Quick answers to common problems

Hadoop MapReduce Cookbook

Recipes for analyzing large and complex datasets with Hadoop MapReduce

Srinath Perera
Thilina Gunarathne

[PACKT] PUBLISHING open source* community experience distilled

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I would like to thank my wife Miyuru and my parents, whose never-ending support keeps me going. I also like to thanks Sanjiva from WSO2 who encourage us to make our mark even though project like these are not in the job description. Finally I would like to thank my colleges at WSO2 for ideas and companionship that have shaped the book in many ways.

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I thank my co-workers.

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Preface

Hadoop MapReduce Cookbook helps readers learn to process large and complex datasets. The book starts in a simple manner, but still provides in-depth knowledge of Hadoop. It is a simple one-stop guide on how to get things done. It has 90 recipes, presented in a simple and straightforward manner, with step-by-step instructions and real world examples.

This product includes software developed at The Apache Software Foundation (`http://www.apache.org/`).

What this book covers

Chapter 1, *Getting Hadoop Up and Running in a Cluster*, explains how to install and run Hadoop both as a single node as well as a cluster.

Chapter 2, *Advanced HDFS*, introduces a set of advanced HDFS operations that would be useful when performing large-scale data processing with Hadoop MapReduce as well as with non-MapReduce use cases.

Chapter 3, *Advanced Hadoop MapReduce Administration*, explains how to change configurations and security of a Hadoop installation and how to debug.

Chapter 4, *Developing Complex Hadoop MapReduce Applications*, introduces you to several advanced Hadoop MapReduce features that will help you to develop highly customized, efficient MapReduce applications.

Chapter 5, *Hadoop Ecosystem*, introduces the other projects related to Hadoop such HBase, Hive, and Pig.

Chapter 6, *Analytics*, explains how to calculate basic analytics using Hadoop.

Chapter 7, *Searching and Indexing*, introduces you to several tools and techniques that you can use with Apache Hadoop to perform large-scale searching and indexing.

Chapter 8, *Classifications, Recommendations, and Finding Relationships*, explains how to implement complex algorithms such as classifications, recommendations, and finding relationships using Hadoop.

Chapter 9, *Mass Text Data Processing*, explains how to use Hadoop and Mahout to process large text datasets, and how to perform data preprocessing and loading operations using Hadoop.

Chapter 10, *Cloud Deployments: Using Hadoop on Clouds*, explains how to use Amazon Elastic MapReduce (EMR) and Apache Whirr to deploy and execute Hadoop MapReduce, Pig, Hive, and HBase computations on cloud infrastructures.

What you need for this book

All you need is access to a computer running Linux Operating system, and Internet. Also, Java knowledge is required.

Who this book is for

For big data enthusiasts and would be Hadoop programmers. The books for Java programmers who either have not worked with Hadoop at all, or who knows Hadoop and MapReduce but want to try out things and get into details. It is also a one-stop reference for most of your Hadoop tasks.

Conventions

In this book, you will find a number of styles of text that distinguish between different kinds of information. Here are some examples of these styles, and an explanation of their meaning.

Code words in text are shown as follows: "From this point onward, we shall call the unpacked Hadoop directory `HADOOP_HOME`."

A block of code is set as follows:

```
public void map(Object key, Text value, Context context)
  throws IOException, InterruptedException
  {
    StringTokenizer itr = new StringTokenizer(value.toString());
    while (itr.hasMoreTokens())
    {
      word.set(itr.nextToken());
      context.write(word, new IntWritable(1));
     }
  }
```

Any command-line input or output is written as follows:

```
>tar -zxvf hadoop-1.x.x.tar.gz
```

New terms and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "Create a S3 bucket to upload the input data by clicking on **Create Bucket**".

Warnings or important notes appear in a box like this.

Tips and tricks appear like this.

