CS6240
Parallel Data Processing
in MapReduce

Fall 2013
Project Report

By

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INTRODUCTION:

Our topic for Final Project is Analysis of Flights and Airlines. Our goals for this project is to learn implementations of HBase, Hive, PigLatin as well as solving more complex problems in plain MapReduce on local as well as on Amazon EMR and perform detailed representation of our analysis on charts.

TASK LIST :

Task 1	HBase	a) On Time Arrival Performance of Airlines b) Average delay at each airport.
Task 2	Hive and Pig Latin	Three legged round trip flight from Boston.
Task 3	Map Reduce	Calculate Page Rank of each Airport.
Task 4	Map Reduce	Hubs and Spokes

DATA:

Name: Airline On-Time Performance and Causes of Flight Delays
Size: 4.34GB with 4336074861 records.

Fields: 55 Columns (such as FlightNo, Date, DepDelayMins, etc.)

View of sample dataset: (with few columns)

flightdate	flightnum	origin	origincityname	dest	destcityname	deptime	arrtime	arrdelay minutes
2007-10-02	415	IND	Indianapolis, IN	MDW	Chicago, IL	1102	1100	30.00
2007-10-02	917	IND	Indianapolis, IN	MDW	Chicago, IL	0728	0712	0.00
2007-10-02	1022	IND	Indianapolis, IN	MDW	Chicago, IL	1855	1842	0.00
2007-10-02	2081	IND	Indianapolis, IN	MDW	Chicago, IL	1530	1522	0.00
2007-10-02	1033	IND	Indianapolis, IN	PHX	Phoenix, AZ	1500	1544	0.00

Here is the link for the dataset:
https://explore.data.gov/Transportation/Airline-On-Time-Performance-and-Causes-of-Flight-D/ar4r-an9z

TECHNICAL DISCUSSION:

TASK 1 : HBASE

a) On-time arrival performance of airlines

Purpose:

Calculating and analyzing performance of airlines based on their arrival delay.

Approach:
We have two mapreduce jobs. The first job computes the average arrival delay of each airline by reading the data from the csv file and storing this intermediate result in reverse order (key: averageDelay, value: airlineID) into a HBase table. Since HBase has the property of sorting by rowkey it sorts the data according to average delay. Here, to take advantage of the HBase property we had to store the averageDelay in bytes array of float values rather than Strings. (which we were doing before). The second mapreduce job is a map-only job that just reads this from the HBase table and writes output to the file. This ensures that the sorting is done using HBase rowkey property.

Pseudo-code:
Job 1:

```
map(key, value) {  // key = line offset , value = each record as String
        airlineId = value.getAirlineID();
        arrDelayMins = value.getArrDelayMinutes();
        emit(airlineId, arrDelayMins);
}

reduce(key, List[values]) {
        sum, total = 0,
        for delayValue in values:
                total ++;
                sum += delayValue;

        // Finally compute average and emit in reducer
        averageDelayMins =(sum / total);
        // HBaseConnection is a utility class that we have additionally created to talk to HBase.
        HBaseConnection.addRecord(tablename, sum/total , "airlineID", "", key.toString());
}
```

Output of Job1 (on 4.34 GB data): *initial few records only*

Key : Airline ID	Value: Average Delay
19386	14.574111
19393	10.166066
19678	3.915491
19690	4.53628
19704	15.95415
19790	12.485989
19805	18.206627
19930	12.79604
19977	17.726479
20304	12.365397

Job 2:

```
map( key, value) {  // key is averageDelay, value is airlineID
        averageDelay = row.get() //convert average delay from Bytes to DoubleWritable
```

```
        byte[] result = value.getValue(CF, ATTR);
        Text airlineID = new Text(Bytes.toString(result));
         emit(averageArrivalDelay, airlineID);
}
```

Output of Job2:

The output of Job2 is same as Job1 but the only difference is that all the rows are sorted according to the arrival delay.

Now to make things more elegant we have a sequential program to convert these airlineID's into actual airline name. *(Top few records only)*

Key : Average Delay	Value: Airline ID
3.9154911041259766	Aloha Air Cargo: KH
4.536280155181885	Hawaiian Airlines Inc.: HA
10.16606616973877	Southwest Airlines Co.: WN
10.564054489135742	Frontier Airlines Inc.: F9
12.040234565734863	Endeavor Air Inc.: 9E
12.365397453308105	SkyWest Airline(s Inc.: OO
12.48598861694336	Delta Air Lines Inc.: DL
12.796039581298828	Alaska Airlines Inc.: AS
13.382158279418945	US Airways Inc.: US (Merged with America West 9/05. Reporting for both starting 10/07.)
13.557802200317383	AirTran Airways Corporation: FL

Source: /HBase/HBase1/src
Log: /HBase/HBase1/logs
Output: /HBase/HBase1/output

b) Average delay at each airport

Purpose:

Calculating the average arrival delay at each airport and analyse on the map of U.S.A.

Approach:

This job computes the average arrival delay of each airport by reading the data from the csv file and storing the result (key: airport (destination), value: averageDelay) into a HBase table.

Pseudo-code:

```
map(key,value) {  // key = line offset , value = each record as String
        destination =value.getDest();
        arrDelayMins = value.getArrDelayMinutes();
        emit (destination, arrDelayMins);
 }
reduce(key, List[values]) { // key is destination(each airport)
                                // values is a list of average delay. This list contains only one value.
        sum, total = 0;
        for value in values:
```

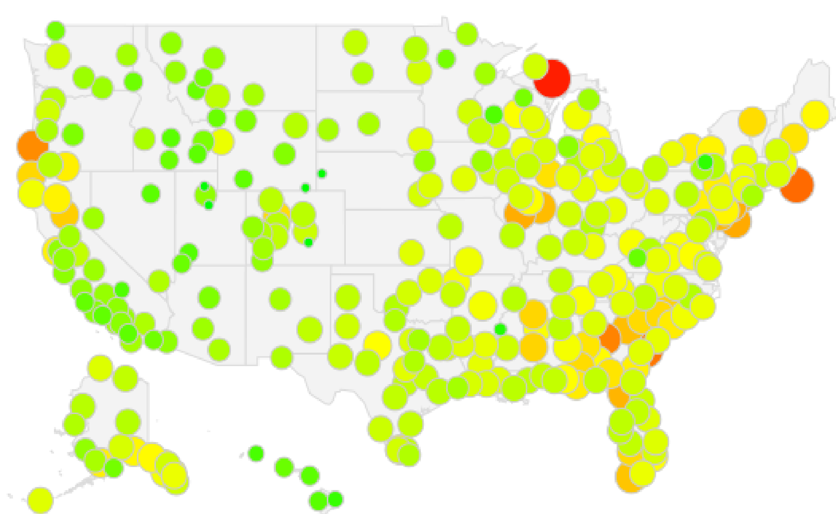
```
                arrDelayMins = float(value);
                total ++;
                sum += arrDelayMins;
        // Finally compute average and emit in reducer
        averageDelayMins =(sum / total);
        // HBaseConnection is a utility class that we have additionally created to talk to HBase.
         HBaseConnection.addRecord(tablename, key, "delay", "", averageDelayMins);
    }
```

