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Learning Big Data Computing with Hadoop

Homework 2 for CS 6220 Big Data Systems & Analytics

Problem 3. Learning Big Data Computing with Hadoop and/or Spark MapReduce

For this homework, I chose to complete Option 1 of Problem 3.

Requirements:

Installed software required to run the programs in this repository:

- Java 14.0.2
- JDK 14.0.2
- Hadoop 3.3.0
- Git 2.28.0 (optional)

My system description:

Specifications of the machine I used to run the programs in this repository:

- macOS Catalina (10.15.6)
- 2 GHz Quad-Core Intel Core i5 (10th Generation)
- 16 GB RAM
- 500 GB SSD
- Hadoop running on Pseudo-Distributed mode

Repository Folder Structure:

- **input:**
  - All text inputs used for the MapReduce jobs.
- **WordCount:**
  - Java MapReduce program to count the occurance of each word in a document or body of documents.
- **Top100Words:**
  - Java MapReduce program to find the top 100 most common words across a body of documents.
- **output:**
  - All outputs from the MapReduce jobs.
- **import_books:**
  - Contains the jupyter notebook used to import books from the Gutenbert Project.
- **images:**
  - Contains all images used in the Readme file.

1. HDFS Installation:

The first step of this homework was to setup HDFS in my local machine. In order to do so, I installed Java and Hadoop and edited the necessary configuration files.

- **Hadoop version:** 3.3.0
- **Hadoop mode:** Pseudo-Distributed (1 on the hdfs-site.xml configuration file)
- **hadoop command** is available globally (hadoop binary files were added to the path)
- **Configuration File Edits:**
  - **hadoop-env.sh**: Make sure to set export **JAVA_HOME** to the the Java home location in your machine.
  - **core-site.xml**:

```
<configuration>
  <property>
    <name>hadoop.tmp.dir</name>
    <value>/usr/local/Cellar/hadoop/hdfs/tmp</value>
    <description>A base for other temporary directories</description>
  </property>
```

```
  <property>
    <name>fs.default.name</name>
    <value>hdfs://localhost:8020</value>
  </property>
</configuration>
```

-
  - **mapred-site.xml**:

```
<configuration>
  <property>
    <name>mapred.job.tracker</name>
    <value>localhost:8021</value>
  </property>
</configuration>
```

-
  - **hdfs-site.xml**:

```
<configuration>
  <property>
    <name>dfs.replication</name>
    <value>1</value>
  </property>
</configuration>
```

Since, my computer was running macOS I found the following installation tutorial very helpful: https://medium.com/beeranddiapers/installing-hadoop-on-mac-a9a3649dbc4d

If you are running Windows you can follow this tutorial: https://towardsdatascience.com/installing-hadoop-3-2-1-single-node-cluster-on-windows-10-ac258dd48aef

If you running Linux, you can follow the offical Apache Hadoop documentation: https://hadoop.apache.org/docs/stable/hadoop-project-dist/hadoop-common/SingleCluster.html

After installing HDFS, start all services by running the start-all.sh script on the sbin folder inside the hadoop folder.

