PROJECT REPORT

PERFOMANCE TUNING OF HADOOP OVER ORANGEFS

CS550-ADVANCED OPERATING SYSTEM

NOV 29, 2017

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ABSTRACT

Hadoop is a simple Java based programming framework which allows processing of large data sets in a distributed computing environment. Hadoop helps to run applications on systems with several number of nodes involving thousands of terabytes. Since Hadoop is distributed framework it provides high data transfer and computing process among the nodes. OrangeFS is a software based scale-out parallel storage system. It is ideal for large storage problems faced by HPC, Big Data, Streaming Video, Genomics and Bioinformatics. OrangeFS is a user-friendly, parallel file system designed specifically for high performance computing and storage clusters. Its distributed file structure provides outstanding scalability and capacity. OrangeFS is a software based parallel file system designed to perform large scale operations on data. It is suitable for extensive capacity issues looked by High Performance Computing, Big Data, Streaming Video, Genomics and Bioinformatics. The project deals with running standards benchmark with OrangeFS as storage layer and explore the optimal configuration of Hadoop and OrangeFS for the best performance. One way to increase the performance is to reduce the number of map task and reduced task without impacting the configuration of the Hadoop cluster. This can be done by reusing Java Virtual machine. Also, to ensure better IO performance, we can use data notes to update meta data instead of name notes for every time the data is accessed. We can also deactivate Access time tracking which renders better IO performance.

1. INTRODUCTION

1.1 Project Name

Performance Tuning Of Hadoop Over OrangeFS

1.2 Goal

The project deals with running standards benchmark with OrangeFS as storage layer and explore the optimal configuration of Hadoop and OrangeFS for the best performance.

1.3 Description

The project deals with running standards benchmark with OrangeFS as storage layer and explore the optimal configuration of Hadoop and OrangeFS for the best performance. One way to increase the performance is to reduce the number of map task and reduced task without impacting the configuration of the Hadoop cluster. This can be done by reusing Java Virtual machine. Also, to ensure better IO performance, we can use data notes to update meta data instead of name notes for every time the data is accessed. We can also deactivate Access time tracking which renders better IO performance.

1.4 PROBLEM STATEMENT

This project is based on Orange FS which is an open source Parallel file system. Recently Hadoop application were running directly on top of OrangeFS instead of native Hadoop Distributed File system. This project explores the possibility of Unified Storage system for both HDFS and OrangeFS. The project deals with running standards benchmark with OrangeFS as storage layer and explore the optimal configuration of Hadoop and OrangeFS for the best performance.

2. HADOOP

Hadoop is a simple Java based programming framework which allows processing of large data sets in a distributed computing environment. Hadoop helps to run applications on systems with several number of nodes involving thousands of terabytes. Since Hadoop is distributed framework it provides high data transfer and computing process among the nodes. This factor reduces the fault tolerance and increases the scalability factor Hadoop consists of MapReduce module which is considered as the heart of Hadoop framework breaks down the input into small data sets or keys. Apache Hadoop system consists of Hadoop kernel common, Map Reduce, the Hadoop distributed file system (HDFS), YARN, MapReduce and a number of other modules such as Apache Hive, HBase and Zookeeper. Companies like Yahoo, IBM,Cloudera relay on Hadoop framework as they use search Engines and Advertising

application which involves large amount of data set The preferred operating systems are Windows and Linux but Hadoop can also work with BSD and OS.

3.HARDWARE SPECIFICATION

- OS – Windows, Linux.
- Processor – Intel® Core i5-7200U 2.5GHz 64-bit processor
- RAM- DDR3 8 GB RAM

4. ARCHITECTURE & SYSTEM DESIGN

4.1. Architecture

Hadoop Distributed File System is a block-structured file component system where each file or component is segregated into blocks of a pre-determined size. These pre-determined block structure file system are stored across a cluster of nodes . HDFS Architecture can be reproduces as a " **Master/Slave Architecture**" . HDFS consists of numerous clusters where each cluster comprises of a single NameNode called as Master node and rest other nodes as DataNodes (Slave nodes).

Map Reduce

Mapper() and Reducer() are two in-built classes and they can be inherited to write map/reduce jobs in java. **void map() and void reduce()** are the two functions present in Mapper and Reduce classes respectively. **map()** assigns a keyword and a corresponding value via output collector < , > and, **reduce()** gets the keyword in text format and does the assigned job. It publishes the result via Output Collector object as **output.collect** (key, value). In the **main()** function, a job is created and Mapper class, Reducer class, FileInputFormat class and FileOutputFormat class –all are set in Command prompt.**job.submit()** is used to start the map/reduce job.

