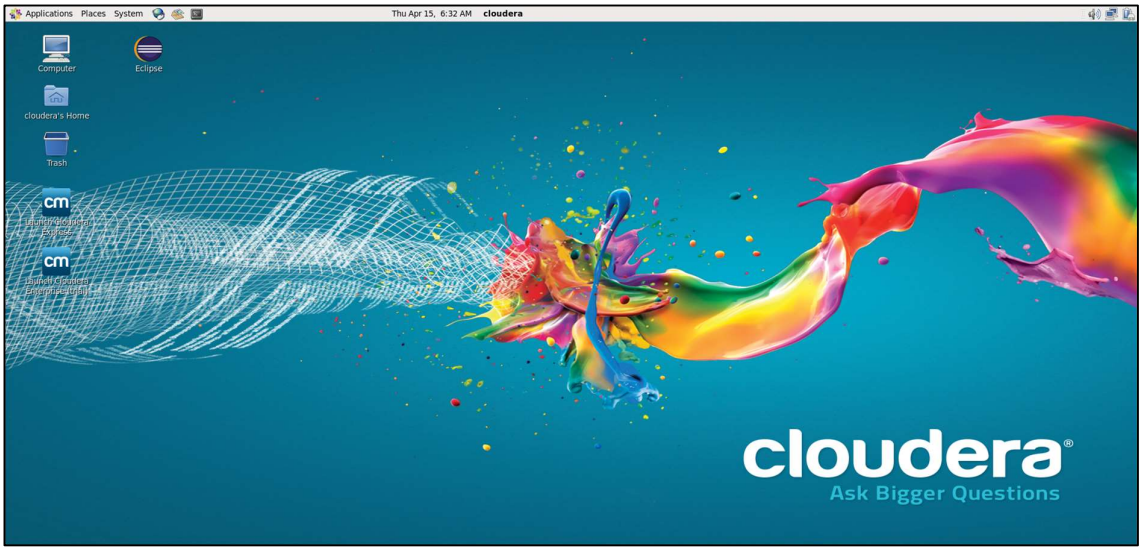
MapReduce for PageRank algorithm on Hadoop:

Let's implement the PageRank algorithm on an input web graph and find the page rank of all the web pages.

Step 1: Open Cloudera Quickstart VM.

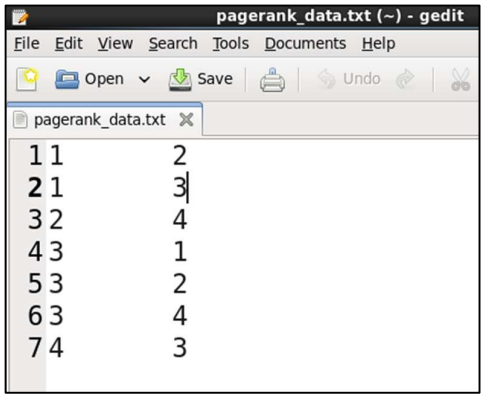


Step 2: Clone the following repository on your local machine.

`www.github.com/NSTiwari/Hadoop-MapReduce-Programs`

You'll see the **`PageRank`** folder inside this repository along with other folders. The **`PageRank`** folder contains the following files –

- **`pagerank_data.txt`** – A placeholder text file for input web graph.
- **`pagerank_mapper1.py`** – First mapper file for PageRank algorithm.
- **`pagerank_reducer1.py`** – First reducer file for PageRank algorithm.
- **`pagerank_mapper2.py`** – Second mapper file for PageRank algorithm.
- **`pagerank_reducer2.py`** – Second reducer file for PageRank algorithm.



In the **`pagerank_data.txt`** file, the first column represents the 'from-nodes' and the second column represents the 'to-nodes'; both separated by tab.

