732A54/TDDE31 Big Data Analytics

Exercise Session

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Lab session schedule

- April 27 10:15-12:00, TDDE31, Nikita
- April 28 13:15-15:00, TDDE31, Nikita
- April 28 15:15-17:00, TDDE31, Nikita
- May 4 10:15-12:00, TDDE31, Nikita
- May 5 13:15-15:00, TDDE31, Nikita
- May 7 08:15-10:00, TDDE31, Nikita
- May 8 15:15-17:00, TDDE31, Nikita
- May 15 15:15-17:00, TDDE31, Jose
- May 19 13:15-15:00, TDDE31, Jose
- May 22 13:15-15:00, TDDE31, Jose
- April 30 08:15-10:00, 732A54, Huanyu
- May 5 15:15-17:00, 732A54, Huanyu
- May 5 17:15-19:00, 732A54, Huanyu
- May 6 17:15-19:00, 732A54, Huanyu
- May 12 15:15-17:00, 732A54, Huanyu
- May 12 17:15-19:00, 732A54, Huanyu
- May 14 08:15-10:00, 732A54, Huanyu
- May 18 10:15-12:00, 732A54, Jose
- May 22 10:15-12:00, 732A54, Jose
- May 26 10:15-12:00, 732A54, Jose

- Limited Thinlinc licenses on Sigma.
- During each session, for each pair of students, use only one thinlinc connection.
- Anytime,
  - ssh –X connection from your machince if you have X forwarding configuration or
  - Thinlinc connection to 'thinlinc.edu.liu.se' first, then ssh –X connection to Sigma.

Agenda

- Aims of this exercise session
- Review
  - ✓ Map-Reduce: Working with key-value pairs
  - ✓ Lambda functions
- How to design and write PySpark code
- Lab introduction and exercises
  - ✓ Conceptual design
  - ✓ Write PySpark code
- How to work on Sigma

Aims

- Give you an overview of the labs
- Help you to understand how to design and write code using Spark in python
- Exercises: start to solve the assignments in the labs

Map-Reduce: Working with key-value pairs

- Data elements: key-value pairs
- Python's tuple structure fit this key-value pair: (key, value)
  - ✓ (1,2), (1,3), (1,4), (1,5), (2,2), (2,3)
- A tuple is a sequence of immutable Python objects

  ('a', 3), (1, (3, 4)), ((1,1), 2)
- Accessing elements done with [index]

  x = (3, ('c', [1])), y = ((3, 'a'), ('c', [1]))

  x[0] = 3, x[1] = x[-1] = ('c', [1]), x[1][1] = [1]

  y[0] = (3, 'a'), y[0][0] = 3, y[1][1] = [1]
- 'Shuffle' operations by a key work on RDDs containing built-in Python tuples
  - ✓ 'repartition' operations
  - ✓ 'byKey' operations
  - ✓ 'join' operations

Lambda functions– a way to pass function to a RDD operation

- General form

  lambda arguments: expression

- Examples:

  *lambda a: 2 * a* –double the argument *a*

  lambda a, b: a + b –produce the sum of arguments *a* and *b*

  lambda input_list : (input_list[0], input_list[1]) *–get the first elements to generate the (key, value) pair*

  lambda input_list : max(input_list) *–get the max element in a list*

RDD - Operations

Transformations	$map(f : \mathrm{T} \Rightarrow \mathrm{U})$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{RDD[U]}$
	$filter(f : \mathrm{T} \Rightarrow \mathrm{Bool})$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{RDD[T]}$
	$flatMap(f : \mathrm{T} \Rightarrow \mathrm{Seq[U]})$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{RDD[U]}$
	$sample(fraction : \mathrm{Float})$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{RDD[T]}$ (Deterministic sampling)
	$groupByKey()$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{RDD[(K, Seq[V])]}$
	$reduceByKey(f : (\mathrm{V}, \mathrm{V}) \Rightarrow \mathrm{V})$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{RDD[(K, V)]}$
	$union()$	:	$(\mathrm{RDD[T]}, \mathrm{RDD[T]}) \Rightarrow \mathrm{RDD[T]}$
	$join()$	:	$(\mathrm{RDD[(K, V)]}, \mathrm{RDD[(K, W)]}) \Rightarrow \mathrm{RDD[(K, (V, W))]}$
	$cogroup()$	:	$(\mathrm{RDD[(K, V)]}, \mathrm{RDD[(K, W)]}) \Rightarrow \mathrm{RDD[(K, (Seq[V], Seq[W]))]}$
	$crossProduct()$	:	$(\mathrm{RDD[T]}, \mathrm{RDD[U]}) \Rightarrow \mathrm{RDD[(T, U)]}$
	$mapValues(f : \mathrm{V} \Rightarrow \mathrm{W})$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{RDD[(K, W)]}$ (Preserves partitioning)
	$sort(c : \mathrm{Comparator[K]})$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{RDD[(K, V)]}$
	$partitionBy(p : \mathrm{Partitioner[K]})$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{RDD[(K, V)]}$
Actions	$count()$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{Long}$
	$collect()$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{Seq[T]}$
	$reduce(f : (\mathrm{T}, \mathrm{T}) \Rightarrow \mathrm{T})$	:	$\mathrm{RDD[T]} \Rightarrow \mathrm{T}$
	$lookup(k : \mathrm{K})$	:	$\mathrm{RDD[(K, V)]} \Rightarrow \mathrm{Seq[V]}$ (On hash/range partitioned RDDs)
	$save(path : \mathrm{String})$	:	Outputs RDD to a storage system, *e.g.*, HDFS

