

On studying the performance of Hadoop Map Reduce vs MPI for Aggregation Operations: A Big Data Challenge

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I. Introduction

IT Revolution has been chiefly responsible for generating a tremendous amount of data, often referred to as Big Data. Parallel and distributed computing systems have largely been utilized for solving problems involving the big data. Of various distributed & parallel computing systems like vector processing systems, coprocessors (e.g. GPU's), and others; Map Reduce and MPI (Message Passing Interface) have found increased attention in recent times. MPI has been a de facto standard of parallel programming for decades [11], while Map Reduce is of comparatively recent development. The major difference between both the platforms is that Map Reduce uses HTTP/RPC protocols for communication which are clearly slower than the MPI's communication (which provides both point-to-point and collective communication). On the flip side, programming in MPI is clearly more difficult and requires lots of skills (in programming, networking, domain knowledge, and others) in comparison with Map Reduce. Both of these programming paradigms have been extensively utilized in their respective domains.

For the proposed work, a comparison in performance of MPI and Map Reduce frameworks would be studied using an aggregate query which calculates minimum value of taxi fare given by month and year for the taxi trip records data collected by New York's Taxi and Limousine Commission [3]. The choice of minimum values by month & year was based on the fact that aggregation tasks are required by both the scientific and business community since they provide summaries of the data before proceeding with any type of analysis or visualization. The challenge here is to optimize the performance of MPI and Map Reduce for aggregation tasks and compare them using wall clock time as a performance measure.

In the following section, a review of past works has been presented. Subsequently, the problem definition has been restated. Section 4 introduces the dataset used for the project. Finally, a discussion and conclusion of the proposed work have been presented.

II. Literature Review

It is a well-established fact that Map Reduce finds application in the business community while MPI has been used more by the research community. There many available implementations of both the technologies to choose from. For instance, available MPI implementations are Open MPI, Boost MPI, MPICH, and others, while available Map Reduce implementations are Apache Hadoop, MongoDB (the database has a built-in map reduce framework.), Clusterpoint XML (another database having a built-in map reduce), and others.

The choice of implementation for MPI would be Intel MPI (OpenMPI) library since it is available on SHARCNET consortium. For Map Reduce, [15] showed that Hadoop Map Reduce performs better than MongoDB build-in Map Reduce and the support for Clusterpoint seems no longer available [14]. Thus, Apache Hadoop would be the solution to test the Map Reduce framework performance which has also been a de facto tool to store big data. For the proposed work, a single node implementation of Hadoop would be utilized.

III. Problem Definition

The focus of the project is to minimize the wall clock time it takes to compute minimum value of taxi ride fare by month and year for NYC TLC taxi trip records. For the same, optimal parameters need to be identified for both Map Reduce & MPI. The parameters for tuning the performance of MPI & Map Reduce are as follows:

- 1) Message Passing Interface: Aggregation task for the given problem which is to calculate the minimum taxi ride fare by month and year may be carried out in one of the following two ways:

Approach 1. The Master node reads the complete data and distributes it to the slave nodes for processing. The slave than returns the processed data. The merit of the technique is its simplicity. The following technique is more favorable in presence of system that have very large main memory.

Approach 2. The master node sends a data chunk for slaves to read and process. This approach works only if data is to be read from a single large file and if the MPI infrastructure supports the relevant function. The approach saves a lot of time by minimizing the time to transfer data.

It has been established that it is possible to split the data file on SHARCNET using Approach 2. Hence Both the approaches would be implemented and tested for run time and utilize the best time for computation.

- 2) Map Reduce: Map Reduce usually works the best when you wish to implement one-pass algorithms. For the given problem, we are finding the minimum value grouped by year and month. Since Map Reduce already is optimized for such works, no programming optimization is required for the Map Reduce code. However, there are several factors such as the amount of data chunk read for each task (AKA input split size), size of the data block, and the choice of intermediate compression format; can impact the processing time of Map Reduce tasks. Thus, we have the following three parameters for the Apache Hadoop Map Reduce implementation to optimize:

- 1) Optimal size of the block: A block (AKA physical record) is a sequence of bytes or bits, usually containing some whole number of records. In Apache Hadoop, the recommended minimum block size is 64MB and may be increased to higher size. However, since each task is carried out on a block of data, a single failure may result into redoing the work for the data of the size of one block. Hence, keeping a large block size may not be ideal. For the given problem we wish to compare the time consumption for aggregation task when block size is 64MB and 128MB.
- 2) Optimal input-split size: While processing the data in blocks, each block is split into manageable sizes called input-split. The size of input-split is a critical factor that determines the total main memory that may be utilized by the Map Reduce function. The decision regarding input-split size is based on the minimum values set in the configuration files and a heuristic that determines a good size based on block size and other parameters or as set by the programmer/developer. These parameters may be controlled easily by using relevant functions in java Map Reduce API.
- 3) Optimal compression format: Data transmission using intermediate stages like between Mapper and Reducer tasks occur by re-writing output of the Mapper onto disk. Since disk operations are 300 times slower than the main memory operations, compressing the data during intermediate stages may save both space and time. Since data needs to be retrievable even after selecting only a portion of the compressed data. It becomes essential to compress using only splittable compressing techniques like LZ0, bzip2, or

snappy. Hence, for the given work we wish to test the optimal compression format for no compressing vs snappy compression technique.