Thus, there are total seven edges in the input web graph.

pagerank_mapper1.py:

```
#!/usr/bin/python

import sys

for line in sys.stdin:
   if line.startswith('#'):
      continue
   else:
      print("%s" % (",".join(line.strip().split())))
```

pagerank_reducer1.py:

```
#!/usr/bin/python

import sys

cur_node = None
prev_node = None
adj_list = []

for line in sys.stdin:
   cur_node, dest_node = line.strip().split(',')
   if cur_node == prev_node:
      adj_list.append(dest_node)
   else:
      if prev_node:
         print("%s\t%s" % (prev_node, ",".join(sorted(adj_list))))

      prev_node = cur_node
      del adj_list [:]
      adj_list.append(dest_node)

if cur_node == prev_node:
   print("%s\t%s" % (prev_node, ",".join(sorted(adj_list))))
```

pagerank_mapper2.py:

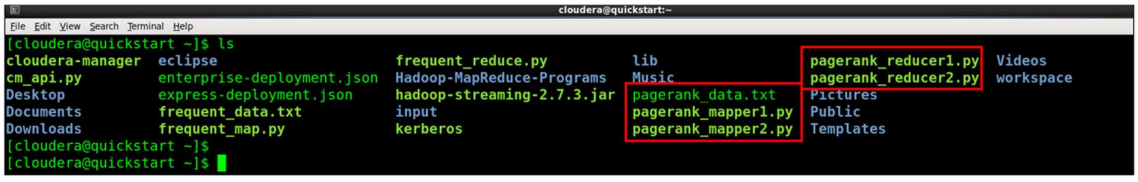
```
#!/usr/bin/python

import sys

pageranks = {'1': '1', '2':'1', '3':'1', '4':'1'}

for line in sys.stdin:
    node, adj_list = line.strip().split('\t')
    adj_list = adj_list.split(',')
    out_num = len(adj_list)


    print("%s,%s" % (node, '0.0'))
    #print("Adjaceny list:", adj_list)


    for out_link in adj_list:
       out_link_contrib = float(pageranks[node]) / out_num
       print("%s,%s" % (out_link, out_link_contrib))
```

pagerank_reducer2.py:

```
#!/usr/bin/python

import sys

cur_node = None
prev_node = None
contrib_sum = 0
damping_factor = 0.85

for line in sys.stdin:
   cur_node, contrib = line.strip().split(',')
   print("\nCurrent node: %s\nContribution by this node: %s" %
  (cur_node, contrib))


  if cur_node == prev_node:
     contrib_sum += float(contrib)

  else:
     if prev_node:
        new_pr = (1 - damping_factor) + (damping_factor *
        contrib_sum)
        new_pr = round(new_pr, 5)
        print("Previous node: %s\nNew page rank of node %s: %s" %
       (prev_node, cur_node, new_pr))

     prev_node = cur_node
     contrib_sum = float(contrib)


if cur_node == prev_node:
   new_pr = (1 - damping_factor) + (damping_factor * contrib_sum)
   new_pr = round(new_pr, 5)
   print("Previous node: %s\nNew page rank of node %s: %s" %
  (prev_node, cur_node, new_pr))
```

Copy these five files inside **/home/cloudera** directory. Once done, check if they are copied at the desired location properly.

ls



All the five required files are present.

Step 3: Test MapReduce programs locally.

Before we run MapReduce program on Hadoop, let's test it locally and see if the results obtained are correct as expected.

To do so, open the terminal and type the following commands one-by-one:

Run the first mapper on the input web graph data.

cat pagerank_data.txt | python pagerank_mapper1.py

```
[cloudera@quickstart ~]$ cat pagerank_data.txt | python pagerank_mapper1.py
1,2
1,3
2,4
3,1
3,2
3,4
4,3
[cloudera@quickstart ~]$
```

This will reformat the input data by separating the 'from-nodes' and 'to-nodes' with a comma (originally separated by a tab).