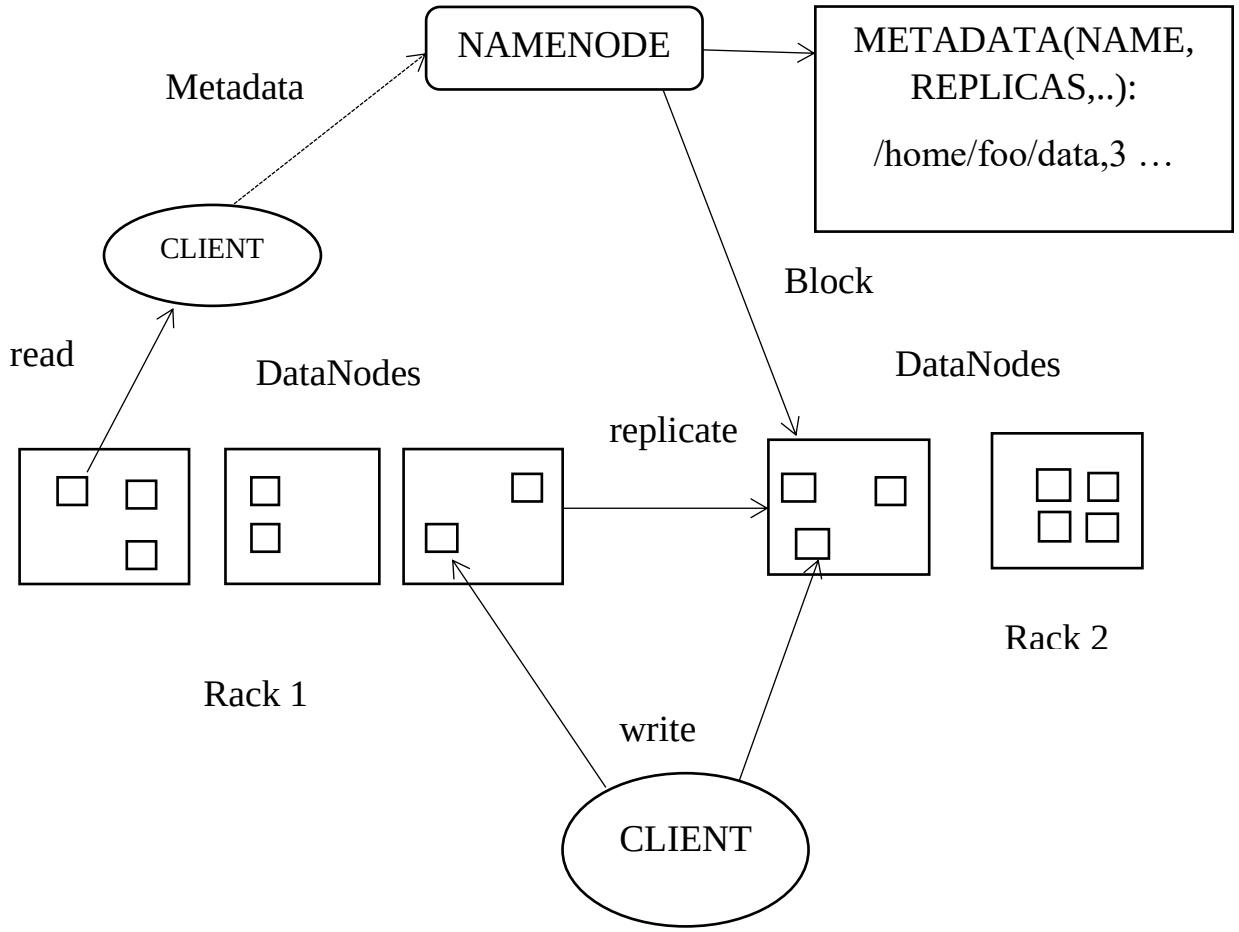


Figure 1: HDFS Architecture

4.2 Modules

NameNode

NameNode can be counted as master node in HDFS Architecture that maintains and allocate the blocks present on the **DataNodes** (slave nodes). Namespace File System and file access by the clients are managed by NameNode. HDFS architecture is built in such a way that the data given by the user never resides on the NameNode. The input data resides on Data Nodes only.

Functions of NameNode

NameNode is the master module which accounts and manages the DataNodes (slave nodes)**.** The metadata information about the file stored in block and cluster is recorded by the name node**.** Information such as Block location, file size, Permission of files, Hierarchical structure. There are two files corresponding with the metadata:

- **FsImage:** Records the entire state of namespace Filesystem.
- **EditLogs:** Changes or modification in the file system with respect to FsImage is recorded in EditLogs.