- **Resource Manager Screenshot:**

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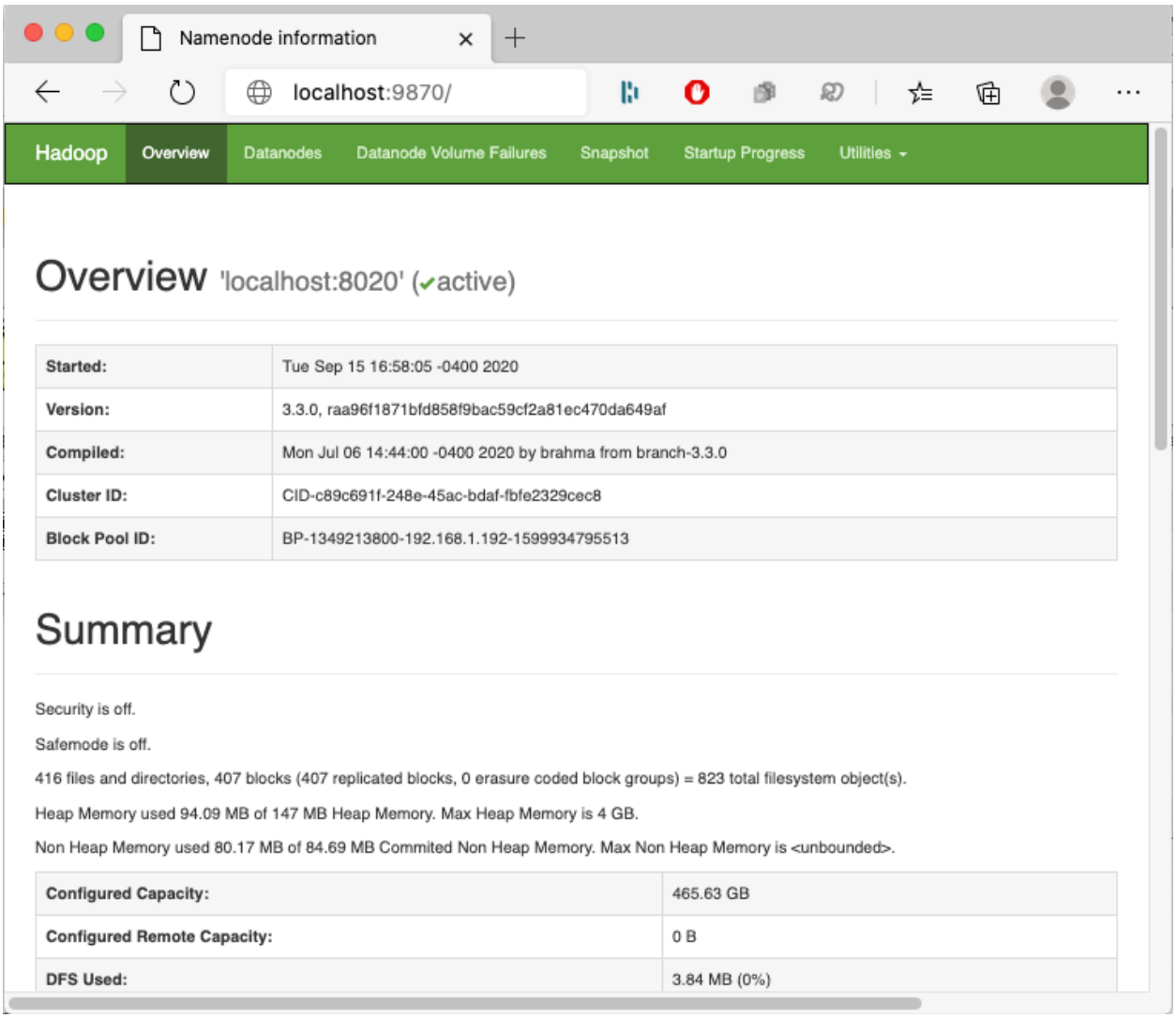
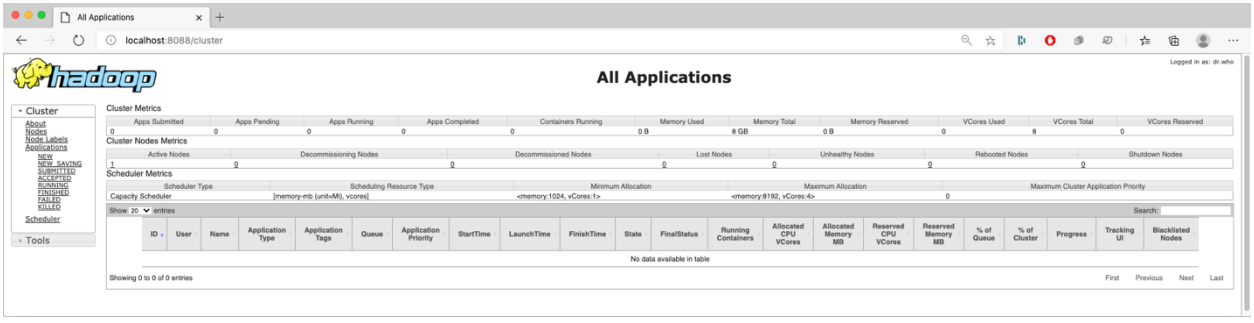
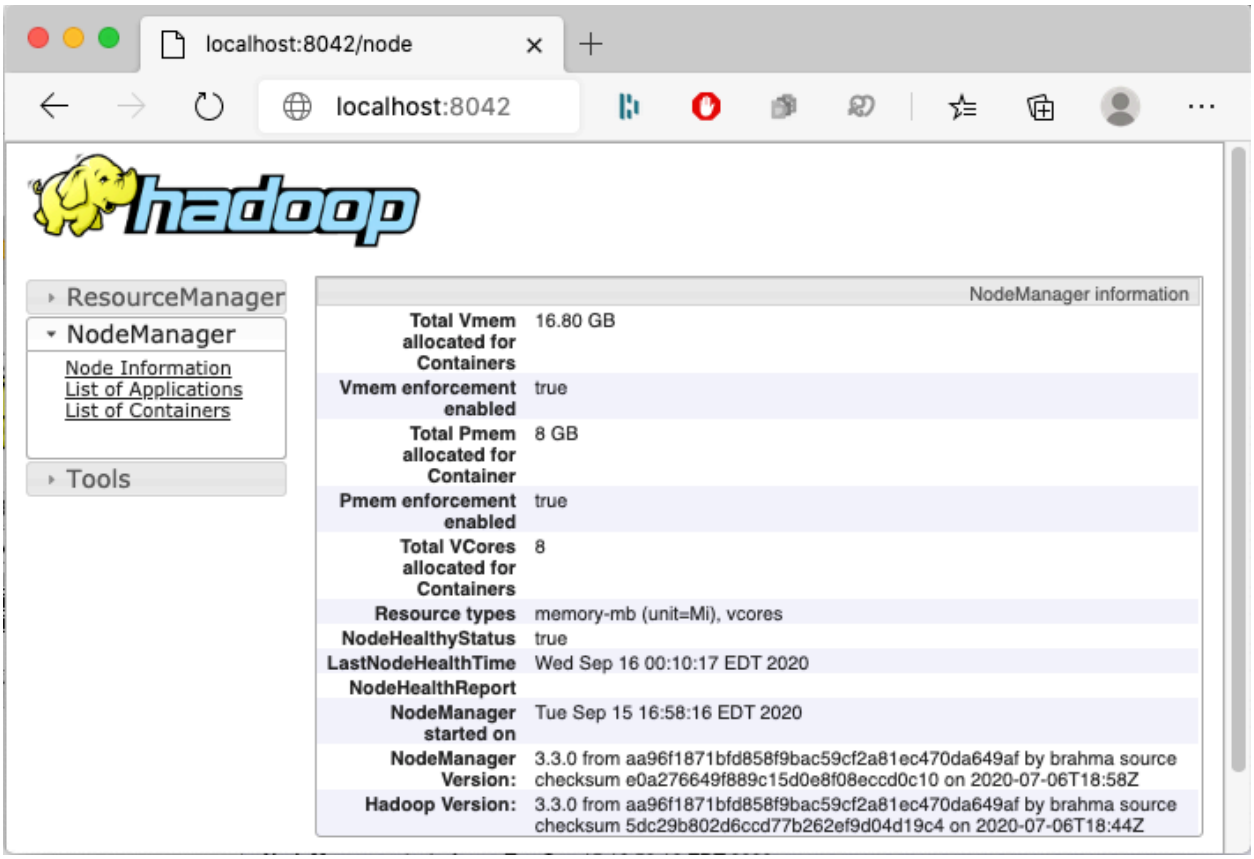


- **JobTracker Screenshot:**



- **Node Manager Screenshot:**



2. Data:

A number of different text files were used was input data for this homework. They are all saved in the input folder.

