PageRank on GCP

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01

Introduction

PageRank (PR) is an algorithm used by Google Search to rank websites in their search engine results.
It works by evaluating both the quantity and quality of links to a page.

This recursive nature of ranking forms the basis of PageRank, which considers not just the number of incoming links but also the importance of the pages providing these links, creating a reliable gauge of a page's relevance and authority on the web.

Design

02

Technology used for this project and Sections are:

GCP- Pyspark

GCP -Scala

03

Implementation

Three subsections involved.

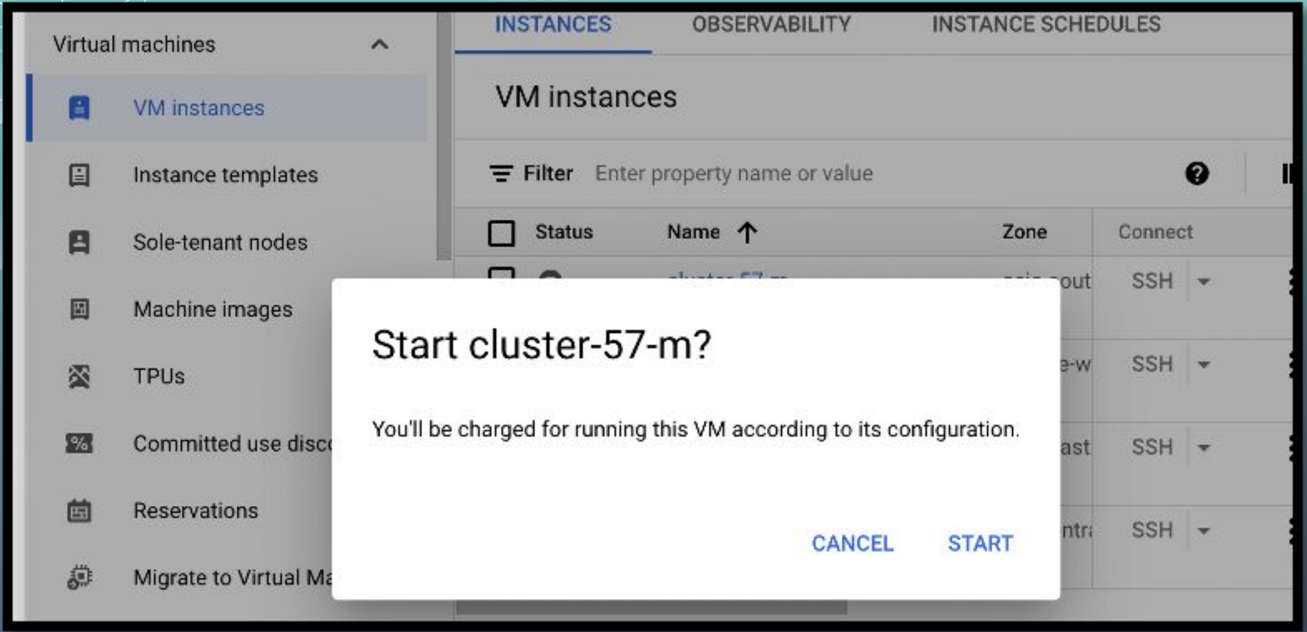
STEP 1: PySpark On GCP

Steps of implementing PageRank with Pyspark on GCP:

- Set up environment(cluster) on GCP for Pyspark
- Create input data file for this problem
- Create Pyspark program for PageRank

Note: To run the project, need to copy the data file to HDFS file system.

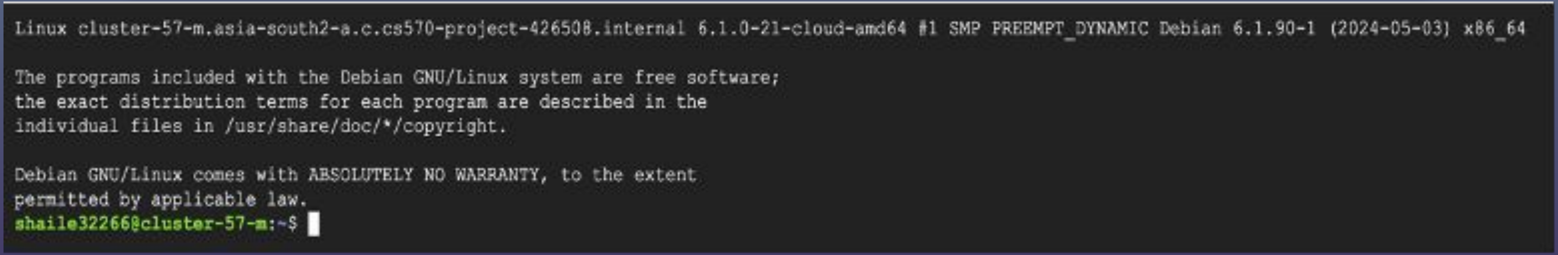
I. Setup PySpark Cluster



Start cluster-57-m?

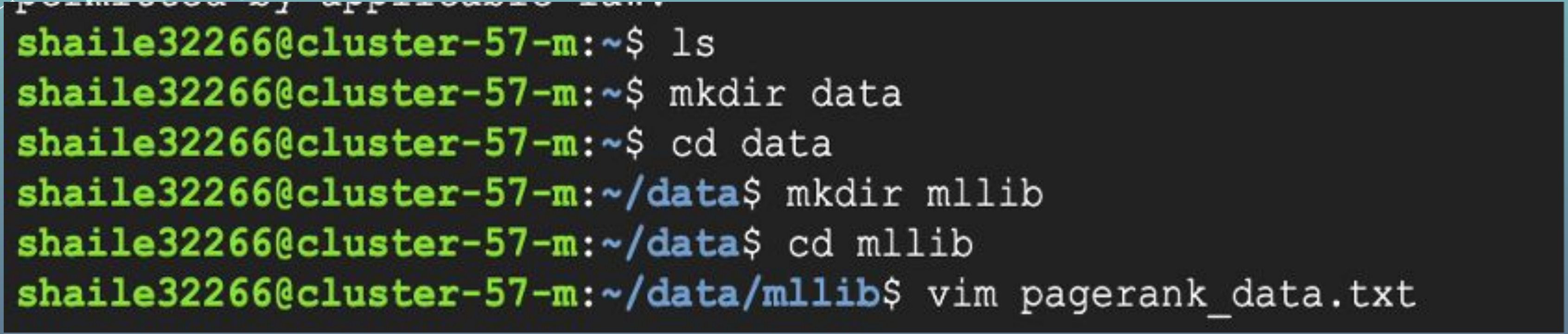
You'll be charged for running this VM according to its configuration.

CANCEL START

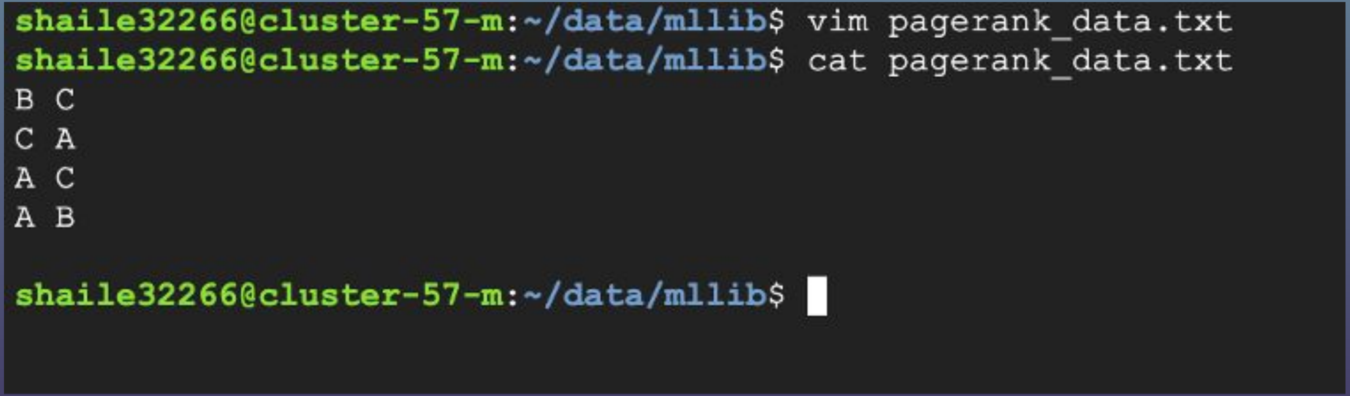


```
Linux cluster-57-m.asia-south2-a.c.cs570-project-426508.internal 6.1.0-21-cloud-amd64 #1 SMP PREEMPT_DYNAMIC Debian 6.1.90-1 (2024-05-03) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
shaile32266@cluster-57-m:~$
```