Run the first reducer.

cat pagerank_data.txt | python pagerank_mapper1.py | python pagerank_reducer1.py

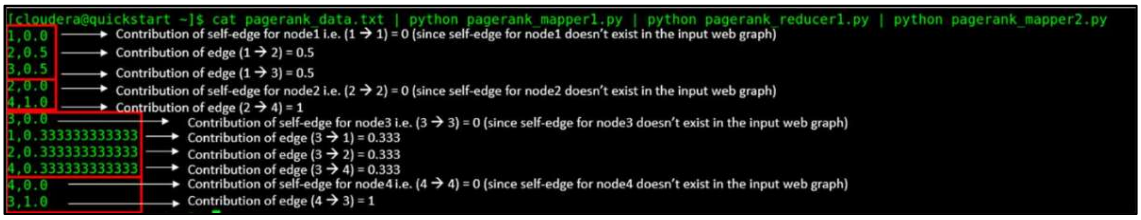
```
[cloudera@quickstart ~]$ cat pagerank_data.txt | python pagerank_mapper1.py | python pagerank_reducer1.py
1       2,3
2       4
3       1,2,4
4       3
[cloudera@quickstart ~]$
```

The first reducer file aggregates the 'to-nodes' for every 'from-node' respectively as shown in the above figure.

As you can see, 1 → 2 and 1 → 3 are reduced to 1 → (2, 3). Similarly, all the 'from-nodes' are reduced as shown in the figure above.

Now, run the second mapper.

cat pagerank_data.txt | python pagerank_mapper1.py | python pagerank_reducer1.py | python pagerank_mapper2.py



The interpretation of the output obtained after applying the second mapper is commented in the image above.

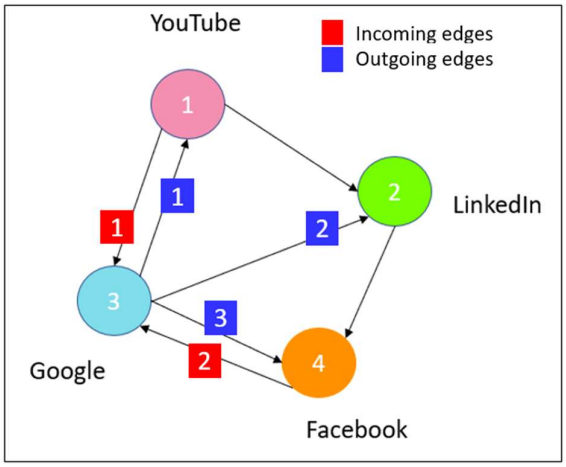
Now finally, run the second reducer.

cat pagerank_data.txt | python pagerank_mapper1.py | python pagerank_reducer1.py | python pagerank_mapper2.py | python pagerank_reducer2.py

```
[cloudera@quickstart ~]$ cat pagerank_data.txt | python pagerank_mapper1.py | python pagerank_reducer1.py | python pagerank_mapper2.py | python pa
gerank_reducer2.py

Current node: 1
Contribution by this node: 0.0

Current node: 2
Contribution by this node: 0.5
Previous node: 1
New page rank of node 2: 0.15

Current node: 3
Contribution by this node: 0.5
Previous node: 2
New page rank of node 3: 0.575

Current node: 2
Contribution by this node: 0.0
Previous node: 3
New page rank of node 2: 0.575

Current node: 4
Contribution by this node: 1.0
Previous node: 2
New page rank of node 4: 0.15

Current node: 3
Contribution by this node: 0.0
Previous node: 4
New page rank of node 3: 1.0

Current node: 1
Contribution by this node: 0.333333333333
Previous node: 3
New page rank of node 1: 0.15        --> Final PR(1) = 0.15

Current node: 2
Contribution by this node: 0.333333333333
Previous node: 1
New page rank of node 2: 0.43333     --> Final PR(2) = 0.4333

Current node: 4
Contribution by this node: 0.333333333333
Previous node: 2
New page rank of node 4: 0.43333     --> Final PR(4) = 0.4333

Current node: 4
Contribution by this node: 0.0

Current node: 3
Contribution by this node: 1.0
Previous node: 4
New page rank of node 3: 0.43333
Previous node: 3
New page rank of node 3: 1.0         --> Final PR(3) = 1
[cloudera@quickstart ~]$
```

So, the final page ranks for node1, node2, node3 and node4 are 0.15, 0.4333, 1 and 0.4333 respectively. From this, it can be deduced that node1 is of least importance and node3 is the most important page.

