Starting task 33.0 in stage 0.0 (TID 33, ip-172-31-43-21.ec2.internal, partition 33,NODE_LOCAL, 2166 bytes)
09:37:46 INFO scheduler.TaskSetManager: Finished task 31.0 in stage 0.0 (TID 31) in 1597 ms on ip-172-31-43-21.ec2.internal (32/75)
09:37:48 INFO scheduler.TaskSetManager: Starting task 34.0 in stage 0.0 (TID 34, ip-172-31-43-21.ec2.internal, partition 34,NODE_LOCAL, 2166 bytes)
09:37:48 INFO scheduler.TaskSetManager: Finished task 32.0 in stage 0.0 (TID 32) in 1577 ms on ip-172-31-43-21.ec2.internal (33/75)
09:37:48 INFO scheduler.TaskSetManager: Starting task 35.0 in stage 0.0 (TID 35, ip-172-31-43-21.ec2.internal, partition 35,NODE_LOCAL, 2166 bytes)
09:37:48 INFO scheduler.TaskSetManager: Finished task 33.0 in stage 0.0 (TID 33) in 1601 ms on ip-172-31-43-21.ec2.internal (34/75)
09:37:49 INFO scheduler.TaskSetManager: Starting task 36.0 in stage 0.0 (TID 36, ip-172-31-43-21.ec2.internal, partition 36,NODE_LOCAL, 2166 bytes)
09:37:49 INFO scheduler.TaskSetManager: Finished task 34.0 in stage 0.0 (TID 34) in 1571 ms on ip-172-31-43-21.ec2.internal (35/75)
09:37:49 INFO scheduler.TaskSetManager: Starting task 37.0 in stage 0.0 (TID 37, ip-172-31-43-21.ec2.internal, partition 37,NODE_LOCAL, 2166 bytes)
09:37:49 INFO scheduler.TaskSetManager: Finished task 35.0 in stage 0.0 (TID 35) in 1612 ms on ip-172-31-43-21.ec2.internal (36/75)
09:37:51 INFO scheduler.TaskSetManager: Starting task 38.0 in stage 0.0 (TID 38, ip-172-31-43-21.ec2.internal, partition 38,NODE_LOCAL, 2166 bytes)
09:37:51 INFO scheduler.TaskSetManager: Finished task 36.0 in stage 0.0 (TID 36) in 1678 ms on ip-172-31-43-21.ec2.internal (37/75)
09:37:51 INFO scheduler.TaskSetManager: Starting task 39.0 in stage 0.0 (TID 39, ip-172-31-43-21.ec2.internal, partition 39,NODE_LOCAL, 2166 bytes)
09:37:51 INFO scheduler.TaskSetManager: Finished task 37.0 in stage 0.0 (TID 37) in 1610 ms on ip-172-31-43-21.ec2.internal (38/75)
09:37:53 INFO scheduler.TaskSetManager: Starting task 40.0 in stage 0.0 (TID 40, ip-172-31-43-21.ec2.internal, partition 40,NODE_LOCAL, 2166 bytes)
09:37:53 INFO scheduler.TaskSetManager: Finished task 38.0 in stage 0.0 (TID 38) in 1624 ms on ip-172-31-43-21.ec2.internal (39/75)
09:37:53 INFO scheduler.TaskSetManager: Starting task 41.0 in stage 0.0 (TID 41, ip-172-31-43-21.ec2.internal, partition 41,NODE_LOCAL, 2166 bytes)
09:37:53 INFO scheduler.TaskSetManager: Finished task 39.0 in stage 0.0 (TID 39) in 1585 ms on ip-172-31-43-21.ec2.internal (40/75)
09:37:54 INFO scheduler.TaskSetManager: Starting task 42.0 in stage 0.0 (TID 42, ip-172-31-43-21.ec2.internal, partition 42,NODE_LOCAL, 2166 bytes)
09:37:54 INFO scheduler.TaskSetManager: Finished task 41.0 in stage 0.0 (TID 41) in 1567 ms on ip-172-31-43-21.ec2.internal (41/75)
09:37:54 INFO scheduler.TaskSetManager: Starting task 43.0 in stage 0.0 (TID 43, ip-172-31-43-21.ec2.internal, partition 43,NODE_LOCAL, 2166 bytes)
09:37:54 INFO scheduler.TaskSetManager: Finished task 40.0 in stage 0.0 (TID 40) in 1651 ms on ip-172-31-43-21.ec2.internal (42/75)
09:37:56 INFO scheduler.TaskSetManager: Starting task 44.0 in stage 0.0 (TID 44, ip-172-31-43-21.ec2.internal, partition 44,NODE_LOCAL, 2166 bytes)
09:37:56 INFO scheduler.TaskSetManager: Finished task 42.0 in stage 0.0 (TID 42) in 1548 ms on ip-172-31-43-21.ec2.internal (43/75)
09:37:56 INFO scheduler.TaskSetManager: Starting task 45.0 in stage 0.0 (TID 45, ip-172-31-43-21.ec2.internal, partition 45,NODE_LOCAL, 2166 bytes)
09:37:56 INFO scheduler.TaskSetManager: Finished task 43.0 in stage 0.0 (TID 43) in 1676 ms on ip-172-31-43-21.ec2.internal (44/75)
09:37:57 INFO scheduler.TaskSetManager: Starting task 46.0 in stage 0.0 (TID 46, ip-172-31-43-21.ec2.internal, partition 46,NODE_LOCAL, 2166 bytes)
09:37:57 INFO scheduler.TaskSetManager: Finished task 44.0 in stage 0.0 (TID 44) in 1538 ms on ip-172-31-43-21.ec2.internal (45/75)