- american_pie.txt:
    - lyrics to the song American Pie by Don McLean, obtained from https://www.letras.com/don-mclean/25411/
- hamlet.txt:
    - William Shakespeare's famous tragedy Hamlet, obtained from https://gist.github.com/provpup/2fc41686eab7400b796b
- charles_dikens:
    - this folder contains the 20 books published by the famous English author Charles Dickens.

    - These files were obtained from *Project Gutenberg* using the Gutenberg python library to fetch the data.
    - You can run the Jupyter notebook /import_books/import_charles_dickens_books.ipynb to understand the process.

- bbc_tech_news:

    - This folder contains 401 news articles by BBC on the topic of Technology.
    - The data was obtained from http://mlg.ucd.ie/datasets/bbc.html

- song_lyrics:

    - This data set contains the lyrics of songs by a number of different aritsts. For each artist, all of his or her lyrics were saved as a single txt file.
    - The data was obtained from https://www.kaggle.com/paultimothymooney/poetry
    - I manually subdivided the artists into four main genres:
        - Pop: 11 aritsts
        - Rock: 13 aritsts
        - Folk/Country: 6 aritsts
        - Hip-Hop: 11 aritsts

- Saving the data on HDFS:

    - To save the input data on HDFS, you just need to run the export_inputs.sh shell script in the root directory of the project by running the following command:

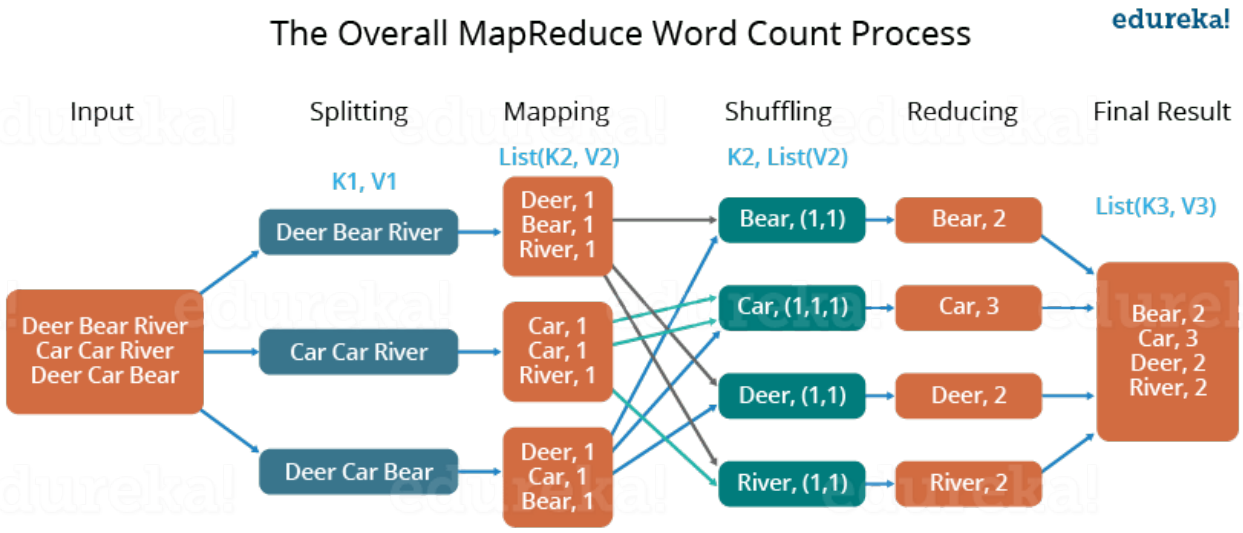
```
    sh export_inputs.sh
```

In my machine, the script took ~25 seconds to run.

3. MapReduce WordCount:

This is a classic MapReduce problem where you take a document (or group of documents) as input and output all the different words sorted alphabetically along with the number of times each one occured in the document or corpus.

- Job Diagram:



This image was obtained from https://www.edureka.co/blog/mapreduce-tutorial/

- As a starting point, I used the MapReducde tutorial on the official Apache Hadoop website https://hadoop.apache.org/docs/current/hadoop-mapreduce-client/hadoop-mapreduce-client-core/MapReduceTutorial.html .
- After compiling and running the program, I noticed that it was not filtering out punctuation or unusual characters after splitting the text based on whitespace " ". This lead to strings like [first,], [who and tears- being considered distinct words.
- Steps to solve this problem:
    - Eliminating all characters besides letters, hyphens (-) and single apostrophes (')
    - After the initial filtering, keep only hyphens or apostrophes that appeared inside a word (e.g. Bye-bye or Nature's)
    - Standardizing the letter case by capitalizing the first letter in each word (e.g. Apple instead of apple, APPLE or aPpLe)

```
while (itr.hasMoreTokens()) {
                word = itr.nextToken();
                String pattern = "[^\\-'A-Za-z]+";
                word = word.replaceAll(pattern,"");
                if (word.length() > 0) {
                    int start = 0;
                    while (start < word.length()){
                        if (!Character.isLetter(word.charAt(start))) ++start;
                        else break;
                    }
```