This can also be supported by comparing the page rank results obtained, with the input web graph.



As you can see, there are 2 incoming edges and 3 outgoing edges to and from node3 respectively. Higher the no. of edges (incoming or outgoing) associated with a node, higher is its importance.

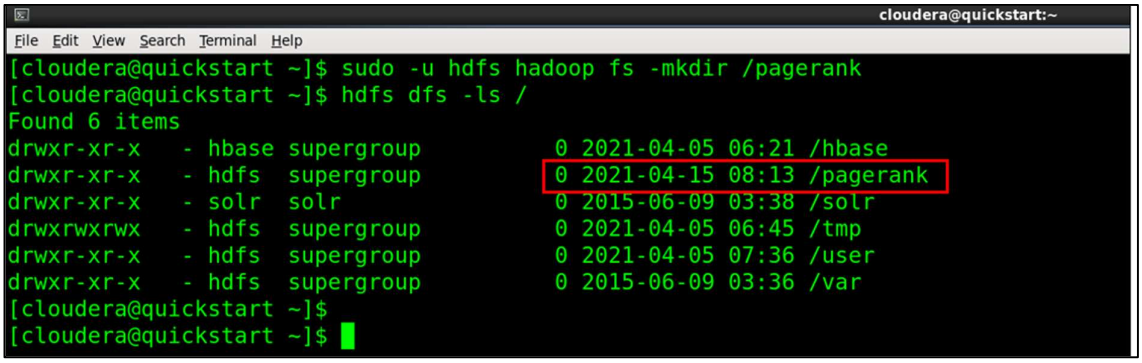
Hence, the order of importance of all the nodes is:

1. Google
2. LinkedIn
3. Facebook
4. YouTube

Now that we know the results of the MapReduce programs we executed are as expected, we are good to go for the Hadoop implementation of the same.

Step 4: Create a directory on HDFS.

sudo -u hdfs hadoop fs -mkdir /pagerank
hdfs dfs -ls /



Step 5: Copy input file on HDFS.

sudo -u hdfs hadoop fs -put /home/cloudera/pagerank_data.txt /pagerank
hdfs dfs -ls /pagerank

The input file is copied successfully inside **`pagerank`** directory.

Step 6: Configure permissions to run MapReduce for PageRank algorithm on Hadoop.

Now, before we execute the MapReduce jobs on Hadoop, we need to give permission to read, write and execute the MapReduce program. We also need to provide permission for the default user (cloudera) to write the output file on HDFS.

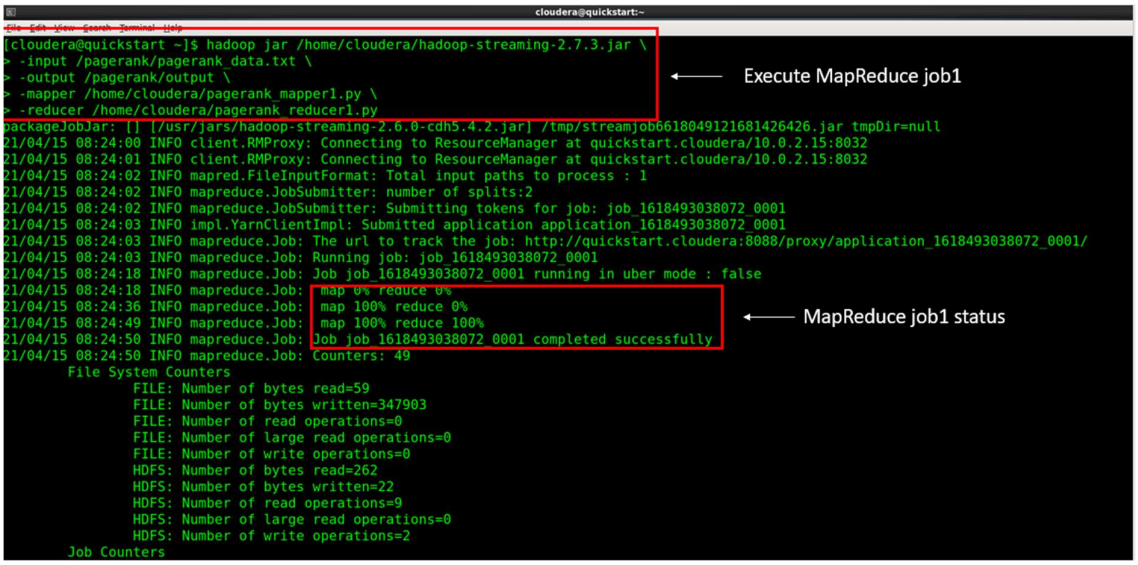
To do so, run the following commands.