2. Create Input File

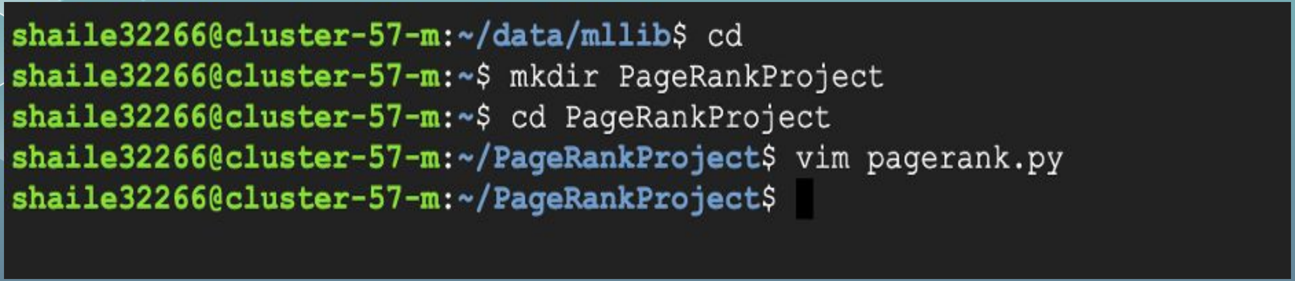


```
permitted by applicable law.
shaile32266@cluster-57-m:~$ ls
shaile32266@cluster-57-m:~$ mkdir data
shaile32266@cluster-57-m:~$ cd data
shaile32266@cluster-57-m:~/data$ mkdir mllib
shaile32266@cluster-57-m:~/data$ cd mllib
shaile32266@cluster-57-m:~/data/mllib$ vim pagerank_data.txt
```

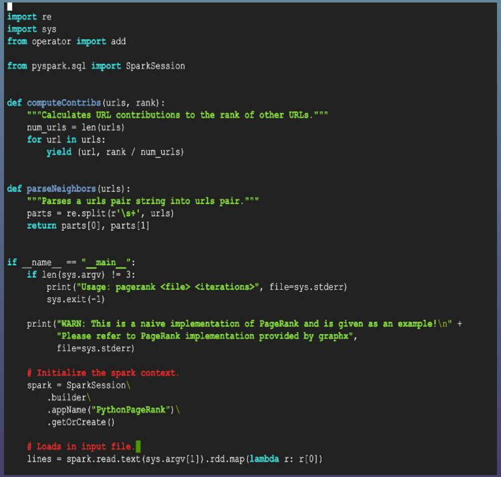


```
shaile32266@cluster-57-m:~/data/mllib$ vim pagerank_data.txt
shaile32266@cluster-57-m:~/data/mllib$ cat pagerank_data.txt
B C
C A
A C
A B

shaile32266@cluster-57-m:~/data/mllib$ 
```

2. Create PageRank PySpark Code



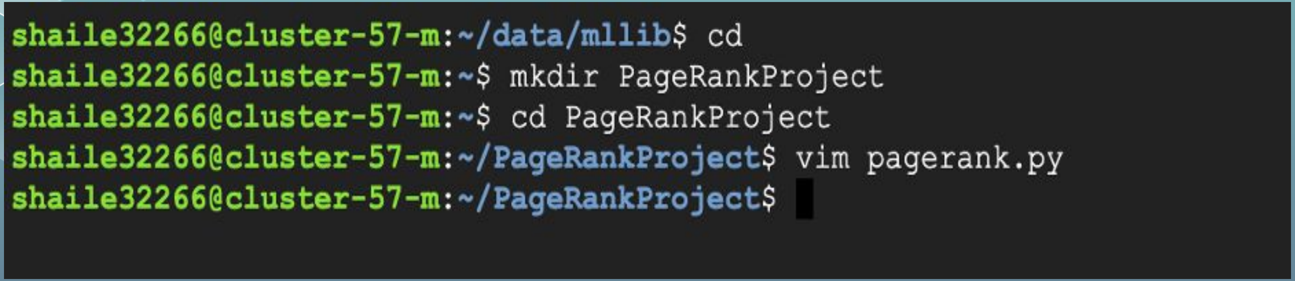
```
shaile32266@cluster-57-m:~/data/mllib$ cd
shaile32266@cluster-57-m:~$ mkdir PageRankProject
shaile32266@cluster-57-m:~$ cd PageRankProject
shaile32266@cluster-57-m:~/PageRankProject$ vim pagerank.py
shaile32266@cluster-57-m:~/PageRankProject$
```



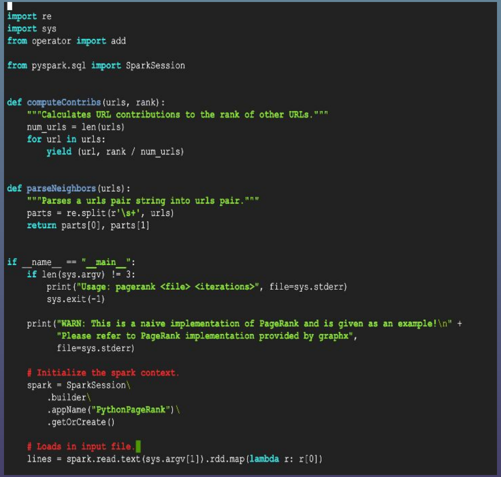
```python
import re
import sys
from operator import add

from pyspark.sql import SparkSession


def computeContribs(urls, rank):
    """Calculates URL contributions to the rank of other URLs."""
    num_urls = len(urls)
    for url in urls:
        yield (url, rank / num_urls)


def parseNeighbors(urls):
    """Parses a urls pair string into urls pair."""
    parts = re.split(r'\s+', urls)
    return parts[0], parts[1]


if __name__ == "__main__":
    if len(sys.argv) != 3:
        print("Usage: pagerank <file> <iterations>", file=sys.stderr)
        sys.exit(-1)

    print("WARN: This is a naive implementation of PageRank and is given as an example!\n" +
          "Please refer to PageRank implementation provided by graphx",
          file=sys.stderr)

    # Initialize the spark context.
    spark = SparkSession\
        .builder\
        .appName("PythonPageRank")\
        .getOrCreate()

    # Loads in input file.
    lines = spark.read.text(sys.argv[1]).rdd.map(lambda r: r[0])
```

For a clear visual visit Github repository provided at the end of this presentation.

3. Create PageRank PySpark Code



```
shaile32266@cluster-57-m:~/data/mllib$ cd
shaile32266@cluster-57-m:~$ mkdir PageRankProject
shaile32266@cluster-57-m:~$ cd PageRankProject
shaile32266@cluster-57-m:~/PageRankProject$ vim pagerank.py
shaile32266@cluster-57-m:~/PageRankProject$
```



```
import re
import sys
from operator import add

from pyspark.sql import SparkSession


def computeContribs(urls, rank):
    """Calculates URL contributions to the rank of other URLs."""
    num_urls = len(urls)
    for url in urls:
        yield (url, rank / num_urls)


def parseNeighbors(urls):
    """Parses a urls pair string into urls pair."""
    parts = re.split(r'\s+', urls)
    return parts[0], parts[1]


if __name__ == "__main__":
    if len(sys.argv) != 3:
        print("Usage: pagerank <file> <iterations>", file=sys.stderr)
        sys.exit(-1)

    print("WARN: This is a naive implementation of PageRank and is given as an example!\n" +
          "Please refer to PageRank implementation provided by graphx",
          file=sys.stderr)

    # Initialize the spark context.
    spark = SparkSession\
        .builder\
        .appName("PythonPageRank")\
        .getOrCreate()

    # Loads in input file.
    lines = spark.read.text(sys.argv[1]).rdd.map(lambda r: r[0])
```

For a clear visual visit Github repository provided at the end of this presentation.