Output:

Actual output contains 316 rows - one for each airport. Here are top few records seen from HBase:

```
tushar@ubuntu: ~/Downloads/hbase-0.94.13/bin
hbase(main):008:0> scan 'average_arrival_delay_airport'
ROW                    COLUMN+CELL
 ABE                   column=delay:, timestamp=1385273156230, value=15.436178
 ABI                   column=delay:, timestamp=1385273156475, value=17.1708
 ABQ                   column=delay:, timestamp=1385273156622, value=11.197535
 ABY                   column=delay:, timestamp=1385273156628, value=17.424364
 ACK                   column=delay:, timestamp=1385273156634, value=27.321066
 ACT                   column=delay:, timestamp=1385273156642, value=11.898975
 ACV                   column=delay:, timestamp=1385273156653, value=16.295553
 ACY                   column=delay:, timestamp=1385273156674, value=22.995174
 ADK                   column=delay:, timestamp=1385273156679, value=15.110526
 ADQ                   column=delay:, timestamp=1385273156684, value=7.856813
 AEX                   column=delay:, timestamp=1385273156691, value=15.545198
 AGS                   column=delay:, timestamp=1385273156758, value=21.567919
 AKN                   column=delay:, timestamp=1385273156762, value=18.128204
 ALB                   column=delay:, timestamp=1385273156787, value=15.653317
 ALO                   column=delay:, timestamp=1385273156792, value=10.74216
 AMA                   column=delay:, timestamp=1385273156803, value=12.934547
 ANC                   column=delay:, timestamp=1385273156830, value=14.513902
 APF                   column=delay:, timestamp=1385273156834, value=19.676895
 ASE                   column=delay:, timestamp=1385273156843, value=12.4784775
 ATL                   column=delay:, timestamp=1385273157369, value=14.7314005
 ATW                   column=delay:, timestamp=1385273157380, value=15.199821
 AUS                   column=delay:, timestamp=1385273157474, value=13.127228
```

Plotting this on the United States map, it is more evident that there are more flights on the east coast compared to the west coast and also more delays on the east coast.



Source: /HBase/HBase2/src
Log: /HBase/HBase2/logs

Output: /HBase/HBase2/output

Performance on EMR:

Program	No. of Worker Machines	Machine Type	Time Taken
HBase1 (Task 1)	2	large	8 minutes
HBase 1 (Task 1)	2	large	9 minutes
HBase2 (Task 2)	5	large	4 minutes
HBase2 (Task 2)	5	large	4 minutes

TASK 2 : HIVE & PIG LATIN - Three legged round trip flight from Boston.

Purpose:

We are finding shortest time taking three legged round trip flights from Boston(e.g. journeys of the form BOS-X-Y-BOS). We have done it in both HQL and PigLatin.

Approach:

HIVE: We have used CSVSerde to create the flight table in hive and have stored it as TEXTFILE.

We are adding CSVSerde jar on EMR as given below:

```
add jar s3n://finalproj-puru/lib/csv-serde-1.1.2-0.11.0-all.jar;
```

The create query is given below:

```
CREATE EXTERNAL TABLE IF NOT EXISTS Flight(
      Year FLOAT,Quarter FLOAT,Month FLOAT,DayofMonth FLOAT,DayOfWeek
      FLOAT,...,LateAircraftDelay FLOAT
row format serde 'com.bizo.hive.serde.csv.CSVSerde'
STORED AS TEXTFILE
LOCATION 's3n://finalproj-puru/table/';
```

We are loading the data in hive as follows:

```
LOAD DATA INPATH 's3n://finalproj-puru/piginput/data.csv' INTO TABLE flight;
```

We are adding up the actual elapsed times all the three flights and also the layovers at the two intermediate airports. We are also checking for the condition that the departure time of second flight should be greater than the arrival time of first flight and the departure time of third flight should be greater than the arrival time of the second flight.

PigLatin:

We are using filter and joins to check for the required conditions as given in the pseudo code.

Pseudo Code:

HIVE:

```
INSERT OVERWRITE DIRECTORY 's3n://finalproj-puru/hiveoutput'
Select a.origin, a.dest, b.dest, c.dest, a.flightdate, a.DepTime, a.ArrTime,
b.DepTime, b.ArrTime, c.DepTime, c.ArrTime, (a.actualelapsedtime +
b.actualelapsedtime + c.actualelapsedtime + (b.DepTime-a.ArrTime) +
(c.DepTime-b.ArrTime)) AS TotalTime from flight a JOIN flight b on (a.dest =
b.origin) JOIN flight c on (b.dest = c.origin) where a.flightdate
```

```
='2008-01-01' AND b.flightdate = '2008-01-01' AND c.flightdate = '2008-01-01'
AND a.origin = 'BOS' AND c.dest = 'BOS'
AND a.DepTime < a.ArrTime
AND b.DepTime < b.ArrTime
AND c.DepTime < c.ArrTime
AND b.DepTime > a.ArrTime
AND c.DepTime > b.ArrTime AND b.DepTime - a.ArrTime > 100 AND c.DepTime -
b.ArrTime > 100
AND a.cancelled != 1 AND b.cancelled != 1 AND b.cancelled != 1
Order by TotalTime LIMIT 20;
```

PigLatin:

```
Flights1_Data = FILTER Flights1_Data by (orig1 == 'BOS') AND (flightDate1 ==
'2008-01-01') AND (cancelled1 != 1);
Flights2_Data = FILTER Flights2_Data by (flightDate2 == '2008-01-01') AND
(cancelled2 != 1);
Flights3_Data = FILTER Flights3_Data by  (dest3 == 'BOS') AND (flightDate3 ==
'2008-01-01') AND (cancelled3 != 1);

f1f2 = JOIN Flights1_Data BY (dest1), Flights2_Data BY (orig2);
f1f2 = FILTER f1f2 BY depTime2 > arrTime1;

f1f2f3 = JOIN f1f2 BY (dest2), Flights3_Data BY (orig3);
f1f2f3 = FILTER f1f2f3 BY  depTime3 > arrTime2;

f1f2f3 = FILTER f1f2f3 BY ((depTime2-arrTime1) > 100) AND ((depTime3-arrTime2)
> 100);

final = FOREACH f1f2f3 GENERATE
orig1,dest1,dest2,dest3,flightDate1,depTime1,arrTime1,depTime2,arrTime2,depTim
e3,arrTime3,  (actualElapsedTime1 + actualElapsedTime2 + actualElapsedTime3 +
(depTime2 - arrTime1) + (depTime3 - arrTime2)) AS totalTripTime;

final = ORDER final BY totalTripTime;
final = limit final 20;
STORE final INTO '$OUTPUT';
```