DataNode

DataNode is considered as the slave nodes in HDFS. DataNode is a commodity hardware, which is a non-expensive system that is not considered as of high quality or high-availability. Local file ext3/ext4 is stored in the blocks of DataNode. Low-level read and write requests which is received from the clients file system is done by DataNode. Regular updates about DataNode which is called as heartbeat is sent to Namenode at regular intervals (3s)

Secondary NameNode

NameNode and secondary node works parallelly as a **helper daemon.** The metadata and the file system record are read from the RAM of Namenode. Later this compiled to hard disk. It is accountable for integrating the EditLogs with FsImage from the NameNode. NameNode updates the EditLogs at regular intervals and applies to FsImage. Whenever the NameNode is started, modified FsImage is copied back to the NameNode.

4.4 Map Reduce

MapReduce is a technique and a programming model for distributed computing based on java. The MapReduce algorithm can be divided into main tasks - Map and Reduce. Firstly, the input data is collected by Map which converts this data into another subset. Each subset is broken down into key/value pairs. Secondly, the broken key values from map task is considered as an input for reduce task. Reduce task combines these subset or key values into smaller set of modules or key values.

4.5 How Does Hadoop Work?

Stage 1

Hadoop job is submitted by user or application. The required information are

- Input and output files location in the distributed file system.
- Implementation of map and reduce functions(java classes in the form of jar file
- The job configuration by setting different parameters specific to the job.

Stage 2

Jar/executable and configuration file is submitted by the Job Client to the JobTracker .This information is distributed to the slaves.These slaves are monitored and information such as scheduling task is monitored and later the status and the diagnostic information is shared to job client

Stage 3

The Task Trackers on different nodes execute the task as per MapReduce implementation and output of the reduce function is stored into the output files on the file system.

5.ORANGEFS

OrangeFS is a software based parallel file system designed to perform large scale operations on data. It is suitable for extensive capacity issues looked by High Performance Computing, Big Data, Streaming Video, Genomics and Bioinformatics. OrangeFS is a cutting edge parallel file system framework in view of PVFS for process and capacity groups without bounds. Its unique contract—to supplement elite processing for bleeding edge look into in scholastic and government activities—is vastly venturing into an adaptable cluster of true applications.

The framework helps I/O execution by putting away records as items over numerous servers and getting to those articles in parallel. Each file and directory in the Orangefs system consists of two or more objects – one containing file data, and the other file metadata. Depending on their role in the file system, objects may contain both data and metadata. None of this is visible to the end users, who see a user-friendly, traditional, logical file view.

5.2 Benefits of Using OrangeFS

When compared to other file systems, OrangeFS provides users with two key benefits:

- OrangeFS is one of the best performing parallel file systems available. Based on the powerful, modular PVFS architecture, this well-designed solution incorporates distributed directories, optimized requests, and a wide variety of interfaces and features.
- OrangeFS is an extremely easy file system to build, install, and run – it has proven to be a highly usable file system.

- OrangeFS has been fine-tuned and hardened through several years of development, testing and support by a professional development team. Although the system remains open source, it is now being deployed and backed up by commercial support from Omni bond for a wide range of scientific and enterprise applications.