09:37:58 INFO scheduler.TaskSetManager: Starting task 47.0 in stage 0.0 (TID 47, ip-172-31-43-21.ec2.internal, partition 47,NODE_LOCAL, 2166 bytes)
09:37:58 INFO scheduler.TaskSetManager: Finished task 45.0 in stage 0.0 (TID 45) in 1638 ms on ip-172-31-43-21.ec2.internal (46/75)
```

```
09:38:10 INFO scheduler.TaskSetManager: Finished task 60.0 in stage 0.0 (TID 60) in 1569 ms on ip-172-31-43-21.ec2.internal (61/75)
09:38:10 INFO scheduler.TaskSetManager: Starting task 63.0 in stage 0.0 (TID 63, ip-172-31-43-21.ec2.internal, partition 63,NODE_LOCAL, 2166 bytes)
09:38:10 INFO scheduler.TaskSetManager: Finished task 61.0 in stage 0.0 (TID 61) in 1588 ms on ip-172-31-43-21.ec2.internal (62/75)
09:38:11 INFO scheduler.TaskSetManager: Starting task 64.0 in stage 0.0 (TID 64, ip-172-31-43-21.ec2.internal, partition 64,NODE_LOCAL, 2166 bytes)
09:38:11 INFO scheduler.TaskSetManager: Finished task 62.0 in stage 0.0 (TID 62) in 1649 ms on ip-172-31-43-21.ec2.internal (63/75)
09:38:12 INFO scheduler.TaskSetManager: Starting task 65.0 in stage 0.0 (TID 65, ip-172-31-43-21.ec2.internal, partition 65,NODE_LOCAL, 2166 bytes)
09:38:12 INFO scheduler.TaskSetManager: Finished task 63.0 in stage 0.0 (TID 63) in 1572 ms on ip-172-31-43-21.ec2.internal (64/75)
09:38:13 INFO scheduler.TaskSetManager: Starting task 66.0 in stage 0.0 (TID 66, ip-172-31-43-21.ec2.internal, partition 66,NODE_LOCAL, 2166 bytes)
09:38:13 INFO scheduler.TaskSetManager: Finished task 64.0 in stage 0.0 (TID 64) in 1635 ms on ip-172-31-43-21.ec2.internal (65/75)
09:38:14 INFO scheduler.TaskSetManager: Starting task 67.0 in stage 0.0 (TID 67, ip-172-31-43-21.ec2.internal, partition 67,NODE_LOCAL, 2166 bytes)
09:38:14 INFO scheduler.TaskSetManager: Finished task 65.0 in stage 0.0 (TID 65) in 1650 ms on ip-172-31-43-21.ec2.internal (66/75)
09:38:15 INFO scheduler.TaskSetManager: Starting task 68.0 in stage 0.0 (TID 68, ip-172-31-43-21.ec2.internal, partition 68,NODE_LOCAL, 2166 bytes)
09:38:15 INFO scheduler.TaskSetManager: Finished task 66.0 in stage 0.0 (TID 66) in 1558 ms on ip-172-31-43-21.ec2.internal (67/75)
09:38:15 INFO scheduler.TaskSetManager: Starting task 69.0 in stage 0.0 (TID 69, ip-172-31-43-21.ec2.internal, partition 69,NODE_LOCAL, 2166 bytes)
09:38:15 INFO scheduler.TaskSetManager: Finished task 67.0 in stage 0.0 (TID 67) in 1641 ms on ip-172-31-43-21.ec2.internal (68/75)
09:38:16 INFO scheduler.TaskSetManager: Starting task 70.0 in stage 0.0 (TID 70, ip-172-31-43-21.ec2.internal, partition 70,NODE_LOCAL, 2166 bytes)
09:38:16 INFO scheduler.TaskSetManager: Finished task 68.0 in stage 0.0 (TID 68) in 1590 ms on ip-172-31-43-21.ec2.internal (69/75)
09:38:17 INFO scheduler.TaskSetManager: Starting task 71.0 in stage 0.0 (TID 71, ip-172-31-43-21.ec2.internal, partition 71,NODE_LOCAL, 2166 bytes)
09:38:17 INFO scheduler.TaskSetManager: Finished task 69.0 in stage 0.0 (TID 69) in 1613 ms on ip-172-31-43-21.ec2.internal (70/75)
09:38:18 INFO scheduler.TaskSetManager: Starting task 72.0 in stage 0.0 (TID 72, ip-172-31-43-21.ec2.internal, partition 72,NODE_LOCAL, 2166 bytes)
09:38:18 INFO scheduler.TaskSetManager: Finished task 70.0 in stage 0.0 (TID 70) in 1585 ms on ip-172-31-43-21.ec2.internal (71/75)
09:38:18 INFO scheduler.TaskSetManager: Starting task 73.0 in stage 0.0 (TID 73, ip-172-31-43-21.ec2.internal, partition 73,NODE_LOCAL, 2166 bytes)
09:38:18 INFO scheduler.TaskSetManager: Finished task 71.0 in stage 0.0 (TID 71) in 1612 ms on ip-172-31-43-21.ec2.internal (72/75)
09:38:19 INFO scheduler.TaskSetManager: Starting task 74.0 in stage 0.0 (TID 74, ip-172-31-43-21.ec2.internal, partition 74,NODE_LOCAL, 2166 bytes)
09:38:19 INFO scheduler.TaskSetManager: Finished task 72.0 in stage 0.0 (TID 72) in 1602 ms on ip-172-31-43-21.ec2.internal (73/75)
09:38:20 INFO scheduler.TaskSetManager: Finished task 73.0 in stage 0.0 (TID 73) in 1605 ms on ip-172-31-43-21.ec2.internal (74/75)
09:38:20 INFO scheduler.TaskSetManager: Finished task 74.0 in stage 0.0 (TID 74) in 764 ms on ip-172-31-43-21.ec2.internal (75/75)