Source: Hive: /Hive/src
PigLatin: /PigLatin/src
Log: Hive:/Hive/logs
PigLatin: /PigLatin/logs
Output: Hive: /HIve/output
PigLatin**:** /PigLatin/output

Origin	Dest1	Dest2	End	Flight Date	F1: DepTime	F1: ArrTime	F2: DepTime	F2: ArrTime	F3: DepTime	F3: ArrTime	TotalTripTime
BOS	DCA	LGA	BOS	1/1/2008	847	1028	1131	1223	1328	1435	428
BOS	DCA	LGA	BOS	1/1/2008	847	1028	1131	1223	1339	1442	435
BOS	DCA	LGA	BOS	1/1/2008	1602	1735	1852	2004	2107	2200	438
BOS	IAD	LGA	BOS	1/1/2008	1021	1211	1320	1420	1528	1625	444
BOS	DCA	LGA	BOS	1/1/2008	847	1028	1131	1223	1354	1452	445
BOS	JFK	PHL	BOS	1/1/2008	1434	1542	1645	1832	1938	2041	447
BOS	LGA	DCA	BOS	1/1/2008	1128	1229	1352	1502	1619	1738	450

BOS	IAD	LGA	BOS	1/1/2008	1021	1211	1320	1420	1530	1632	451
BOS	IAD	LGA	BOS	1/1/2008	1021	1211	1320	1420	1556	1647	466
BOS	IAD	PHL	BOS	1/1/2008	1411	1604	1715	1808	1938	2041	470

Performance on EMR:

Program	No. of Machines	Machine Type	Time Taken
HIVE	11	small	32 Mins
HIVE	20	small	15 Mins
PigLatin	11	small	14 Mins 49 Secs
PigLatin	20	small	13 Mins 23 Secs

TASK 3 : PLAIN MAP REDUCE - Calculate PageRank of each Airport.

Purpose: To identify the busyness of the airport based on the traffic and the busyness value of it's neighbors

Approach: This task is divided into two sub-tasks. First task is responsible for creating an intermediate input file which will consist of only required information along with the initial pagerank value i.e. 1/total number of airports. This intermediate input will then be provided to the pagerank algorithm.

FIRST SUB-TASK:

This task was performed using in-mapper aggregation. While analyzing the input it was observed that flight details of the same airport was often in the same data chunk. Hence, in-mapper aggregation was the chosen pattern. Also, to keep the source code dynamic and adaptable to any graph change i.e. new node or new vertex, we calculated the marginal value (total number of nodes) using the order inversion design pattern.

Source: /Pagerank/src/pagerank/InitAirportRank.java
Log: /Pagerank/logs/syslog - initialize pagerank using in-mapper aggregation
Output: /pagerank/output/initialize
Pseudo-code:

```
setup()
        Set airports
        Map originCounter<String,Integer>

map(Key k, Value v)
        flight = parse(v)
        airports.add(flight.destination)
        airport.add(flight.origin)  //to handle dangling nodes
        if(originCounter.containsKey(flight.origin))
                originCounter[flight.destination][flight.origin]++
        else
                originCounter[flight.destination].put(flight.origin,1)

cleanup()
        foreach d in airports
```

```
        emit('*',[d,1]) // to count # of airports (nodes)
    foreach o in originCounter
        emit(o.flightDestination,[o.flightOrigin,o.count])
         // neighbor list of each airport along the count from each origin

reduce(Key k, Values v1,v2,v3,...)
    if(k=='*')
        for each v in v1,v2,v3…
            add v in set
        marginal = set size
    else
        for each v in v1,v2,v3
            add count of all similar input links
        emit(k,[(pagerank,1/marginal),(origin1,count1),(origin2,count2),...])
```

Input: snapshot of few records

Origin	Destination
ORD	LAX
ORD	LAX
ORD	LAX
BOS	JFK
JFK	LAX
BOS	ORD

Output:

```
BOS    PageRank,0.14285714285714285
CLE    PageRank,0.14285714285714285
DEN    PageRank,0.14285714285714285;SFO,1
DTW    PageRank,0.14285714285714285;CLE,1
LAX    PageRank,0.14285714285714285;ORD,15;BOS,2
ORD    PageRank,0.14285714285714285
SFO    PageRank,0.14285714285714285
```

SECOND SUB_TASK:

This task follows the pagerank algorithm.

Source: /Pagerank/src/pagerank/PageRank.java
Log: /Pagerank/logs/syslog - pagerank using 10 machines
Output: /pagerank/output/part-r-00000 to part-r-00015
Pseudo-code:

```
map(nid n, node N)
    emit(nid n, N)
    foreach o in originCounter
        total+=o.count
    p = N.pageRank / total
    for all nid m in N.incomingLinks do
        emit(nid m, p)

reduce(nid m, [p1,p2,...])
```

```
s=0; M = null
for all p in [p1,p2,...] do
        if isNode(p) then
                M=p
        else
                s += p
M.pageRank = alpha /totalNumberOfAirports +  (1-alpha)*s
emit(nid m, node M)
```

Input:

```
BOS     PageRank,0.14285714285714285
CLE     PageRank,0.14285714285714285
DEN     PageRank,0.14285714285714285;SFO,1
DTW     PageRank,0.14285714285714285;CLE,1
LAX     PageRank,0.14285714285714285;ORD,15;BOS,2
ORD     PageRank,0.14285714285714285
SFO     PageRank,0.14285714285714285
```

Output:

```
BOS     PageRank,0.03509803921568627
CLE     PageRank,0.06333333333333332
DEN     PageRank,0.03333333333333333;SFO,1
DTW     PageRank,0.03333333333333333;CLE,1
LAX     PageRank,0.03333333333333333;ORD,15;BOS,2
ORD     PageRank,0.03509803921568627
SFO     PageRank,0.06333333333333332
```

Things done different:

1. Multiple direct connections between two nodes were taken into account because it effects the busyness value of the airport. 10 flights from BOS to JFK were represented as (JFK   BOS,10)
2. Performed comparison between 'In-mapper aggregation using 10 machine' vs 'No aggregation using 20 machines'
3. Performed comparison between 'Pagerank using 10 machines' vs 'Pagerank using 20 machines (both using In-mapper aggregation)

Performance on EMR:

Initialization: In-Mapper Aggregation Vs No Aggregation

	In-Mapper Aggregation	No Aggregation
# of machines	10	20
machine type	small	small
map output records	163749	26790152
time taken (in secs)	295	297

Interesting Observation: Even with half the amount of workers, in-mapper was faster

Pagerank: 10 machines Vs 20 machines

	10 small machines	20 small machines
Iteration #1	140	170
Iteration #2	143	168
Iteration #3	141	169

Iteration #4	142	171

Surprising observation: With 20 machines the runtime for each iteration increased as compared to 10 machines. The possible reason being given the small size of input (only 316 keys), it takes more time and overhead for the master to distribute the job. So, more the # of machines, more is the overhead and more is the runtime.