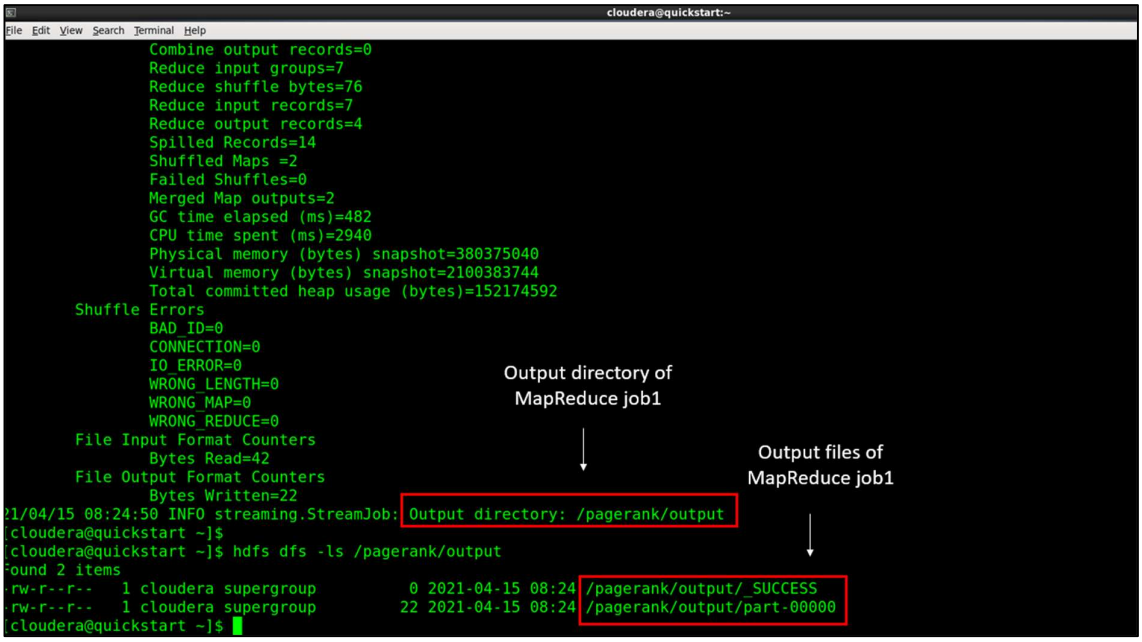
chmod 777 pagerank_mapper1.py pagerank_reducer1.py pagerank_mapper2.py pagerank_reducer.2.py
sudo -u hdfs hadoop fs -chown cloudera /pagerank

Step 7: Run MapReduce on Hadoop.