5.3. ARCHITECTURE

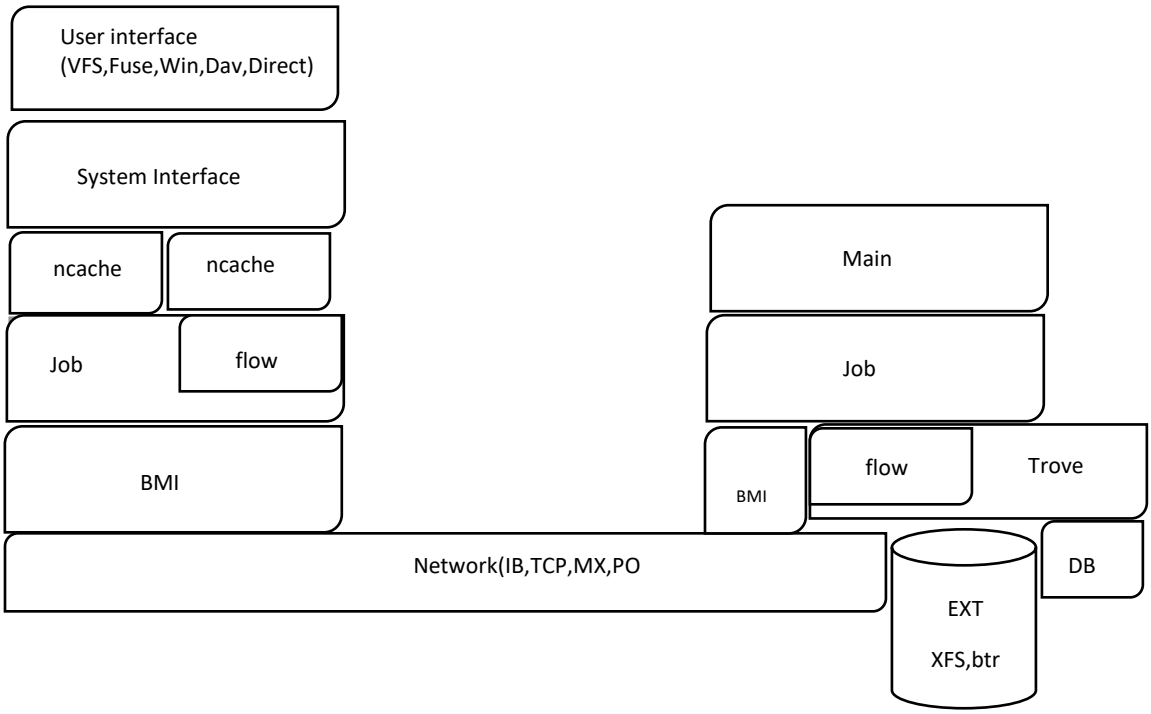


Figure 2 : OrangeFS Architecture

5.4 MODULES

OrangeFS architecture can be divided into modules

- OrangeFS servers manage objects
  - ❖ Objects map to a specific server
  - ❖ Objects store data or metadata
  - ❖ Request protocol specifies operations on one or more objects

- OrangeFS object implementation
  - ❖ Distributed DB for indexing key/value data
  - ❖ Local block file system for data stream of bytes

5.5 Software Components

Two major software components

- Server Daemon -This runs on each server node and server requests sent by the client library, which is linked to client node on compute nodes
- Client library – Links to a separate server daemon on a remote system. Contains the files in its local directory.

5.6 Auxiliary components

- Client core daemon
- Kernel module

5.7 Other Components

- Networking -Client and server communicating using an interface called BMI which supports tcp/ip ,ib,Mail Exchanger (MX) protocol.
- Server -Server Communication - Server operation can be classified into two approaches
  - ❖ Traditional Metadata Operation - Client creates request for it to communicate with all servers at once. The first server that responds connects to the client's metadata.
  - ❖ Scalable Metadata Operation - Client creates a communication request with only one server at start and that server in turn communicates with other available servers using a tree based protocol.

- Storage : OrangeFs server interacts with storage on the host using an interface layered named trove and referenced with a handle .Storage consists of two components
  - ❖ Bytestream -sequence of data
  - ❖ Key/value pairs -data item that are accessed by key

- File Model : It consists of two or more objects . Metadata objects handles Traditional File metadata and also list of data object that handles both metadata and data on files.

- Directories: Directory entries have entry name and handle of that entry's metadata object Extendable hash function selects which data object contain each entry. Directory and file list are maintained by hashing. This improves access time if there are a large number of entries.

- Polices

  Polices consists of User defined attributes for servers and clients . This is used for data location, replication location and multi support.

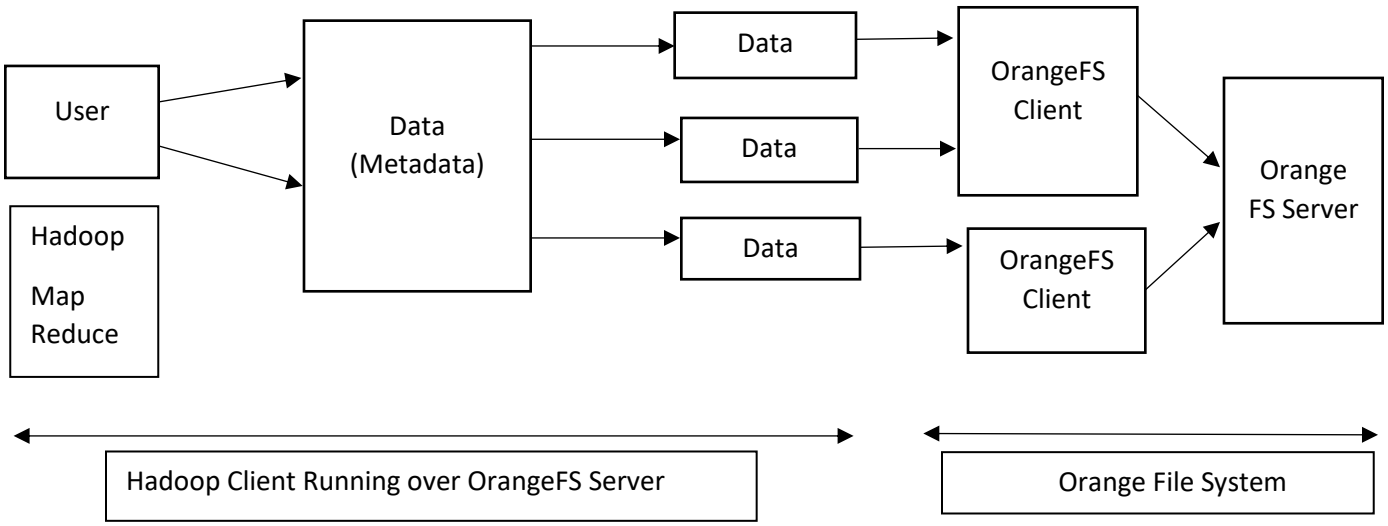


Fig 3 : Running Hadoop with OrangeFS as storage

6. ALGORITHM

Algorithm1 – Word Count in Hadoop

Input: A file which contains a list of words in HDFS and OrangeFS directory.

