Big Data Processing and Visualization in the Context of Unstructured data set

A Thesis Submitted to School of Information Science

By: Temesgen Desalegn

Advisor: Million Meshesha (Ph.D.)

7/27/2016

DECLARATION

I, the undersigned, certify that this research is my original work and does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Name: Temesgen Desalegn

Signature: _____

This thesis has been submitted for examination with my approval as university advisor.

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ADDIS ABABA UNIVERISTY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF INFORMATION SCIENCE

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A Thesis submitted to the School of Graduates Studies of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Information Science

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To my beloved families!

Acknowledgements

"Commit to the **LORD** whatever you do, and **HE** will establish your plans." – Proverbs 16:3

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Acronyms

3Vs – Volume, Velocity and Variety

ACID – Atomicity, Consistency, Integrity and Durability

API – Application Programming Interface

BI – Business Intelligence

CAP – Consistency, Availability and Partition

DISC – Data Intensive Scalable Computing

DML – Data Modification Language

DRIP – Data Rich Information Poor

HDFS – Hadoop Distributed File System

HiPPO – Highest Paid Person's Opinion

HQL – Hive Query Language

IoT – Internet of Things

MPP – Massively Parallel Processing

NoSQL – Not only Structured Query Language

NSF – US National Science Foundation

RDBMS – Relational Database Management System

SSBI – Self-Service Business Intelligence

Abstract

Today, it is not uncommon to face data deluge that has brought challenges to every sector across all industries. The rate of data growth is exceeding currently available storage capacity as a result of data creation by everything which is connected to internet; in addition to human activities over cyberspace, Internet of Things (IoT) are playing crucial role in business activities by generating highly valuable information and insights that cannot be tapped otherwise. On the other hand, social networks has brought a platform that facilitates human interaction among themselves which is creating a room to everyone to produce huge data sets using computers and smart phones as well. Moreover, data creation rate in variety of formats is yielding real challenges to traditional technologies. Big Data processing and visualization is current challenge due to data growth with high velocity in variety of data type.

To tackle Big Data problems, the methodology applied is in detail investigation of current challenges, identification of technology frameworks and ecosystems, design solutions, implementation of the designed solution and test of implemented solution using Big Data set is taken place. Hadoop ecosystem which is starting point of technological shift from traditional technologies to more advanced and different has shown the change of data and technology landscape.

The result of experimentation has revealed that Big Data processing and visualization requires comprehensive framework and collaborative ecosystem. In addition, change of model of data storage and processing is changed to send process where data resides rather than bring data to process. Huge and complex data sets visualization is not possible to realize using accustomed set of technologies.

Key words: Big Data, Hadoop, MapReduce, NameNode, DataNode, JobTracker, TaskTracker, Hadoop Distributed File System, Visualization

Chapter One

Introduction

1.1. Background

Nowadays, more devices are coming to cyberspace with a lot of functionalities that provide services at different level, for instance, individual, group and community. Now, people are at a verge of simplifying life questions which could be expressed in terms of space and time. Interactions of Internet of Things (IoT) and people are generating data that cannot be left alone due to its value. World data growth in the years (2011 and 2012) was 90 percent of total human history of data creation [1]. Current infrastructure and applications are allowing human kind freedom for communication and doing activities in the format of digital data which was inconceivable some years ago. These all-encompassing facilities and capabilities are pouring data from different sources and directions to global data storage which is accumulated to about 1,800 EB (Exabyte) or 1.8 ZB (Zettabytes) [2]. The continuation of data accumulation, which is expected to be 50 times in 2020, at an alarming rate within a variety of formats makes it difficult for current practice of management of data.

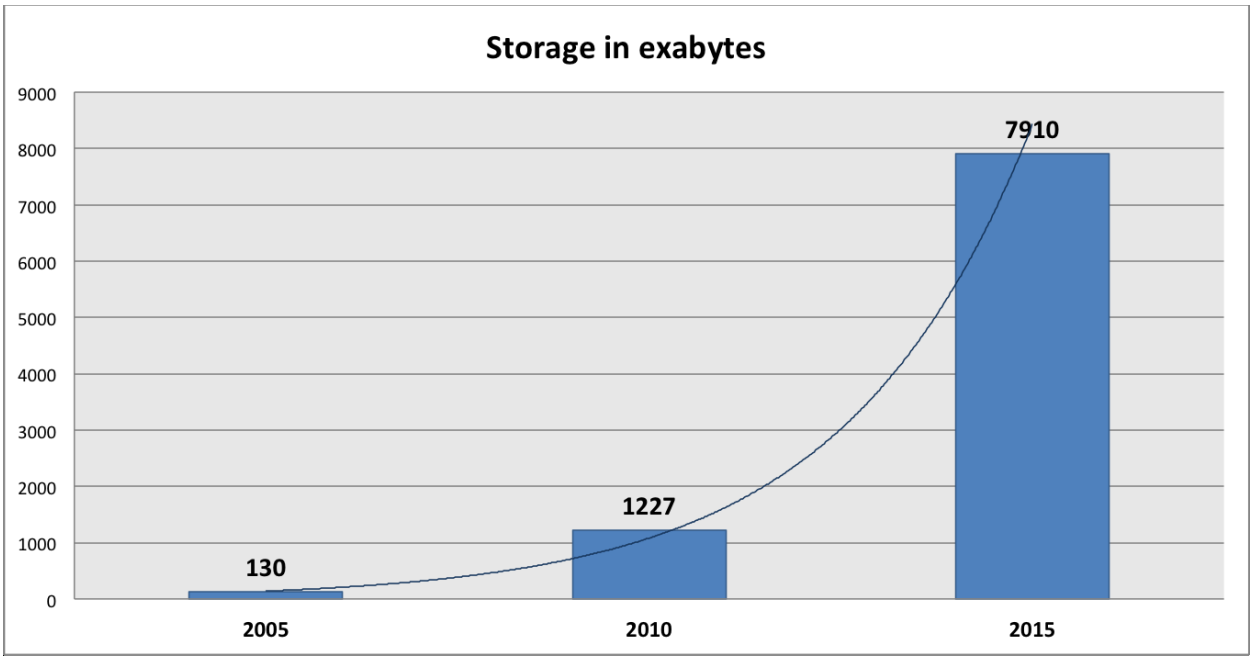


Fig. 1.1: Data growth over time [3]

As shown in Fig. 1.1, Big Data refers to the explosion of available and potentially relevant data, largely the result of recent and unprecedented advancements in data recording and storage technology. In this new and exciting world, data is accruing at the rate of several gigabytes per day [4].

Volume is the key issue that is bringing challenge to current art of state of technologies with regard to storage capacities and accessibilities. It is critical for business organizations as well as scientific communities to get full picture of environments surrounding them in order to act or react in the way that enhances their outcomes. Highly competitive organizations are looking for more data to take advantage of competitive edge over their competitors. More importantly, the output of data driven decisions are by far greater than decisions that are dependent on intuitions or guts of individuals who is also known as Highest Paid Person's Opinion (HiPPO) in an organization. In addition, scientific researches become more dependent on accumulated data ever.

Creating data is now on finger print of everyone within few seconds [5]. Mobile devices, social medias, sensor embedded devices and others are the major means to create data instantaneously. Rapid velocity is creating a room for transient data which is short lived by nature. However, it should be channeled to drop its value to organization bed rock data accumulations. Data in motion gives insight for decision as well as actions.