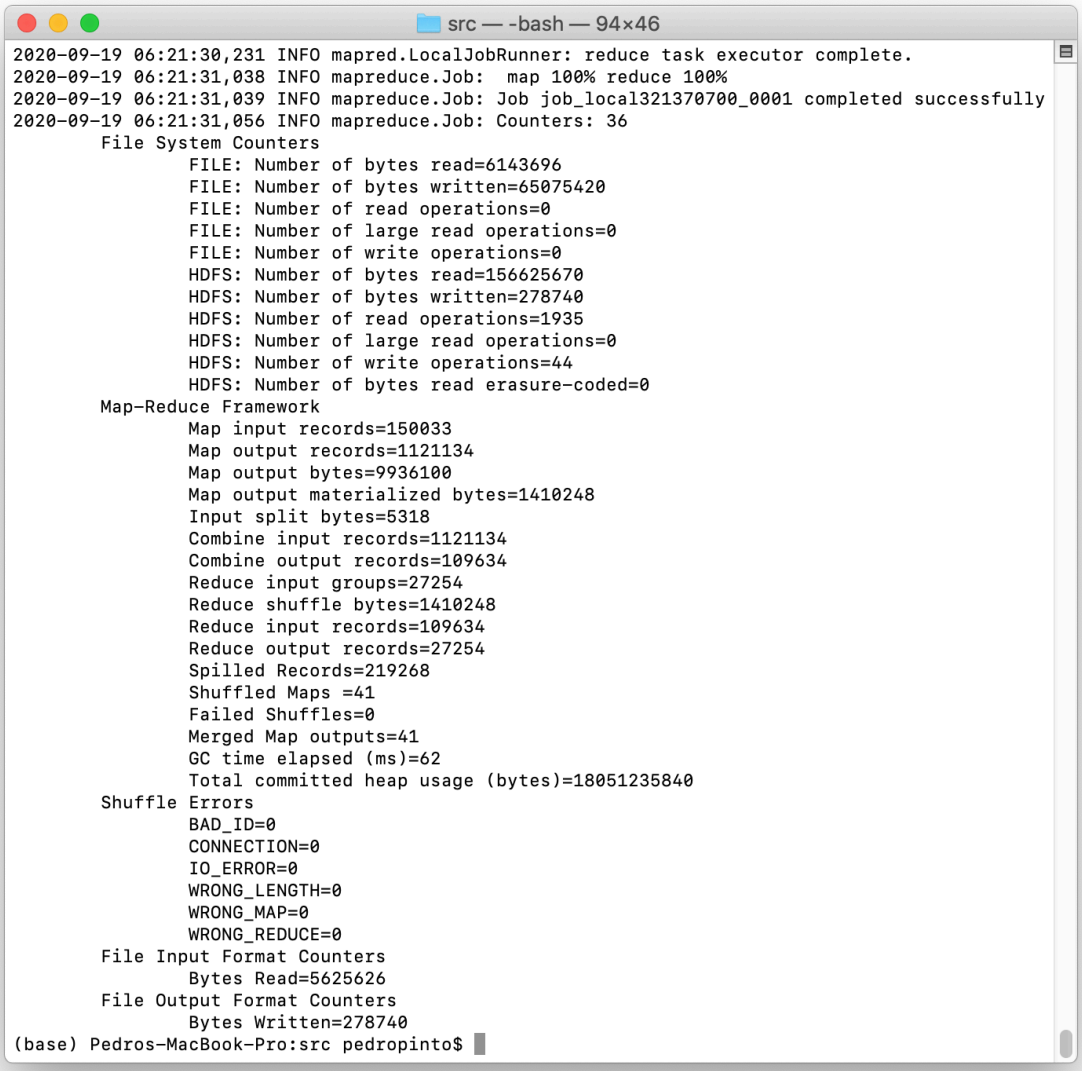
```
                    int end = Character.isLetter(word.charAt(word.length()-1)) ?
word.length() : word.length() - 1;
                    if (end < start) end = start;
                    word = word.substring(start,end);
                    if (word.length() > 0) {
                        word = word.substring(0, 1).toUpperCase() +
word.substring(1).toLowerCase();
                        clean_word.set(word);
                        context.write(clean_word, one);
                    }
                }
```

- **Running the program:**
    - To run the MapReduce job, you need to change directories to WordCount/src and run the word_count.sh shell script by running the following commands from the root directory of the repository:

```
    cd WordCount/src
    sh word_count.sh
```

In my machine, the script took **~40 seconds** to run (including the time it takes to print all the progress reports to the terminal).