Table 2: Transformations and actions available on RDDs in Spark. Seq[T] denotes a sequence of elements of type T.

- You need more than the above to solve all assignments in the lab.
  - ✓ PySpark library: https://spark.apache.org/docs/2.4.3/api/python/index.html
  - ✓ Spark 2.4.3 RDD programming guide: https://spark.apache.org/docs/2.4.3/rdd-programming-guide.html

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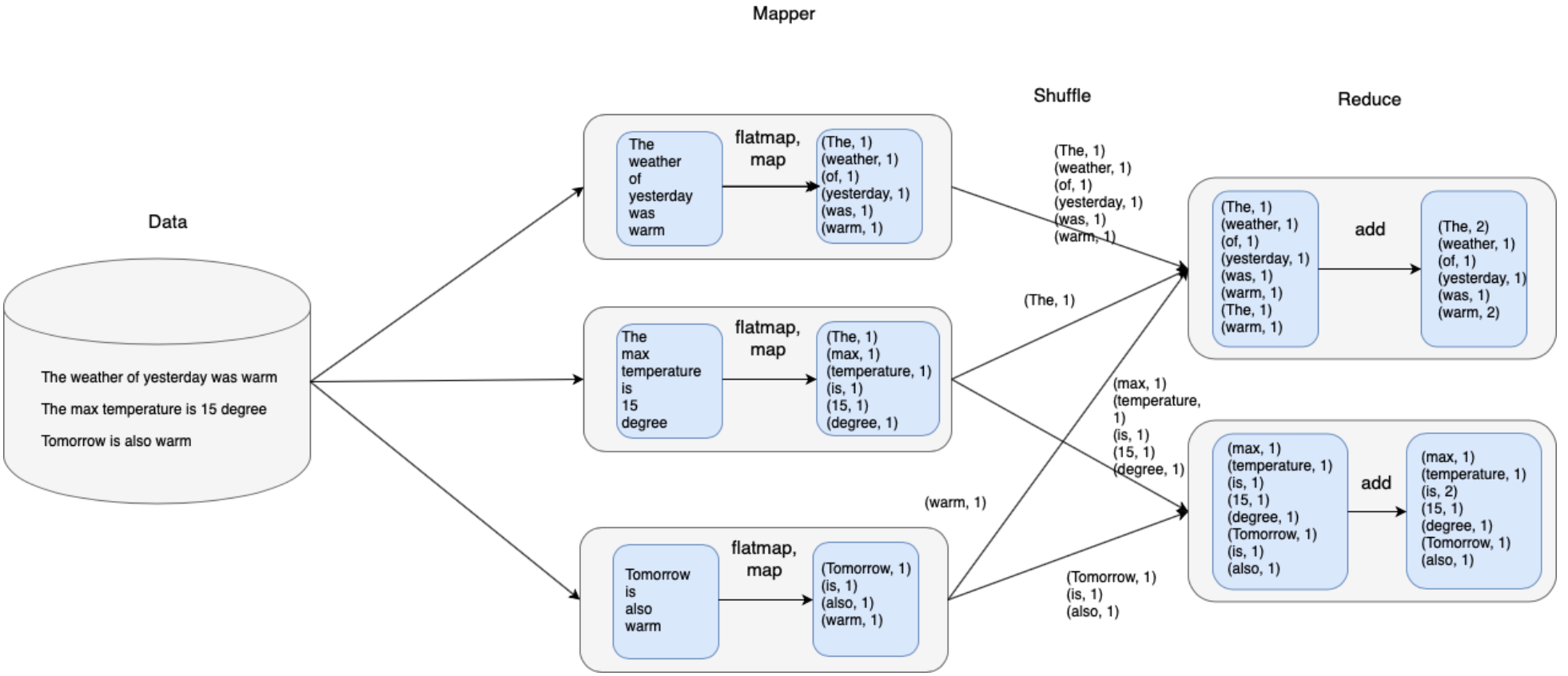
  - ✓ Write PySpark code
- *How to work on Sigma

Word Count – Conceptual Design

- In terms of map-reduce programming model, how to form key, value pair and what kind of transforms are needed, etc.
- During reduce process, what functions are needed on the values.