The parameters for comparison for the above technologies are wall clock time for task completion.

IV. Dataset

To serve the purpose of the given work, taxi trip record dataset from New York's Taxi and Limousine Commission (TLC) for yellow taxis has been used [3]. The dataset has information about vendor id, total fare with breakups, co-ordinates for pick and drop-off, and pick up and drop of time. The data is available as files storing monthly data that begins from January, 2009 and runs till June, 2018. Total size of the dataset is 215 GB. For the given problem, we would calculate the minimum value of taxi fare by month and year to calculate the wall clock time for Map Reduce and MPI.

V. Discussion:

Use of distributed & parallel programming platforms have been known to require a considerable efforts in getting the right libraries, debugging network problems, and implementation of data distribution logic. For the proposed work, we have two sets of techniques wherein the said efforts would be required. Both of these techniques need a different form of skillsets and expertise. While Map Reduce requires competency in programming language java (for better control over the jobs which is available through only Java Map Reduce API), handling library issues (majorly library version problems or corrupted library builds) and YARN based scheduler policy issues (especially in allocating virtual memory and main memory); MPI requires expertise in programming language C/C++ and debugging skills.

For the proposed work, so far following issues have been encountered and few which have been solved:

For Map Reduce:

- 1) Oracle Java version problem: Apache Hadoop build process displayed error because Java 9 removed the activation package as a part of its main release. Initially, the problem was solved by using JAVA_OPTS as -D.javax.activation. However, later due to consideration of issues of the same package for running the software, Java 9 was degraded to Java 8.

- 2) Compression Library Issues: There were issues encountered during the build process of Snappy library support with Apache Hadoop build on Windows 10. This was solved by custom building the snappy library using Microsoft Visio. However, the build errors with snappy still prevailed. Finally, the system was shifted to Linux Mint for hosting the Apache Hadoop solution. This worked well and passed the initial debugging tests for the snappy library and has not given any warnings or errors related to Snappy library for four Map Reduce job tests. These tests were carried out using Map Reduce standard word count program.
- 3) Memory issues: Virtual memory limit issues had been encountered while performing Map Reduce on relatively small data of 700 MB. The culprit was identified to be a YARN policy. YARN does not allow virtual memory to exceed the size of main memory reserved. This was handled by suppressing the test of virtual memory calculation by setting the “yarn.nodemanager.vmem-check-enabled” flag as false. This is because it was found that enough virtual memory is available (The system has a swap space of 8GB of which less than 3GB was utilized as found using the “top” command and confirmed using “VmStat”). Another work around the same was found to be using the right value for “yarn.nodemanager.vmem-pmem-ratio”. It was identified that 2.1 usually works as the best estimate for “yarn.nodemanager.vmem-pmem-ratio” and the same may be considered in the future if a related situation arises in the future.
- 4) Storage size estimation: The amount of data to be analyzed is 215 GB for Map Reduce. However, an estimation of the size of the data during intermediate stages must be carried out to make sure that there is enough space for the intermediate data.
- 5) Data ingestion problem. Since we have data in 102 files to be loaded into HDFS before being able to perform analysis, it becomes essential to have software to ingest the data. From the literature we found multiple ingestion software's like Apache Gobblin, Apache NIFI, Apache Kafka, and others [16]. From a review of these solutions, it was found that most of them use Web HDFS to ingest data and hence it was decided that a layer of abstraction by using another software is not a good way to ingest the data. Hence, data would be ingested by using the traditional approach using the hdfs command-line tools.

For MPI:

- 1) Debugging challenges especially for unsafe codes.
- 2) Memory issues: Usually segmentation faults and data access issues.
- 3) Algorithm for chunking data files: It would be essentially difficult to program an algorithm that may read a chunk of data and process it. Finally, it was found that MPI implementation at SHARCNET allows the same.
- 4) Due to limitations of the penalty imposed by SHARCNET on long-running jobs, I wish to cut down the dataset for processing of MPI to 1 GB. If time permits, analysis with even larger dataset size may be carried out.

Time Management Issues:

A lot of tasks must be accomplished in the given project and the same would be carried out using plan as shown in Figure 1.

VI. Conclusion

To tie a bow, an aggregate query to find the minimum value of taxi fare by month and year has been proposed to compare the performance of Map Reduce & MPI. For the same after review Intel MPI over SHARCNET and Apache Hadoop for Map Reduce have been suggested for measuring the performance. The parameters for comparison suggested is wall clock time. For performing the proposed analysis, usage of NYC TLC taxi trip records dataset has been suggested.

Tasks\Month		October			November			
		2nd Week	3rd Week	4th Week	1st Week	2nd Week	3rd Week	4th Week
MPI SHARCNET Tasks	Optimal no of Processors		Y					
Map Reduce	Optimal block size	Y						
	Optimal input-split size		Y					
	Optimal Compression format			Y				
Compile Results					Y			
Report Writing					Y			

Figure 1. Plan for the project

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