Conclusion:

1. Pagerank of a particular airport de

TASK 4 : PLAIN MAP REDUCE - Hubs and Spokes.

Purpose:

In this Task we are identifying the Major Hubs and Major Spokes from the Airline data of flights that we have.

We have to spilt the task first into two separate Jobs:

JOB 1 : Setup the Graph Structure from the flight data. The flight data provided represents edges. Now we need to convert these edges into Node structure. Where each Node represents the following information

1. AirPort
2. Hub Value
3. Spoke Value
4. In Links
5. Out Links

JOB 2 :Now after getting these Node structures which we obtained in Job 1, We iteratively run HITS algorithm on the available Nodes there by computing the values for Hub and Spoke.

Format of Output: Airport HubVal SpokeVal [List of In-Links]---[List of Out-Links]

Sample Output of Job 1

ACY 1.0 1.0
ATL:1.0:1.0,MCO:1.0:1.0,ATL:1.0:1.0,---BWI:1.0:1.0,JFK:1.0:1.0,LGA:1.0:1.0,ATL:1.0:1.0,BOS:1.0:1.0,MYR:1.0:1.0,MCO:1.0:1.0,ATL:1.0:1
.0,
ADK 1.0 1.0 AKN:1.0:1.0,ANC:1.0:1.0,AKN:1.0:1.0,---AKN:1.0:1.0,ANC:1.0:1.0,AKN:1.0:1.0,

Sample Output of Job 2

ACY 0.21 1.0
ATL:1.0:1.0,MCO:1.0:1.0,ATL:1.0:1.0,---BWI:1.0:1.0,JFK:1.0:1.0,LGA:1.0:1.0,ATL:1.0:1.0,BOS:1.0:1.0,MYR:1.0:1.0,MCO:1.0:1.0,ATL:1.0:1
.0,
ADK 1.0 0.132 AKN:1.0:1.0,ANC:1.0:1.0,AKN:1.0:1.0,---AKN:1.0:1.0,ANC:1.0:1.0,AKN:1.0:1.0,

Pseudo-code:

Job 1:

```
map( Key k, Value V) // Here Key : Object , Value: Text [Each line of input]
{
        Flight f = parse(v)
```

```
        emit(f.origin,"Out_FLIGHT"+","+f.destination)
        emit(f.destination,"In_FLIGHT"+","+f.origin)
}



// Here Key : Text [ Each Airport ] Values : [List of in-link airports and out-link airports]
reduce(Key k, [v1,v2,v3,...])
{
        Node N = new node();
        for airport in values{
                if (airport is "In_FLIGHT")
                        N.addInlink(airport)
                else
                        N.addOutlink(airport)
        emit(N,"")
}
```

Job 2:

MAPPER:

```
map(Key k, Value v) // Here Key: Object Value: Text
{       Node n = parse(v)
        emit(n.nid, N )
        for(Node p in n.getInList()){
                n.setIsIn("YES")
                emit(p.nid,n)
        }
        for(Nope p in n.getOutList()){
                n.setIsIn("NO")
                emit(p.nid,n)
        }
}
```

REDUCER

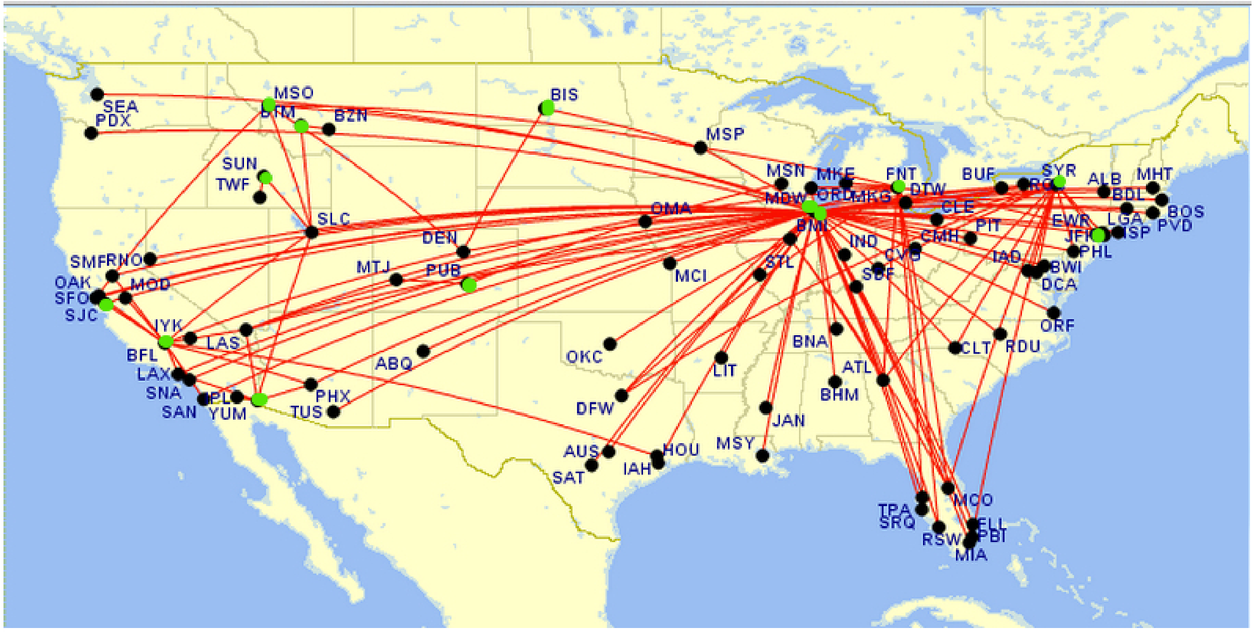
```
setup()
{
        map = new Map(); // initialise hashmap
}

reduce(Key k, Values[v1,v2,v3,....  ]) // Here Key : Text Values:[ Node n1. Node n2,......]
{
        Node M = null
        HubVal = 0
```