How to write PySpark code

- Pre-Step. Upload your data to Hadoop Distributed File System (HDFS)
- Step 1. To create a SparkContext object which tells Spark how to access a cluster.
- Step 2. To create distributed datasets (RDD)
  - ✓ Use external datasets by local file system or HDFS
- Step 3. RDD operating: transformation, action

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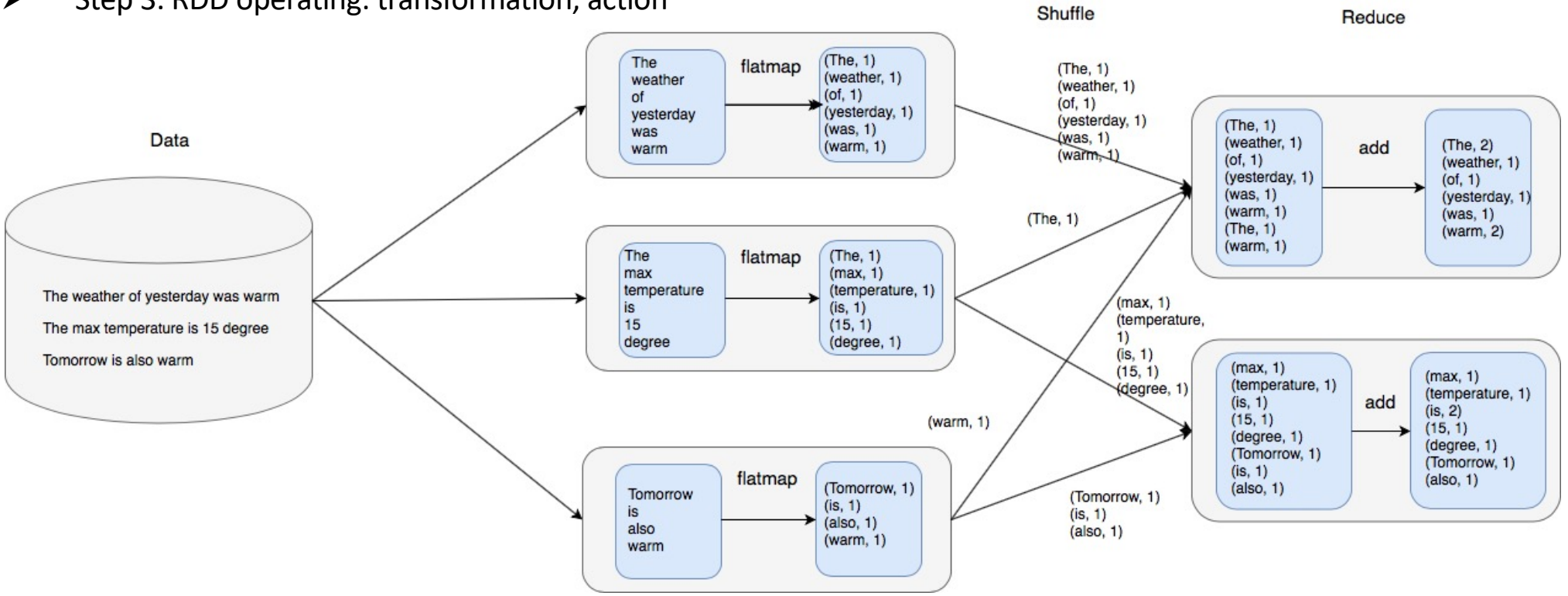


```
1 from pyspark import SparkContext
2 sc = SparkContext(appName = "exercise test")
3 news_file = sc.textFile("/user/x_huali/data/news.txt")
4 words = news_file.flatMap(lambda line: line.split(" "))
5 word_count = words.map(lambda word: (word, 1))
6 counts = word_count.reduceByKey(lambda v1, v2: v1+v2)
7 counts.saveAsTextFile("word_count_result")
```

step 1

step 2

step 3: RDD transformation(s)

step 3: RDD action

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Lab Introduction

- Working with the historical meteorological data from Swedish Meteorological Hydrological Institute (SMHI)
  - ✓ The data includes air temperature and precipitation readings from 812 stations in Sweden.
- Three labs
  - ✓ BDA1 – Spark: 5 assignments
    - In general, you need to do filtering, grouping, aggregating … over the data.
    - Map-reduce programming model, PySpark,
    - working with key-value pairs
  - ✓ BDA2 – Spark SQL: Redo the 5 assignments in BDA1 with Spark SQL
  - ✓ BDA3 – Machine Learning with Spark:
- Example: Find highest temperature for a certain period
  - ✓ temperature-readings.csv