09:38:20 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 0.0, whose tasks have all completed, from pool
09:38:20 INFO scheduler.DAGScheduler: ResultStage 0 (sortByKey at <console>:29) finished in 62.194 s
09:38:20 INFO scheduler.DAGScheduler: Job 0 finished: sortByKey at <console>:29, took 62.266086 s
: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[7] at map at <console>:29
```

Reduce Phase

```
09:50:46 INFO scheduler.TaskSetManager: Starting task 62.0 in stage 2.0 (TID 212, ip-172-31-43-21.ec2.internal, partition 62,NODE_LOCAL, 1894 bytes)
09:50:46 INFO scheduler.TaskSetManager: Finished task 60.0 in stage 2.0 (TID 210) in 16640 ms on ip-172-31-43-21.ec2.internal (61/75)
09:50:49 INFO scheduler.TaskSetManager: Starting task 63.0 in stage 2.0 (TID 213, ip-172-31-43-21.ec2.internal, partition 63,NODE_LOCAL, 1894 bytes)
09:50:49 INFO scheduler.TaskSetManager: Finished task 61.0 in stage 2.0 (TID 211) in 16180 ms on ip-172-31-43-21.ec2.internal (62/75)
09:51:00 INFO scheduler.TaskSetManager: Starting task 64.0 in stage 2.0 (TID 214, ip-172-31-43-21.ec2.internal, partition 64,NODE_LOCAL, 1894 bytes)
09:51:00 INFO scheduler.TaskSetManager: Finished task 62.0 in stage 2.0 (TID 212) in 14203 ms on ip-172-31-43-21.ec2.internal (63/75)
09:51:04 INFO scheduler.TaskSetManager: Starting task 65.0 in stage 2.0 (TID 215, ip-172-31-43-21.ec2.internal, partition 65,NODE_LOCAL, 1894 bytes)
09:51:04 INFO scheduler.TaskSetManager: Finished task 63.0 in stage 2.0 (TID 213) in 15539 ms on ip-172-31-43-21.ec2.internal (64/75)
09:51:16 INFO scheduler.TaskSetManager: Starting task 66.0 in stage 2.0 (TID 216, ip-172-31-43-21.ec2.internal, partition 66,NODE_LOCAL, 1894 bytes)
09:51:16 INFO scheduler.TaskSetManager: Finished task 64.0 in stage 2.0 (TID 214) in 15185 ms on ip-172-31-43-21.ec2.internal (65/75)
09:51:18 INFO scheduler.TaskSetManager: Starting task 67.0 in stage 2.0 (TID 217, ip-172-31-43-21.ec2.internal, partition 67,NODE_LOCAL, 1894 bytes)
09:51:18 INFO scheduler.TaskSetManager: Finished task 65.0 in stage 2.0 (TID 215) in 13913 ms on ip-172-31-43-21.ec2.internal (66/75)
09:51:30 INFO scheduler.TaskSetManager: Starting task 68.0 in stage 2.0 (TID 218, ip-172-31-43-21.ec2.internal, partition 68,NODE_LOCAL, 1894 bytes)
09:51:30 INFO scheduler.TaskSetManager: Finished task 66.0 in stage 2.0 (TID 216) in 14794 ms on ip-172-31-43-21.ec2.internal (67/75)
09:51:34 INFO scheduler.TaskSetManager: Starting task 69.0 in stage 2.0 (TID 219, ip-172-31-43-21.ec2.internal, partition 69,NODE_LOCAL, 1894 bytes)
09:51:34 INFO scheduler.TaskSetManager: Finished task 67.0 in stage 2.0 (TID 217) in 16066 ms on ip-172-31-43-21.ec2.internal (68/75)
09:51:44 INFO scheduler.TaskSetManager: Starting task 70.0 in stage 2.0 (TID 220, ip-172-31-43-21.ec2.internal, partition 70,NODE_LOCAL, 1894 bytes)
09:51:44 INFO scheduler.TaskSetManager: Finished task 68.0 in stage 2.0 (TID 218) in 13949 ms on ip-172-31-43-21.ec2.internal (69/75)
09:51:51 INFO scheduler.TaskSetManager: Starting task 71.0 in stage 2.0 (TID 221, ip-172-31-43-21.ec2.internal, partition 71,NODE_LOCAL, 1894 bytes)
09:51:51 INFO scheduler.TaskSetManager: Finished task 69.0 in stage 2.0 (TID 219) in 16213 ms on ip-172-31-43-21.ec2.internal (70/75)
09:51:54 INFO scheduler.TaskSetManager: Starting task 72.0 in stage 2.0 (TID 222, ip-172-31-43-21.ec2.internal, partition 72,NODE_LOCAL, 1894 bytes)
09:51:54 INFO scheduler.TaskSetManager: Finished task 70.0 in stage 2.0 (TID 220) in 9732 ms on ip-172-31-43-21.ec2.internal (71/75)
09:52:02 INFO scheduler.TaskSetManager: Starting task 73.0 in stage 2.0 (TID 223, ip-172-31-43-21.ec2.internal, partition 73,NODE_LOCAL, 1894 bytes)
09:52:02 INFO scheduler.TaskSetManager: Finished task 71.0 in stage 2.0 (TID 221) in 11590 ms on ip-172-31-43-21.ec2.internal (72/75)
09:52:06 INFO scheduler.TaskSetManager: Starting task 74.0 in stage 2.0 (TID 224, ip-172-31-43-21.ec2.internal, partition 74,NODE_LOCAL, 1894 bytes)
