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I would also like to thank Marcel Izumi for, as always, providing creative visuals. Publication date: July 2015

In this chapter, we will set up Spark and configure it. Last but not least, special thanks to our valuable clients, partners, and employees, who have made InfoObjects the best place to work at and, needless to say, an immensely successful organization. InfoObjects combines the power of open source and big data to solve business challenges for its clients and has a special focus on Apache Spark. Tachyon solves some of the challenges with Spark RDD management. There is no need to specify Spark master in either mode as it's picked from the Hadoop configuration, and the master parameter is either yarn-client or yarn-cluster. The following figure shows how Spark is run with YARN in the client mode: The following figure shows how Spark is run with YARN in the cluster mode: The following configuration parameters can be set: `num-executors` - Configure how many executors will be allocated - `executor-memory` - RAM per executor - `executor-cores` - CPU cores per executor Spark RDDs are a great way to store datasets in memory while ending up with multiple copies of the same data in different applications. About 12 years ago, Rishi started InfoObjects, a company that helps data-driven businesses gain new insights into data. To assign another value for the total memory (for example, 24 GB) to be used by all executors combined, execute the following setting: There are some settings you can do at the driver level: To specify the maximum number of CPU cores to be used by a given application across the cluster, you can set the `spark.cores.max` configuration in Spark submit or Spark shell as follows: To specify the amount of memory each executor should be allocated (the minimum recommendation is 8 GB), you can set the `spark.executor.memory` configuration in Spark submit or Spark shell as follows: The following diagram depicts the high-level architecture of a Spark cluster: Mesos is slowly emerging as a data center operating system to manage all compute resources across a data center. Mesos is built using the same principles as Linux kernel. The most recent package for the Mesos distribution can be installed from the Mesosphere repositories by performing the following steps: Execute Mesos on Ubuntu OS with the trusty version: Update the repositories: Install Mesos: To connect Spark to Mesos to integrate Spark with Mesos, make Spark binaries available to Mesos and configure the Spark driver to connect to Mesos. Use Spark binaries from the first recipe and upload to HDFS: The master URL for single master Mesos is `mesos://zk:/host:2181`. Set the following variables in `spark-env.sh`: Run from the Scala program: Run from the Spark shell: Mesos has two run modes: Fine-grained. In fine-grained (default) mode, every Spark task runs as a separate Mesos task. Coarse-grained. This mode will launch only one long-running Spark task on each Mesos machine. To run in the coarse-grained mode, set the `spark.mesos.coarse` property. Yet another resource negotiator (YARN) is Hadoop's compute framework that runs on top of HDFS, which is Hadoop's storage layer. YARN follows the master-slave architecture. Note that you cannot allocate how much memory each specific executor will use (you can control this from the driver configuration). Mesos runs on any computer running the Linux operating system. This book is dedicated to my parents, Ganesh and Bhagwati Yadav; I would not be where I am without their unconditional support, trust, and providing me the freedom to choose a path of my own. What sets Spark apart from its predecessors, such as MapReduce, is its speed, ease-of-use, and sophisticated analytics. Apache Spark was originally developed at AMPLab, UC Berkeley, in 2009. Spark can be either built from the source code or precompiled binaries can be downloaded from . You can also add more standby masters on the fly, if needed. The compute slave daemon is called worker and is on each slave node. It also has a web UI at port 8088. Please SSH to master node and start slaves: Rather than manually starting master and slave daemons on each node, it can also be accomplished using cluster launch scripts. First, create the `conf/slaves` file on a master node and add one line per slave hostname (using an example of five slaves nodes, replace with the DNS of slave nodes in your cluster): Once the slave machine is set up, you can call the following scripts to start/stop cluster: Connect an application to the cluster through the Scala code: Connect to the cluster through Spark shell: In standalone mode, Spark follows the master-slave architecture, very much like Hadoop, MapReduce, and YARN. Browse publications by this author: It also provides a rich set of higher-level libraries for different big data compute tasks, such as machine learning, SQL processing, graph processing, and real-time streaming. I cannot miss thanking our dog, Sparky, for giving me company on my long nights out. Put `/opt/infoobjects/spark/sbin` in path on every node: Start the standalone master server (SSH to master first): Master, by default, starts on port 7077, which slaves use to connect to it. Binaries are developed with a most recent and stable version of Hadoop. They have a free tier of micro-instances to try. The `spark-ec2` script comes bundled with Spark and makes it easy to launch, manage, and shut down clusters on Amazon EC2. Before you start, you need to do the following things: Log in to the Amazon AWS account (). Click on Security Credentials under your account name in the top-right corner. Click on Access Keys and Create New Access Key. Note down the access key ID and secret access key. Now go to Services | EC2. Click on Key Pairs in left-hand menu under NETWORK & SECURITY. Click on Create Key Pair and enter `kp-spark` as key-pair name: Download the private key file and copy it in the `~/home/hduser/keypairs` folder: Set permissions on key file to 600. Set environment variables to reflect access key ID and secret access key (please replace sample values with your own values): Spark comes bundled with scripts to launch the Spark cluster on Amazon EC2. As soon as MLlib gets this library, this particular job can be moved to Spark. Let's consider a cluster of six nodes as an example setup: one master and five slaves (replace them with actual node names in your cluster): Since Spark's standalone mode is the default, all you need to do is to have Spark binaries installed on both master and slave machines. You simply bid on spare Amazon EC2 instances and run them whenever your bid exceeds the current spot price, which varies in real-time based on supply and demand (source: amazon.com). After everything is launched, check the status of the cluster by going to the web UI URL that will be printed at the end. Check the status of the cluster: Now, to access the Spark cluster on EC2, let's connect to the master node using secure shell (SSH): You should get something like the following: Check directories in the master node and see what they do: Check the HDFS version in an ephemeral instance: Check the HDFS version in persistent instance with the following command: Change the configuration level in logs: The default log level information is too verbose, so let's change it to Error: Create the `log4j.properties` file by renaming the template: Open `log4j.properties` in vi or your favorite editor: Change second line from `log4j.rootCategory=ERROR, console` to `log4j.rootCategory=INFO, console`. Copy the configuration to all slave nodes after the change: You should get something like this: Destroy the Spark cluster: Compute resources in a distributed environment need to be managed so that resource utilization is efficient and every job gets a fair chance to run. Special thanks go to my life partner, Anjali, for providing immense support and putting up with my long, arduous hours (yet again). Our 9-year-old son, Vedant, and niece, Kashmir, were the unrelenting force behind keeping me and the book on track. InfoObjects has also been named the best place to work in the Bay Area in 2014 and 2015. The following is a quick cheat sheet: At the time of writing this, Spark's current version is 1.4. Please check the latest version from Spark's download page at . Rishi Yadav has 19 years of experience in designing and developing enterprise applications. The worker daemon does the following: Reports the availability of compute resources on a slave node, such as the number of cores, memory, and others, to Spark master. Spawns the executor when asked to do so by Spark master. Restarts the executor if it dies. There is, at most, one executor per application per slave machine. Both Spark master and worker are very lightweight. These libraries make development faster and can be combined in an arbitrary fashion. Though Spark is written in Scala, and this book only focuses on recipes in Scala, Spark also supports Java and Python. Spark is an open source community project, and everyone uses the pure open source Apache distributions for deployments, unlike Hadoop, which has multiple distributions available with vendor enhancements. The following figure shows the Spark ecosystem: The Spark runtime runs on top of a variety of cluster managers, including YARN (Hadoop's compute framework), Mesos, and Spark's own cluster manager called standalone mode. This layer, being off-heap, is immune to process crashes and is also not subject to garbage collection. Let's see how we can install Mesos. Mesosphere provides a binary distribution of Mesos. To use a specific version of Hadoop, the recommended approach is to build from sources, which will be covered in the next recipe. The following are the installation steps: Open the terminal and download binaries using the following command: Unpack binaries: Rename the folder containing binaries by stripping the version information: Move the configuration folder to the `/etc` folder so that it can be made a symbolic link later: Create your company-specific installation directory under `/opt`. Amazon EC2 provides the following features: On-demand delivery of IT resources via the Internet. The provision of as many instances as you like. Payment for the hours you use instances like your utility bill. No setup cost, no installation, and no overhead at all when you no longer need instances, you either shut down or terminate and walk away. The availability of these instances on all familiar operating systems. EC2 provides different types of instances to meet all compute needs, such as general-purpose instances, micro instances, memory-optimized instances, storage-optimized instances, and others. It was made open