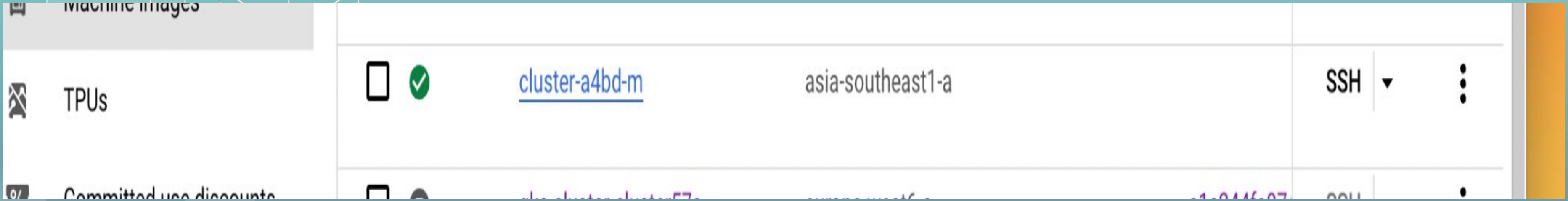
STEP 2: Scala On GCP

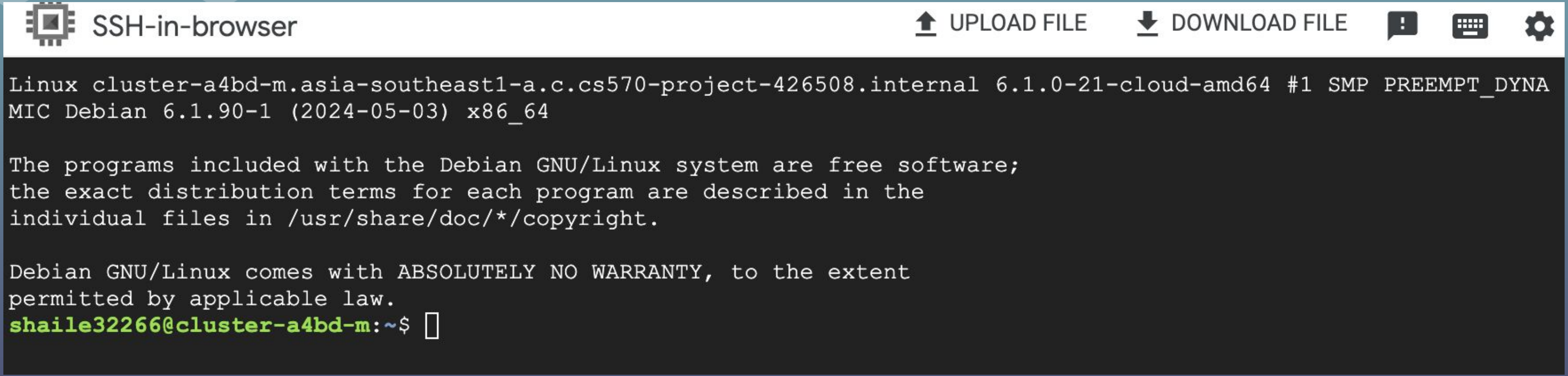
Steps of implementing PageRank with Scala on GCP:

- Set up environment(cluster) on GCP for Scala
- Create input data file for this problem
- Create Scala program for PageRank

Note: To run the project, need to copy the data file to HDFS file system.

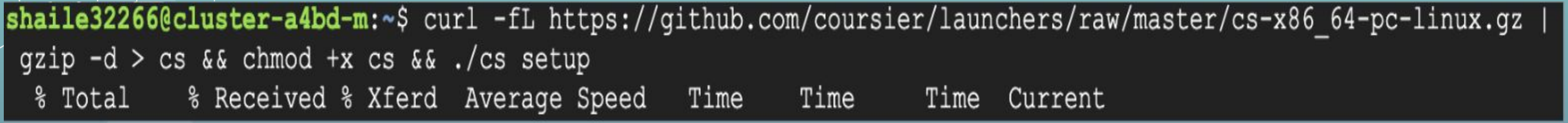
I. Setup Scala Cluster



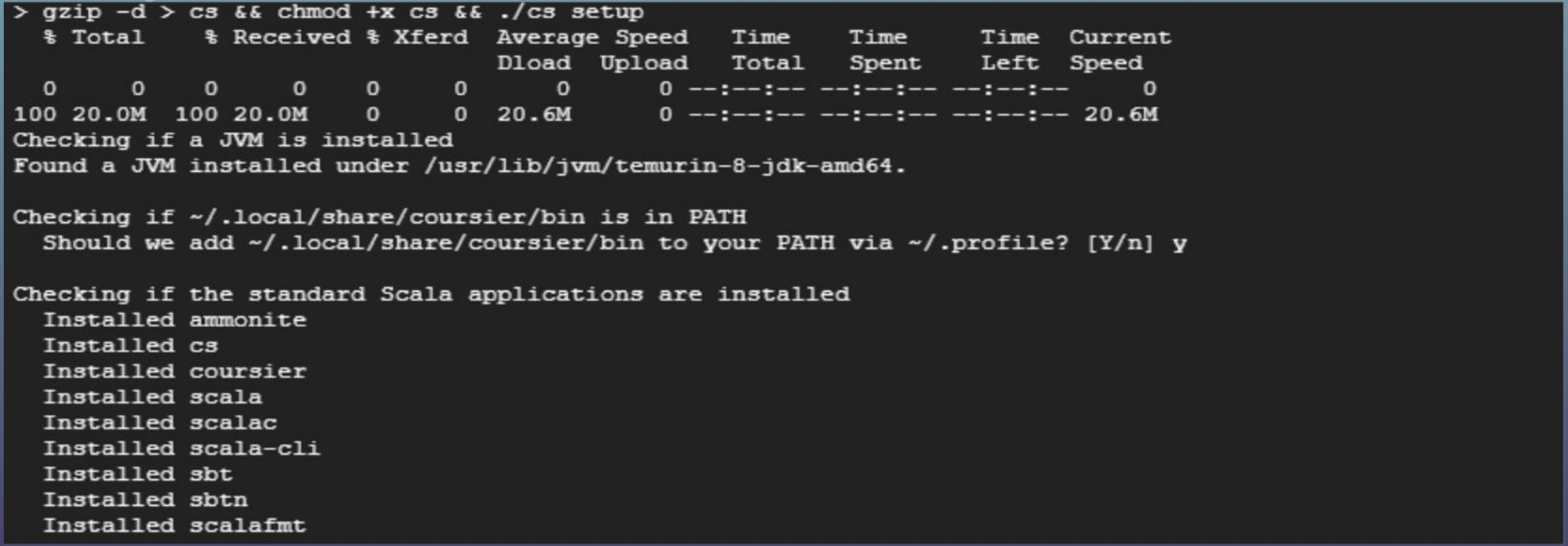


```
Linux cluster-a4bd-m.asia-southeast1-a.c.cs570-project-426508.internal 6.1.0-21-cloud-amd64 #1 SMP PREEMPT_DYNA
MIC Debian 6.1.90-1 (2024-05-03) x86_64

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
shaile32266@cluster-a4bd-m:~$
```

2. Install Coursier Launcher for Linux

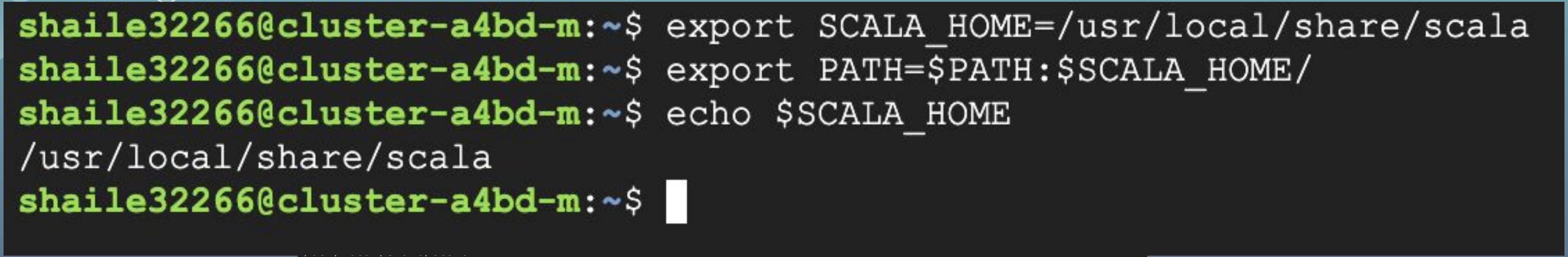


```
shaile32266@cluster-a4bd-m:~$ curl -fL https://github.com/coursier/launchers/raw/master/cs-x86_64-pc-linux.gz |
 gzip -d > cs && chmod +x cs && ./cs setup
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
```