09:52:06 INFO scheduler.TaskSetManager: Finished task 72.0 in stage 2.0 (TID 222) in 11669 ms on ip-172-31-43-21.ec2.internal (73/75)
09:52:18 INFO scheduler.TaskSetManager: Finished task 73.0 in stage 2.0 (TID 223) in 16036 ms on ip-172-31-43-21.ec2.internal (74/75)
09:52:21 INFO scheduler.TaskSetManager: Finished task 74.0 in stage 2.0 (TID 224) in 15224 ms on ip-172-31-43-21.ec2.internal (75/75)
09:52:21 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:32) finished in 505.233 s
09:52:21 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
09:52:21 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextFile at <console>:32, took 755.692807 s
```

Virtual Cluster (1-node i3.4xlarge):

Provide job to map and reduce

```
23:34:21 INFO scheduler.TaskSetManager: Finished task 711.0 in stage 0.0 (TID 704) in 1771 ms on ip-172-31-55-74.ec2.internal (719/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 723.0 in stage 0.0 (TID 712) in 1641 ms on ip-172-31-61-180.ec2.internal (720/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 722.0 in stage 0.0 (TID 717) in 1565 ms on ip-172-31-48-246.ec2.internal (721/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 717.0 in stage 0.0 (TID 726) in 1432 ms on ip-172-31-48-29.ec2.internal (722/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 735.0 in stage 0.0 (TID 727) in 1434 ms on ip-172-31-55-251.ec2.internal (723/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 716.0 in stage 0.0 (TID 719) in 1522 ms on ip-172-31-63-212.ec2.internal (724/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 706.0 in stage 0.0 (TID 715) in 1645 ms on ip-172-31-48-246.ec2.internal (725/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 709.0 in stage 0.0 (TID 708) in 1754 ms on ip-172-31-62-70.ec2.internal (726/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 727.0 in stage 0.0 (TID 716) in 1648 ms on ip-172-31-60-86.ec2.internal (727/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 738.0 in stage 0.0 (TID 718) in 1619 ms on ip-172-31-60-86.ec2.internal (728/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 712.0 in stage 0.0 (TID 721) in 1575 ms on ip-172-31-55-74.ec2.internal (729/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 731.0 in stage 0.0 (TID 742) in 1023 ms on ip-172-31-51-31.ec2.internal (730/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 740.0 in stage 0.0 (TID 730) in 1495 ms on ip-172-31-55-251.ec2.internal (731/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 742.0 in stage 0.0 (TID 741) in 1088 ms on ip-172-31-51-136.ec2.internal (732/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 718.0 in stage 0.0 (TID 723) in 1572 ms on ip-172-31-56-112.ec2.internal (733/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 728.0 in stage 0.0 (TID 731) in 1517 ms on ip-172-31-48-246.ec2.internal (734/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 733.0 in stage 0.0 (TID 732) in 1387 ms on ip-172-31-62-70.ec2.internal (735/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 732.0 in stage 0.0 (TID 725) in 1578 ms on ip-172-31-62-70.ec2.internal (736/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 736.0 in stage 0.0 (TID 734) in 1441 ms on ip-172-31-63-212.ec2.internal (737/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 730.0 in stage 0.0 (TID 735) in 1503 ms on ip-172-31-61-180.ec2.internal (738/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 729.0 in stage 0.0 (TID 733) in 1663 ms on ip-172-31-56-112.ec2.internal (739/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 743.0 in stage 0.0 (TID 739) in 1442 ms on ip-172-31-56-112.ec2.internal (740/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 734.0 in stage 0.0 (TID 738) in 1609 ms on ip-172-31-56-112.ec2.internal (741/745)
23:34:21 INFO scheduler.TaskSetManager: Finished task 719.0 in stage 0.0 (TID 737) in 1686 ms on ip-172-31-55-74.ec2.internal (742/745)
