GENERAL

practical hadoop by example

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When the term **Hadoop**first surfaced, it was a buzzword that promised to tame the ever growing avalanche of data. Today, Hadoop remains a cornerstone of modern data engineering, powering everything from e commerce recommendation engines to real time fraud detection systems. Yet, for many newcomers, the sheer number of components—HDFS, MapReduce, YARN, Hive, Spark—can be intimidating. This article delivers a practical, example driven approach that walks you through setting up a Hadoop cluster, running core workloads, and applying best practices. By the end, you'll have a solid foundation that you can extend to larger, production grade environments.

1. What Is Hadoop and Why Does It Matter?

Hadoopis an open source ecosystem that allows distributed storage and parallel processing of large datasets across commodity hardware. Its core components are:

- HDFS (Hadoop Distributed File System) – a fault tolerant file system that splits data into blocks and replicates them across nodes.
- MapReduce – a programming model for batch processing that maps input data to key/value pairs and reduces them to aggregated results.
- YARN (Yet Another Resource Negotiator) – a resource manager that schedules tasks across the cluster.
- Hive, Pig, Spark, Flink, etc. – higher level frameworks that sit on top of Hadoop to simplify SQL like queries, iterative processing, and streaming.

Hadoop's design is rooted in the idea that you can scale horizontally: add more machines to increase capacity and performance without rewriting your code. This flexibility has made Hadoop indispensable for organizations that need to process petabytes of data cost effectively.

Key Advantages of Hadoop

- Cost effective storage and compute using commodity hardware.
- Fault tolerance through data replication and automatic job retries.
- Scalability to thousands of nodes.
- Extensive ecosystem of tools for ETL, analytics, and machine learning.

Despite the rise of cloud data warehouses, Hadoop remains relevant because it can handle batch and streaming workloads at scale while giving developers full control over the environment.

2. Preparing the Playground: Setting Up a Mini Cluster

Before diving into real workloads, let's create a lightweight Hadoop environment on a single machine. This "pseudo distributed" setup mimics a multi node cluster and is ideal for learning and experimentation.

2.1 System Requirements

- Linux (Ubuntu 20.04 LTS recommended) or macOS with Homebrew.
- Java Development Kit (JDK) 8 or 11.
- Python 3 (for optional scripting).
- At least 8 /GB RAM (16 /GB recommended for smoother performance).

2.2 Installing Java

sudo apt update
sudo apt install openjdk-11-jdk
java -version

Verify the Java installation by running java -version. You should see output similar to:

openjdk version "11.0.18" 2023-03-21
OpenJDK Runtime Environment (build 11.0.18+10-Ubuntu-0ubuntu0.20.04.1)
OpenJDK 64 bit Server VM (build 11.0.18+10-Ubuntu-0ubuntu0.20.04.1, mixed mode, sharing)

2.3 Downloading Hadoop

Choose the latest stable release from the Apache Hadoop releases page. For this guide, we'll use Hadoop 3.3.6.

wget https://downloads.apache.org/hadoop/common/hadoop-3.3.6/hadoop-3.3.6.tar.gz
tar -xzvf hadoop-3.3.6.tar.gz
sudo mv hadoop-3.3.6 /opt/hadoop

2.4 Configuring Environment Variables

Append the following lines to ~/.bashrc:

export HADOOP_HOME=/opt/hadoop
export PATH=$PATH:$HADOOP_HOME/bin:$HADOOP_HOME/sbin
export JAVA_HOME=/usr/lib/jvm/java-11-openjdk-amd64
export HADOOP_CONF_DIR=$HADOOP_HOME/etc/hadoop

Reload the profile:

source ~/.bashrc

2.5 HDFS Configuration

Open $HADOOP_HOME/etc/hadoop/core-site.xml and add:

<configuration>
  <property>
    <name>fs.defaultFS</name>
    <value>hdfs://localhost:9000</value>
  </property>
</configuration>

Next, edit hdfs-site.xml:

```
&lt;configuration&gt;
  &lt;property&gt;
    &lt;name&gt;dfs.replication&lt;/name&gt;
    &lt;value&gt;1&lt;/value&gt;
  &lt;/property&gt;
  &lt;property&gt;
    &lt;name&gt;dfs.namenode.name.dir&lt;/name&gt;
    &lt;value&gt;file:///opt/hadoop/hdfs/namenode&lt;/value&gt;
  &lt;/property&gt;
  &lt;property&gt;
    &lt;name&gt;dfs.datanode.data.dir&lt;/name&gt;
    &lt;value&gt;file:///opt/hadoop/hdfs/datanode&lt;/value&gt;
  &lt;/property&gt;
&lt;/configuration&gt;
```