- Portion of a MapReduce successful job feedback message:



- Portion of a MapReduce WordCount job output:

```
A       18
About   1
Above   1
Adjourned       1
Admire  1
Again   1
Ago     1
Air     1
All     3
```

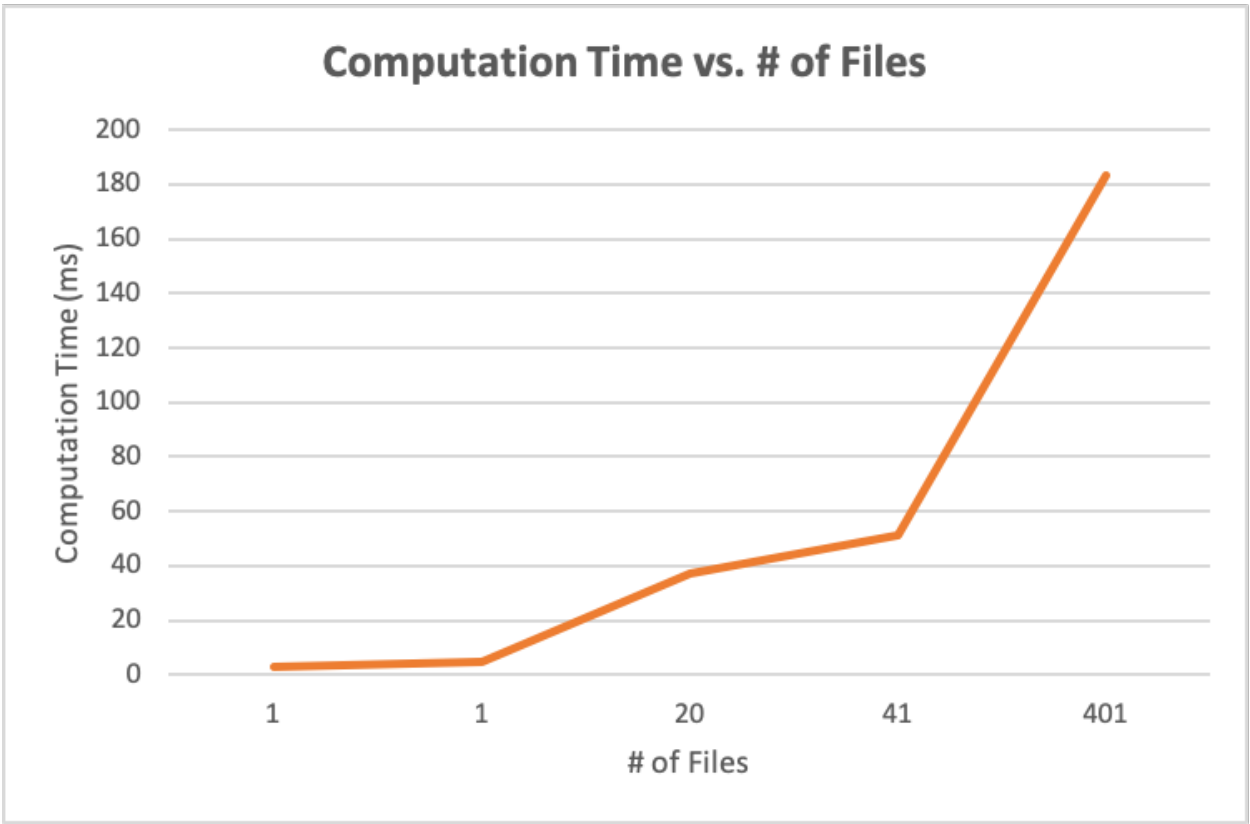
```
American        7
And     37
Angel   1
As      2
Asked   1
Away    1
Bad     1
Band    1
Be      17
Been    1
```

- **Performance Analysis:**

Dataset	Size	# of Files	Time Elapsed	# of Unique Words
American Pie	4 KB	1	3 ms	313
Hamlet	192 KB	1	5 ms	4835
Charles Dickens	6.4 MB	20	37 ms	45,331
BBC Tech News	1.2 MB	401	183 ms	12,673
Song Lyrics	5.6 MB	41	51 ms	27,254

As can be seen from the table above, while the size of the data set does influence in the computation time, the total number of files has a way more significant impact. That makes perfect since given that writing to and reading from disk are time-consuming tasks (if my machine had a traditional hard drive instead of a solid state drive this discrepancy would probably be even higher).

- **Computation Time vs # of Files Graph:**



It would be very interesting to run this program on an actual Hadoop cluster with multiple nodes and compare its performance to my single machine running Hadoop on pseudo-distributed mode. Hadoop excels in the world of Big Data by providing horizontal expansion capabilities with commodity hardware, parallel computation performed where the data resides and robust fault-tolerance.

4. MapReduce Top100Words:

This is a more complicated MapReduce problem where you take group of documents (corpus) as input and output **Top 100 words ranked in 3 different ways**:

- First, by the number of files in the corpus where that word appears.
- Second, by the total number of times that word appears in the corpus (in case multiple words appear on the same number of files).
- Third, sort the words alphabetically (as a final tie-breaker if necessary).

The final output will contain **100 words** displaying the number of documents where it appears and total number of occurances in the corpus separated by tabs (e.g.: **World 33 215**)

In order to achieve this, I made several changes to the WordCount program:

- Used a **HashMap to count the total occurances of each word per document** during the Mapper stage instead of writing it to the context every iteration:

```
    Map<String, Integer> word_list = new HashMap<String, Integer>();

    if (word.length() > 0) {
        word = word.substring(0, 1).toUpperCase() + word.substring(1).toLowerCase();

        Integer count = word_list.get(word);

        if (count == null) word_list.put(word, 1);
        else word_list.put(word, count + 1);
    }
```

- **Overrode the Mapper's cleanup method** to write compounded sums to the context only once. This way, each word will be written to context once for every document that contains that word (containing the number of times it appears in that document):

```
@Override
        protected void cleanup(Context context) throws IOException,
InterruptedException {
            for (String key : word_list.keySet()) {
                word_count.set(word_list.get(key));
                clean_word.set(key);
                context.write(clean_word, word_count);
            }
```