23:34:22 INFO scheduler.TaskSetManager: Finished task 739.0 in stage 0.0 (TID 743) in 1426 ms on ip-172-31-55-74.ec2.internal (743/745)
23:34:22 INFO scheduler.TaskSetManager: Finished task 744.0 in stage 0.0 (TID 744) in 1046 ms on ip-172-31-63-212.ec2.internal (744/745)
23:34:23 INFO scheduler.TaskSetManager: Finished task 741.0 in stage 0.0 (TID 740) in 2849 ms on ip-172-31-51-136.ec2.internal (745/745)
23:34:23 INFO scheduler.DAGScheduler: ResultStage 0 (sortByKey at <console>:29) finished in 24.891 s
23:34:23 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 0.0, whose tasks have all completed, from pool
23:34:23 INFO scheduler.DAGScheduler: Job 0 finished: sortByKey at <console>:29, took 25.072833 s
: org.apache.spark.rdd.RDD[String] = MapPartitionsRDD[11] at map at <console>:29

l sortedMap = inputFile.flatMap(line => line.split("\n")).map(line => (line.substring(0,10), line.substring(10,98))).sortByKey().map{case(k,v) => k+ v + " "}
```

```
23:42:17 INFO scheduler.TaskSetManager: Finished task 716.0 in stage 2.0 (TID 2206) in 25970 ms on ip-172-31-62-91.ec2.internal (718/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 710.0 in stage 2.0 (TID 2200) in 29060 ms on ip-172-31-63-212.ec2.internal (719/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 734.0 in stage 2.0 (TID 2224) in 22090 ms on ip-172-31-61-180.ec2.internal (720/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 724.0 in stage 2.0 (TID 2214) in 24998 ms on ip-172-31-55-251.ec2.internal (721/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 715.0 in stage 2.0 (TID 2205) in 27859 ms on ip-172-31-51-136.ec2.internal (722/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 717.0 in stage 2.0 (TID 2207) in 26416 ms on ip-172-31-56-112.ec2.internal (723/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 735.0 in stage 2.0 (TID 2225) in 21801 ms on ip-172-31-56-212.ec2.internal (724/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 720.0 in stage 2.0 (TID 2210) in 25690 ms on ip-172-31-48-29.ec2.internal (725/745)
23:42:18 INFO scheduler.TaskSetManager: Finished task 727.0 in stage 2.0 (TID 2217) in 24200 ms on ip-172-31-55-251.ec2.internal (726/745)
23:42:19 INFO scheduler.TaskSetManager: Finished task 707.0 in stage 2.0 (TID 2197) in 31585 ms on ip-172-31-51-136.ec2.internal (727/745)
23:42:19 INFO scheduler.TaskSetManager: Finished task 740.0 in stage 2.0 (TID 2230) in 21326 ms on ip-172-31-48-246.ec2.internal (728/745)
23:42:19 INFO scheduler.TaskSetManager: Finished task 718.0 in stage 2.0 (TID 2208) in 27600 ms on ip-172-31-59-187.ec2.internal (729/745)
23:42:20 INFO scheduler.TaskSetManager: Finished task 719.0 in stage 2.0 (TID 2209) in 27266 ms on ip-172-31-63-212.ec2.internal (730/745)
23:42:20 INFO scheduler.TaskSetManager: Finished task 739.0 in stage 2.0 (TID 2229) in 21740 ms on ip-172-31-62-70.ec2.internal (731/745)
23:42:20 INFO scheduler.TaskSetManager: Finished task 733.0 in stage 2.0 (TID 2223) in 24246 ms on ip-172-31-56-212.ec2.internal (732/745)
23:42:21 INFO scheduler.TaskSetManager: Finished task 722.0 in stage 2.0 (TID 2212) in 28306 ms on ip-172-31-48-29.ec2.internal (733/745)
23:42:21 INFO scheduler.TaskSetManager: Finished task 726.0 in stage 2.0 (TID 2216) in 27698 ms on ip-172-31-62-70.ec2.internal (734/745)
23:42:21 INFO scheduler.TaskSetManager: Finished task 702.0 in stage 2.0 (TID 2192) in 35480 ms on ip-172-31-55-251.ec2.internal (735/745)
23:42:21 INFO scheduler.TaskSetManager: Finished task 700.0 in stage 2.0 (TID 2190) in 37772 ms on ip-172-31-61-180.ec2.internal (736/745)
23:42:22 INFO scheduler.TaskSetManager: Finished task 706.0 in stage 2.0 (TID 2196) in 34216 ms on ip-172-31-61-61.ec2.internal (737/745)
23:42:22 INFO scheduler.TaskSetManager: Finished task 732.0 in stage 2.0 (TID 2222) in 26803 ms on ip-172-31-61-61.ec2.internal (738/745)