Period of structured data repositories and management have been coming to end as technologies are advancing from time to time. In this challenging time for organizations, modality of data creation is shifted from employees to users or consumers. Practically, consumers or users are not willing to enter to limited set of columns or fields of data entry. Variety of data such as structured, semi structured and unstructured is streaming of data to organization so that organizations get opportunities to act upon it so as to extract insight and take decisions based on extracted insight.

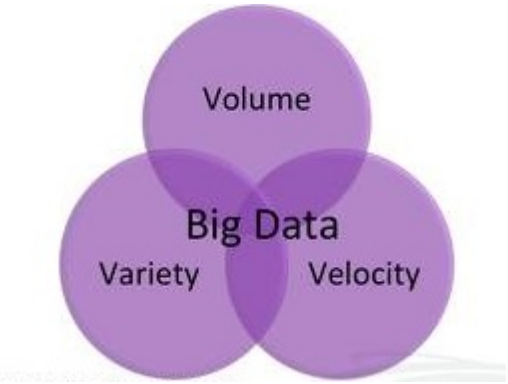


Fig 1.2: 3Vs of Big Data [6]

As shown in Fig. 1.2, combination of Volume, Velocity and Variety (3Vs) [7] are current challenges of every industry due to advancement or new model of communication and transaction. Globalization is pushing cross-cultural unification to modernize of societies those who were isolated or lagging behind for centuries from technological progress in developed countries. As a

result, peoples have started to consume and produce data in huge, with high frequency and in different format.

Extraction of values from big data is a challenging task that needs a means of processing and visualization so as to get in depth insight. The challenges that are creating and retrieving data especially unstructured data set is imposing to look for new way of processing and visualization. Furthermore, data growth becomes indistinguishable phenomena that initiates swift action to tap its benefits.

1.2. Statement of the Problem

Our planet is becoming host of data creation and repository at alarming rate. Everyone in everywhere is generating data from their day to day activities, communications, transactions, and so on. The main sources of data are human-generated digital footprints which comprises 70%, machine generated data and sensory data. Nowadays, organizations are overwhelmed by external data sources on the top of their internal data source which is called dark data. The challenges that organizations are facing is multifaceted such as the availability of big storage space (volume), the speed at which data creations takes place (velocity) and diversification of data types (variety). Tsunami of data from smarter planet whereby Internet of Things and people are introducing values extractions from big data [8].

In general, big data is immersed with wealth of new insights across all industries, expertise and life to provide and guide discoveries and innovations. Smart devices are the main actors in creations and utilization of big data that shifts tradition practices into modern life style and even research direction is reversed from ‘theory to data’ to ‘data to theory’ paradigm. It is estimated that total population and total mobile phones are approximately 6.8 billion and 6 billion

respectively [9]. Moreover, mobile applications have changed the way people think, live and transact in smart spaces and time.

However, traditional tools and techniques have no capabilities to serve big data in the way that accommodates three Vs (volume, velocity, variety). Data Rich Information Poor (DRIP) is a scenario where there are vast data but inadequate useful information for a given purpose. This is because of limitation of RDBMS, data warehouse and data analysis tools.

Even though there are researches that have been conducted on area of Big Data in general, there is no clearly solidified or identified agreement what Big Data is all about. Some of them are discussing traditional data mining under umbrella of Big Data; and others are dealing with samples and statistics to explain or explore Big Data. Actually there are some handful researches so far encountered to spot what is done in the area. As described in [10], Big Data components, challenges and opportunities is discussed in terms of seven dimensions, historical background, what's big data?, data collection, data analysis, data visualization, impact, human capital, and infrastructure & solutions. It indicates that Big Data and Analytics require all the above dimensions in today's business environment. Large scale web mining by utilizing Data Intensive Scalable Computing (DISC) system to extract information and models from web data necessitates traditional algorithms by putting power of parallelism [11]. DISC system is considered as one of powerful, fault tolerant and inexpensive to process large data sets. Shown in [12], design of conceptual big data adoption model within organizations by employing business case development, technical, organizational, and information privacy related processes. As indicated in [3], real time big data processing using Storm system is used instead of MapReduce which is appropriate for batch processing. Storm is distributed and fault tolerance system which achieves processing in collaboration with other tools such as Cassandra, Redis and Kafka over NoSQL.

Experimental researches on Big Data architecture, data processing using DISC System, real time data processing using Storm and conceptual framework have been studied in arena of Big Data; however, no research is found that shows experimental study on actual data set for Big Data processing and visualization using emerging Hadoop ecosystem to date. So in this research an attempt is made, to investigate and identify techniques and tools to process Big Data to extract values and visualize to audiences. The 1V (Volume) is experimented using Hadoop ecosystem in this study; however, remaining 2Vs (Variety and Velocity) requires further investigation.

1.3. Research Questions

In conducting this study, the following research questions are explored and addressed:

- What are the challenges and opportunities of big data?
- To what extent the current available toolset enables to process and visualize unstructured data sets of big data?
- How does data growth be handled?

1.4. Objective of the Study

The purpose of this research is to identify and investigate the means of big data processing and visualization using Hadoop ecosystem.

1.4.1. General Objective

The general objective of this study is to process and visualize unstructured data sets of Big Data so as to analyze execution time, memory requirement and fault tolerance.

1.4.2. Specific Objectives

The specific objectives of this study to fulfill general objective are:

- To identify big data technologies landscape

- To experiment unstructured data sets of Big Data using Hadoop ecosystem
- To explore means and impacts of big data visualization
- To recommend further study in the area

1.5. Scope and Limitation of the Study

The scope of this research is specifically conducting big data value extraction for Volume using available technology stacks that facilitates knowing the landscape of data processing technologies. At the same time, utilization of available technologies in an arena of data science might lead to in detail investigation of created capabilities to handle current problems.

The limitation of the study is that it does not encompass the other 2Vs; for instance Variety and Velocity are not experimented. In addition, large data size such as Terabytes and Petabytes are not experimented in this study. These factors need well equipped labs with clusters of machines in order to conduct complete experimentation on top of adequate timespan.

In this study, we are not dealing with clusters of machines to process Big Data in its full scale which requires high fund and collaboration of experts. While processing huge data sets, there are violations of privacy of individuals; and privacy is not considered under this study. In addition, security is becoming central focus of discussion and real challenges of everyone; nevertheless, we are not encompassing it in this study.

1.6. Methodology of the study

1.6.1. Literature review

Extensive literature review is conducted from books, journals, conference procedures and the internet in order to gain deeper understanding of Big Data landscape and its value proposition to

society at different level. It gives the spot of current data challenges as well as its application in wide areas.

1.6.2. Data sources

There is organization that provides free datasets or eBooks in different file formats such as text, pdf, epub e.t.c.: http://www.gutenberg.org

From the above source, philosophy category of five hundred books are downloaded which is text format data set that is used for experimentation as well as testing for big data technology stack implementation. Actually, the link has vast number, more than 50,000, of free eBooks with different categories which are easily and freely accessible but some other companies provide links as open data sources but they may require payment or processing in their custody and then they charge service fee. In addition, there are also claiming that they provide public open data set by requiring registration as citizens of a country.