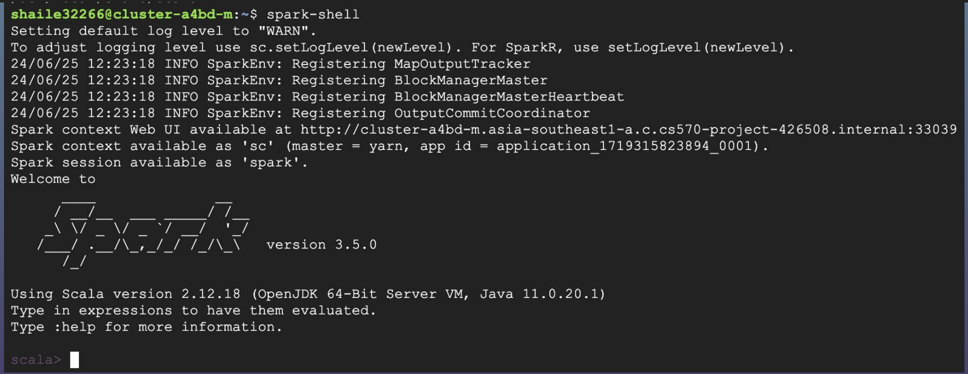


```
> gzip -d > cs && chmod +x cs && ./cs setup
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
  0     0    0     0    0     0      0      0 --:--:-- --:--:-- --:--:--     0
100 20.0M  100 20.0M    0     0  20.6M      0 --:--:-- --:--:-- --:--:-- 20.6M
Checking if a JVM is installed
Found a JVM installed under /usr/lib/jvm/temurin-8-jdk-amd64.

Checking if ~/.local/share/coursier/bin is in PATH
  Should we add ~/.local/share/coursier/bin to your PATH via ~/.profile? [Y/n] y

Checking if the standard Scala applications are installed
  Installed ammonite
  Installed cs
  Installed coursier
  Installed scala
  Installed scalac
  Installed scala-cli
  Installed sbt
  Installed sbtn
  Installed scalafmt
```

3. Set SCALA_HOME and update PATH for Scala

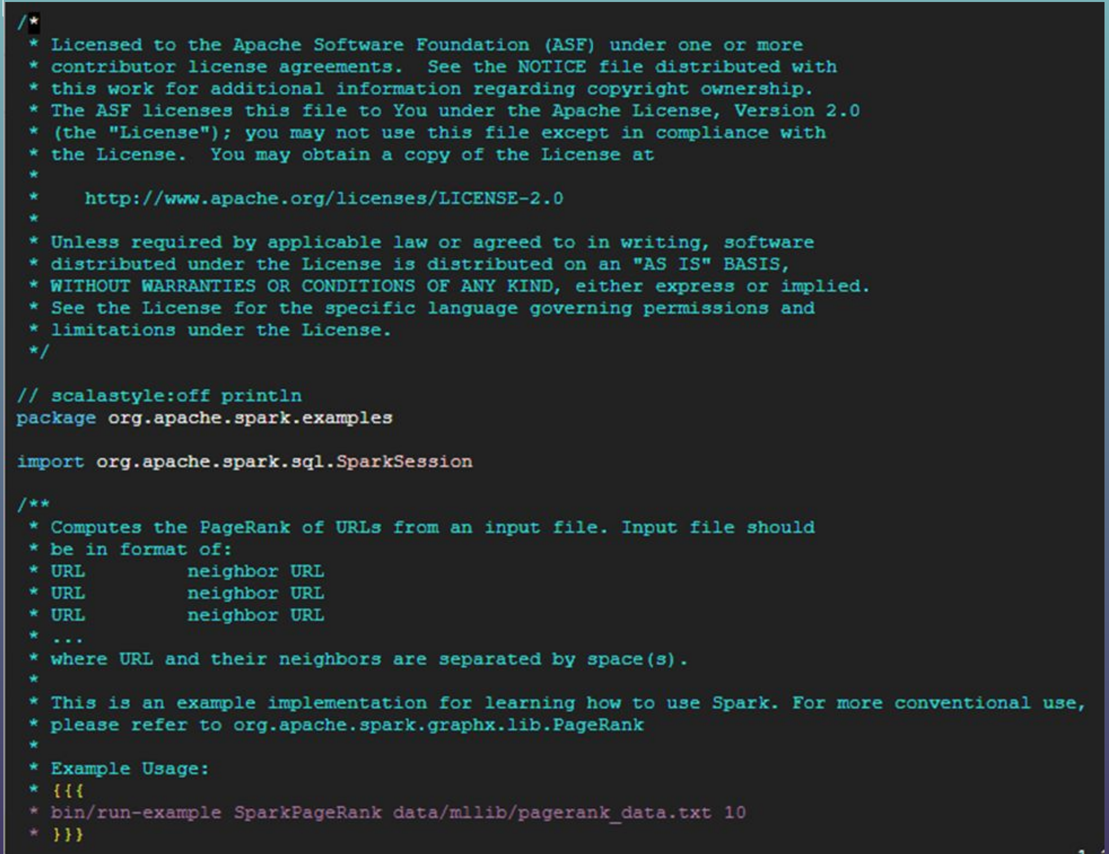


```
shaile32266@cluster-a4bd-m:~$ export SCALA_HOME=/usr/local/share/scala
shaile32266@cluster-a4bd-m:~$ export PATH=$PATH:$SCALA_HOME/
shaile32266@cluster-a4bd-m:~$ echo $SCALA_HOME
/usr/local/share/scala
shaile32266@cluster-a4bd-m:~$
```



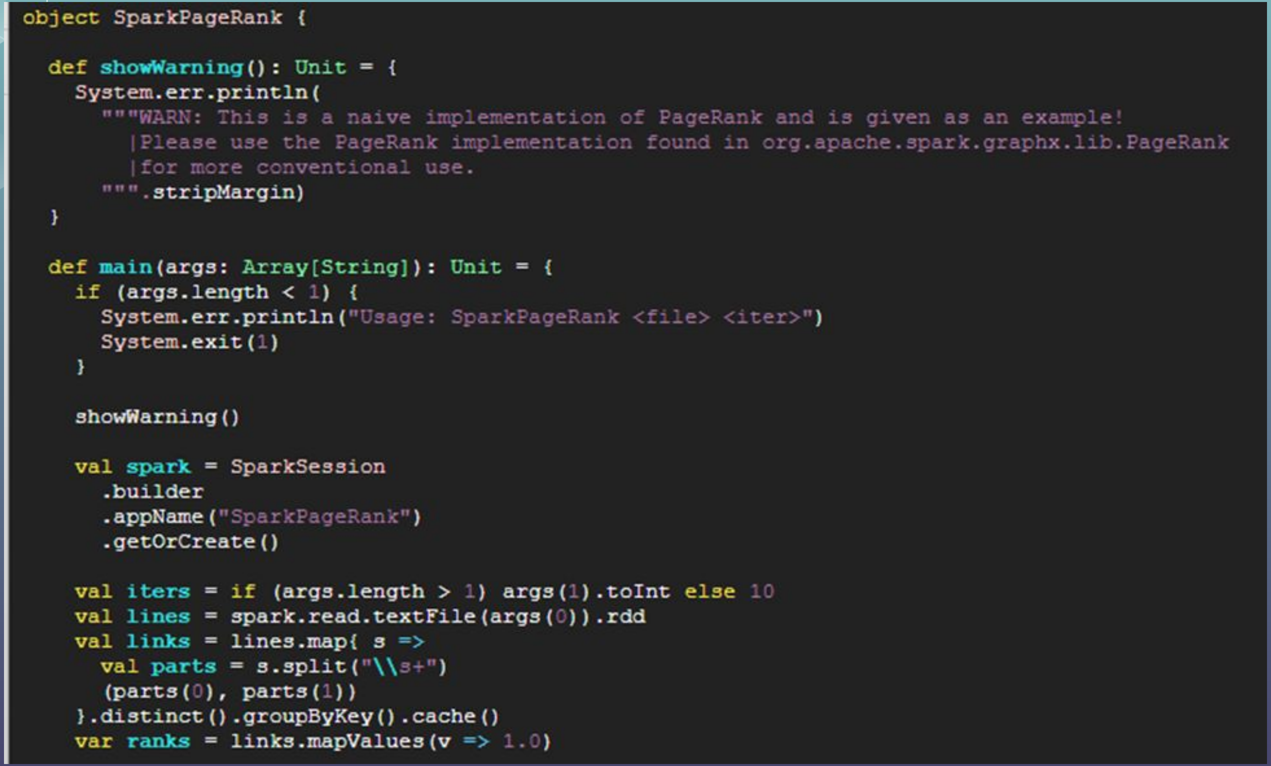
```
shaile32266@cluster-a4bd-m:~$ spark-shell
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use setLogLevel(newLevel).
24/06/25 12:23:18 INFO SparkEnv: Registering MapOutputTracker
24/06/25 12:23:18 INFO SparkEnv: Registering BlockManagerMaster
24/06/25 12:23:18 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/25 12:23:18 INFO SparkEnv: Registering OutputCommitCoordinator
Spark context Web UI available at http://cluster-a4bd-m.asia-southeast1-a.c.cs570-project-426508.internal:33039
Spark context available as 'sc' (master = yarn, app id = application_1719315823894_0001).
Spark session available as 'spark'.
Welcome to
      ____              __
     / __/__  ___ _____/ /__
    _\ \/ _ \/ _ `/ __/  '_/
   /___/ .__/\_,_/_/ /_/\_\   version 3.5.0
      /_/

Using Scala version 2.12.18 (OpenJDK 64-Bit Server VM, Java 11.0.20.1)
Type in expressions to have them evaluated.
Type :help for more information.

scala>
```