- Created the ***WordTuple*** class that implements the ***Comparable*** class inside the ***Reducer*** class to make the **"triple sorting"** process easier.

```
    public class WordTuple implements Comparable<WordTuple> {

            private int id = 1;
            private String word;
            private int document_count;
            private int total_count;

            WordTuple(String word, int document_count, int total_count) {
                this.word = word;
                this.document_count = document_count;
                this.total_count = total_count;
            }

            public int getDocCount() {
                return this.document_count;
            }
```

```
            public int getTotalCount() {
                return this.total_count;
            }

            public String getWord() {
                return this.word;
            }

            @Override
            public int compareTo(WordTuple o) {
                return this.id - o.id;
            }
        }
```

- **Overrode the Reducers's cleanup method** to receive an ***ArrayList of WordTuple*** objects, perform the "triple sort" and write top 100 words, the number of documents they appear in and the total number of occurances all documents separated by tabs:

```
   ArrayList<WordTuple> master_list = new ArrayList<>();

    @Override
        protected void cleanup(Context context) throws IOException,
InterruptedException {

            Comparator<WordTuple> comparison = Comparator
                    .comparing(WordTuple::getDocCount)
                    .thenComparing(WordTuple::getTotalCount)
                    .thenComparing(WordTuple::getWord);

            master_list.sort(comparison.reversed());

            int counter = 0;

            for (int i = 0; i < master_list.size(); i++) {
                if (counter++ > 99) break;
                String word = master_list.get(i).getWord();
                int occ = master_list.get(i).getDocCount();
                int tot = master_list.get(i).getTotalCount();
                final_result.set(Integer.toString(occ) + "\t" +
Integer.toString(tot));
                context.write(new Text(word), final_result);
            }
        }
```

Additionally, I also decided to include a look-up HashSet of the 150 most common words in the English language (found at http://shabanali.com/upload/1000words.pdf) and exclude them from the output. Since words like "The", "Be" and "Of" are so commonly used, that they would not add much value when comparing different groups of documents.

- I achieved this by always checking if the word was **contained in the HashSet** before adding any object to the WordTuple Arraylist.

```
    String[] common_words = {"The", "Of", "And", "A", "To", "In", "Is", "You",
"That", "It", "He", "Was", "For",
                    "On", "Are", "As", "With", "His", "They", "I", "At", "Be",
"This", "Have", "From", "Or", "One",
                    "Had", "By", "Word", "But", "Not", "What", "All", "Were", "We",
"When", "Your", "Can", "Said",
                    "There", "Use", "An", "Each", "Which", "She", "Do", "How",
"Their", "If", "Will", "Up", "Other",
                    "About", "Out", "Many", "Then", "Them", "These", "So", "Some",
"Her", "Would", "Make", "Like",
                    "Him", "Into", "Time", "Has", "Look", "Two", "More", "Write",
"Go", "See", "Number", "No", "Way",
                    "Could", "People", "My", "Than", "First", "Water", "Been",
"Call", "Who", "Oil", "Its", "Now",
                    "Find", "Long", "Down", "Day", "Did", "Get", "Come", "Made",
"May", "Part", "Over", "New", "Sound",
                    "Take", "Only", "Little", "Work", "Know", "Place", "Year",
"Live", "Me", "Back", "Give", "Most",
                    "Very", "After", "Thing", "Our", "Just", "Name", "Good",
"Sentence", "Man", "Think", "Say", "Great",
                    "Where", "Help", "Through", "Much", "Before", "Line", "Right",
"Too", "Mean", "Old", "Any", "Same",
                    "Tell", "Boy", "Follow", "Came", "Want", "Show", "Also",
"Around", "Form", "Three", "Small"};

            Set<String> common_words_set = new
HashSet<>(Arrays.asList(common_words));

            if (!common_words_set.contains(key.toString())) master_list.add(new
WordTuple(key.toString(), doc_count, total_count))
```

- **Running the program:**
    - To run the MapReduce job, you need to change directories to Top100Words/src and run the top_100_words.sh shell script by running the following commands from the root directory of the repository:

```
    cd Top100Words/src
    sh top_100_words.sh
```

In my machine, the script took **~45 seconds** to run (including the time it takes to print all the progress reports to the terminal).

- Portion of a MapReduce Top100Words job output:

```
    Such 201    377
    Technology  196     504
    Us  178     366
    Mr  175     509
    Users       173     407
```