1.6.3. Development and Processing Tools

Open source framework, Apache Hadoop Framework, is mostly customized for academic purpose and it is Hadoop Distributed File System (HDFS) which alleviates current processors limitation that processing capacity is at its ceiling point [13].

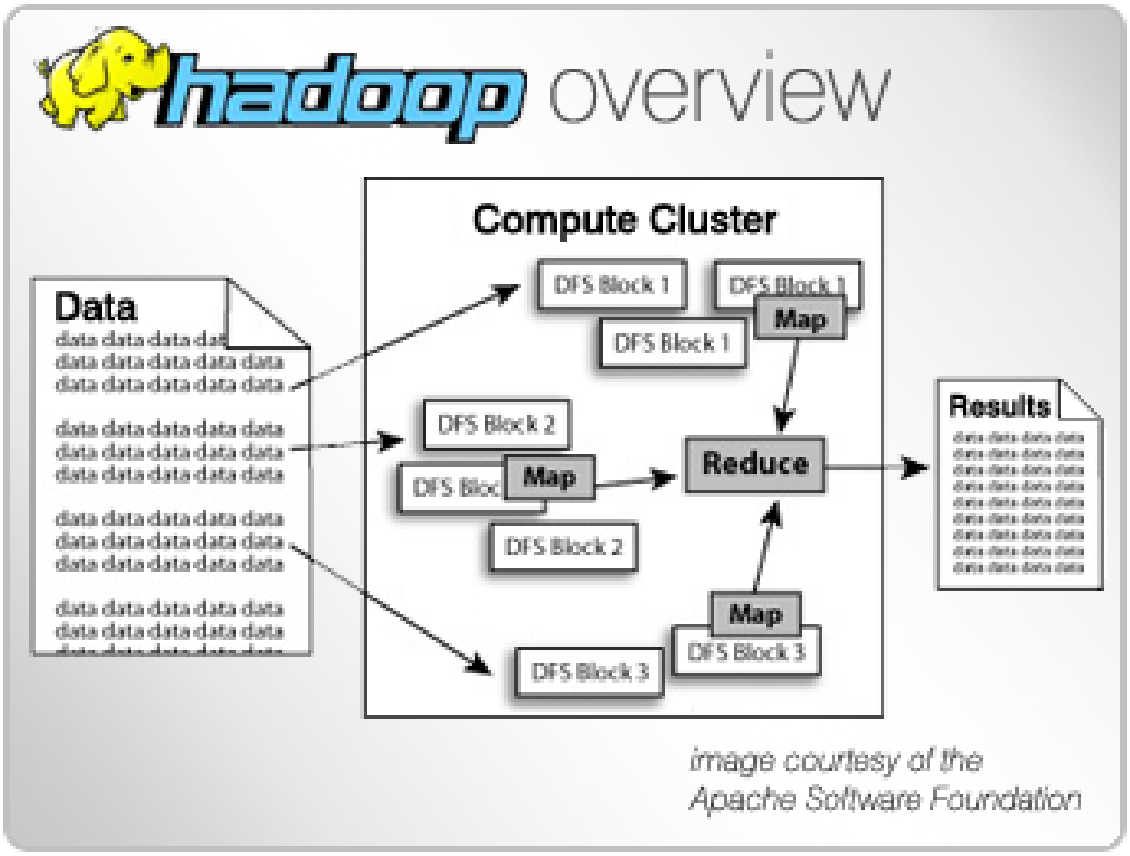


Fig. 1.3: Apache Hadoop Framework [14]

As shown in Fig. 1.3, Apache Hadoop Framework provides a platform so that data sets passes a number of phases from input or raw data stage to output or result stage.

Hadoop is open source platform which is used for data storage and processing of very large volumes of data at high speed with low costs. It is possible to build large scale distributed data processing system using commodity computers that lowers cost of computation. It is also possible to run Hadoop on single desktop or laptop for testing [15].

1.6.4. Visualization Tools

After processing data sets, the next step is converting the output or result of processing as input into visualization tools. Visualization is key companion of big data processing so that the result of

huge data set processing can easily be grasped by experts as well as others. Without using visualization tools, it requires a lot of effort and time to comprehend output of big data processing. There are few big data visualization tools that are powerful and with a capability of accommodating vast data elements within a single screen [16]. In fact, data sets of population, big data, cannot be easy task to present using customary visualization tools as its fitness for sample data set in case of limited variables. Tableau, visualization tool, is marketing leading and its application in wide industries including research makes it as a tool of choice to visualize in this study.

1.6.5. Evaluation Procedure

Studies in this area are at their infant stage; so, it is difficult to find common or conventional evaluation procedures that can be utilized for this study. So, results of the study are evaluated with major three dimensions; namely execution time, memory requirement and presentation. Firstly, the output of experimentation is evaluated in terms of time of execution that has taken to ingest, process and yield result. Secondly, memory utilization to process from client command to output file. Lastly, the output of experiment is required to fit for consumption by audiences so its easiness for presentation is taken in account. The result of evaluation is expected to show better parameters value in comparison with traditional data warehouse.

1.7. Significance of the Study

The output of the study benefits research communities as well as others such business, government, scientific communities. The global scenario is now utilizing big data as source of insight, bases of decisions and development; for instance, U.S. government is taking wide initiatives in big data projects as priority. In perusing innovations and values propositions within data as commodity, we

have opportunities and at the same time burden to make and bring all necessary resources to tackle current practice of data management so as to avoid falling behind in battles of globalization if we are not alert enough to go head to head. Moreover, the impact of this study is strong enough to show and motivate the immerse of values that are related to data creation, storage, processing and utilization by individuals, groups, organizations and government bodies who are interested in getting values of data for their decisions. As a matter of fact data silos, data errors and data governance are the main obstacles to provide timely analysis and decision for mega projects in developing countries. So, this study tries to give clue on value and commoditization of data.

1.8. Organization of the Thesis

The thesis is organized as follows:

- Chapter One discusses Background; Statement of the problem; Research questions; Objective of the study: General objective and Specific objective; Scope and Limitation of the study; Methodology of the study: Literature review, Data sources, Development tools Visualization Tools and Evaluation procedure; Significance of the study; and Organization of the thesis.
- Chapter Two discusses literature review particularly Big Data and its challenges; Tools and Framework: Hadoop, Hadoop Distributed File System, MapReduce, Data Processing; Data Visualization; and Related Work.
- Chapter Three discusses Data Collection and Design particularly Data Collection: Data Type/Nature, Data size and Data Sources; Planning of Technology stacks; Architecture of the system; Design: Approaches and Techniques, Design goals, Data analytics design and Data visualization design; and Implementation particularly Algorithms: Mapper algorithm and Reducer algorithm; and Visual components.

- Chapter Four discusses Experimentation and Results particularly Experimentation; and Results: Data processing and Data visualization.
- Chapter Five discusses Conclusion and Recommendation
- Appendices

Chapter Two

Literature Review

Companies are now overwhelmed by the blast of data flows from sensors, radio frequency identification or other devices which is either voluminous or unstructured to be processed using traditional practices. This real time data or information is consumed for new product development, service enhancements or ways to respond to changes in the environment [17]. Values embedded in stream of structured and unstructured data that answers most of questions that could not be raised by business yet due to technological limitations. Only 5% of data available in organization is utilized but 95% values of data have option to be tapped as big data technology advances. Anything that goes through digitalization speaks about who is utilizing it, how it is utilized further why it is utilized. Actually, BI has no capabilities to process data which is diverse, more granular, real time and iterative, demands organization to get in depth information from specific moment in time before changes happen. The old thinking is “too much data is bad thing” is reversed nowadays to “more is better” [18].