Open sparkshell and copy paste this code



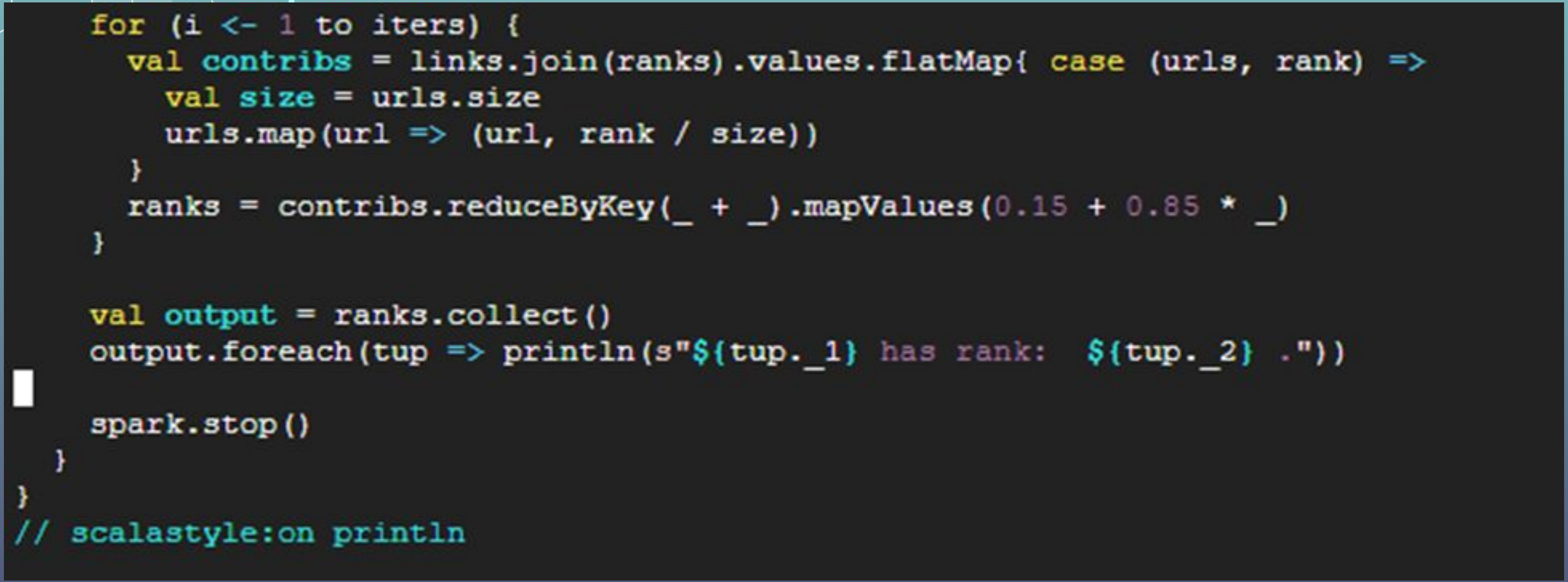
```
/*
 * Licensed to the Apache Software Foundation (ASF) under one or more
 * contributor license agreements.  See the NOTICE file distributed with
 * this work for additional information regarding copyright ownership.
 * The ASF licenses this file to You under the Apache License, Version 2.0
 * (the "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
 *
 * 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.
 */

// scalastyle:off println
package org.apache.spark.examples

import org.apache.spark.sql.SparkSession

/**
 * Computes the PageRank of URLs from an input file. Input file should
 * be in format of:
 * URL         neighbor URL
 * URL         neighbor URL
 * URL         neighbor URL
 * ...
 * where URL and their neighbors are separated by space(s).
 *
 * This is an example implementation for learning how to use Spark. For more conventional use,
 * please refer to org.apache.spark.graphx.lib.PageRank
 *
 * Example Usage:
 * {{{
 * bin/run-example SparkPageRank data/mllib/pagerank_data.txt 10
 * }}}
```

Scala Code



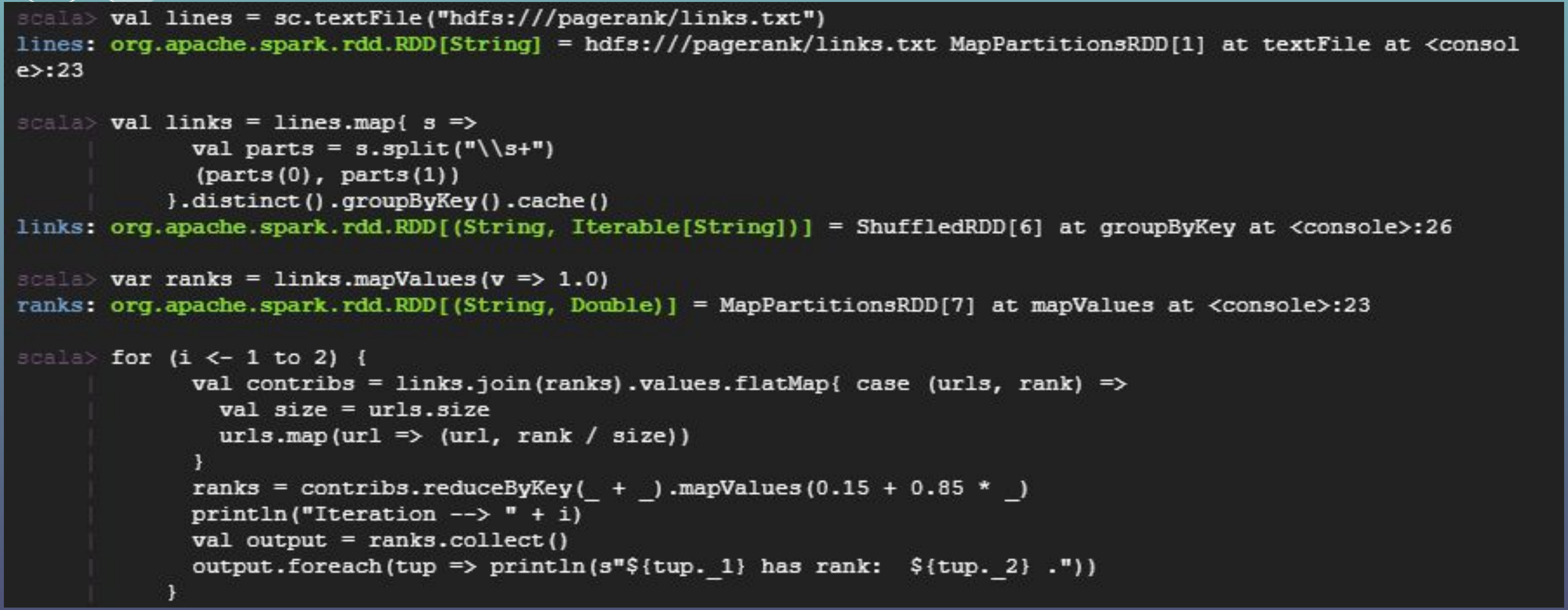
```scala
object SparkPageRank {

  def showWarning(): Unit = {
    System.err.println(
      """WARN: This is a naive implementation of PageRank and is given as an example!
        |Please use the PageRank implementation found in org.apache.spark.graphx.lib.PageRank
        |for more conventional use.
      """.stripMargin)
  }

  def main(args: Array[String]): Unit = {
    if (args.length < 1) {
      System.err.println("Usage: SparkPageRank <file> <iter>")
      System.exit(1)
    }

    showWarning()

    val spark = SparkSession
      .builder
      .appName("SparkPageRank")
      .getOrCreate()

    val iters = if (args.length > 1) args(1).toInt else 10
    val lines = spark.read.textFile(args(0)).rdd
    val links = lines.map{ s =>
      val parts = s.split("\\s+")
      (parts(0), parts(1))
    }.distinct().groupByKey().cache()
    var ranks = links.mapValues(v => 1.0)
```

Scala Code



```scala
    for (i <- 1 to iters) {
      val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
        val size = urls.size
        urls.map(url => (url, rank / size))
      }
      ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
    }

    val output = ranks.collect()
    output.foreach(tup => println(s"${tup._1} has rank:  ${tup._2} ."))

    spark.stop()
  }
}
// scalastyle:on println
```