23:42:24 INFO scheduler.TaskSetManager: Finished task 731.0 in stage 2.0 (TID 2221) in 28808 ms on ip-172-31-55-251.ec2.internal (739/745)
23:42:24 INFO scheduler.TaskSetManager: Finished task 736.0 in stage 2.0 (TID 2226) in 27409 ms on ip-172-31-51-230.ec2.internal (740/745)
23:42:24 INFO scheduler.TaskSetManager: Finished task 728.0 in stage 2.0 (TID 2218) in 30215 ms on ip-172-31-51-31.ec2.internal (741/745)
23:42:25 INFO scheduler.TaskSetManager: Finished task 729.0 in stage 2.0 (TID 2219) in 30719 ms on ip-172-31-48-29.ec2.internal (742/745)
23:42:26 INFO scheduler.TaskSetManager: Finished task 741.0 in stage 2.0 (TID 2231) in 27685 ms on ip-172-31-51-31.ec2.internal (743/745)
23:42:27 INFO scheduler.TaskSetManager: Finished task 744.0 in stage 2.0 (TID 2234) in 28407 ms on ip-172-31-51-230.ec2.internal (744/745)
23:42:28 INFO scheduler.TaskSetManager: Finished task 737.0 in stage 2.0 (TID 2227) in 29977 ms on ip-172-31-51-230.ec2.internal (745/745)
23:42:28 INFO scheduler.TaskSchedulerImpl: Removed TaskSet 2.0, whose tasks have all completed, from pool
23:42:28 INFO scheduler.DAGScheduler: ResultStage 2 (saveAsTextFile at <console>:32) finished in 312.420 s
23:42:28 INFO scheduler.DAGScheduler: Job 1 finished: saveAsTextFile at <console>:32, took 432.429212 s
```

```
part-00028  part-00067  part-00114  part-00161  part-00208  part-00255  part-00302  part-00349  part-00396  part-00443  part-00490  part-00537  part-00584  part-00631  part-00678  part-00725
part-00021  part-00068  part-00115  part-00162  part-00209  part-00256  part-00303  part-00350  part-00397  part-00444  part-00491  part-00538  part-00585  part-00632  part-00679  part-00726
part-00022  part-00069  part-00116  part-00163  part-00210  part-00257  part-00304  part-00351  part-00398  part-00445  part-00492  part-00539  part-00586  part-00633  part-00680  part-00727
part-00023  part-00070  part-00117  part-00164  part-00211  part-00258  part-00305  part-00352  part-00399  part-00446  part-00493  part-00540  part-00587  part-00634  part-00681  part-00728
part-00024  part-00071  part-00118  part-00165  part-00212  part-00259  part-00306  part-00353  part-00400  part-00447  part-00494  part-00541  part-00588  part-00635  part-00682  part-00729
part-00025  part-00072  part-00119  part-00166  part-00213  part-00260  part-00307  part-00354  part-00401  part-00448  part-00495  part-00542  part-00589  part-00636  part-00683  part-00730
part-00026  part-00073  part-00120  part-00167  part-00214  part-00261  part-00308  part-00355  part-00402  part-00449  part-00496  part-00543  part-00590  part-00637  part-00684  part-00731
part-00027  part-00074  part-00121  part-00168  part-00215  part-00262  part-00309  part-00356  part-00403  part-00450  part-00497  part-00544  part-00591  part-00638  part-00685  part-00732
part-00028  part-00075  part-00122  part-00169  part-00216  part-00263  part-00310  part-00357  part-00404  part-00451  part-00498  part-00545  part-00592  part-00639  part-00686  part-00733
part-00029  part-00076  part-00123  part-00170  part-00217  part-00264  part-00311  part-00358  part-00405  part-00452  part-00499  part-00546  part-00593  part-00640  part-00687  part-00734
part-00030  part-00077  part-00124  part-00171  part-00218  part-00265  part-00312  part-00359  part-00406  part-00453  part-00500  part-00547  part-00594  part-00641  part-00688  part-00735
part-00031  part-00078  part-00125  part-00172  part-00219  part-00266  part-00313  part-00360  part-00407  part-00454  part-00501  part-00548  part-00595  part-00642  part-00689  part-00736
part-00032  part-00079  part-00126  part-00173  part-00220  part-00267  part-00314  part-00361  part-00408  part-00455  part-00502  part-00549  part-00596  part-00643  part-00690  part-00737
part-00033  part-00080  part-00127  part-00174  part-00221  part-00268  part-00315  part-00362  part-00409  part-00456  part-00503  part-00550  part-00597  part-00644  part-00691  part-00738