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1
Getting Hadoop Up and Running in a Cluster

In this chapter, we will cover:

- Setting up Hadoop on your machine
- Writing the WordCount MapReduce sample, bundling it, and running it using standalone Hadoop
- Adding the combiner step to the WordCount MapReduce program
- Setting up HDFS
- Using the HDFS monitoring UI
- HDFS basic command-line file operations
- Setting Hadoop in a distributed cluster environment
- Running the WordCount program in a distributed cluster environment
- Using the MapReduce monitoring UI

Introduction

For many years, users who want to store and analyze data would store the data in a database and process it via SQL queries. The Web has changed most of the assumptions of this era. On the Web, the data is unstructured and large, and the databases can neither capture the data into a schema nor scale it to store and process it.

Google was one of the first organizations to face the problem, where they wanted to download the whole of the Internet and index it to support search queries. They built a framework for large-scale data processing borrowing from the "map" and "reduce" functions of the functional programming paradigm. They called the paradigm **MapReduce**.

Hadoop is the most widely known and widely used implementation of the MapReduce paradigm. This chapter introduces Hadoop, describes how to install Hadoop, and shows you how to run your first MapReduce job with Hadoop.

Hadoop installation consists of four types of nodes—a **NameNode**, **DataNodes**, a **JobTracker**, and **TaskTracker** HDFS nodes (NameNode and DataNodes) provide a distributed filesystem where the JobTracker manages the jobs and TaskTrackers run tasks that perform parts of the job. Users submit MapReduce jobs to the JobTracker, which runs each of the Map and Reduce parts of the initial job in TaskTrackers, collects results, and finally emits the results.

Hadoop provides three installation choices:

- **Local mode**: This is an unzip and run mode to get you started right away where all parts of Hadoop run within the same JVM
- **Pseudo distributed mode**: This mode will be run on different parts of Hadoop as different Java processors, but within a single machine
- **Distributed mode**: This is the real setup that spans multiple machines

We will discuss the local mode in the first three recipes, and Pseudo distributed and distributed modes in the last three recipes.

Setting up Hadoop on your machine

This recipe describes how to run Hadoop in the local mode.

Getting ready

Download and install Java 1.6 or higher version from `http://www.oracle.com/technetwork/java/javase/downloads/index.html`.

How to do it...

Now let us do the Hadoop installation:

1. Download the most recent Hadoop 1.0 branch distribution from `http://hadoop.apache.org/`.
2. Unzip the Hadoop distribution using the following command. You will have to change the `x.x` in the filename with the actual release you have downloaded. If you are using Windows, you should use your favorite archive program such as WinZip or WinRAR for extracting the distribution. From this point onward, we shall call the unpacked Hadoop directory `HADOOP_HOME`.

   ```
   >tar -zxvf hadoop-1.x.x.tar.gz
   ```

3. You can use Hadoop local mode after unzipping the distribution. Your installation is done. Now, you can run Hadoop jobs through `bin/hadoop` command, and we will elaborate that further in the next recipe.

How it works...

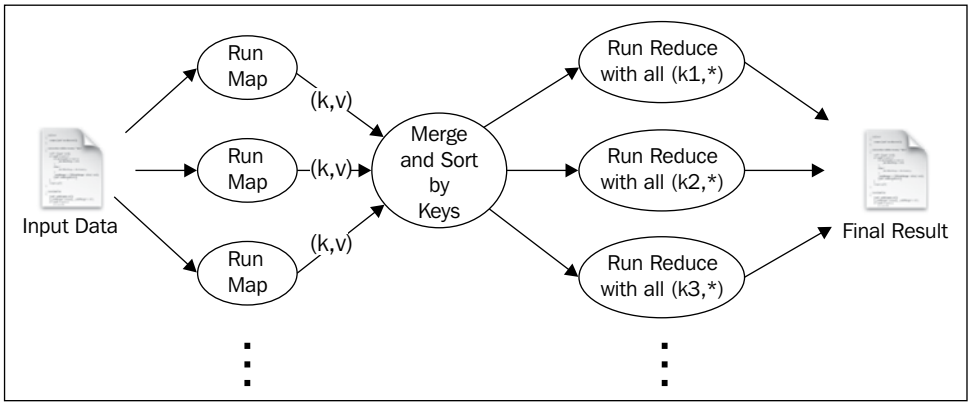
Hadoop local mode does not start any servers but does all the work within the same JVM. When you submit a job to Hadoop in the local mode, that job starts a JVM to run the job, and that JVM carries out the job. The output and the behavior of the job is the same as a distributed Hadoop job, except for the fact that the job can only use the current node for running tasks. In the next recipe, we will discover how to run a MapReduce program using the unzipped Hadoop distribution.