Improved Scala Code



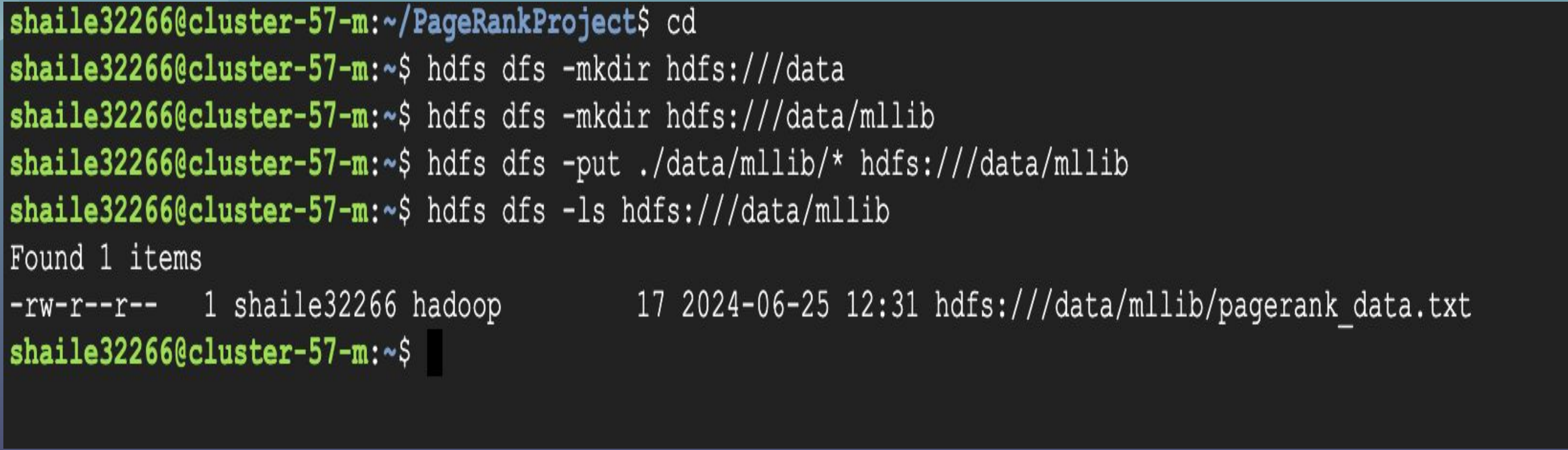
```
scala> val lines = sc.textFile("hdfs:///pagerank/links.txt")
lines: org.apache.spark.rdd.RDD[String] = hdfs:///pagerank/links.txt MapPartitionsRDD[1] at textFile at <consol
e>:23

scala> val links = lines.map{ s =>
     |        val parts = s.split("\\s+")
     |        (parts(0), parts(1))
     |      }.distinct().groupByKey().cache()
links: org.apache.spark.rdd.RDD[(String, Iterable[String])] = ShuffledRDD[6] at groupByKey at <console>:26

scala> var ranks = links.mapValues(v => 1.0)
ranks: org.apache.spark.rdd.RDD[(String, Double)] = MapPartitionsRDD[7] at mapValues at <console>:23

scala> for (i <- 1 to 2) {
     |        val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
     |          val size = urls.size
     |          urls.map(url => (url, rank / size))
     |        }
     |        ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
     |        println("Iteration --> " + i)
     |        val output = ranks.collect()
     |        output.foreach(tup => println(s"${tup._1} has rank:  ${tup._2} ."))
     |      }
```

04

Testing

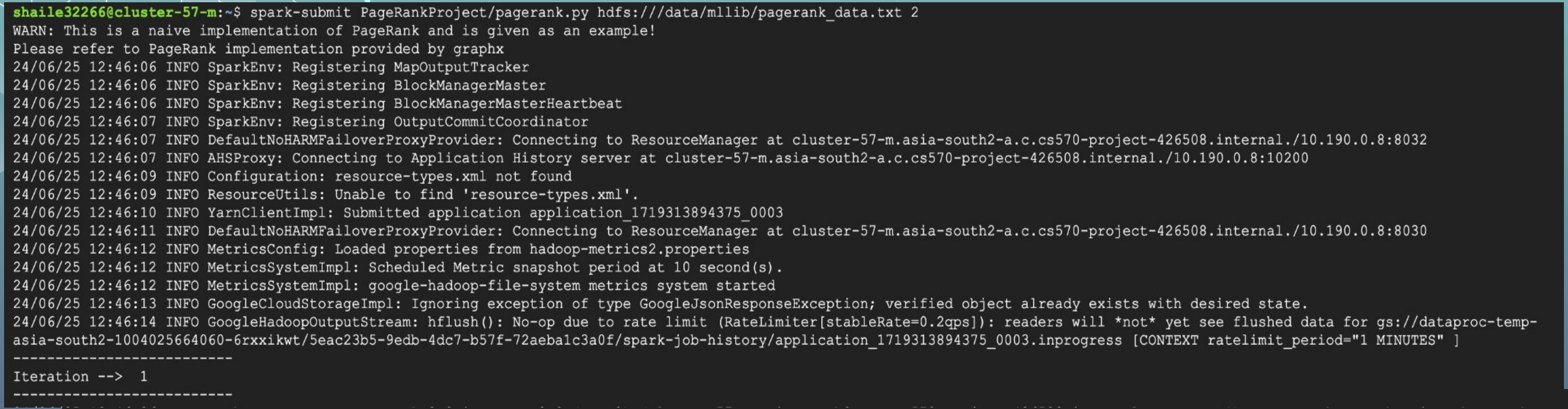
Run the program with input data file to test.

Pyspark: Create HDFS file system and copy input data file from local to hdfs:

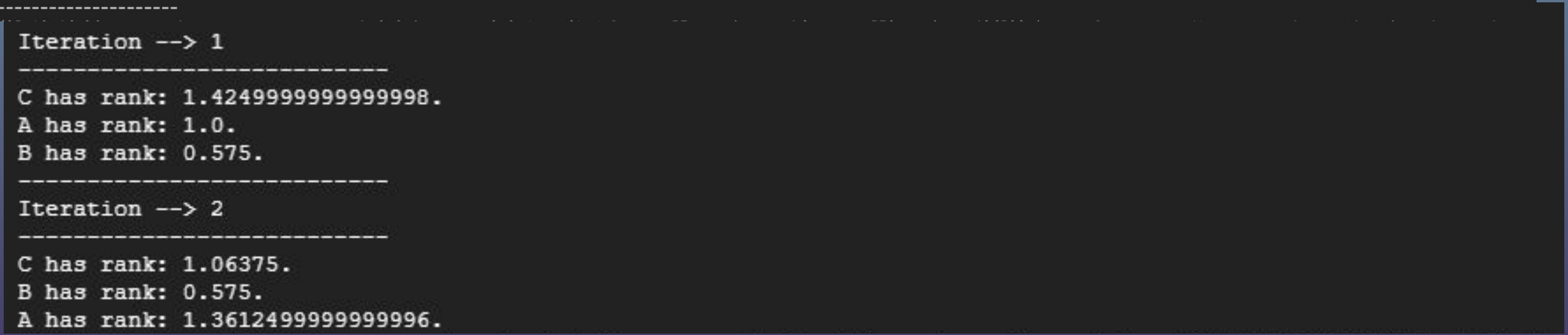


```
shaile32266@cluster-57-m:~/PageRankProject$ cd
shaile32266@cluster-57-m:~$ hdfs dfs -mkdir hdfs:///data
shaile32266@cluster-57-m:~$ hdfs dfs -mkdir hdfs:///data/mllib
shaile32266@cluster-57-m:~$ hdfs dfs -put ./data/mllib/* hdfs:///data/mllib
shaile32266@cluster-57-m:~$ hdfs dfs -ls hdfs:///data/mllib
Found 1 items
-rw-r--r--   1 shaile32266 hadoop         17 2024-06-25 12:31 hdfs:///data/mllib/pagerank_data.txt
shaile32266@cluster-57-m:~$
```