Output: A file in the HDFS and OrangeFS directory which contains the number of words contained in the input file.

Steps: Initialize job and path of directory in which the files are available.

Initialize Sum to zero.

Algorithm:

- The input and output path can be set using command line arguments while compiling and executing the program.
- Use mapper class to write the contents of the file into a WritableObject
- Use the reducer class to increment a counter variable each time the object accesses a word in the file.
- Write the object to the file in the output directory.

Algorithm2: Two Step Matrix Multiplication in Hadoop

Input: A file which contains two matrices A and B in HDFS and OrangeFS directory

Output: A single matrix which is the product of A and B in a file in HDFS and OrangeFS directory.

Steps: Initialize job and path of directory in which the files are available.

Algorithm:

- The input and output path can be set using command line arguments while compiling and executing the program.
- In the mapper class, use a list to separate the two matrices A and B based on the input given which starts with the corresponding matrix name, that is, either A or B.
- Write the two matrices to a Context object
- In the reducer class, check whether the number of columns in matrix and the number of rows in matrix B are equal.
- If so, for every element in matrix A and B, multiply them and store them in a separate matrix C.
- Write the value of C to new Context.WriteObject
- Output the result.

Algorithm 3 – KMeans Clustering

Input: A file which contains a set of possible list of data points for which a cluster can be formed.

Output: A list of possible clusters

Algorithm:

- The input and output path can be set using command line arguments while compiling and executing the program.
- Each centroid contains a set of on of the clusters.
- In mapper step, each data point is assigned to one of the clusters based on squared Eucledian distance. A minimum value from each data point is extracted and then written to a context.writeObject.
- In reducer class, the centroids are recomputed by taking mean of all data points assigned to that cluster.
- Then the centroid is updated iteratively for each data point present in the cluster.
- The exact value for the cluster can be found by iterating the above steps until a minimum value cluster has been found.
- The output is then written into the file present in the HDFS and OrangeFS directory.

7. DEPLOYMENT

7.1 Configuration of Hadoop

Step1: Extract Hadoop 2.3.0.tar.gz in C:\ in Windows

Step2: Set the environment variable *HADOOP_HOME = "C:\hadoop-2.3.0\bin"*

Step3: Open Command prompt as administrator and use javac and java commands to run java jdk version 1.8.0

Step4: Use "hadoop" command to start hadoop system in Windows.

Step5: Use the command "*start-yarn"* to start hadoop Resource Manager and "start-dfs" to start HDFS,Name Node Manager and Data node Manager.

Step6: Use command *"Hadoop namenode format*" to create a new namenode and a datanode and then format it.

Step7:*"localhost:50070\127.0.0.1:50070"* will open the Hadoop Distributed file system in a browser.

7.2 Execution of Java in Hadoop:

Step 1: To compile the java file, *use javac classpath* which references to all the hadoop based jar files.

Step 2: Create a jar file using the command*: jar –cvf File.jar *.class.*

Step 3: Create a directory in hdfs: *hadoop fs –mkdir \in.*

Step 4: Copy a file from local file system to hdfs using the command: "*hadoop fs –copyfromLocal Location /in"*.

Step 5: To run the jar on hadoop, use the command "*hadoop jar.File.jar ClassName /in /out*".

Step 6: Record all the results like execution time, no of map jobs, no of reduce jobs etc.

7.3 DEPLOYMENT OF ORANGEFS

Step 1: Extract Orangefs-2.9.6.zip.

Step 2: Install orangefs client and configure the orangefs-server.conf configuration file.

Step 3: Configure theorangefs server using the following command *: /opt/orangefs/bin/pvfs2-genconfig /opt/orangefs/etc/orangefs-server.conf.*

Step 4: Now start the orangefs server using the following command*: /opt/orangefs/sbin/pvfs2-server -a hostname /opt/orangefs/etc/orangefs-server.conf.*

Where *hostname* = hostname of the server. For example, hostname can be tcp://ofs1:3334/pvfs2-fs

Step 5: The server is set up and it is running on a separate host.

Step 6: To run the client, create a separate space where the pvfs2 should mount the client data.