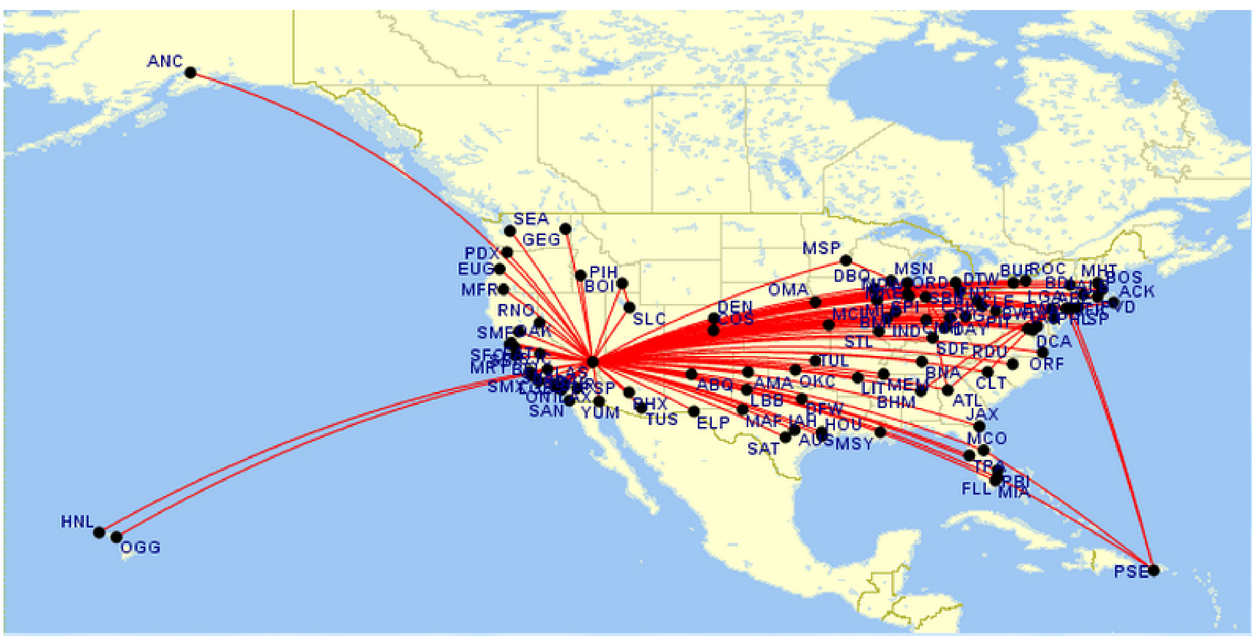
```
	SpokeVal = 0
	for(Node n in values)
	{
		if(isNode(N))
			M=n
		else
			if(n.isInList())
				SpokeVal +=n.getHubVal()
			else
				HubVal += n.getSpokeVal()
	}
	map.put(n)
}

cleanup()
{
	HubNorm = 0
	SpokeNorm = 0
	for(val in  map)
		HubNorm += Math.pow(val.Hubval,2)
		SpokeNorm +=Math.pow(val.SpokeVal,2)
	for(val in map)
		val.HubVal = val.HubVal/HubNorm
		val.SpokeVal = val.getSpokeVal/SpokeNorm
		emit(val,"")
}
```

Top Hubs Denoted By Green Dots:



Top Spokes:



Source:/HubsAndSpokes/src/
Log:/HubsAndSpokes/logs/
Output:/HubsAndSpokes/output/
Performance on EMR:

Program	No. of Worker Machines	Machine Type	Time Taken

HubsAndSpokes	5	small	1 hour 8 minutes
HubsAndSpokes	10	small	50 minutes

Setup challenges:

1. ***Loading data.csv on S3 into hive table:*** On our local machines we used the following command to load data.csv into our hive table:
   `LOAD DATA LOCAL INPATH 'path_to_data.csv' INTO TABLE flight;`
   `Which clearly doesn’t work on aws.`
   We removed `LOCAL` from the above query. Also in the create table statement we specified an additional clause `‘LOCATION 's3n://finalproj-puru/table/';’` so that the table is created on S3 instead of hdfs.

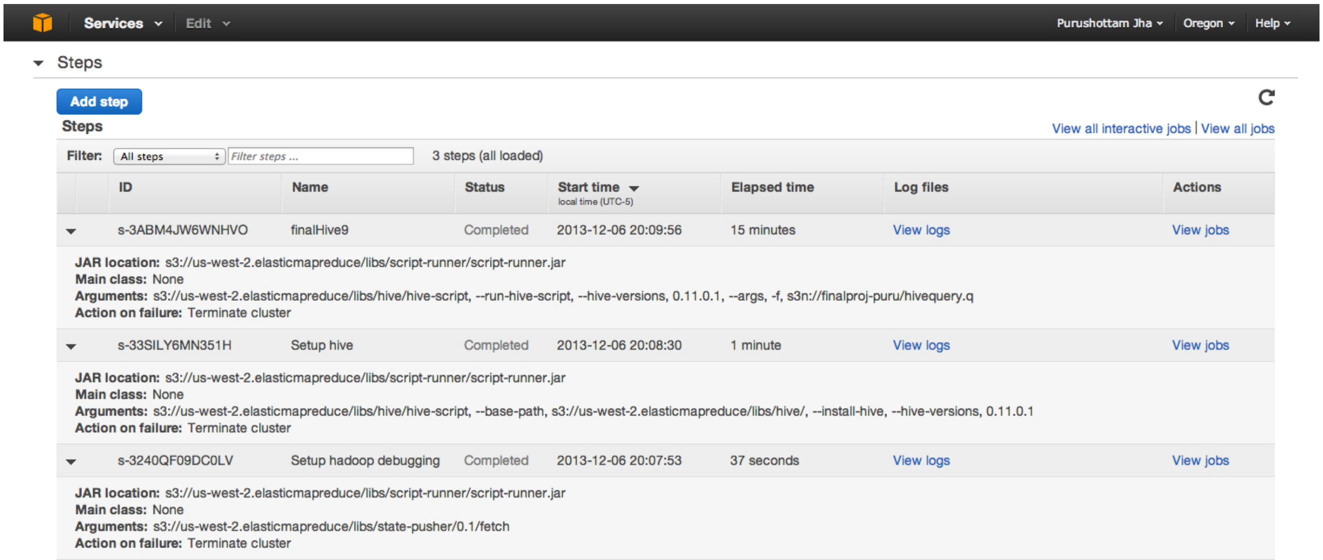
2. ***Adding external libraries(e.g. CSVSerDe) on EMR:*** As data.csv is a csv file, hive create table needed CSVSerDe so that it parses the data properly. We added the following line to the hive code to include the external library which was stored in our S3.
   `add jar s3n://finalproj-puru/lib/csv-serde-1.1.2-0.11.0-all.jar;`

3. ***Writing hive output on S3: Writing output of our hive program to S3 was also tricky. We used the following code to do it:***
   `INSERT OVERWRITE DIRECTORY 's3n://finalproj-puru/hiveoutput'`