Test: Pyspark



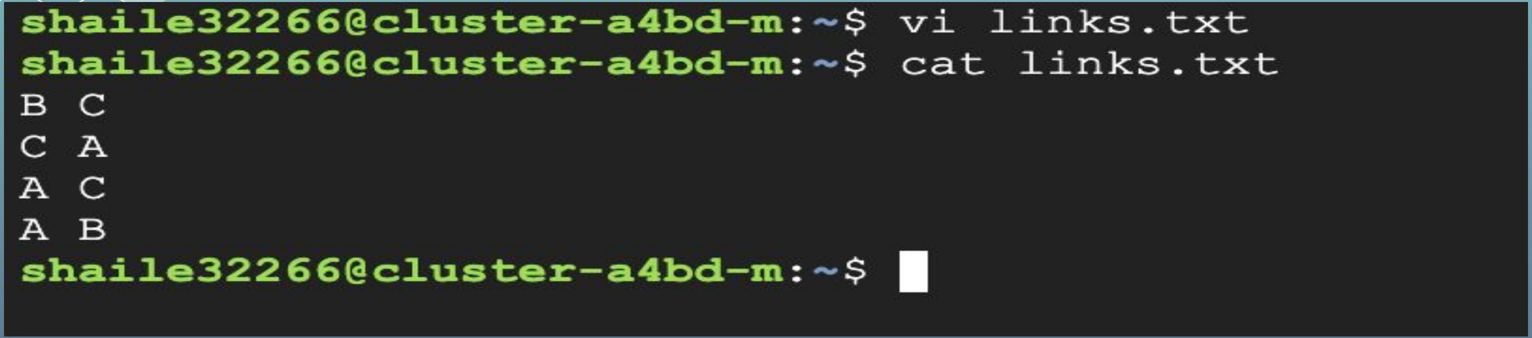
```
shaile32266@cluster-57-m:~$ spark-submit PageRankProject/pagerank.py hdfs:///data/mllib/pagerank_data.txt 2
WARN: This is a naive implementation of PageRank and is given as an example!
Please refer to PageRank implementation provided by graphx
24/06/25 12:46:06 INFO SparkEnv: Registering MapOutputTracker
24/06/25 12:46:06 INFO SparkEnv: Registering BlockManagerMaster
24/06/25 12:46:06 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
24/06/25 12:46:07 INFO SparkEnv: Registering OutputCommitCoordinator
24/06/25 12:46:07 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-57-m.asia-south2-a.c.cs570-project-426508.internal./10.190.0.8:8032
24/06/25 12:46:07 INFO AHSProxy: Connecting to Application History server at cluster-57-m.asia-south2-a.c.cs570-project-426508.internal./10.190.0.8:10200
24/06/25 12:46:09 INFO Configuration: resource-types.xml not found
24/06/25 12:46:09 INFO ResourceUtils: Unable to find 'resource-types.xml'.
24/06/25 12:46:10 INFO YarnClientImpl: Submitted application application_1719313894375_0003
24/06/25 12:46:11 INFO DefaultNoHARMFailoverProxyProvider: Connecting to ResourceManager at cluster-57-m.asia-south2-a.c.cs570-project-426508.internal./10.190.0.8:8030
24/06/25 12:46:12 INFO MetricsConfig: Loaded properties from hadoop-metrics2.properties
24/06/25 12:46:12 INFO MetricsSystemImpl: Scheduled Metric snapshot period at 10 second(s).
24/06/25 12:46:12 INFO MetricsSystemImpl: google-hadoop-file-system metrics system started
24/06/25 12:46:13 INFO GoogleCloudStorageImpl: Ignoring exception of type GoogleJsonResponseException; verified object already exists with desired state.
24/06/25 12:46:14 INFO GoogleHadoopOutputStream: hflush(): No-op due to rate limit (RateLimiter[stableRate=0.2qps]): readers will *not* yet see flushed data for gs://dataproc-temp-
asia-south2-1004025664060-6rxxikwt/5eac23b5-9edb-4dc7-b57f-72aeba1c3a0f/spark-job-history/application_1719313894375_0003.inprogress [CONTEXT ratelimit_period="1 MINUTES" ]
--------------------------
Iteration -->  1
--------------------------
```



```
Iteration --> 1
----------------------------
C has rank: 1.4249999999999998.
A has rank: 1.0.
B has rank: 0.575.
----------------------------
Iteration --> 2
----------------------------
C has rank: 1.06375.
B has rank: 0.575.
A has rank: 1.3612499999999996.
```

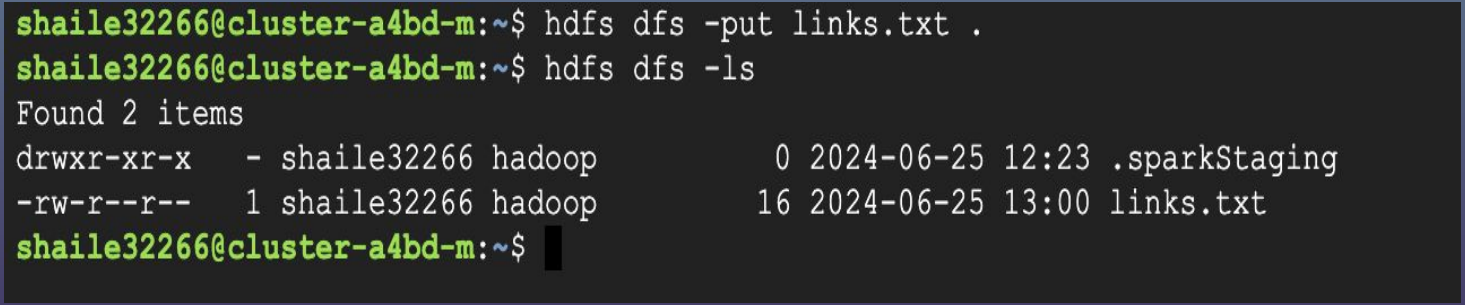
Test: Scala

1. Create file: links.txt



```
shaile32266@cluster-a4bd-m:~$ vi links.txt
shaile32266@cluster-a4bd-m:~$ cat links.txt
B C
C A
A C
A B
shaile32266@cluster-a4bd-m:~$ 
```

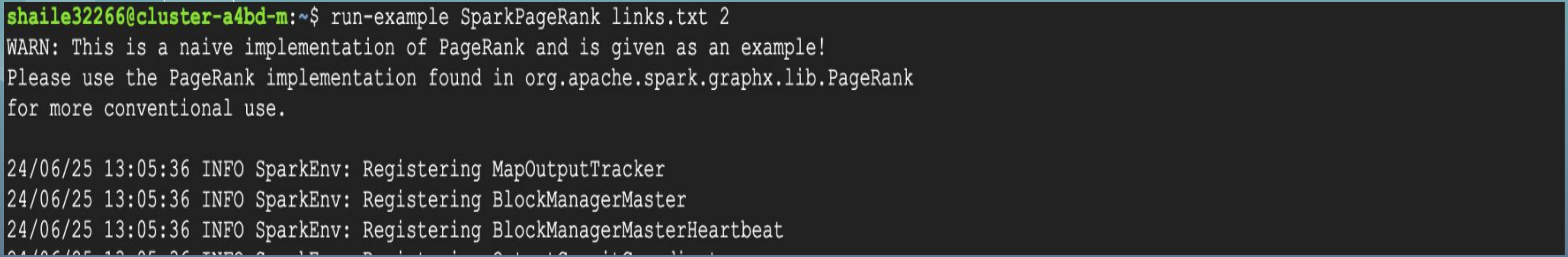
2. Copy input file from local to HDFS



```
shaile32266@cluster-a4bd-m:~$ hdfs dfs -put links.txt .
shaile32266@cluster-a4bd-m:~$ hdfs dfs -ls
Found 2 items
drwxr-xr-x   - shaile32266 hadoop          0 2024-06-25 12:23 .sparkStaging
-rw-r--r--   1 shaile32266 hadoop         16 2024-06-25 13:00 links.txt
shaile32266@cluster-a4bd-m:~$ 
```