Headers for *temperature-readings.csv*

Station number	Date	Time	Air temperature (in °C)	Quality[3]

```
102170;2013-11-01;06:00:00;6.8;G
102170;2013-11-01;18:00:00;3.8;G
102170;2014-11-02;06:00:00;5.8;G
102170;2014-11-02;18:00:00;-1.1;G
102170;2015-11-03;06:00:00;-0.2;G
102170;2015-11-03;18:00:00;5.6;G
102170;2015-11-04;06:00:00;6.5;G
……
```

Find the highest temperature in 2014 and 2015.

Show the year and highest temperature in the result

- Conceptual design
  - ✓ Understand the question and data
  - ✓ How to form key, value pair and what RDD operations are needed
  - ✓ What operations are needed during mapping and reducing?
- Write pyspark code

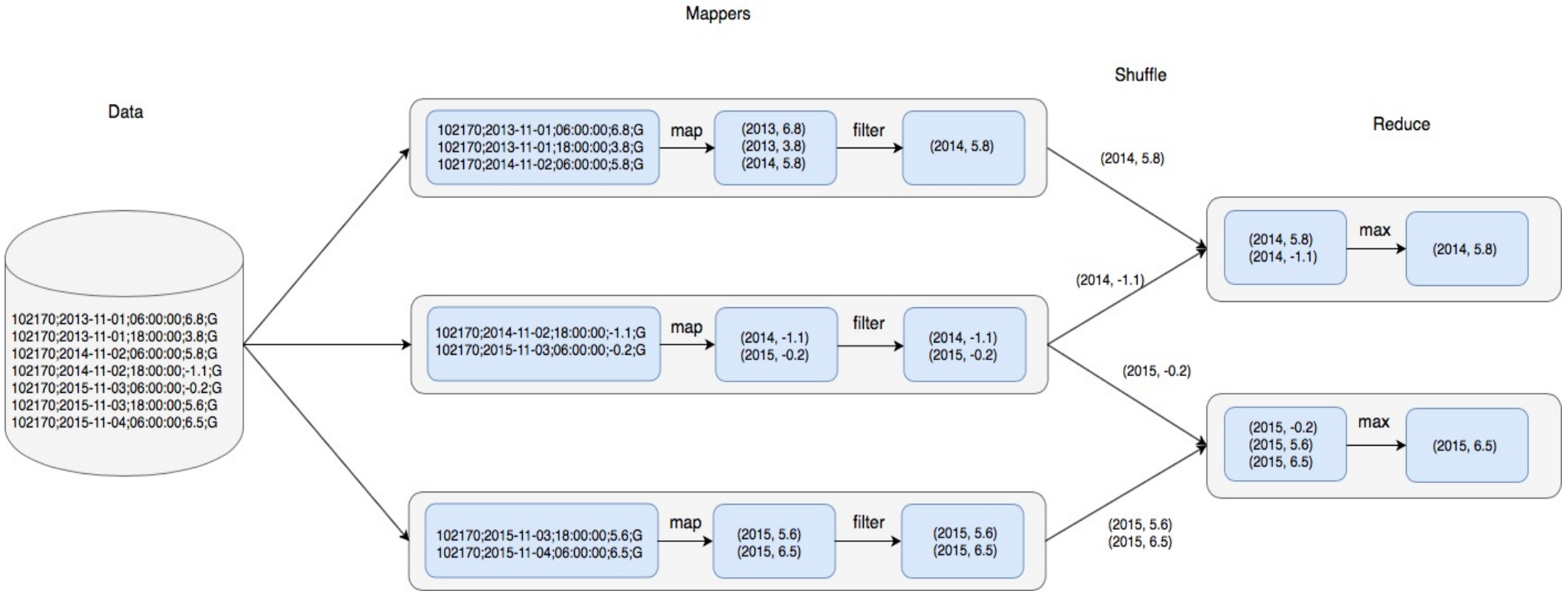
Headers for *temperature-readings.csv*

Station number	Date	Time	Air temperature (in °C)	Quality[3]

102170;2013-11-01;06:00:00;6.8;G
102170;2013-11-01;18:00:00;3.8;G
102170;2014-11-02;06:00:00;5.8;G
102170;2014-11-02;18:00:00;-1.1;G
102170;2015-11-03;06:00:00;-0.2;G
102170;2015-11-03;18:00:00;5.6;G
102170;2015-11-04;06:00:00;6.5;G
……

Solution – Conceptual design

- Extract year as key and temperature as value
- Filter data (2014 and 2015)
- Reduce by key and then compare each two values to get the higher temperature.