part-00034  part-00081  part-00128  part-00175  part-00222  part-00269  part-00316  part-00363  part-00410  part-00457  part-00504  part-00551  part-00598  part-00645  part-00692  part-00739
part-00035  part-00082  part-00129  part-00176  part-00223  part-00270  part-00317  part-00364  part-00411  part-00458  part-00505  part-00552  part-00599  part-00646  part-00693  part-00740
part-00036  part-00083  part-00130  part-00177  part-00224  part-00271  part-00318  part-00365  part-00412  part-00459  part-00506  part-00553  part-00600  part-00647  part-00694  part-00741
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part-00038  part-00085  part-00132  part-00179  part-00226  part-00273  part-00320  part-00367  part-00414  part-00461  part-00508  part-00555  part-00602  part-00649  part-00696  part-00743
part-00039  part-00086  part-00133  part-00180  part-00227  part-00274  part-00321  part-00368  part-00415  part-00462  part-00509  part-00556  part-00603  part-00650  part-00697  part-00744
part-00040  part-00087  part-00134  part-00181  part-00228  part-00275  part-00322  part-00369  part-00416  part-00463  part-00510  part-00557  part-00604  part-00651  part-00698  _SUCCESS
part-00041  part-00088  part-00135  part-00182  part-00229  part-00276  part-00323  part-00370  part-00417  part-00464  part-00511  part-00558  part-00605  part-00652  part-00699
part-00042  part-00089  part-00136  part-00183  part-00230  part-00277  part-00324  part-00371  part-00418  part-00465  part-00512  part-00559  part-00606  part-00653  part-00700
part-00043  part-00090  part-00137  part-00184  part-00231  part-00278  part-00325  part-00372  part-00419  part-00466  part-00513  part-00560  part-00607  part-00654  part-00701
part-00044  part-00091  part-00138  part-00185  part-00232  part-00279  part-00326  part-00373  part-00420  part-00467  part-00514  part-00561  part-00608  part-00655  part-00702
part-00045  part-00092  part-00139  part-00186  part-00233  part-00280  part-00327  part-00374  part-00421  part-00468  part-00515  part-00562  part-00609  part-00656  part-00703
part-00046  part-00093  part-00140  part-00187  part-00234  part-00281  part-00328  part-00375  part-00422  part-00469  part-00516  part-00563  part-00610  part-00657  part-00704
root@ip-172-31-48-180 Output.txt]$ head -10 part-00000
    !4+ABv  000000000000000000000000017F7E829  EEEE333344441111222288883333444466663333222200DDDEEEE
    "0!uve  000000000000000000000000001228D4  7777888800002222444400000000EEEE000000000CCC77770000
    %!$sU(  00000000000000000000000032E6C821C  22223333777744445555511119999CCCC4444EEEEFFFF11115555
    &5rX|X  000000000000000000000000003398C288  5555CCCCBBBB99999999DDDD1111000011111EEEE7777DDDD9999
    'ic%So  0000000000000000000000003331F9687D  EEEEBBBBAAAA88880000DDDD7777222244441111666644444AAAA
    *0G]lo  000000000000000000000000385E85A1  1111AAAA9999CCCC8888111199991111333399991111AAAA6666
    ,[GhT_  0000000000000000000000002D0172DC  1111CCCC1111DDDDCCCCEEEE9999CCCC8888CCCCFFFF55555555
    0*vYm3  000000000000000000000000326D61578  DDDD7777AAAAEEEEEEEE6666AAAA2222CCCC5555555522229999
    2C>)8d  0000000000000000000000003267C79E66  4444000011112CCCC6666BBBB55557777666655CCCC2222AAAABBBB
    PMd32~  000000000000000000000000003440CC1  FFFFEEEE6666CCCC8888999933335555DDDDDDDD7777888866666
root@ip-172-31-48-180 Output.txt]$ tail -10 part-00744
~~~~#iaylX  000000000000000000000000325D35EDF  6666AAAA555599999777700002222333388888FFFF999922220000
~~~~+@p){@  0000000000000000000000003854286F4  77773333555511111111666655555999AAAA7777DDDDDDDD
~~~~,R^_?n  000000000000000000000001034E347  1111111199990000111188880AAAA55554444EEEE999933330000
~~~~.Ey^^)  00000000000000000000000016F0E66B  CCCC6666DDDD2222DDDD1111888899995EEEEEEEEEEEEBBBB4444
~~~~4!kA7x  000000000000000000000001F1A1E26  EEEE777711117777888B1111EEEE88884444DDDDDDDDEEEEBBBB
~~~~8Ii/!@  000000000000000000000001F05932F  1111999988884444777766661111444CCCCAAAA6666DDDD0000