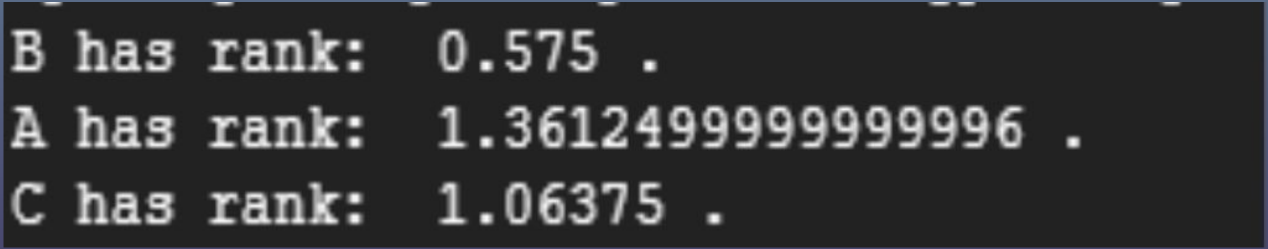
Test: Scala

3. Run-example SparkPageRank links.txt 2



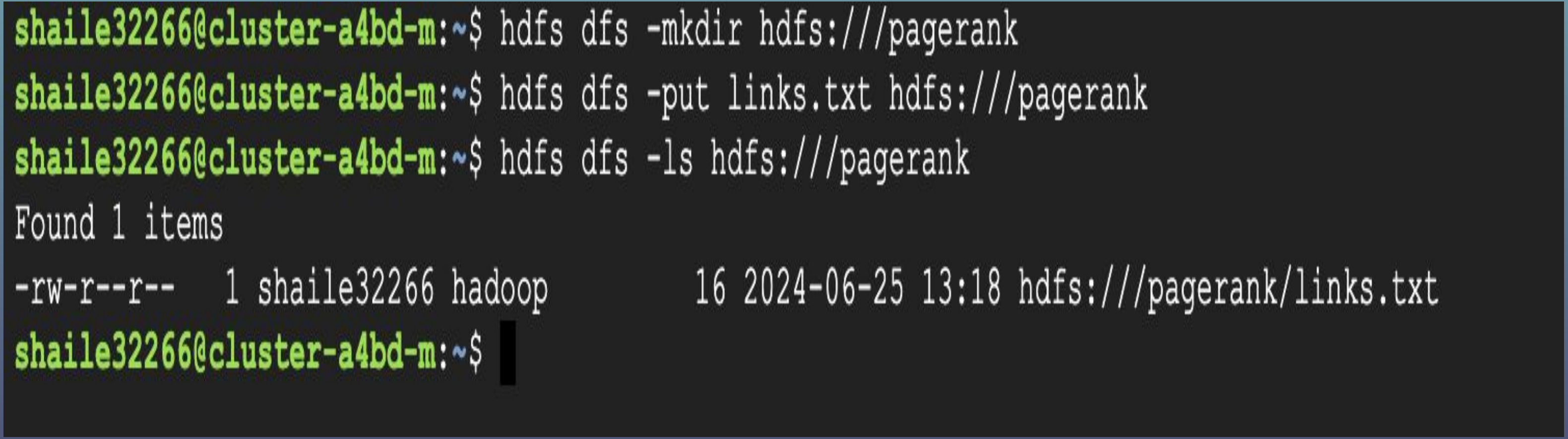
```
shaile32266@cluster-a4bd-m:~$ run-example SparkPageRank links.txt 2
WARN: This is a naive implementation of PageRank and is given as an example!
Please use the PageRank implementation found in org.apache.spark.graphx.lib.PageRank
for more conventional use.

24/06/25 13:05:36 INFO SparkEnv: Registering MapOutputTracker
24/06/25 13:05:36 INFO SparkEnv: Registering BlockManagerMaster
24/06/25 13:05:36 INFO SparkEnv: Registering BlockManagerMasterHeartbeat
```

4. Result



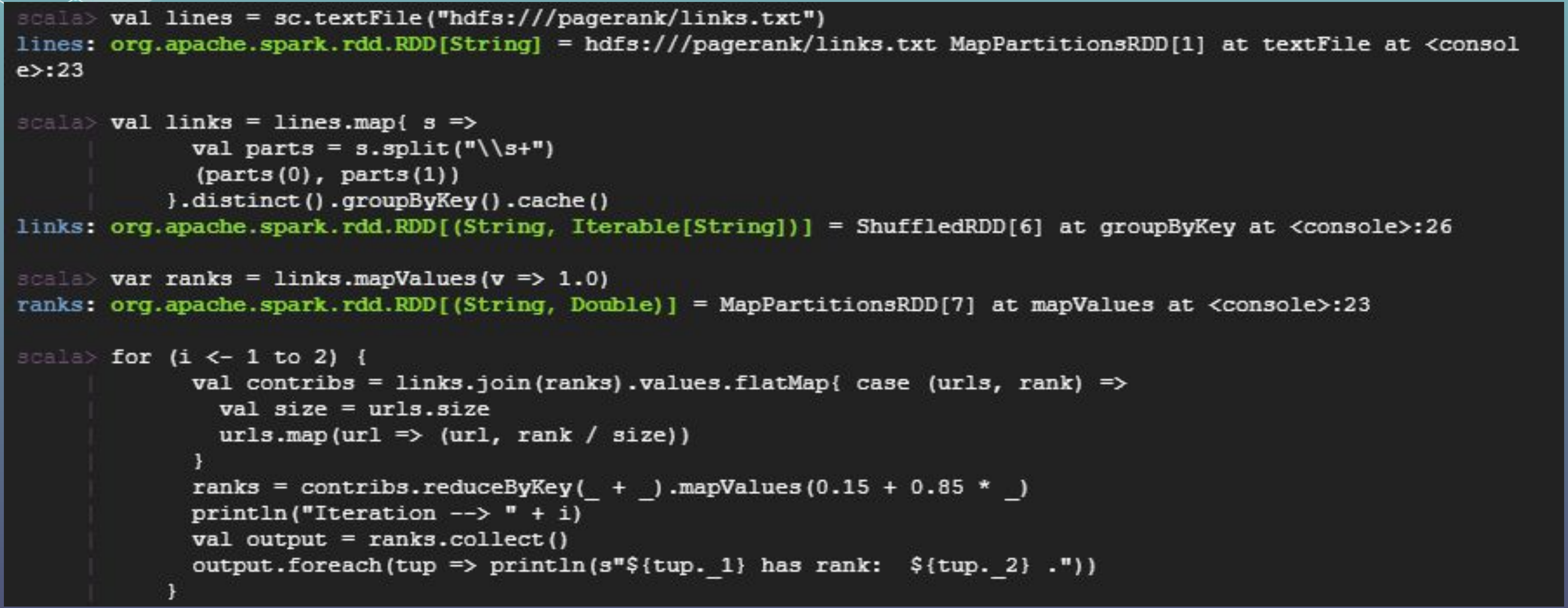
```
B has rank:  0.575 .
A has rank:  1.3612499999999996 .
C has rank:  1.06375 .
```

5. Test in Spark Shell with Modified Code



```
shaile32266@cluster-a4bd-m:~$ hdfs dfs -mkdir hdfs:///pagerank
shaile32266@cluster-a4bd-m:~$ hdfs dfs -put links.txt hdfs:///pagerank
shaile32266@cluster-a4bd-m:~$ hdfs dfs -ls hdfs:///pagerank
Found 1 items
-rw-r--r--   1 shaile32266 hadoop         16 2024-06-25 13:18 hdfs:///pagerank/links.txt
shaile32266@cluster-a4bd-m:~$
```

The modified code



```
scala> val lines = sc.textFile("hdfs:///pagerank/links.txt")
lines: org.apache.spark.rdd.RDD[String] = hdfs:///pagerank/links.txt MapPartitionsRDD[1] at textFile at <consol
e>:23

scala> val links = lines.map{ s =>
     |        val parts = s.split("\\s+")
     |        (parts(0), parts(1))
     |      }.distinct().groupByKey().cache()
links: org.apache.spark.rdd.RDD[(String, Iterable[String])] = ShuffledRDD[6] at groupByKey at <console>:26

scala> var ranks = links.mapValues(v => 1.0)
ranks: org.apache.spark.rdd.RDD[(String, Double)] = MapPartitionsRDD[7] at mapValues at <console>:23

scala> for (i <- 1 to 2) {
     |        val contribs = links.join(ranks).values.flatMap{ case (urls, rank) =>
     |          val size = urls.size
     |          urls.map(url => (url, rank / size))
     |        }
     |        ranks = contribs.reduceByKey(_ + _).mapValues(0.15 + 0.85 * _)
     |        println("Iteration --> " + i)
     |        val output = ranks.collect()
     |        output.foreach(tup => println(s"${tup._1} has rank:  ${tup._2} ."))
     |      }
```

Enhancement 05

- Integrate Google Cloud Storage (GCS) for data management.
- Optimize Spark configurations for better performance.
- Implement advanced data partitioning strategies.
- Explore real-time data processing with Apache Kafka.
- Create interactive dashboards for PageRank visualization.
- Utilize GCP’s autoscaling for resource management

Conclusion

06

- Implemented PageRank with PySpark and Scala on GCP.
- Gained practical experience in cloud-based big data processing.
- Achieved efficient handling of large datasets.
- Demonstrated scalability and high performance on GCP.
- Enhanced skills in cloud computing and data analytics.
- Ready to apply techniques to broader data projects.

GITHUB LINK

https://github.com/Sharon20222/Cloud-Computing/tree/main/Spark/PageRank

References

- https://www.scala-lang.org/

- https://spark.apache.org/docs/latest/api/python/index.html