Downloading the example code

You can download the example code files for all Packt books you have purchased from your account at `http://www.packtpub.com`. If you purchased this book elsewhere, you can visit `http://www.packtpub.com/support` and register to have the files e-mailed directly to you.

Writing a WordCount MapReduce sample, bundling it, and running it using standalone Hadoop

This recipe explains how to write a simple MapReduce program and how to execute it.



To run a MapReduce job, users should furnish a `map` function, a `reduce` function, input data, and an output data location. When executed, Hadoop carries out the following steps:

1. Hadoop breaks the input data into multiple data items by new lines and runs the `map` function once for each data item, giving the item as the input for the function. When executed, the `map` function outputs one or more key-value pairs.
2. Hadoop collects all the key-value pairs generated from the `map` function, sorts them by the key, and groups together the values with the same key.
3. For each distinct key, Hadoop runs the reduce function once while passing the key and list of values for that key as input.
4. The `reduce` function may output one or more key-value pairs, and Hadoop writes them to a file as the final result.

Getting ready

From the source code available with this book, select the source code for the first chapter, `chapter1_src.zip`. Then, set it up with your favorite **Java Integrated Development Environment** (**IDE**); for example, Eclipse. You need to add the `hadoop-core` JAR file in `HADOOP_HOME` and all other JAR files in the `HADOOP_HOME/lib` directory to the classpath of the IDE.

Download and install Apache Ant from `http://ant.apache.org/`.

How to do it...

Now let us write our first Hadoop MapReduce program.

1. The WordCount sample uses MapReduce to count the number of word occurrences within a set of input documents. Locate the sample code from `src/chapter1/Wordcount.java`. The code has three parts—mapper, reducer, and the main program.
2. The mapper extends from the `org.apache.hadoop.mapreduce.Mapper` interface. When Hadoop runs, it receives each new line in the input files as an input to the mapper. The `map` function breaks each line into substrings using whitespace characters such as the separator, and for each token (word) emits `(word,1)` as the output.

```
public void map(Object key, Text value, Context context
                    ) throws IOException, InterruptedException
{
      StringTokenizer itr = new StringTokenizer(value.toString());
       while (itr.hasMoreTokens())
```

```
        {
           word.set(itr.nextToken());
           context.write(word, new IntWritable(1));
         }
}
```

3. The `reduce` function receives all the values that have the same key as the input, and it outputs the key and the number of occurrences of the key as the output.

```
public void reduce(Text key, Iterable<IntWritable> values,
                      Context context
                      ) throws IOException, InterruptedException
{
      int sum = 0;
      for (IntWritable val : values)
      {
         sum += val.get();
      }
      result.set(sum);
      context.write(key, result);
}
```

4. The `main` program puts the configuration together and submits the job to Hadoop.

```
Configuration conf = new Configuration();
String[] otherArgs = new GenericOptionsParser(conf, args).
getRemainingArgs();
if (otherArgs.length != 2) {
System.err.println("Usage: wordcount <in><out>");
System.exit(2);
}
Job job = new Job(conf, "word count");
job.setJarByClass(WordCount.class);
job.setMapperClass(TokenizerMapper.class);
//Uncomment this to
//job.setCombinerClass(IntSumReducer.class);
job.setReducerClass(IntSumReducer.class);
job.setOutputKeyClass(Text.class);
job.setOutputValueClass(IntWritable.class);
FileInputFormat.addInputPath(job, new Path(otherArgs[0]));
FileOutputFormat.setOutputPath(job, new Path(otherArgs[1]));
System.exit(job.waitForCompletion(true) ? 0 : 1);
```

5. You can compile the sample by running the following command, which uses Apache Ant, from the root directory of the sample code:

```
>ant build
```

   If you have not done this already, you should install Apache Ant by following the instructions given at `http://ant.apache.org/manual/install.html`. Alternatively, you can use the compiled JAR file included with the source code.