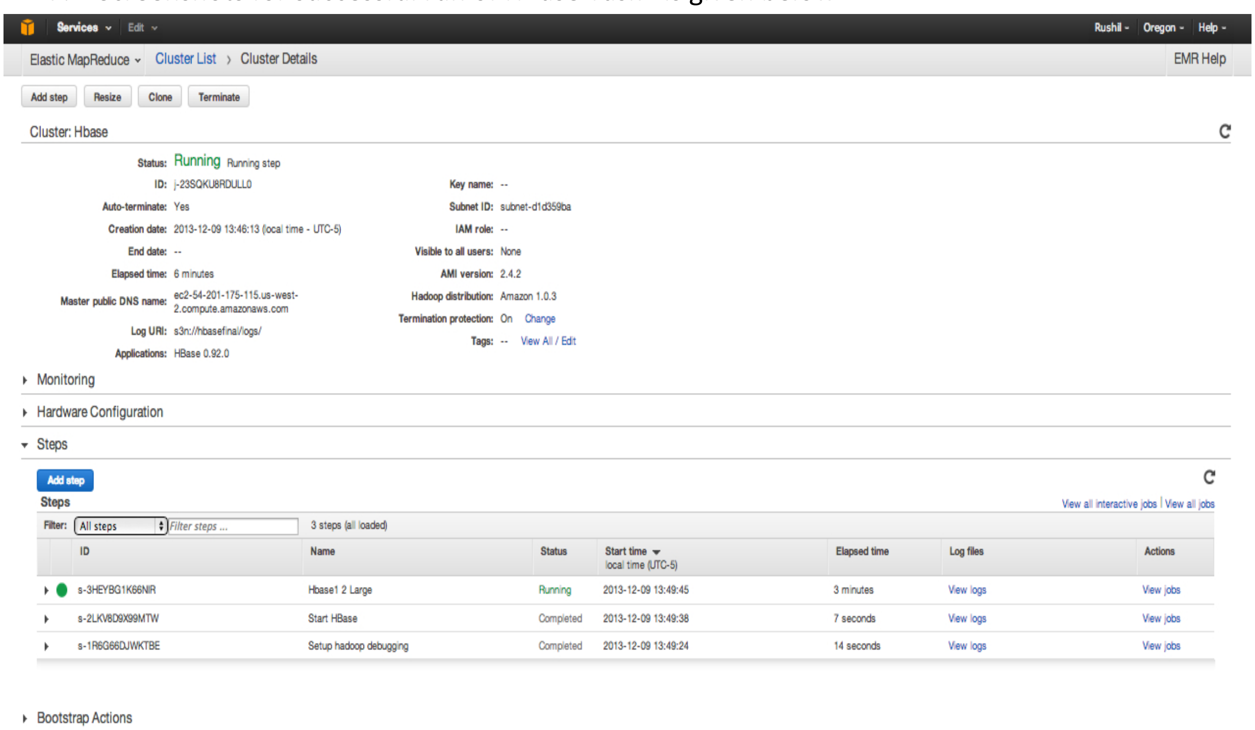
4. ***Insertion into and reading from HBase:*** Initially, we were storing strings as bytes into HBase table into the key column because we wanted the average delay to be sorted in increasing key order. Since that is not going to give correct results for strings, we changed that to Double. As HBase stores the records in bytes, it would return results as bytes array of Double and was not readable. Therefore, we had another map-only job that would read from HBase and write into file. The map-only job would ensure that the sorting is because of HBase row key property.

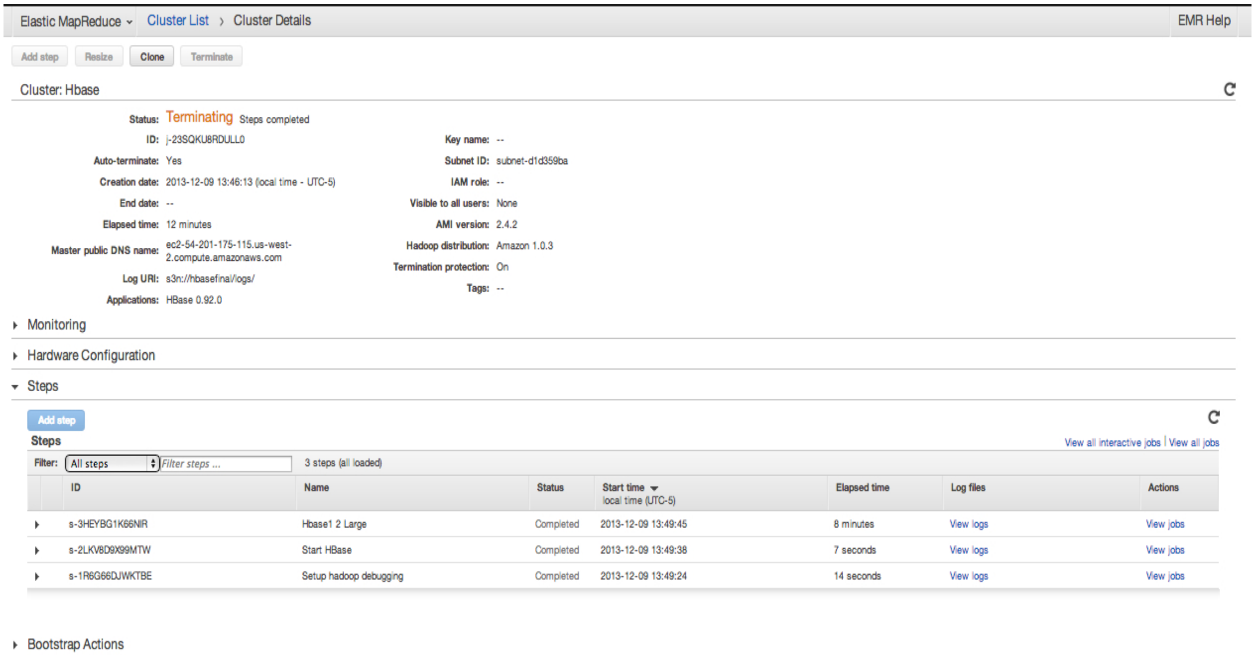
5. ***HBase on EMR**:* When we run HBase on EMR its persistent and we need to keep the Cluster running for the 2 jobs and deal with restoring HBase. In order to reduce these complexities, we run both the Jobs in the same Main function therefore the cluster need not be kept alive. We just needed to follow these steps and it worked:
   1. Create a jar as we do for plain MapReduce.
   2. Create a cluster on EMR and just select to add HBase. Also we can now select Auto-terminate to YES as the second mapreduce job will take the required input from HBase and create our output file in S3.
   3. The rest of the procedure remains the same as we did for plain MapReduce.