Step 7: To start the client process, run the following command: */opt/orangefs/sbin/pvfs2-client*

Step8: To mount the orangefs data, run the following data: mount -t pvfs2 *protocol://hostname:port/pvfs2-fs* /mnt/orangefs

Where *protocol* = protocol of the network where orangefs runs.

Hostname = host name of the orangefs server the user will mount.

Port = number of TCP/IP port on which the orangefs communicates. Normally it would be 3334.

7.4 Configuring Hadoop with OrangeFS

The below steps are used for installing OrangeFS and Apache Hadoop across a cluster of nodes, replacing HDFS with OrangeFS configured as the distributed file system, layered across all nodes running MapReduce.

Deploying an Apache Hadoop cluster, configured to use OrangeFS as the distributed file system, involves six main steps, with one additional recommended step for deployment verification.

- **Install System Software**

  1. First step is to install Java Development kit with latest version .
  2. Set the environment variable for Hadoop and java.
  3. To configure Hadoop Binaries download and extract the contents of a supported Apache Hadoop release from http://hadoop.apache.org/releases.html and copy it to the temporary directory on the Hadoop build system.
  4. To build OrangeFS,download the OrangeFS tar file and copy it to the Hadoop build system from http://www.orangefs.org/download/
  5. Extract the contents of the archive into source folder.
  6. On the Hadoop build system, generate a Makefile that enables the OrangeFS Hadoop Client and OrangeFS JNI Shim for OrangeFS
  7. Once OrangeFS is bult and installed,OrangeFS Hadoop Client jar is built.
  8. URL of the node is hosted in OrangeFS tab file.
  9. Since all nodes in configuration act as clients with respect to OrangeFS, pvfs2tab file is created in Hadoop etc directory.

- **Configure Hadoop to Use OrangeFS**

  1. On the Hadoop build system, modify the files in the Hadoop default configuration directory to use OrangeFS.
  2. Set the following environment variables in the hadoop-env.sh file.

     # The java implementation to use.

     export JAVA_HOME=path_to_jdk

  3. Set the following properties in the core-site.xml file:

     <property>

     <name>fs.default.name</name>

<value>ofs://localhost:3334</value>
</property>

4. The following property directs Hadoop to use the OrangeFS file system implementation:

<property>
<name>fs.ofs.impl</name>
<value>org.apache.hadoop.fs.ofs.OrangeFileSystem</value>
<description>An extension of filesystem for OrangeFS URIs.</description>
</property>

5. The following property represents a comma separated list of OrangeFS installations.

<property>
<name>fs.ofs.systems</name>
<value>localhost:3334</value>
</property>

6. The following property represents the mount location of an OrangeFS client.

<property>
<name>fs.ofs.mntLocations</name>
<value>/mnt/orangefs</value>
<description>Location of OrangeFS mount point.</description>
</property>

7. Set the following properties in the mapred-site.xml file:

<property>
<name>mapred.job.tracker</name>
<value>node001:8021</value>
</property>

8. Add hosts to the slaves file. The slaves file contains a list of hostnames that run mapreduce. Assuming node001 is the ResourceManager, the slaves list would include the remaining clients.

- **Configure OrangeFS**

1. Create OrangeFS configuration file “orangefs-server.conf”.

<Defaults>
UnexpectedRequests 50

```
    EventLogging none
    EnableTracing no
    LogStamp datetime
    BMIModules bmi_tcp
    FlowModules flowproto_multiqueue
    PerfUpdateInterval 1000
    ServerJobBMITimeoutSecs 30
    ServerJobFlowTimeoutSecs 30
    ClientJobBMITimeoutSecs 300
    ClientJobFlowTimeoutSecs 300
    ClientRetryLimit 5
    ClientRetryDelayMilliSecs 2000
    PrecreateBatchSize 0,1024,1024,1024,32,1024,0
    PrecreateLowThreshold 0,256,256,256,16,256,0

    .../orangefs-2.9.6/storage/data
    .../orangefs-2.9.6/storage/meta

    LogFile /home/deepak/AOS/orangefs-2.9.6/log/orangefs-server.log

    <Security>
       TurnOffTimeouts yes
    </Security>
</Defaults>

<Aliases>
    Alias ofs1 tcp://ofs1:3334
    Alias ofs2 tcp://ofs2:3334
    Alias ofs3 tcp://ofs3:3334
    Alias ofs4 tcp://ofs4:3334
</Aliases>

<Filesystem>
    Name orangefs
```