- Step 1. To create a SparkContext object which tells Spark how to access a cluster.
- Step 2. To create distributed datasets (RDD) from HDFS.
- Step 3. RDD operating: transformation, action

Solution

- Question : Find the highest temperature in 2014 and 2015.

```
1  from pyspark import SparkContext
2  def max_temperature(a,b):
3      if a>=b:
4          return a
5      else:
6          return b
7  sc = SparkContext(appName = "exercise test")
8  temperature_file = sc.textFile("/user/x_huali/data/temperature-readings.csv")
9  lines = temperature_file.map(lambda line: line.split(";"))
10 year_temperature = lines.map(lambda x: (x[1][0:4], float(x[3])))
11 year_temperature = year_temperature.filter(lambda x: int(x[0])==2014 or int(x[0])==2015)
12 #max_temperatures = year_temperature.reduceByKey(lambda a,b: a if a>=b else b)
13 #max_temperatures = year_temperature.reduceByKey(max)
14 max_temperatures = year_temperature.reduceByKey(max_temperature)
15 max_temperatures.saveAsTextFile("max_temperature_2014_2015")
```

- line 7: create SparkContext object
- line 8: get the file on hdfs, default home path '/user/USERNAME/
- line 9: transform the data by splitting each line
- line 10: transform the data by extracting year and temperature as tuple
- line 11: filter data by year
- line 14: reducer, to get the max temperature,
  - line 12, line 13, line 14 show the different ways of passing functions to Spark
- line 15: save result in a directory

For the first assignment in BDA1

- 1) What are the highest temperatures measured each year for the period 1950-2014. Provide the listed sorted in the descending order with respect to the maximum temperature
- Exercise
  - ✓ Conceptual design (how to form key, value pairs and what RDD operations are needed)
  - ✓ Write pyspark code (Pseudocode)

Headers for *temperature-readings.csv*

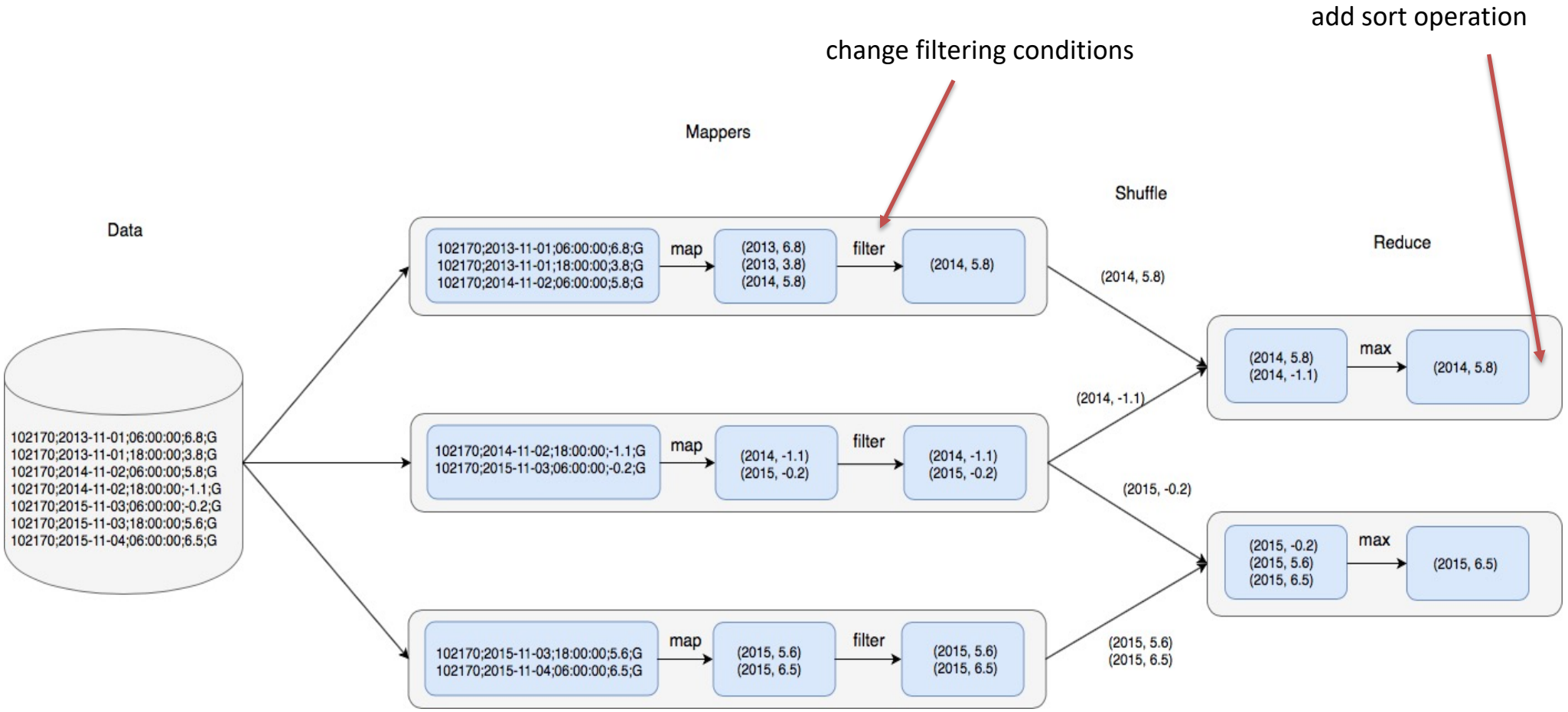
Station number	Date	Time	Air temperature (in °C)	Quality[3]