~~~~<I'5>F  0000000000000000000000368CB2293  8888333388881111666699990888855558888888822228888CCCC
~~~~G-)m^)  000000000000000000000013397F73  DDDDFFFFBBBBCCCCFFFF44446666AAAA1111333333333AAAACCCC
~~~~c+I&cP  0000000000000000000000003974BDF64  88880000555500006DDDD22227777AAAA9999333322222AAAADDDD
~~~~hb&5X*  000000000000000000000003320E06B  7777888888889999EEEEAAAAAAAA0000CCCCDDDD4444BBBB4444
root@ip-172-31-48-180 Output.txt]$
```
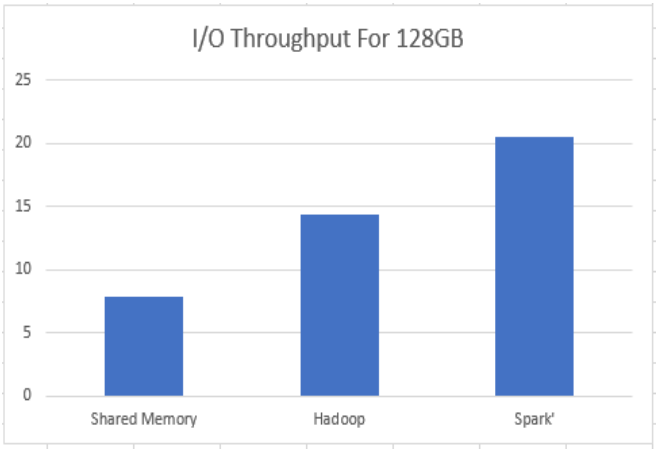
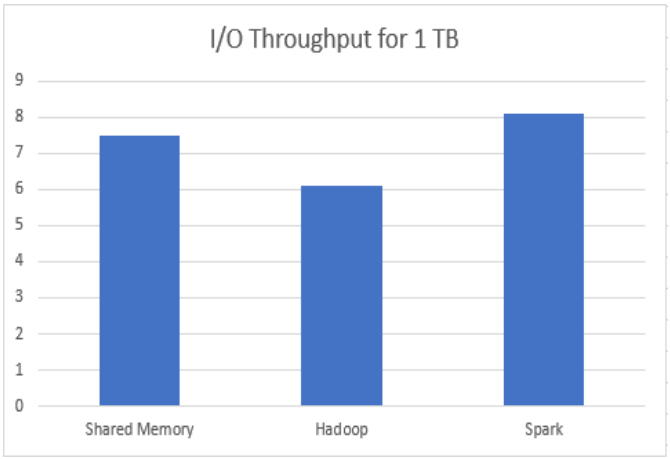
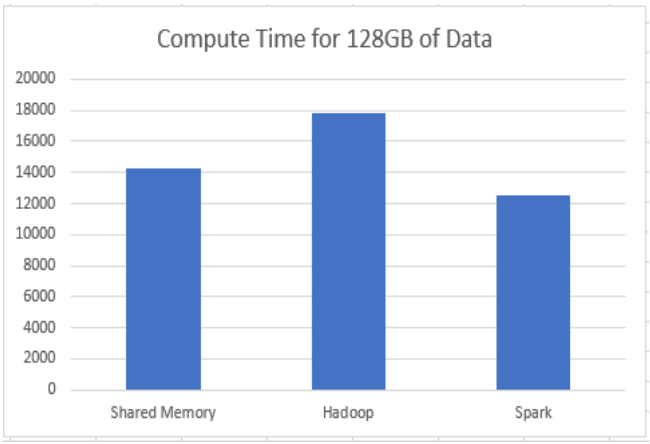
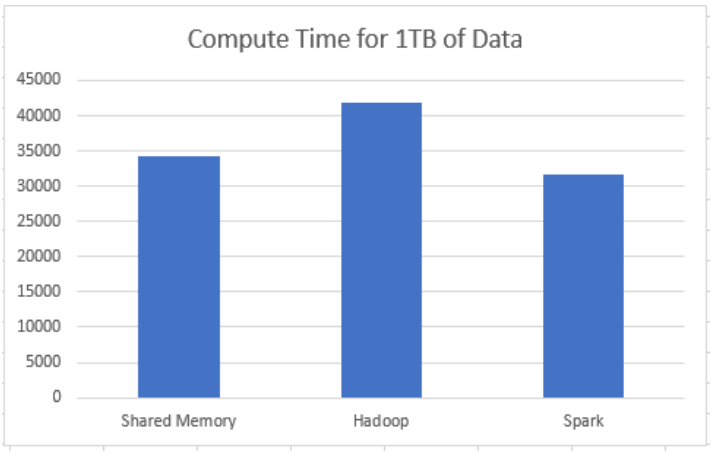

Performance Evaluation and Analysis:

	Shared Memory TeraSort	Hadoop TeraSort	Spark TeraSort
Compute Time (sec) [1xi3.large 128GB]	14256	17806.78	12492
Data Read (GB) [1xi3.large 128GB]	128 GB	128 GB	128 GB
Data Write (GB) [1xi3.large 128GB]	128 GB	128 GB	128 GB
I/O Throughput (MB/sec) [1xi3.large 128GB]	7.9	14.37	20.49
Compute Time (sec) [1xi3.4xlarge 1TB]	34200	41946.79	31586
Data Read (GB) [1xi3.4xlarge 1TB]	1 TB	1 TB	1 TB
Data Write (GB) [1xi3.4xlarge 1TB]	1 TB	1 TB	1 TB
I/O Throughput (MB/sec) [1xi3.4xlarge	7.485	6.103	8.1
Compute Time (sec) [8xi3.large 1TB]	N/A	40312	30952
Data Read (GB) [8xi3.large 1TB	N/A	1 TB	1 TB
Data Write (GB) [8xi3.large 1TB]	N/A	1 TB	1 TB
I/O Throughput (MB/sec) [8xi3.large 1TB]	N/A	6.3	8.27
Speedup (weak scale)	3.33	3.39	3.16
Efficiency (weak scale)	41.68	42.44	39.54









Analysis:

- Spark sort is faster for 128GB and 1TB on single node setup.
- From the above table and graph, we can say that Spark performs much better than hadoop, when comparing 8 Nodes cluster scale and large amount of data
- Spark saves the intermediate data generated, hence one when finished with some experiment in our case sorting, if we need to perform the same experiment.
- Ideally throughput for Hadoop 128 GB should less than 1TB because, its running on i3.4xlarge instance. But we are getting opposite results. This is because we put number of map and reduce set to 2. If we increase the number then it will give us the desired output.
- If we increase the node, throughput will increase. But in our case its decreasing. In this case instance is also playing key role, as i3.4xlarge is 4 times faster than i3.large. This factor also responsible for the throughput.

Performance Questions and Answers:

Which seems to be best at 1 node scale?

For 1 Node scale, for both 128 GB and 1 TB Spark seems to be the best, as we get more throughput for that. If we saw the efficiency, Hadoop is better.

What about 8 nodes?

Sparks perform better than Hadoop

Can you predict which would be best at 100 node scale? How about 1000 node scales?

Scaling up from 8 nodes to 100 nodes to 1000 node, would make spark and hadoop come closer in terms of throughput but Spark will perform much better at these. But it also depends on what kind of data is given for job execution, if it is iterative data like Data Mining Application or Machine Learning Application, thenSpark will definitely be faster than Hadoop. So along with scaling we also need to look into kind of data given to the map-reduce jobs.

Compare your results with those from the Sort Benchmark [9], specifically the winners in 2013 and 2014 who used Hadoop and Spark.

Specifications	Spark (2014 Winner)	Hadoop (2013 Winner)
Dataset Size	100 TB	102.5 TB
Instances type used	Amazon EC2 i2.8xlarge	Dell R720xd
System Specs.	32 vCores - 2.5Ghz Intel Xeon E5-2670 v2	2.3Ghz hexcore Xeon E5-2630
Memory	244 GB	64 GB
Disks	8 * 800 GB SSD	12 * 3TB Disks
Throughput	4.27 TB/min	1.42 TB/min
Time	1,406 seconds	4,328 seconds

Comparing with sort implemented by me which is pretty smaller than dataset used above for sort benchmarking, I can see the same trend of Spark performing faster than Hadoop.

OS Specifications:

	OS	JAVA	Hadoop	Spark	ANT
Version	- Ubuntu Server 14.04 LTS	java-8-openjdk-amd64	Hadoop2.8.2	Spark 2.2.0	1.9.9