source in 2010 under the BSD license and switched to the Apache 2.0 license in 2013. A few of them are: RDD only exists for the duration of the Spark application. The same process performs the compute and RDD in-memory storage; so, if a process crashes, in-memory storage also goes away. Different jobs cannot share an RDD even if they are for the same underlying data, for example, an HDFS block that leads to disk duplication of data in memory, higher memory footprint if the output of one application needs to be shared with the other application, it's slow due to the replication in the disk. Tachyon provides an off-heap memory layer to solve these problems. The compute master daemon is called Spark master and runs on one master node. Typically, memory allocation between 500 MB to 1 GB is sufficient. Mesos is emerging as a data center operating system to conveniently manage jobs across frameworks, and is very compatible with Spark. If the Spark framework is the only framework in your cluster, then standalone mode is good enough. Make sure you have sudo as the super user before running it: By default, each slave node has one worker instance running on it. Spark uses memory both to compute and store objects. Spark also provides a unified runtime connecting to various big data storage sources, such as HDFS, Cassandra, HBase, and S3. Tachyon is a memory-centric distributed file system that enables reliable file sharing at memory speed across cluster frameworks. In MapReduce, memory is primarily used for actual computation. Spark also supports working with YARN and Mesos cluster managers. The cluster manager that should be chosen is mostly driven by both legacy concerns and whether other frameworks, such as MapReduce, are sharing the same compute resource pool. If your cluster has legacy MapReduce jobs running, and all of them cannot be converted to Spark jobs, it is a good idea to use YARN as the cluster manager. As the recipes in this book are tested on InfoObjects sandbox, we are going to use InfoObjects as directory name. Big thanks to InfoObjects' CTO and my business partner, Sudhir Jangir, for providing valuable feedback and also contributing with recipes on enterprise security, a topic he is passionate about; to our SVP, Bert Hickenlooper, for taking the charge in leading the company to the next level; to Tammy Chowdhury and Neeraj Gupta for their valuable advice; to Yogesh Chandani, Animesh Chauhan, and Katie Nelson for running operations skillfully so that I could focus on this book; and to our internal review team (especially Rakesh Chandran) for ironing out the kinks. Spark expects Java to be installed and the `JAVA_HOME` environment variable to be set. In Linux/Unix systems, there are certain standards for the location of files and directories, which we are going to follow in this book. The company has been on the Inc. In that case, you can spawn more than one worker on that machine by the following configuration (only on those machines): Spark worker, by default, uses all cores on the slave machine for its executors. For example, the following configuration will set the memory to 1 gigabit for both master and worker daemon. The master daemon is called ResourceManager and the slave daemon is called NodeManager. For example, some jobs may be using Apache Mahout at present because MLlib does not have a specific machine-learning library, which the job needs. For a standard use case, binaries are good enough, and this recipe will focus on installing Spark using binaries. All the recipes in this book are developed using Ubuntu Linux but should work fine on any POSIX environment. Replace the version with the current version. Let's launch the cluster using the following command: Launch the cluster with the example value: This is the name of EC2 key-pair created in AWS: This is the private key file you downloaded: This is the number of slave nodes to launch: This is the name of the cluster. Sometimes, the default availability zones are not available; in that case, retry sending the request by specifying the specific availability zone you are requesting: If your application needs to retain data after the instance shuts down, attach EBS volume to it (for example, a 10 GB space): If you use Amazon spot instances, here's the way to do it: Spot instances allow you to name your own price for Amazon EC2 computing capacity. Rishi was honored as one of Silicon Valley's 40 under 40 in 2014. This chapter is divided into the following recipes: Installing Spark from binaries. Building the Spark source code with Maven. Launching Spark on Amazon EC2. Deploying Spark on a cluster in standalone mode. Deploying Spark on a cluster with Mesos. Deploying Spark on a cluster with YARN. Using Tachyon as an off-heap storage layer. Apache Spark is a general-purpose cluster computing system to process big data workloads. YARN is Hadoop's compute framework that has a robust resource management feature that Spark can seamlessly use. 5000 list of the fastest growing companies for 6 years in a row. Sometimes, you may have a few machines that are more powerful than others. Create the `/opt/infoobjects` directory: Move the spark directory to `/opt/infoobjects` as it's an add-on software package: Change the ownership of the spark home directory to root: Change permissions of the spark home directory: `0755 = user:rx group:rx world:rx`: Move