102170;2013-11-01;06:00:00;6.8;G
102170;2013-11-01;18:00:00;3.8;G
102170;2014-11-02;06:00:00;5.8;G
102170;2014-11-02;18:00:00;-1.1;G
102170;2015-11-03;06:00:00;-0.2;G
102170;2015-11-03;18:00:00;5.6;G
102170;2015-11-04;06:00:00;6.5;G
…….

How to write PySpark code
Step 1: To create a SparkContext object
Step 2: To create distributed datasets (RDD)
Step 3: RDD operating

Solution – Conceptual design

- Extract year and temperature
- Filter data ~~(2014 and 2015)~~ 1950-2014
- Reduce by key to get maximum
- Sort



The previous design for finding max temperatures in 2014 and 2015

Solution

- Pre steps: Distribute your data
- Step 1. To create a SparkContext object which tells Spark how to access a cluster.
- Step 2. To create distributed datasets (RDD) from HDFS.
- Step 3. RDD operating: transformation, action

```
1  from pyspark import SparkContext
2  def max_temperature(a,b):
3      if a>=b:
4          return a
5      else:
6          return b
7  sc = SparkContext(appName = "exercise test")
8  temperature_file = sc.textFile("/user/x_huali/data/temperature-readings.csv")
9  lines = temperature_file.map(lambda line: line.split(";"))
10 year_temperature = lines.map(lambda x: (x[1][0:4], float(x[3])))
11 year_temperature = year_temperature.filter(lambda x: int(x[0])>=1950 and int(x[0])<=2014)
12 #max_temperatures = year_temperature.reduceByKey(lambda a,b: a if a>=b else b)
13 #max_temperatures = year_temperature.reduceByKey(max)
14 max_temperatures = year_temperature.reduceByKey(max_temperature)
15 max_temperaturesSorted = max_temperatures.sortBy(ascending = False, keyfunc=lambda k: k[1])
16 max_temperaturesSorted.saveAsTextFile("max_temperature")
```

- line 7: create SparkContext object
- line 8: get the file on hdfs, default home path '/user/USERNAME/
- line 9: transform the data by splitting each line
- line 10: transform the data by extracting year and temperature as tuple
- line 11: filter data by a time period
- line 14: reducer, to get the max temperature,
  - line 12, line 13, line 14 show the different ways of passing functions to Spark
- line 15: sort result by temperature
- line 16: save result in a directory