Execute the first MapReduce job on Hadoop.

hadoop jar /home/cloudera/hadoop-streaming-2.7.3.jar \
> -input /pagerank/pagerank_data.txt \
> -output /pagerank/output \
> -mapper /home/cloudera/pagerank_mapper1.py \
> -reducer /home/cloudera/pagerank_reducer1.py





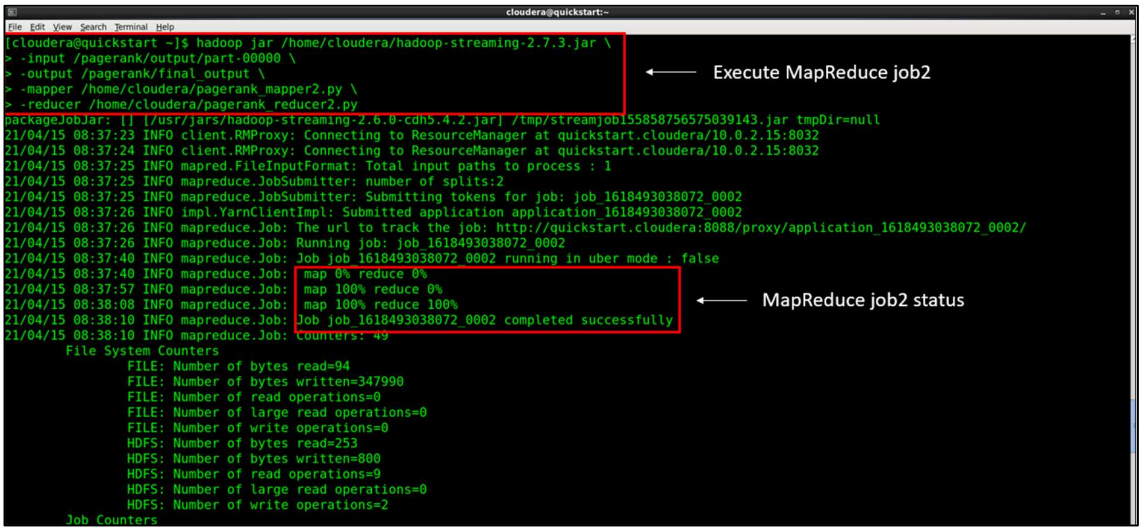
Let's read the output of the first MapReduce job.

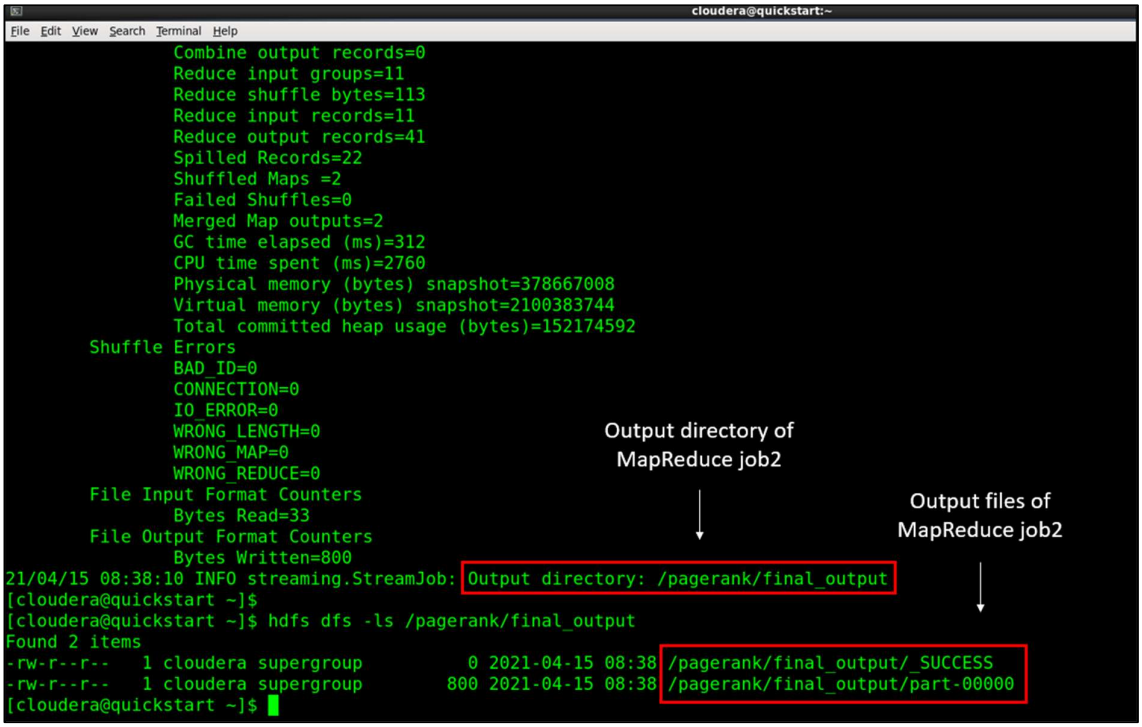
hdfs dfs -cat /pagerank/output/part-00000