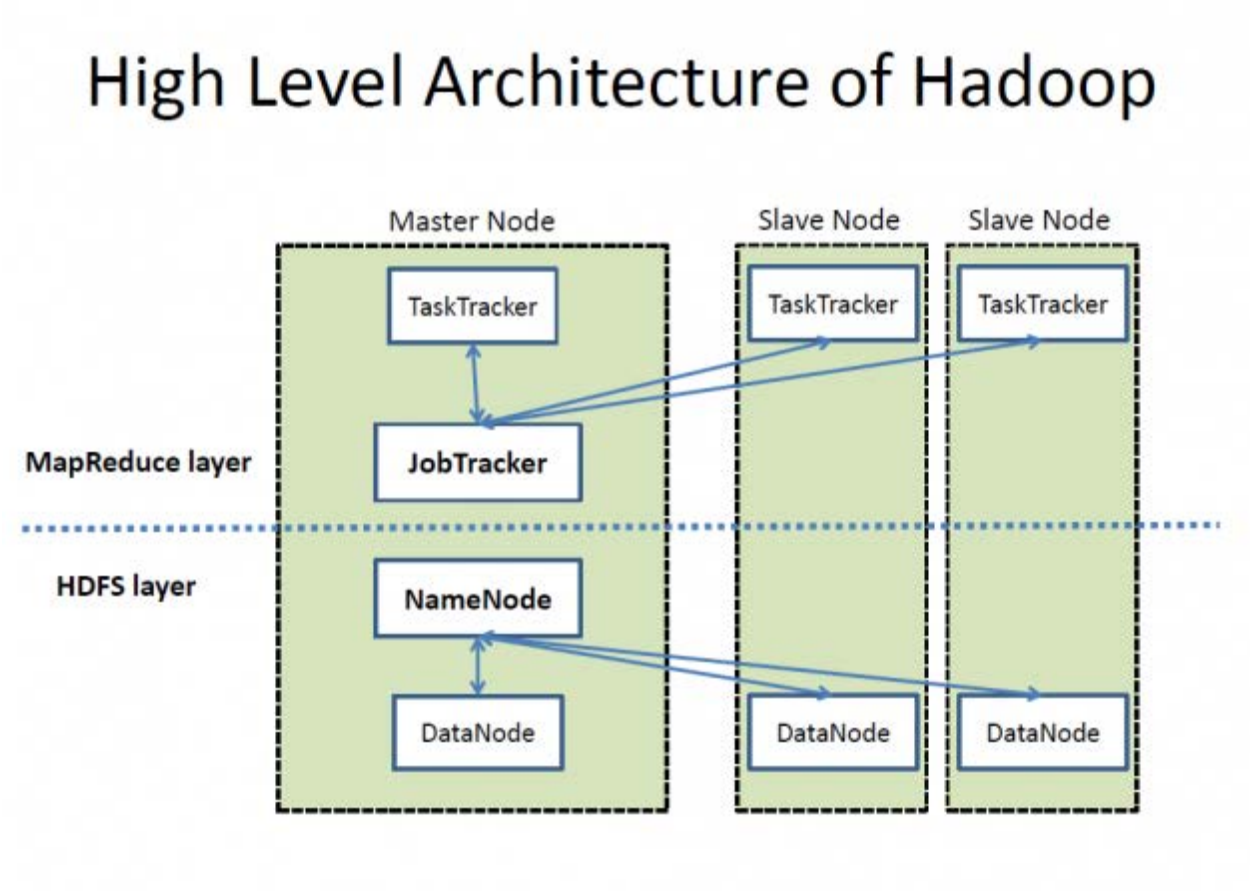


Fig. 2.1: High Level Hadoop Architecture [19]

Files are distributed and taken in Hadoop HDFS to store across all computers in the Hadoop cluster(s). A file will be chopped into smaller blocks with size greater than or equal 64MB and distributed over other nodes in order to assure replications and fault tolerance. For instance, whenever one or more node(s) fail(s), the chunk of a file or data in failed node(s) will be replicated to other nodes. So there will never be data loss. As shown in Fig. 2.1, Hadoop HDFS comprises NameNode as master node, secondary NameNode as checkpoint and DataNode as slave node which stores actual data [15].

2.1. Big data and Its Challenges

Streaming of data from different sources is accumulating large volume of data with variety of forms at high speed, velocity. Big data is different from “lotsa data” or “massive data” in the way that it should incorporate all Vs (volume, variety and velocity) in order to be treated as big data. It is not analyzed in its totality so it is required to pass through multiple steps like data extraction, data filtration, data transformation and data analysis. The difference between small and big data is goal, location, data structure and content, data preparation, longevity, measurement, reproducibility, stakes, introspection and analysis. These dimensions help to distinguish big data from small data [20].

Sources of data are Call logs, mobile-banking transactions, online user generated content such as blog posts and tweets, online searches, satellite images and so on. Insight from big data narrows gap between information and time. Big data is industrial revolution of data. Data is taken as raw good with little “intent and capacity” [21]. However, big data is not without challenges as it is under development stage. It has data challenges (Volume, Velocity, Variety), process challenge (display complex analytics on mobile devices) and management challenges (data privacy, security, governance, ethics) [9]. On the other hand, benefits of big data which are by far overwhelming such as its application to medicine (e.g. flu trend analysis by Google), climate change, food safety, science, business, technology, manufacturing, financial markets, cyber security, etc. There are a number of giant companies like E-bay, Facebook, Wal-mart, Yahoo, Google … who are implementing as well as enhancing big data technologies; additionally they have started selling big data as services for small and medium sized companies [22].

Business firms that use big data are apart from traditional analytics implemented in a way that by focusing on data flow, depending on data scientists and process and product developers rather than

data analysts, and analytics is become part of core business. Commonly used tools like MPP Databases, Apache Hadoop Framework or Internet and Storage System provides capabilities to load, store and query large datasets in near real time. Moreover, it executes advanced analytics which is developed under information ecosystem. Big data analytics tools are considered as next generation of IT processes and systems that is designed for insight but not just for automation [17].

In most organizations, information is taken as boarding spring of successful business activities and similarly they give full attention for every drop of information by considering it as life blood of business activities as product or service to be sold to customers. So they are exercising information management practices as a means of managing available information for innovation and decision making. However, current trend of data overwhelm from inside as well as outside of organization is creating burden on processing capability of data as usual. The era of big data puts thinking of data storage rather than value creation from stored datasets to deliver innovative solutions and at the same time coping changing environment in the way that enhances organization's competitive position in an industry. Even to the existent, some organizations are focusing their effort only on lighting of operation of current activities rather than enabling business as well as differentiating their services or products. Big data technologies, especially open source framework such as Apache Hadoop Framework, are creating conducive environment for processing large volume of data with low cost and high speed and it has capability to scale out as capacity of the organization grows to accommodate more data sources. It scales horizontally without need of rework in order to scale up processing capability of already in placed system [23].