*How to work on Sigma

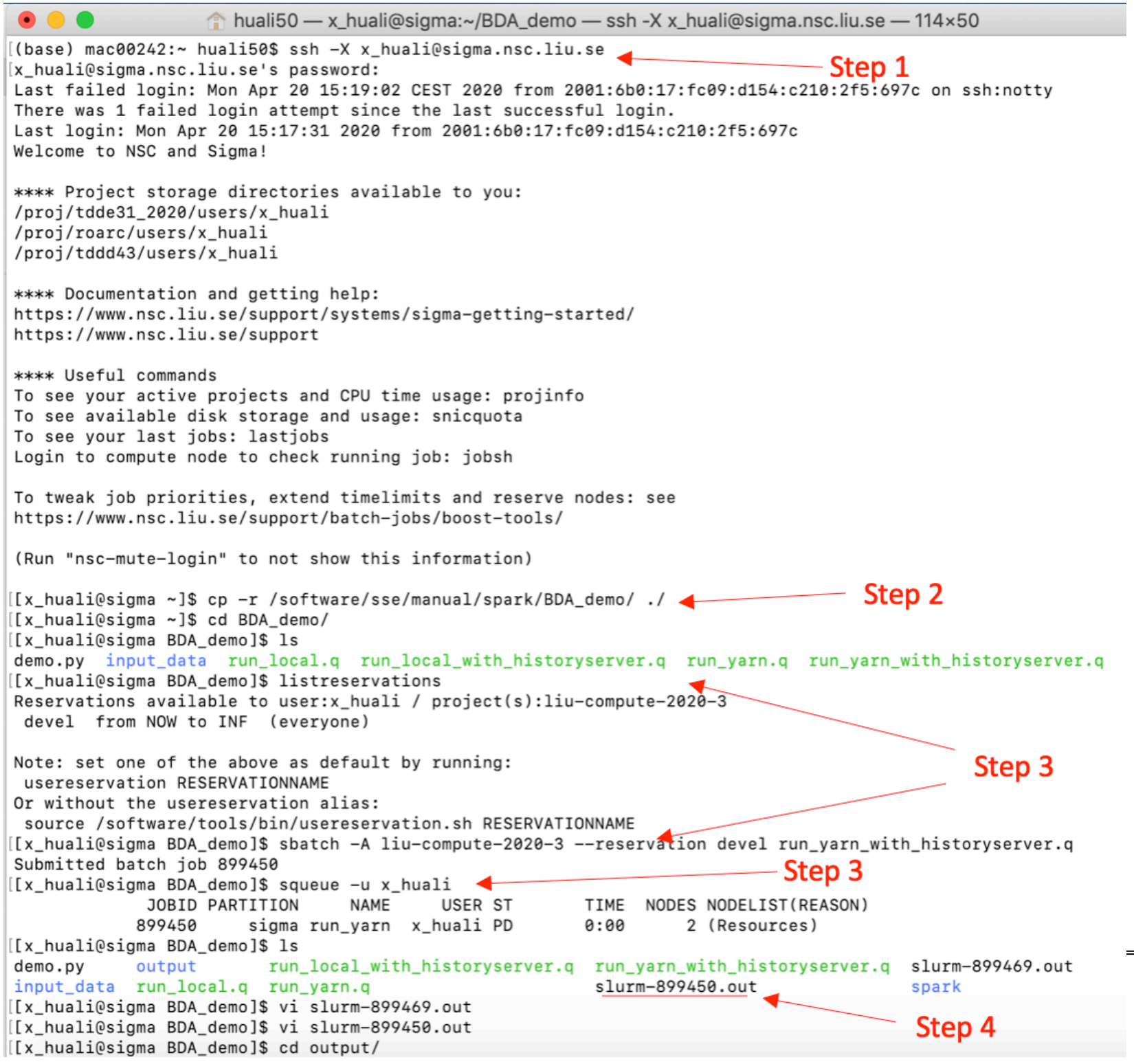
- Connection
  - Thinlinc connection (sigma.nsc.liu.se)
  - ssh –X username@sigma.nsc.liu.se
    - If don't have X forwarding configuration on you machine. You can use thinlinc to connect 'thinlinc.edu.liu.se', then use 'ssh -X' to connect sigma.
- Submit, monitor, cancel jobs at Sigma

  sbatch, squeue, scancel commands
- Demo on sigma

  /software/sse/manual/spark/BDA_demo/

  /software/sse/manual/spark/examples/pyspark_on_hdfs/
- The script for interacting with HDFS and running pyspark code

  run_local.q, run_local_with_historyserver.q, run_yarn.q, run_yarn_with_historyserver.q