The output matches with that obtained during local implementation. Now, we move forward to execute the second MapReduce job. The output of the first MapReduce job becomes the input of the second MapReduce job.

Execute the second MapReduce job on Hadoop.

```
hadoop jar /home/cloudera/hadoop-streaming-2.7.3.jar \
> -input /pagerank/output/part-00000 \
> -output /pagerank/final_output \
> -mapper /home/cloudera/pagerank_mapper2.py \
> -reducer /home/cloudera/pagerank_reducer2.py
```

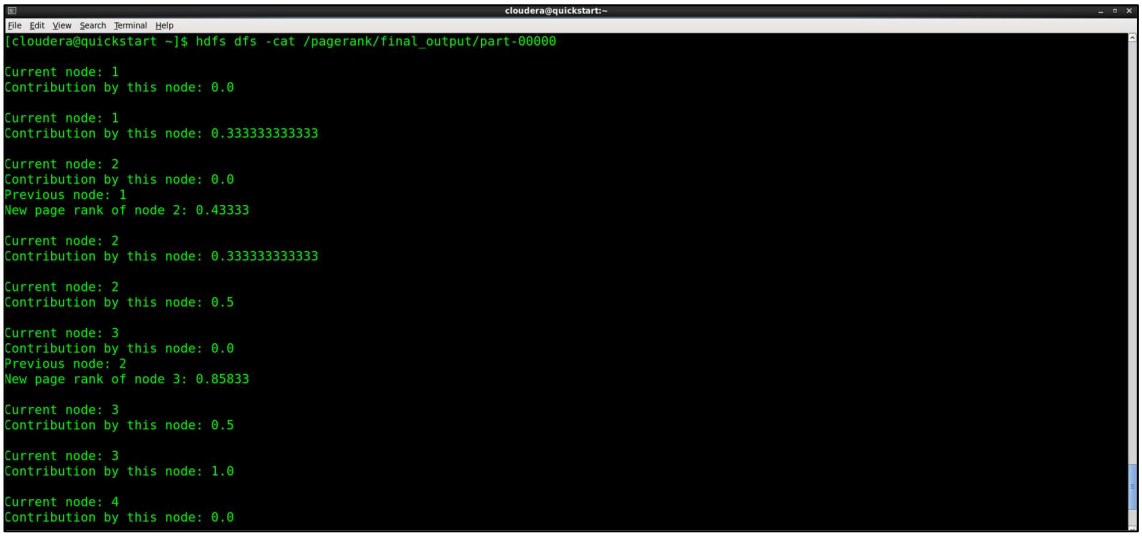




Alright, both the MapReduce jobs have been executed successfully. We can now read the final output. The final output is written inside the **`final_output`** directory on HDFS.

To read the file, simply run the command below.

```
hdfs dfs -cat /pagerank/final_output/part-00000
```



Great, we received the same output as we did while executing locally.

Congratulations, for successfully executing PageRank algorithm using MapReduce on Hadoop. Note that the page rank values would vary, depending upon the no. of nodes in the input web graph, no. of incoming and outgoing edges associated with each node and the damping factor you choose for the same.