ID 1691885129
RootHandle 1048576
FileStuffing yes
DistrDirServersInitial 1
DistrDirServersMax 1
DistrDirSplitSize 100
<MetaHandleRanges>
Range ofs1 3-1152921504606846977
Range ofs2 1152921504606846978-2305843009213693952
Range ofs3 2305843009213693953-3458764513820540927
Range ofs4 3458764513820540928-4611686018427387902
</MetaHandleRanges>
<DataHandleRanges>
Range ofs1 4611686018427387903-5764607523034234877
Range ofs2 5764607523034234878-6917529027641081852
Range ofs3 6917529027641081853-8070450532247928827
Range ofs4 8070450532247928828-9223372036854775802
</DataHandleRanges>
<StorageHints>
TroveSyncMeta yes
TroveSyncData no
TroveMethod alt-aio
</StorageHints>
</Filesystem>

- **Copy Build System Software to Remaining Nodes**

1. Copy the below Hadoop Build System software to remaining nodes.

   a. */opt/hadoop-version*
   b. */opt/orangefs*
   c. */etc/pvfs2tab*
   d. */etc/orangefs-server.conf*

- **Start OrangeFS**

    1. Intialize OrangeFS using the below command:
       /opt/orangefs/sbin/pvfs2-start-all -c config_file_path -p prefix_path -s f

       config_file_path = path to the OrangeFS server configuration file on all OrangeFS servers

       prefix_path = path of OrangeFS prefix (installation directory)
    2. OrangeFS server is started

       opt/orangefs/sbin/pvfs2-start-all -c config_file_path -p prefix_path -m orangefs_mnt_point.
    3. OrangeFS servers can be stopped by following command

       /opt/orangefs/sbin/pvfs2-stop-all -c config_file_path

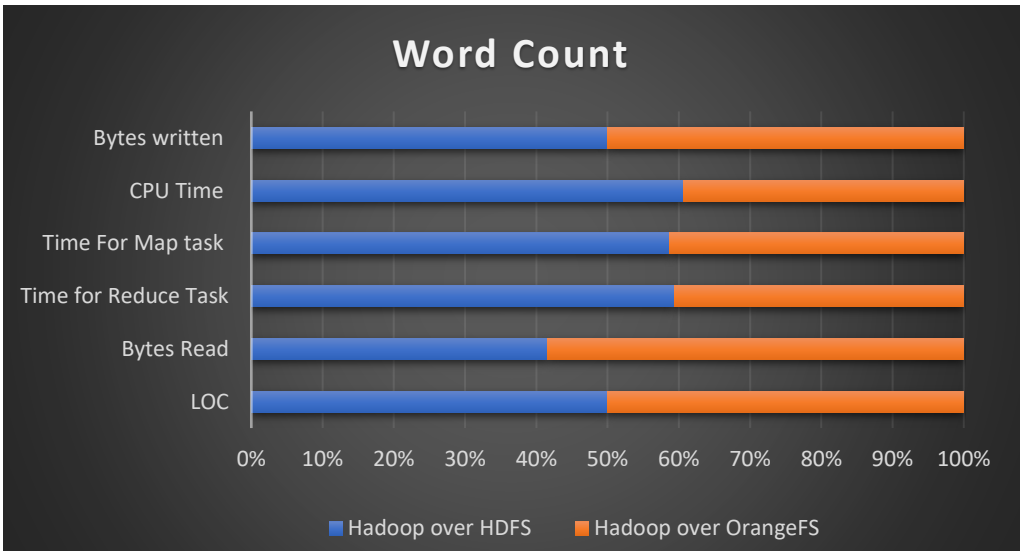
- **Start Hadoop**

    1. To start the necessary Hadoop daemons (JobTracker and TaskTrackers), run start-mapred.sh on the node configured to be the JobTracker
       /opt/hadoop-version/bin/start-mapred.sh
    2. To use the JobTracker's web UI, open the following in a web browser: http://localhost:50030
    3. To stop the JobTracker and TaskTrackers, run stop-mapred.sh
       .. */opt/hadoop-version/bin/stop-mapred.sh*