In near real time, data is required to be processed to extract insight and achieve tangible time value of data in transit. More data does not allow us to see more rather it allows us to see new, better

and different. Big data as resource or tool helps to advance society; moreover, it supports to address recurring global challenges such as energy, environment, drought, poverty and so on [23].

The benefit of big data is awesome in all paths of life despite the obstacles and the risks, the potential value of Big Data is inestimable ... NSF aims to advance the core scientific and technological means of managing, analyzing, visualizing, and extracting useful information from large, diverse, distributed and heterogeneous data sets so as to:

- accelerate the progress of scientific discovery and innovation
- lead to new fields of inquiry that would not otherwise be possible
- encourage the development of new data analytic tools and algorithms
- facilitate scalable, accessible, and sustainable data infrastructure
- increase understanding of human and social processes and interactions
- promote economic growth and improved health and quality of life

The new knowledge, tools, practices, and infrastructures produced will enable breakthrough discoveries and innovation in science, engineering, medicine, commerce, education, and national security. However, finding and using standards and measurement for big data analysis is limited due to its infant stage; so big data analysts especially data scientists are developing a set of strategies as well as tools to align data with meaning and reality. On the other hand, in small data defining “control” is common practice; practically, groups are divided into control and test groups. But defining “control” group in big data is impractical because data analysts have no controls over big data. In addition, experiment results are difficult to repeat with given population [20].

Testing hypothesis using big data resources could lead to false confirmation; so, forcing big data to answer specific question is act of self-deceive which might produce wrong conclusion.

Moreover, retesting results pass through hectic and long path that require a lot of resources and time. Finally, confirmation of the result could not be as expected due to a number of factors. As matter of fact, big data projects are done or processed without help of statistical or analytical software packages. On the contrary, human beings are better in processing large information, organizing and visualizing it as appropriate. For instance, "… we humans have a long-term memory capacity in the petabyte range and that we process many thousands of thoughts each day. In addition, we obtain new information continuously and rapidly in many formats (visual, auditory, olfactory, proprioceptive, and gustatory)." [20].

Smart machines are nowadays inseparable human companions in every aspect of endeavor which ranges from dressing to spacecraft. As Internet of Things, smart homes, smart cities are getting broad bases and controlling business sectors and research centers. They are becoming sources of high volume data at very high speed as result they have surpassed data generation by digital human foot print. This phenomenon is stressing the importance of complete suite of tools to analyze and extract relevant value so as to arrive important decisions. Even though big data is the answer, it is difficult to formulate the questions [24].

2.2. Tools and Framework

2.2.1. Hadoop

Hadoop is a framework that comprised of a number of components for its proper functioning and returning intended results. As shown in Fig. 2.2, major components are NameNode, secondary NameNode, DataNode, JobTracker and TaskTracker. Each of these components has well designed to accomplish certain task in general. NameNode is the master or brain of the whole Hadoop system and its main duties are tracking address of all stored files, listening heartbeat message of all DataNodes, manages schedules of JobTracker, holds information about inter rack status and so on. Secondary NameNode is taken as backup node which takes snapshot of NameNode in order to restore normal functioning after its failure. DataNode is a slave node where the data is deposited and data manipulation takes place before aggregation activities started. JobTracker is the one that orchestrates all tasks to be carried out throughout across task assigned nodes. TaskTracker is a slave by its very nature and its responsibility is carrying out ordered task to be performed at low level which is individual nodes or commodity machines where data is stored [25].

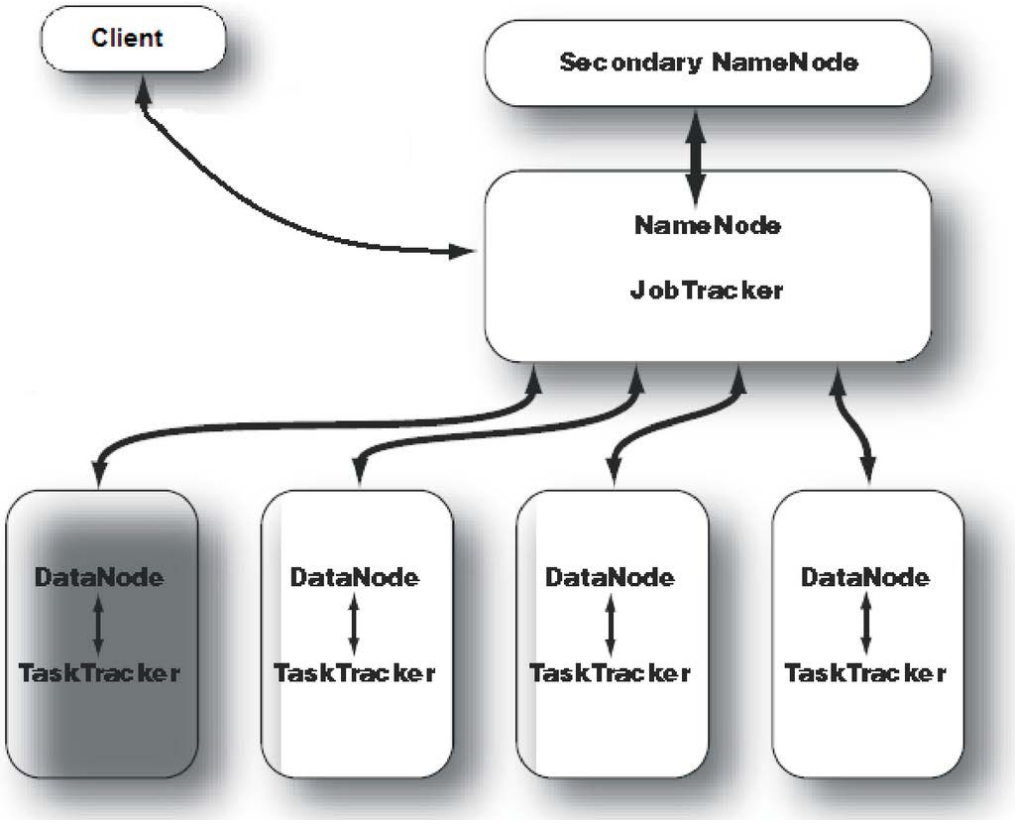


Fig. 2.2: Hadoop Components [26]

Hadoop is also an ecosystem which consists of a set of related projects that are implemented to facilitate customization based on experience and expertise of organizations. The major projects are Hadoop Streaming which enables script writing for those who are familiar on script languages, Hadoop Hive which provides SQL writing capabilities for those who are working with SQL languages, Hadoop Pig which is purely procedural language that supports data pipeline scenarios and Hadoop HBase that stands with real time data retrieval rather than batch processing. On top of these, Hadoop Distributed File System and MapReduce are the major projects that can be taken as backbone of the ecosystem [27].

In general, Hadoop MapReduce architecture provides an environment where parallel processing is done in large set of commodity nodes. Each node is a single unit of machine which executes

assigned task in full responsibilities without depending on other machines for its execution. As mentioned above, Hadoop MapReduce framework is purely software solution for current limitation of space and processing capacity. Instead of putting single machine with vast space and high speed like super computer which is actually very expensive; additionally, it demands top expertise to setup and for ongoing operations as well, there comes very cheap solution that can be implemented with reasonable investment. Return on investment of new big data technologies is amazingly high in terms of insight that may be extracted from processing untapped, unstructured, data set due to traditional technological limitation. From overall dataset 90% of data is unstructured data and it is rich with insights that can shape usual practices of every industry to modern way of accomplishing activities or achieving objectives [28].