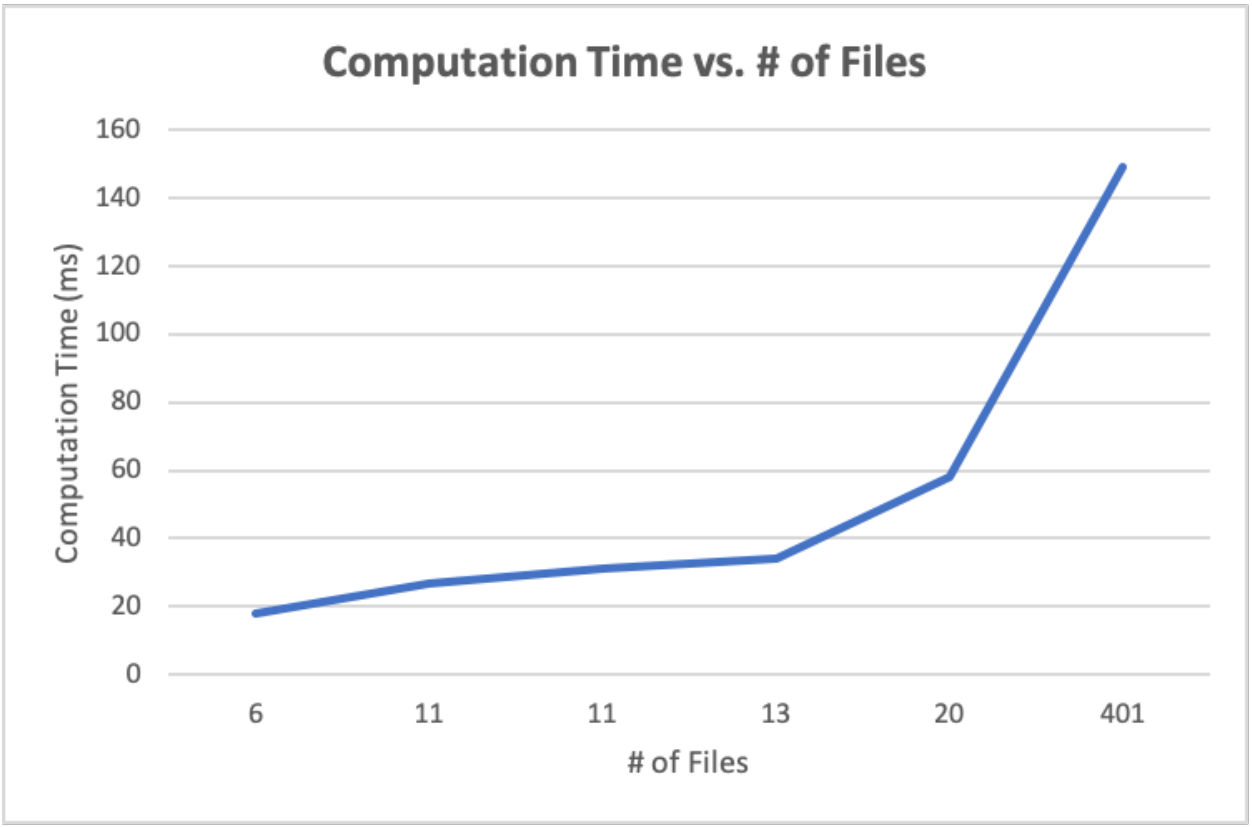
```
Being       169     279
Because     159     246
Used 156    281
Using       152     238
Those       149     251
Digital     139     373
Computer    136     299
Last 135    186
Million     134     253
Online      133     307
```

- **Performance Analysis:**

Dataset	Size	# of Files	Time Elapsed
Charles Dickens	6.4 MB	20	58 ms
BBC Tech News	1.2 MB	401	149 ms
Pop Lyrics	1.4 MB	11	27 ms
Rock Lyrics	1.4 MB	13	34 ms
Folk/Country Lyrics	672 KB	6	18 ms
Hip-Hop Lyrics	2.2 MB	11	31 ms

Once again, it can be confirmed how the total number of documents is most important factor when predicting computational time. It would also be very interesting to see how much faster this program would run in a larger scale Hadoop clsuter.

- **Computation Time vs # of Files Graph:**



- **Output Analysis:**

In order to illustrate the outputs of this MapReduce job, I created a few *Word Clouds* using the website https://worditout.com/word-cloud/:

- **Charles Dickens' Books:**

- **BBC Technology News:**

- **Pop Song Lyrics:**

- **Rock Song Lyrics:**

- **Folk/Country Song Lyrics:**

- **Hip-Hop Song Lyrics:**

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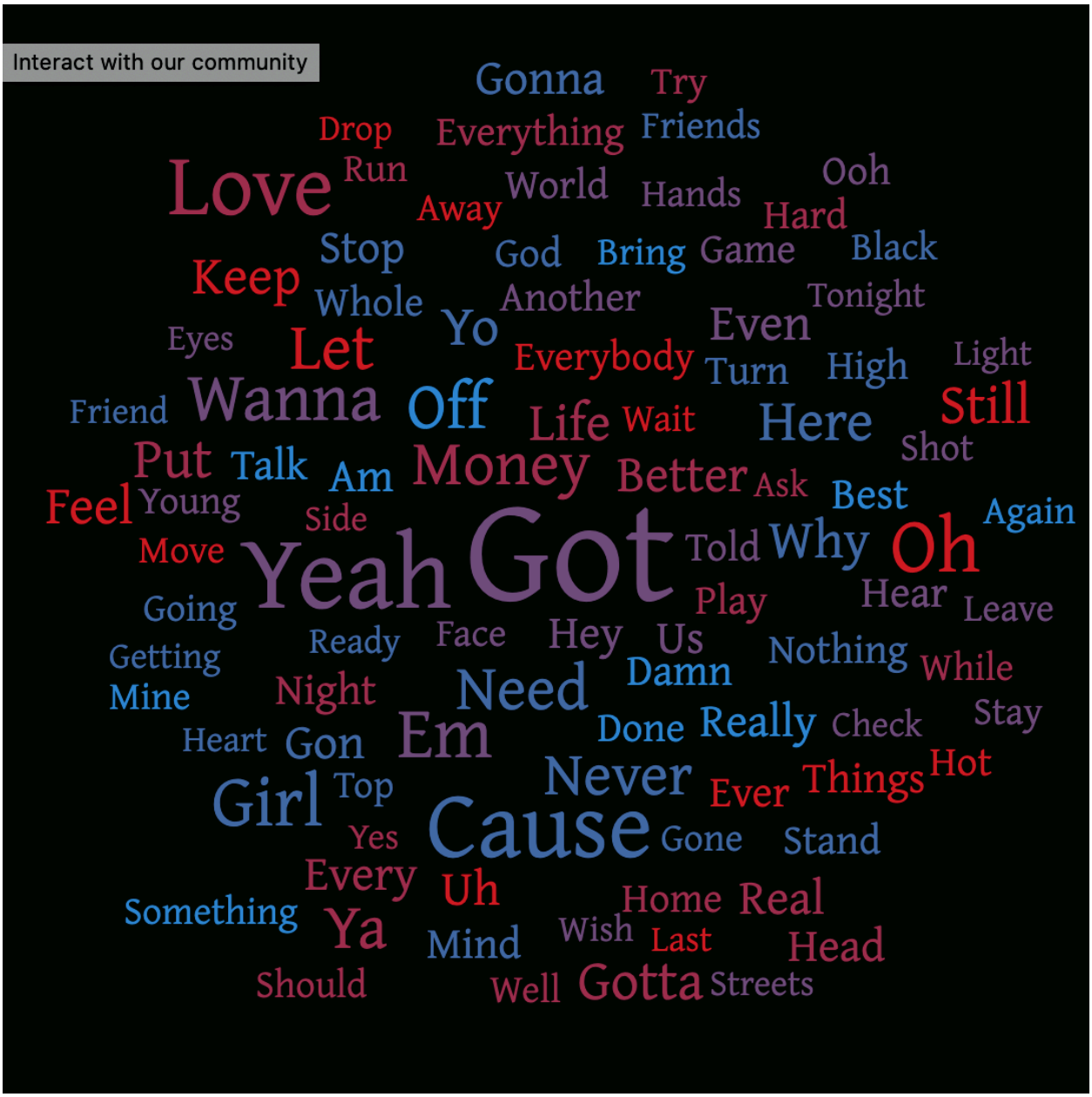