6. Change the directory to `HADOOP_HOME`, and copy the `hadoop-cookbook-chapter1.jar` file to the `HADOOP_HOME` directory. To be used as the input, create a directory called `input` under `HADOOP_HOME` and copy the `README.txt` file to the directory. Alternatively, you can copy any text file to the `input` directory.

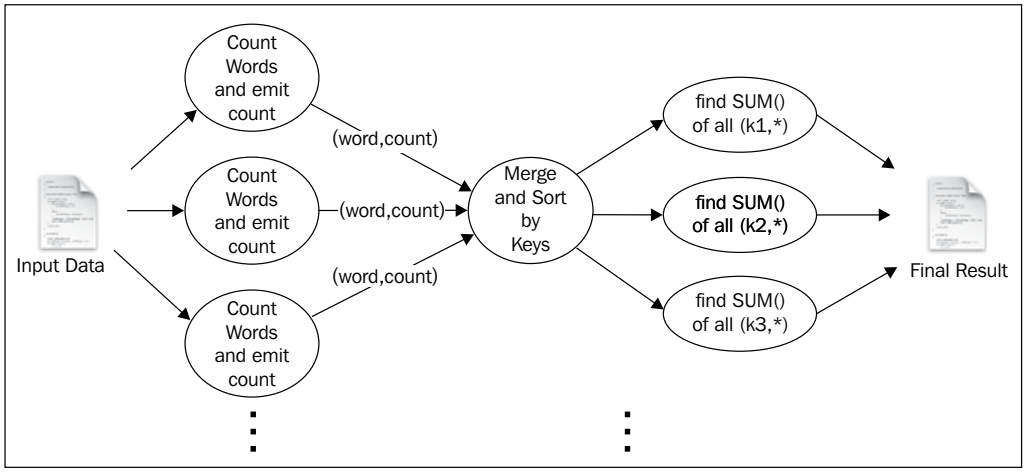
7. Run the sample using the following command. Here, `chapter1.WordCount` is the name of the `main` class we need to run. When you have run the command, you will see the following terminal output:

```
>bin/hadoop jar hadoop-cookbook-chapter1.jar chapter1.WordCount
input output
12/04/11 08:12:44 INFO input.FileInputFormat: Total input paths to
process : 16
12/04/11 08:12:45 INFO mapred.JobClient: Running job: job_
local_0001
12/04/11 08:12:45 INFO mapred.Task: Task:attempt_
local_0001_m_000000_0 is done. And is in the process of commiting
.....
.....
12/04/11 08:13:37 INFO mapred.JobClient: Job complete: job_
local_0001
.....
```

8. The output directory will have a file named like `part-r-XXXXX`, which will have the count of each word in the document. Congratulations! You have successfully run your first MapReduce program.

How it works...

In the preceding sample, MapReduce worked in the local mode without starting any servers and using the local filesystem as the storage system for inputs, outputs, and working data. The following diagram shows what happened in the WordCount program under the covers:



The workflow is as follows:

1. Hadoop reads the input, breaks it by new line characters as the separator and then runs the map function passing each line as an argument.
2. The map function tokenizes the line, and for each token (word), emits a key value pair `(word, 1)`.
3. Hadoop collects all the `(word,1)` pairs, sorts them by the word, groups all the values emitted against each unique key, and invokes the reduce once for each unique key passing the key and values for that key as an argument.
4. The reduce function counts the number of occurrences of each word using the values and emits it as a key-value pair.
5. Hadoop writes the final output to the output directory.

There's more...

As an optional step, copy the `input` directory to the top level of the IDE-based project (Eclipse project) that you created for samples. Now you can run the `WordCount` class directly from your IDE passing `input output` as arguments. This will run the sample the same as before. Running MapReduce jobs from IDE in this manner is very useful for debugging your MapReduce jobs.

Although you ran the sample with Hadoop installed in your local machine, you can run it using distributed Hadoop cluster setup with a HDFS-distributed filesystem. The recipes of this chapter, *Setting up HDFS* and *Setting Hadoop in a distributed cluster environment* will discuss how to run this sample in a distributed setup.