The limitations of traditional RDBMS [7] and analysis tools are mainly scalability challenge which means as the size of data increases their retrieving and manipulation do not be scaling up to proportionally. In addition, schema oriented data storage and manipulation has been becoming bottleneck for diversification of data set processing. The foundational building blocks of traditional technologies such as data warehousing, transactional databases, ETLs, business intelligence etc. is directly related with structured data [27]. So, its application for semi-structured and unstructured data would be very laborious. Even though there are a number of attempts to alleviate scalability limitations of these technologies, their ceiling point to embrace changes is not elastic enough [29]. Moreover, ACID (Atomicity, Consistency, Integrity and Durability) [30] property of relational databases is not relaxing to elasticity for growth of data. Transactional nature of relational databases which is all transaction processing shall be committed at once or fail altogether makes it strict rule to be abided [3].

On the other hand, CAP (Consistency, Availability and Partition) [30] theorem has brought a room to achieve two of the three CAP tolerances by taking a context as guiding principle. It is impossible to secure all of the three tolerance variables in distributed computing environment. Especially, when big data is taken as platform to process large dataset at high speed of variety data in distributed setting, it is of sure there is trade off among CAP tolerance variables to properly achieve all of them once. As the theorem indicates, there is always compromise between Consistency and Availability in distributed computing situation. Whenever Consistency is given priority to achieve right response for requesters, Availability is sacrificed in terms of speed of response for requesters. On the contrary, if Availability is given priority in distributed computing environment, Consistency is relaxed to ensure uptime of the system [3].

In a nutshell, Hadoop has changed the landscape of data analytics in the way that eases data processing regardless of structure of data, with high performance and fault tolerant manner.

2.2.2. Hadoop Distributed File System (HDFS)

File storage structure has been changed to maintain distributed file storage along with ensuring fault tolerance. In 2004 [31], Google started to change algorithm in order to boost its search capability by indexing whole files in the internet. As result, it has released white paper on Google File System which was initiated new file system, Hadoop Distributed File System, to be developed by open source community. It is a mechanism to handle large files in distributed manner over multiple of nodes in the form of chunks that each chunk will be replicated as per set replication factor at time of configuration. Whenever there is failure of one or more nodes, data will be moved from failed nodes to active nodes where accommodation space is available. In addition, it creates

an environment where horizontal scaling is easily achieved to scale out to hundreds of thousands of commodity machines [25].

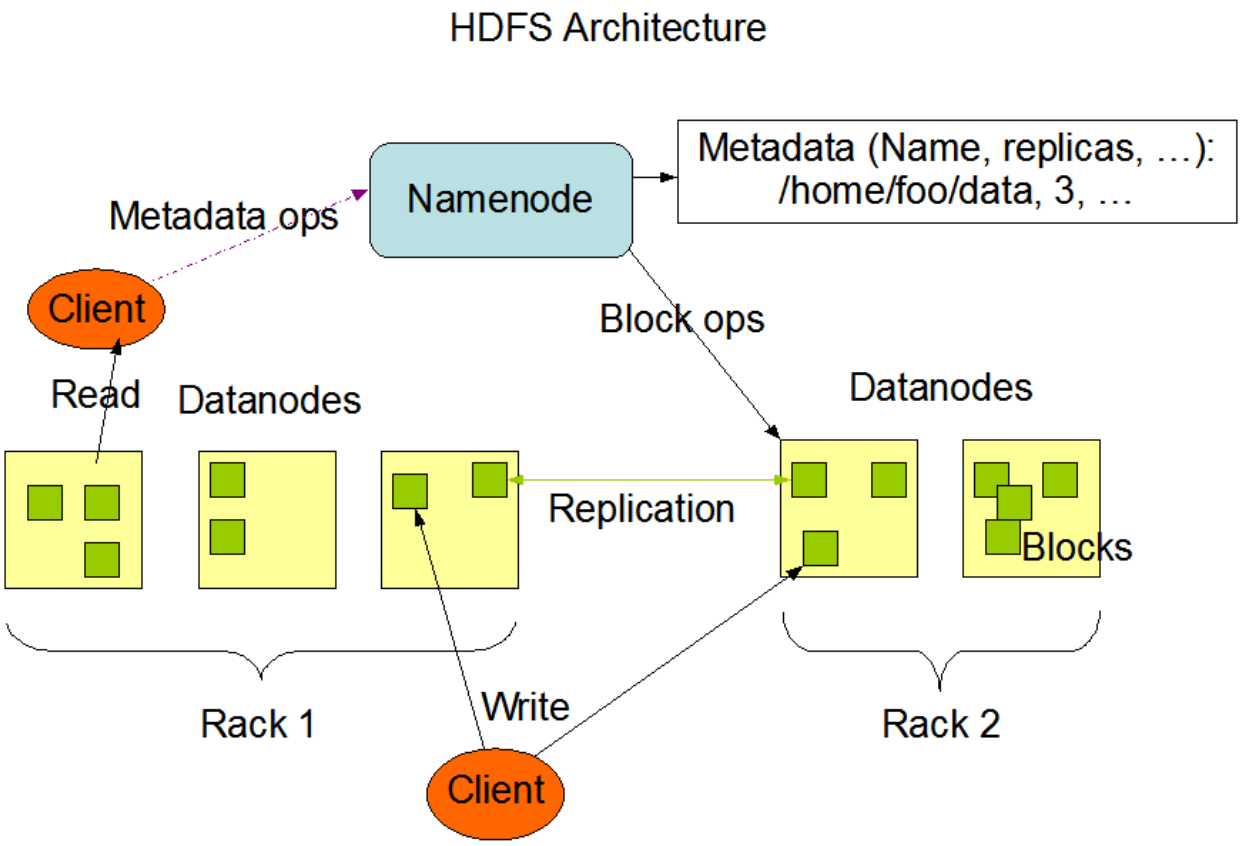


Fig. 2.3: HDFS architectural view [32]

In addition, as shown in Fig. 2.3, HDFS is becoming the center of architectural change for current computational practice by improving performance of latency and throughput. The impact of performance improvement, at level of software (Hadoop Framework) rather than hardware, is attracting giant companies like facebook, google, yahoo etc. so as to adopt the principle and practice as well. It enhances read/write operations of local file chunks by moving computation to where data is stored. It handles very large files which be gigabytes or more by reading or writing

sequentially to/from nodes therefore there is no need to bring data to memory in order to manipulate so the role of primary memory is becoming insignificant [12].

2.2.3. MapReduce

MapReduce is a programing model for processing large scale datasets in a single pass in clusters of thousands of nodes by assuring fault tolerance and it supports two types of functions for different purpose of duties [33]. Map Task is a function which is used to allocate data to nodes based on replication factor set. On the other hand, Reduce Task is also a function for aggregation of data results according to request initiated by client.