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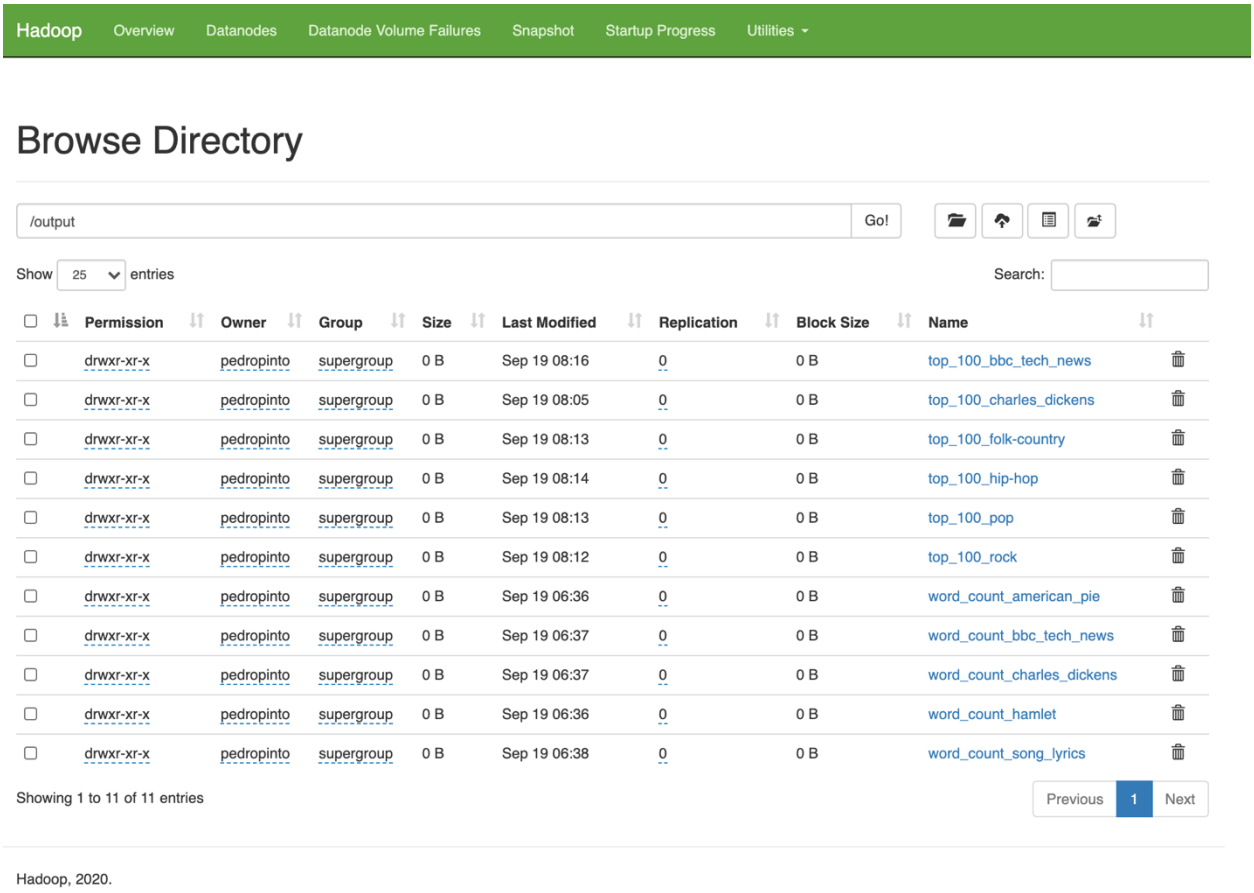
Final View of my HDFS Dashboard:



Conclusion:

This Homework was an amazing hands-on experience with big data processing in Hadoop. For the first time, I fully installed HDFS from scratch in my local machine, developed some really interesting MapReduce programs and tested them out with a variety of textual data sets. It was clear that, while the size of the files does influence performance, the number of files being processed influences way more due to the long time it takes to read/write to disk.

I'm looking forward to building on top of this knowledge in future homeworks by building more intricate MapReduce programs, comparing its performance with other tools like Spark and start performing more in depth analytics using libraries such as Apache Mahout and Spark ML lib.