huali50 — x_huali@sigma:~/BDA_demo — ssh -X x_huali@sigma.nsc.liu.se — 114×50
(base) mac00242:~ huali50$ ssh -X x_huali@sigma.nsc.liu.se
x_huali@sigma.nsc.liu.se's password:
Last failed login: Mon Apr 20 15:19:02 CEST 2020 from 2001:6b0:17:fc09:d154:c210:2f5:697c on ssh:notty
There was 1 failed login attempt since the last successful login.
Last login: Mon Apr 20 15:17:31 2020 from 2001:6b0:17:fc09:d154:c210:2f5:697c
Welcome to NSC and Sigma!
**** Project storage directories available to you:
/proj/tdde31_2020/users/x_huali
/proj/roarc/users/x_huali
/proj/tddd43/users/x_huali
**** Documentation and getting help:
https://www.nsc.liu.se/support/systems/sigma-getting-started/
https://www.nsc.liu.se/support
**** Useful commands
To see your active projects and CPU time usage: projinfo
To see available disk storage and usage: snicquota
To see your last jobs: lastjobs
Login to compute node to check running job: jobsh
To tweak job priorities, extend timelimits and reserve nodes: see
https://www.nsc.liu.se/support/batch-jobs/boost-tools/
(Run "nsc-mute-login" to not show this information)
[x_huali@sigma ~]$ cp -r /software/sse/manual/spark/BDA_demo/ ./
[x_huali@sigma ~]$ cd BDA_demo/
[x_huali@sigma BDA_demo]$ ls
demo.py input_data run_local.q run_local_with_historyserver.q run_yarn.q run_yarn_with_historyserver.q
[x_huali@sigma BDA_demo]$ listreservations
Reservations available to user:x_huali / project(s):liu-compute-2020-3
devel from NOW to INF (everyone)
Note: set one of the above as default by running:
usereservation RESERVATIONNAME
Or without the usereservation alias:
source /software/tools/bin/usereservation.sh RESERVATIONNAME
[x_huali@sigma BDA_demo]$ sbatch -A liu-compute-2020-3 --reservation devel run_yarn_with_historyserver.q
Submitted batch job 899450
[x_huali@sigma BDA_demo]$ squeue -u x_huali
JOBID PARTITION NAME USER ST TIME NODES NODELIST(REASON)
899450 sigma run_yarn x_huali PD 0:00 2 (Resources)
[x_huali@sigma BDA_demo]$ ls
demo.py output run_local_with_historyserver.q run_yarn_with_historyserver.q slurm-899469.out
input_data run_local.q run_yarn.q slurm-899450.out spark
[x_huali@sigma BDA_demo]$ vi slurm-899469.out
[x_huali@sigma BDA_demo]$ vi slurm-899450.out
[x_huali@sigma BDA_demo]$ cd output/
Step 1
Step 2
Step 3
Step 3
Step 4

huali50 — x_huali@sigma:~/BDA_demo — ssh -X x_huali@sigma.nsc.liu.se — 139×71

```
#!/bin/bash
#SBATCH --time=10:00
#SBATCH --nodes=2
#SBATCH --exclusive

module add spark/.2.4.3-hadoop-2.7-nsc1

# Cleanup and start from scratch
rm -rf spark

echo "START AT: $(date)"

hadoop_setup

echo "Prepare output and input directories and files..."
# The following command will make folders on your home folder on HDFS, the input and output folders should be corresponding to the paramete
r you give to textFile and saveAsTextFile functions in the code
hadoop fs -mkdir -p "BDA" "BDA/input"
hadoop fs -test -d "BDA/output"
if [ "$?" == "0" ]; then
    hadoop fs -rm -r "BDA/output"
fi

hadoop fs -copyFromLocal ./input_data/temperature-readings-small.csv "BDA/input/"
# Remove the comment when you need specifc file below
#hadoop fs -copyFromLocal ./input_data/temperature-readings.csv "BDA/input/"
#hadoop fs -copyFromLocal ./input_data/precipitation-readings.csv "BDA/input/"
#hadoop fs -copyFromLocal ./input_data/stations.csv "BDA/input/"
#hadoop fs -copyFromLocal ./input_data/stations-Ostergotland.csv "BDA/input/"

# Run your program
echo "Running Your program..."
exec 5>&1
APPLICATION_ID=$(spark-submit --conf spark.eventLog.enabled=true --deploy-mode cluster --master yarn --num-executors 9 --driver-memory 2g -
-executor-memory 2g --executor-cores 4 demo.py 2>&1 | tee >(cat - >&5) | awk '!found && /INFO.*Yarn.*Submitted application/ {tmp=gensub(/^.
*Submitted application (.*)$/,"\\1","g");print tmp; found=1}')

echo "================ FINAL OUTPUT ============================================="
hadoop fs -cat "BDA/output"/*
echo "==========================================================================="
echo "Applicaton id: $APPLICATION_ID"
echo "==========================================================================="
echo "=                              stderr                                     ="
echo "==========================================================================="
yarn logs -applicationId "$APPLICATION_ID" | awk -F: '/^LogType/ {if($2=="stderr") {output=1} else {output=0}} output==1 {print}'
echo "==========================================================================="
echo "=                              result                                     ="
echo "==========================================================================="
yarn logs -applicationId "$APPLICATION_ID" | awk -F: '/^LogType/ {if($2=="stdout") {output=1} else {output=0}} output==1 {print}' | grep -v
 "WARN\|INFO"

rm -rf output
hadoop fs -copyToLocal 'BDA/output' ./
hadoop_stop

echo "END AT: $(date)"
```

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