8.PERFORMANCE EVALUATION

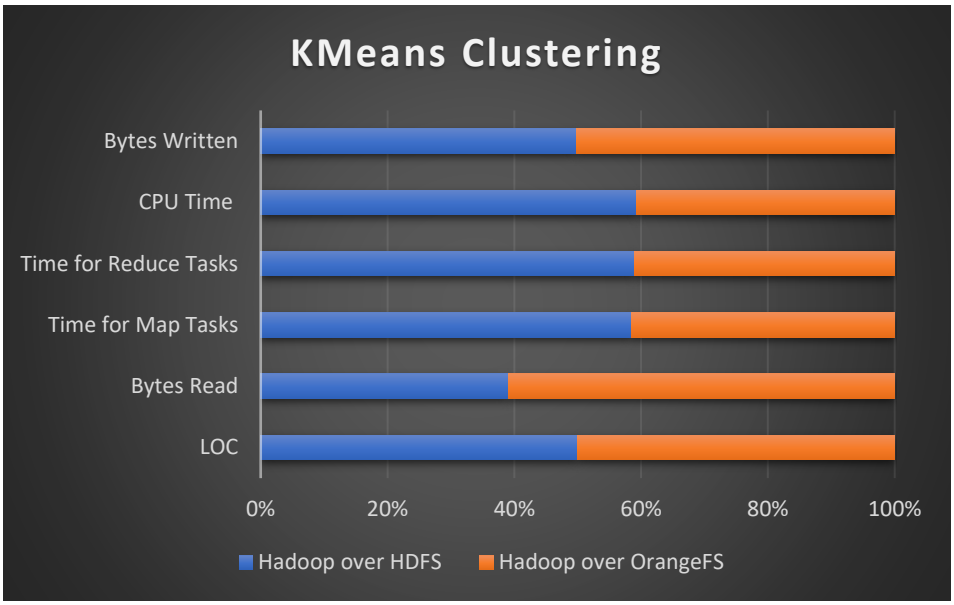
Word Count

	Hadoop over HDFS	Hadoop over OrangeFS
Lines of Code (LOC)	61	61
Bytes Read	47	66
Time Taken for all map tasks (ms)	2330	1593
Time Taken for all reduce tasks (ms)	2738	1922
CPU Time (ms)	1528	991
Bytes Written	172861	172562



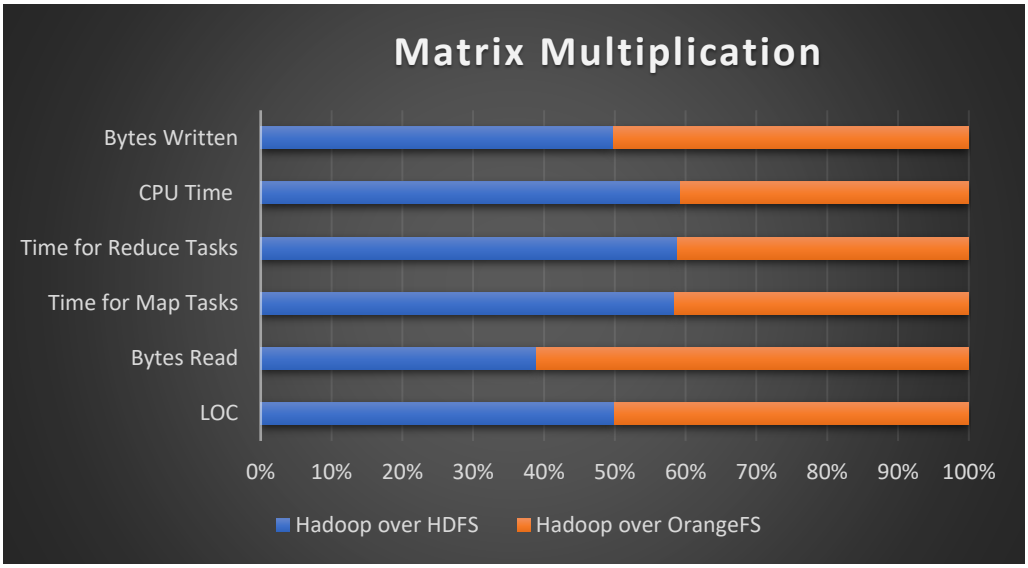
K MEANS CLUSTERING

	Hadoop over HDFS	Hadoop over OrangeFS
Lines of Code (LOC)	213	213
Bytes Read	204	319
Time taken for all map tasks (ms)	7227	5138
Time taken for all reduce tasks (ms)	2861	1995
CPU Time (ms)	1589	1091
Bytes Written	263795	186381



MATRIX MULTIPLICATION

	Hadoop over HDFS	Hadoop over OrangeFS
Lines of Code (LOC)	97	97
Bytes Read	106	134
Time taken for all map tasks (ms)	6965	5684
Time taken for all reduce tasks (ms)	2807	1798
CPU Time (ms)	1356	1165
Bytes Written	260188	287452



9.RESULT

By reducing the number of map and reduce tasks in each program, we can find that the execution time has been substantially been reduced by almost 25% in Orangefs and has proven improvement over Hadoop Distributed File System.

10.CONCLUSION AND FUTURE ENHANCEMENT

OrangeFS yields a 25 percentage faster run time than traditional approach. While doubling the number of nodes accessing the OrangeFS, cluster results in 300 percent improvement on run time. By increasing the additional servers we can obtain additional space, memory and better IO performance. While providing the improvement of a good general purpose file system, Orangefs can also provide an excellent concurrent working file system for other applications running MapReduce code. Further improvements can be done by using redundant metadata and using fully redundant data by maintaining a set of duplicates. Also depopulating a server out of service, ie to move the contents of server to a nearby client.

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