6. Screenshot for the successful run of hive program is given below:

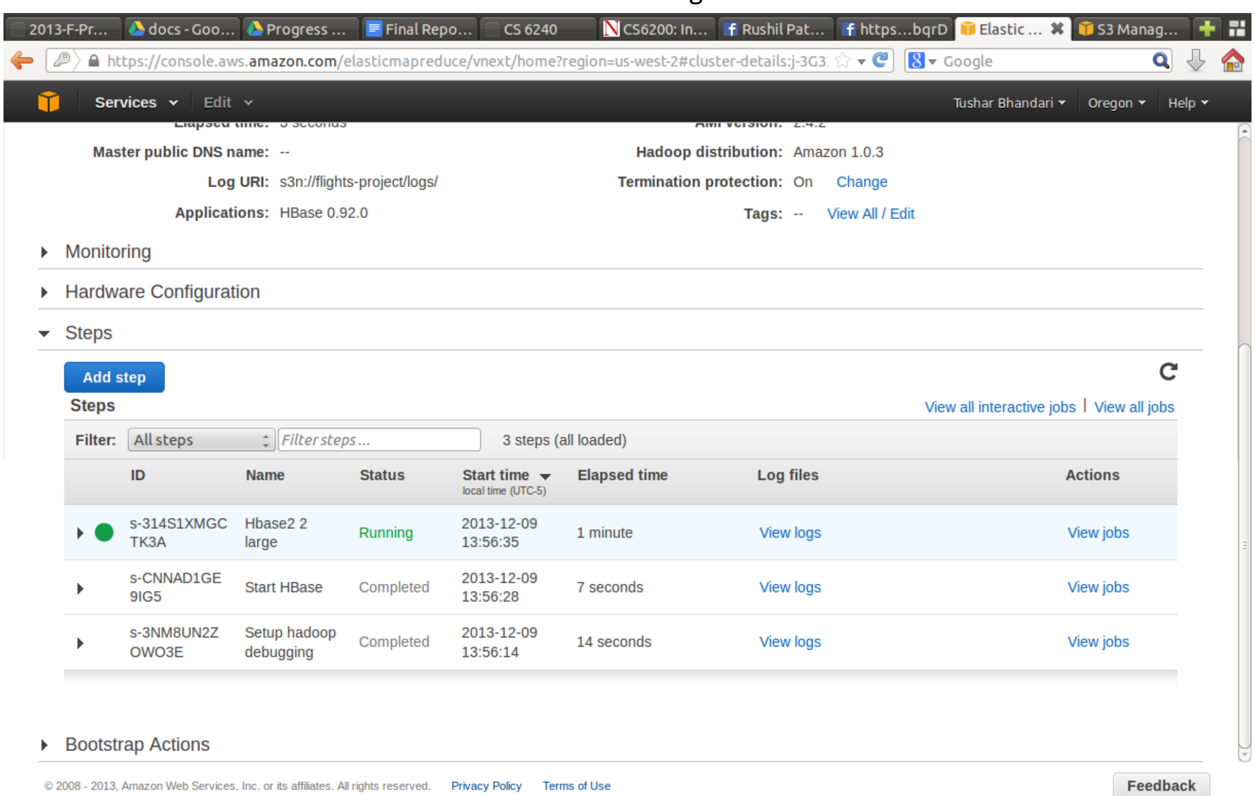


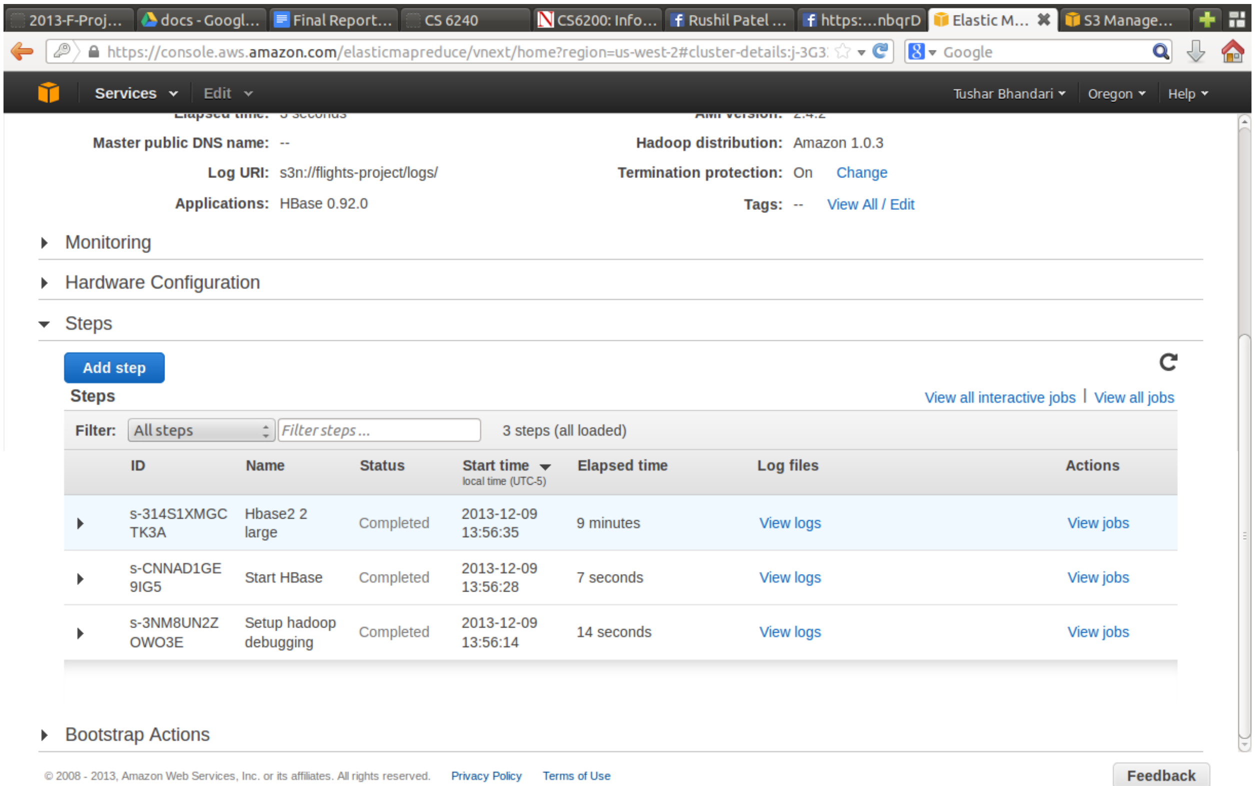
7. Screenshots for successful run of HBase Task1 is given below