Even though Map Task and Reduce Task are two functions that are clearly visible to all parties, there are other functions in between Map Task and Reduce Task to play a role for supportive activities such as splitting, sorting, shuffling etc. Map Task depends on split function before distributing chunks of a file to nodes as per replication factor. In the same fashion, Reduce Task is heavily reliance on shuffle and sort functions in order to aggregate the result. Split function accomplishes the task of chopping file into preset size of chunks so that Map Task will able to send these chunks to a designated nodes after gathering information for free space availability. As shown in Fig. 2.4, Mappers create key/value pair for all coming chunks while storing them. Shuffle function, in addition, is responsible for taking input from Mappers and categorizing keys based on their groups. Sort function plays a role of sorting keys according their values before Reducers take in. Finally, Reducers combine similar keys and aggregate their values at each node which is local disk where the data resides.

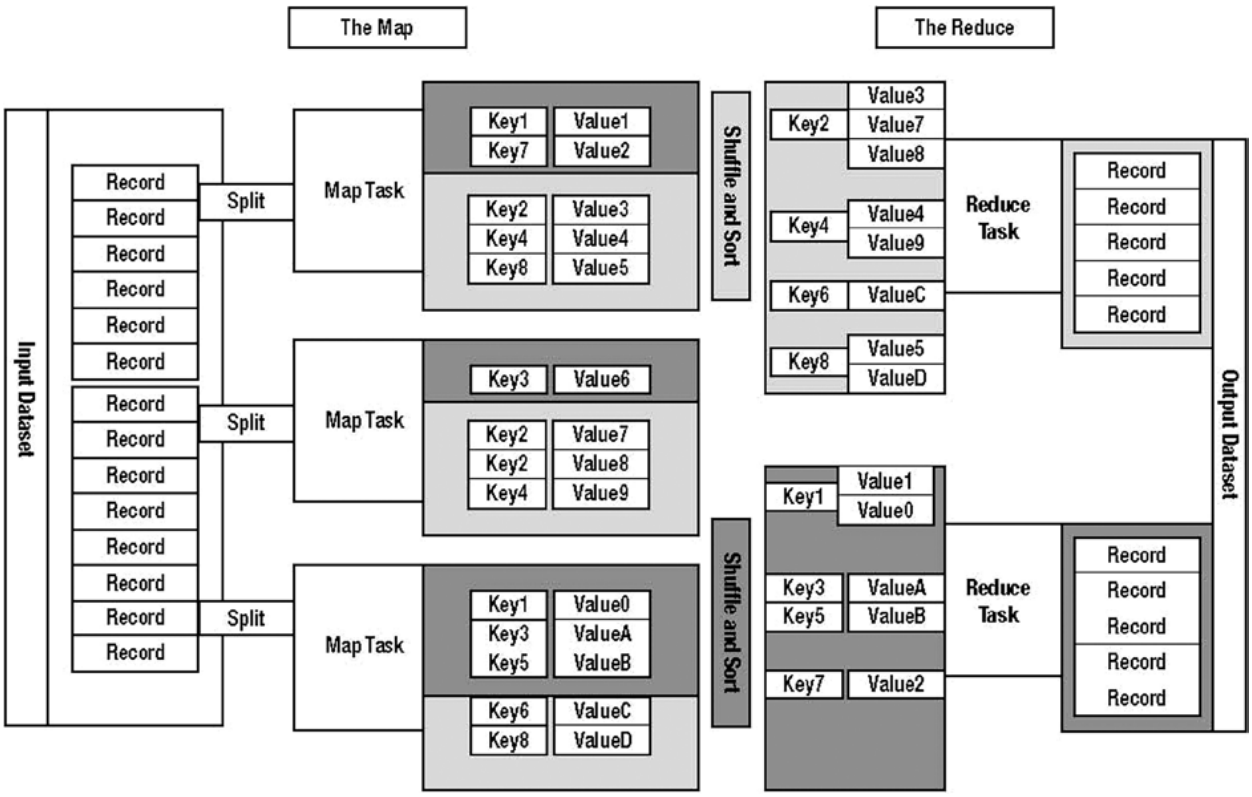


Fig. 2.4: MapReduce framework [34]

2.2.4. Data Processing (Technology Stack)

In big data technology stack scenarios as depicted in Fig. 2.6 below, style of data processing is shifted from retrieval of data from hard disk and sending it primary memory for processing to sending computation where data resides. This is great innovation for petascale data in order to avoid disk access and network traffic bottlenecks so that results will be achieved in reasonable time.

Major data processing paradigm shifts has been brought through implementation of MapReduce framework on top of Hadoop Distributed File System. Even though this has reduced burden of data transfer and manipulation to the level of uniformity in dealing big data, it has still challenge

in terms of generality to the specialists in the field by forcing them to know programming language implementation and its complexity.

Java [35] is the programming language which has been used to implement as an open source code and it is customizable by interested parties in order to adopt wherever Hadoop is used as a means to process big data. A lot of companies as well as expert communities are adopting Hadoop ecosystem and then adapting it to their own favorite environment by adding projects as depicted in Fig. 2.6. For instance, Microsoft is one of big providers of Big Data products as well as services but it has adopted Hadoop for big data storage and processing so its projects are totally dependent on Java libraries as foundation. Other programming and scripting languages are becoming part of Hadoop ecosystem as plugin onto MapReduce framework so that working on Hadoop is made as simple as performing usual projects using those languages. To mention some of these languages: Python, Ruby, SQL-like languages, Script-like languages etc. all of them run on the top of MapReduce framework.

Apache Hive [33] is a project that act like data warehouse for Hive Query Language (HQL) which provides for users a capability to process data using SQL-like language. In general, it abstracts details of MapReduce implementation such that users can inject their task into MapReduce without delving how it functions. The tasks are either sending data for storage or retrieval specific result after processing data from a set of nodes, commodity hardware. Actually, Hive queries are converted into Hadoop Jobs to run whether Map Task or Reduce Task which does not mean that rational database structure is imposed on MapReduce framework rather HQL queries are interpreted as task so that users will not be forced to write Map or Reduce Task programs to achieve data analysis objectives. Even if HQL is SQL-like language, it has additional features that are completely dissimilar to SQL queries, for example structs, maps (key/value pairs) and array.

Apache Pig [33] is a scripting language that eases to write jobs and send as MapReduce jobs so as to be executed against Hadoop. It is a platform which is openly extensible for data loading, manipulating and transforming by using scripting language is called Pig Latin. It supports complex and sophisticated data manipulation though it is simple scripting language.

SQOOP [7] is one of highest projects that is used to link relational database and Hadoop projects together. So it facilitates data movement from relational databases, structured data, to Hadoop, schema less or unstructured data, and vice versa. It is plug and play extensible framework that helps developers to program through the SQOOP application programming interface (API) so as to add new connectors.

Apache HCatalog [30] has a role to abstract data view from HDFS files stored in Hadoop into tabular form. It provides integrated abstraction form for all other projects that relay on tabular structure of data view. For instance, Pig and Hive use this abstraction in order to reduce complexity of reading data from HDFS. Despite the fact that HDFS can be any data format and stored anyplace in the cluster, HCatalog gives a means for mapping to file formats and locations into tabular view of the data. In addition, it is open and extensible for proprietary file formats.