Create the directories:

```
mkdir -p /opt/hadoop/hdfs/namenode
mkdir -p /opt/hadoop/hdfs/datanode
```

2.6 Formatting the Namenode

```
hdfs namenode -format
```

2.7 Starting the Cluster

Launch HDFS and YARN daemons:

```
start-dfs.sh
start-yarn.sh
```

Verify that the services are running:

```
jps
```

You should see NameNode, DataNode, ResourceManager, and NodeManager among the Java processes.

3. The First Step Into Big Data: A Hello World MapReduce Job

Now that the cluster is up, let’s run a classic word count example. MapReduce jobs are written in Java, but you can

also use higher level languages like Python (via Hadoop Streaming) or Scala (via Spark). For this demonstration, we'll use the built in Java example.

3.1 Preparing the Input Data

Create a sample text file:

```
echo "Hello Hadoop world! Hadoop is powerful." > /tmp/input.txt
hdfs dfs -mkdir -p /user/$(whoami)/input
hdfs dfs -put /tmp/input.txt /user/$(whoami)/input/
```

3.2 Running the WordCount Example

Execute the pre packaged job:

```
hadoop jar $HADOOP_HOME/share/hadoop/mapreduce/hadoop-mapreduce-examples-3.3.6.jar wordcount /user/$(whoami)/input /user/$(whoami)/output
```

Check the results:

```
hdfs dfs -cat /user/$(whoami)/output/part-r-00000
```

The output should look like:

```
Hadoop 1
Hello 1
world! 1
is 1
powerful. 1
```

Congratulations! You've just processed data across a distributed file system with a parallel MapReduce job.

4. From Batch to Interactive: Leveraging Hive for SQL Like Queries

While MapReduce is powerful, writing Java code for every query can be tedious. **Apache Hive**brings SQL semantics to Hadoop, allowing analysts to write familiar queries that run on the underlying MapReduce or Tez engines.

4.1 Installing Hive

Download Hive 3.1.2:

```
wget https://downloads.apache.org/hive/hive-3.1.2/apache-hive-3.1.2-bin.tar.gz
tar -xzvf apache-hive-3.1.2-bin.tar.gz
sudo mv apache-hive-3.1.2-bin /opt/hive
```

4.2 Configuring Hive

Set environment variables in ~/.bashrc:

```
export HIVE_HOME=/opt/hive
export PATH=$PATH:$HIVE_HOME/bin
export HIVE_CONF_DIR=$HIVE_HOME/conf
```

Copy the Hadoop configuration files into Hive's conf directory:

```
cp $HADOOP_HOME/etc/hadoop/core-site.xml $HIVE_CONF_DIR/
cp $HADOOP_HOME/etc/hadoop/hdfs-site.xml $HIVE_CONF_DIR/
cp $HADOOP_HOME/etc/hadoop/yarn-site.xml $HIVE_CONF_DIR/
```

Initialize the Hive Metastore database (using the built in Derby for simplicity):

```
schematool -dbType derby -initSchema
```

4.3 Running a Hive Query

Start Hive CLI:

```
hive
```

Inside the CLI, create a table that points to our input file:

```
CREATE TABLE words(word STRING)
ROW FORMAT DELIMITED
FIELDS TERMINATED BY " "
STORED AS TEXTFILE
LOCATION "/user/$(whoami)/input";
```

Run a simple query:

```
SELECT word, COUNT(*) AS freq FROM words GROUP BY word;
```

The result should mirror the MapReduce output but delivered via SQL.

5. Scaling Up: Running Spark on Hadoop

Apache Spark offers a more expressive API for iterative algorithms and real time analytics. Spark can run on top of YARN, allowing you to share the same cluster resources with Hadoop.

5.1 Installing Spark

Download Spark 3.5.0 with Hadoop 3.2 support:

wget https://downloads.apache.org/spark/spark-3.5.0/spark-3.5.0-bin-hadoop3.2.tgz
tar

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