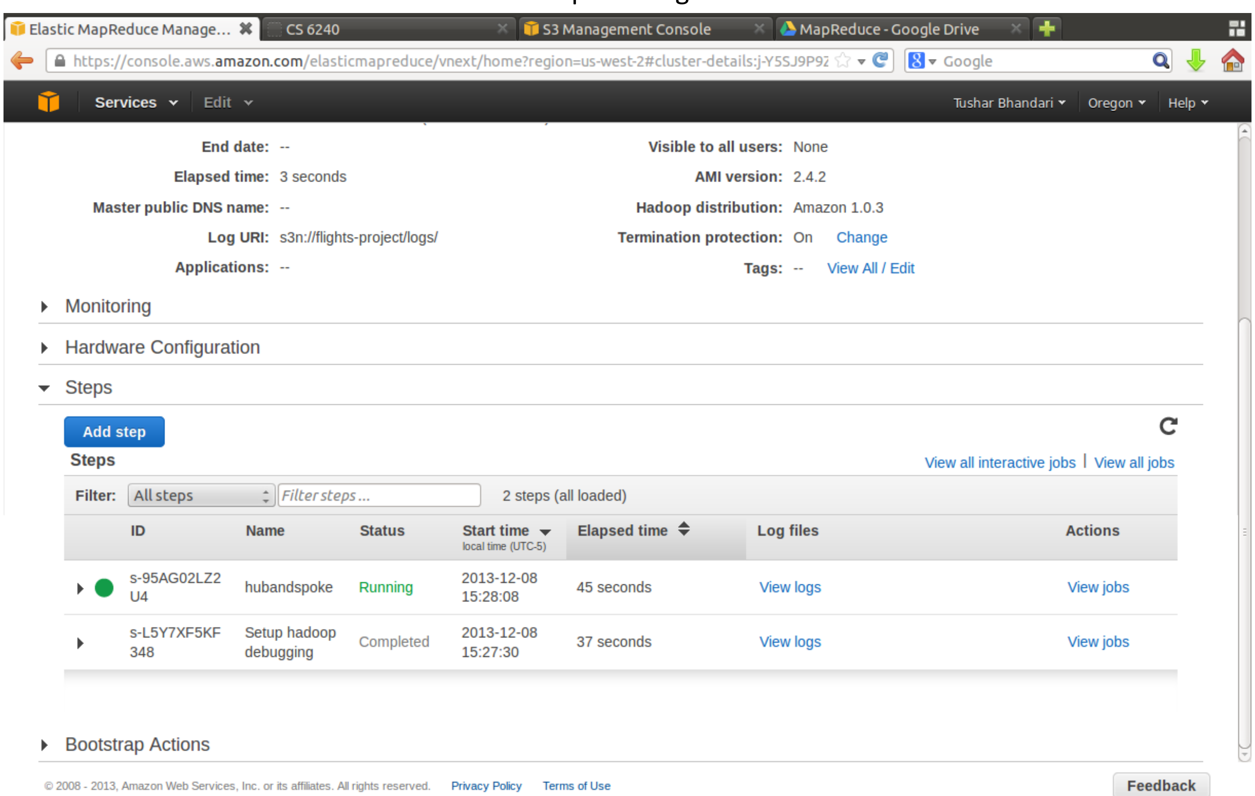


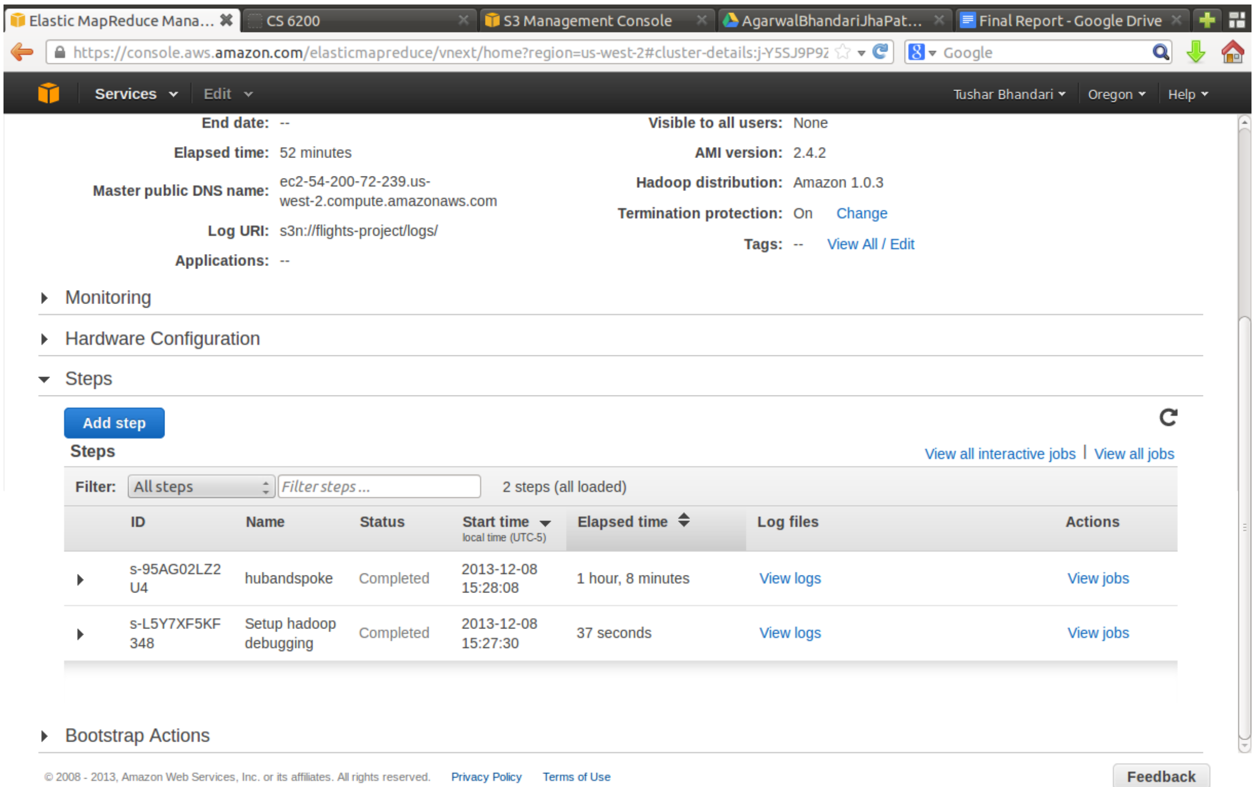
8. Screenshots for successful run of HBase Task2 is given below:





9. Screenshots for successful run of Hubs and Spokes is given below:





Conclusion:

Here is a summary of our main results and contributions for every task:

1. HBase: The task focuses on calculating average arrival delay for airlines and airport. Airports on the east coast have more delays followed by airports on the west coast followed by airports in the central part of the United States. This can be because of the following reasons:

a. Weather conditions on the east coast are more severe compared to the other parts of the United States.

b. Also airports are busier in the eastern part compared to west and central US.

For airlines, Aloha Air Cargo has the least average delay whereas JetBlue airways has the maximum average delay.

2. Hive and PigLatin: This task focuses on finding three legged flights of the form BOS-X-Y-BOS. We used both Hive and PigLatin for the same task and PigLatin performed better compared to Hive. One of the reasons is PigLatin directly reads data from file and converts the job to MapReduce program. On the other hand, there is some time spent on creating a table and loading data into the tables in Hive and then finally executing the query.

3. Page Rank:

4. Hubs and Spokes: This task focuses on finding the hubs and spokes for the given dataset. We used HITS algorithm to determine hub and spoke values for each airport. We also plotted this on a map to make it more intuitive. The following were the results:
Airport with the best hub value is : Syracuse, NY
Airport with the best spoke value is: Colorado Springs, CO