to the spark home directory: Create a symbolic link: Put the Spark executable in the path by editing `bashrc`: Create the log directory in `/var`: Make `hduser` the owner of the Spark log directory: Create the Spark tmp directory: Configure Spark with the help of the following command lines: Installing Spark using binaries works fine in most cases. As Spark evolves as technology, you will see more and more use cases of Spark being used as the standalone framework serving all big data compute needs. Besides this application, life cycle management is done by ApplicationMaster, which can be spawned on any slave node and is alive for the lifetime of an application. When Spark is run on YARN, ResourceManager performs the role of Spark master and NodeManagers work as executor nodes. While running Spark with YARN, each Spark executor is run as YARN container. Running Spark on YARN requires a binary distribution of Spark that has YARN support. Rishi is an open source contributor and active blogger. To achieve such low latency, Spark makes use of the memory for storage. He is an open source software expert and advises American companies on big data and public cloud trends. If you would like to limit the number of cores the worker can use, you can set it to that number (for example, 12) by the following configuration: Spark worker, by default, uses all the available RAM (1 GB for executors). Spark master can be made highly available using ZooKeeper. In short, it is an off-heap storage layer in memory. Mesos is a cluster manager, which is evolving into a data center operating system. Toward the later part of 2013, the creators of Spark founded Databricks to focus on Spark's development and future releases. Talking about speed, Spark can achieve sub-second latency on big data workloads. In both Spark installation recipes, we have taken care of it. To run Spark on YARN, the first step is to set the configuration: You can see this in the following screenshot: The following command launches YARN Spark in the yarn-client mode: Here's an example: The following command launches Spark shell in the yarn-client mode: The command to launch in the yarn-cluster mode is as follows: Here's an example: Spark applications on YARN run in two modes: yarn-client. Spark Driver runs in the client process outside of YARN cluster, and ApplicationMaster is only used to negotiate resources from ResourceManager. yarn-cluster: Spark Driver runs in ApplicationMaster spawned by NodeManager on a slave node. The yarn-cluster mode is recommended for production deployments, while the yarn-client mode is good for development and debugging when you would like to see immediate output. For advanced cases, such as the following (but not limited to), compiling from the source code is a better option: Compiling for a specific Hadoop version. Adding the Hive integration. Adding the YARN integration. The following are the prerequisites for this recipe to work: Java 1.6 or a later version. Maven 3.x. The following are the steps to build the Spark source code with Maven: Increase MaxPermSize for heap: Open a new terminal window and download the Spark source code from GitHub: Unpack the archive: Move to the spark directory: Compile the sources with these flags: Yarn enabled, Hadoop version 2.4, Hive enabled, and skipping tests for faster compilation: Move the conf folder to the etc folder so that it can be made a symbolic link: Move the spark directory to `/opt` as it's an add-on software package: Change the ownership of the spark home directory to root: Change the permissions of the spark home directory: `0755 = user:rx group:rx world:rx`: Move to the spark home directory: Create a symbolic link: Put the Spark executable in the path by editing `bashrc`: Create the log directory in `/var`: Make `hduser` the owner of the Spark log directory: Create the Spark tmp directory: Configure Spark with the help of the following command lines: Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute instances in the cloud. This also lets RDDs be shared across applications and outlive a specific job or session; in essence, one single copy of data resides in memory, as shown in the following figure: Let's download and compile Tachyon (Tachyon, by default, comes configured for Hadoop 1.0.4, so it needs to be compiled from sources for the right Hadoop version). Spark comes along with its own cluster manager conveniently called standalone mode. He earned his bachelor's degree from the prestigious Indian Institute of Technology, Delhi, in 1998. The current version at the time of writing this book is 0.6.4: Unarchive the source code: Remove the version from the tachyon source folder name for convenience: Change the directory to the tachyon folder: Comment the following line: Uncomment the following line: Change the following properties: Replace `$(tachyon.home)` with `/var/log/tachyon`. Create a new core-site.xml file in the conf directory: Add `/bin` to the path: Restart the shell and format Tachyon: Tachyon's web interface is `!Run` the sample program to see whether Tachyon is running fine: You can stop Tachyon any time by running the following command: `!Run` Spark on Tachyon: Read more. Unlock this book with a 7 day free trial. This value can be set in `conf/spark-env.sh` by setting the `SPARK_DAEMON_MEMORY` parameter.

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