HBase [36] is a project that supports the functionality of NoSQL (Not only SQL) database on the top of HDFS. It is a storage of large column that could be limitless number of columns along with billions of rows that facilitate fast access to huge datasets or large tables which is sparsely stored. It has a functionality of Data Modification Language (DML) [37] which supports inserts, updates and deletes; however, Hadoop by its nature it is a write once and read many or infinite times. In spite of its rational database nature, it does not provide full features of relational databases such as typed columns, security, enhanced data programmability and query language capabilities.

Flume [38] is a framework that handles streaming data of events besides the batch processing system nature of Hadoop ecosystem. It ingests incoming data stream into stages: collect, aggregate and shifts large volumes of data before commits to HDFS. It has major components – client, source, channel, sink and destination so that events flow through all components from client to destination.

Apache Mahout [39] is a machine learning and its overall goal is developing scalable machine learning libraries which is implemented on the top of Hadoop using MapReduce framework. Currently, it is based on four use cases: recommendation mining is used as core for recommendation engine, clustering is used to group documents based on related topics, classification is an algorithm that consumes already classified documents so as to classify new documents and frequent item set mining is a means of understanding bucketed items together.

Ambari, Oozie and Zookeeper are supporting tools for Hadoop ecosystem to work efficiently and effectively data analyzing process. Ambari [40] is a system center to Hadoop ecosystem for provisioning, operational insight and management of cluster. Oozie [41] is a scheduling application for Hadoop that manages chain of events, processing or processes which must be initiated and completed at specific time interval. Zookeeper [42], on the other hand, is used to support to manage and store configuration information.

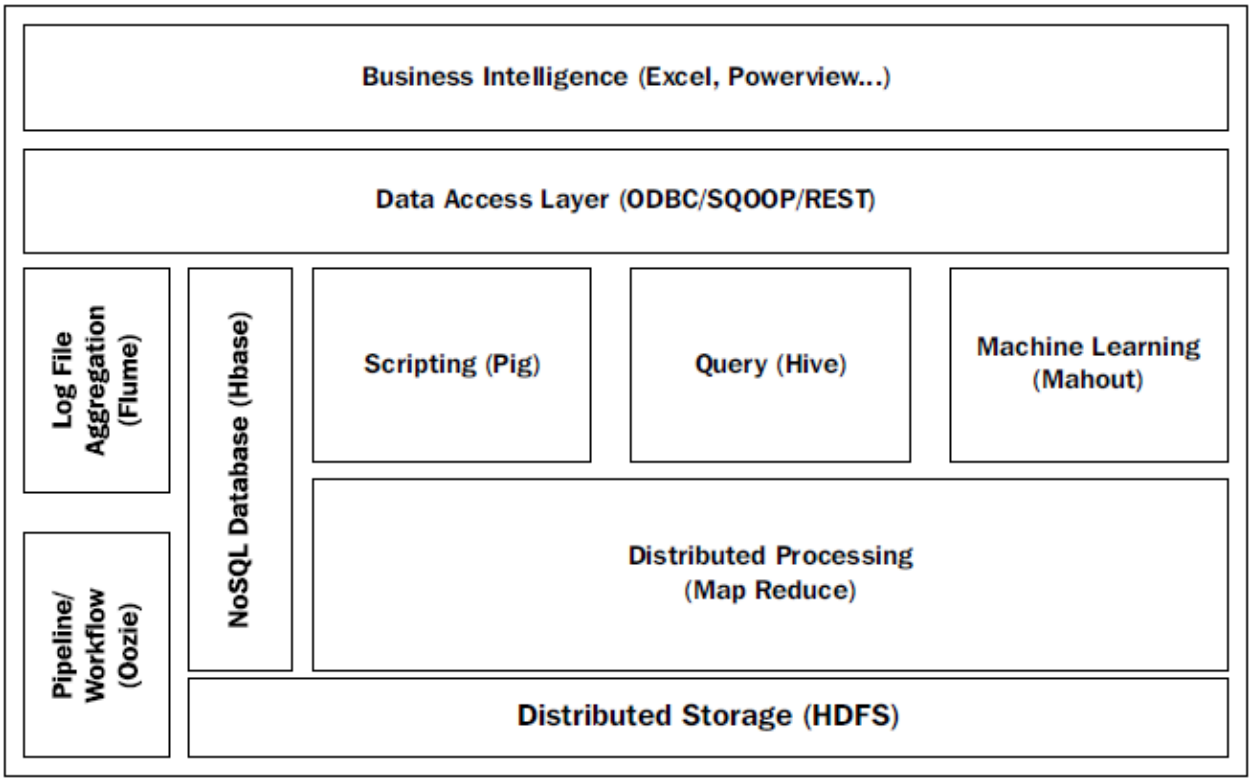


Fig. 2.5: Hadoop ecosystem [43]

2.2.5. Data Visualization (Presentation)

Using visualizations to express or communicate ideas is one of preexisting or oldest practice of human being before start of written materials. It is the most primitive means of communication which is dated back 3,000 B.C. because vision is the first and most used form of communication. Moreover, it is single important faculty of sense which helps to process and grasp huge information as compared to others. Beginning cave drawings to modern charts have been playing major roles in conveying pertinent information among people, organizations and others. The benefits of visualization is multidimensional in terms of vast volume of information at a time and its space usage is very small when compared to tables and textual data. Visualization system provides deep understanding independent of any language which is enlarges grasping capabilities of complexity of information. As Tufte [44] said, "Graphical excellence is that which gives to the viewer the

greatest number of ideas in the shortest time with the least ink in the smallest space." Actually, data visualization has two targets which are explanatory and exploratory for its users; where explanatory shows direct information that viewer begins with specific question whereas exploratory firstly presents information and then encourages viewer to generate questions from presented information [45].

Presentation of big data, requires exploratory type of visualization, differs from traditional Business Intelligence (BI), highly dependent on explanatory visualization type, in many different ways. Traditional BI tools have been focusing on models and reports that are consumable by few highly trained data analysts and executives. These models and reports are narrower in scope and additionally relays on historical and internal data only. As the size or volume of data bursts their embracing power would be shrink in much proportion so organizations decision making based on vast data keeping aside velocity and variety would be limited. Even variety and velocity present more challenges for data visualization by traditional BI technology stacks. In addition, it takes weeks or months to generate reports and dashboards from which necessary figures, issue static, rearview reports are pulled for executives and employees by highly trained data experts [46].

Emergence of big data has brought opportunities to create and utilize a number of self-serving data visualization tools into existence as shown in Fig. 2.6. These tools provide enormous options to all levels of users so that they can consume appropriate information regardless of time and space which is ubiquitous visualization of data. One of the tools is Self-Service Business Intelligence (SSBI) visualization platform which improves accessibility through smartphones, tablets, notebooks, laptops, desktops and so on. It provides a capability to "mash up" data from a number of sources: click stream, social media, log files, videos, and more. So users are able to analyze and visualize in real time with their high performing desktops as well as mobile devices in order to get

insight for their business. And it is supplied by TIBCO software which is second largest data discovery vendor in the world [46].

Limitation of visualization processing and display especially for big data depends on a number of factors such as nature of data, processing capacity of the machine, screen size and its resolution. The data items to be visualized has impact on type of visual means such as bar chart, pie chart, scatterplot, bubble chart, boxplot, heat maps, and others which have inbuilt size of accommodation. However, it is not without solution for this challenges; for instance, data analytics plays its role in reducing data size and complexity to the point that the level of appropriate information consumable by intended audiences [44].

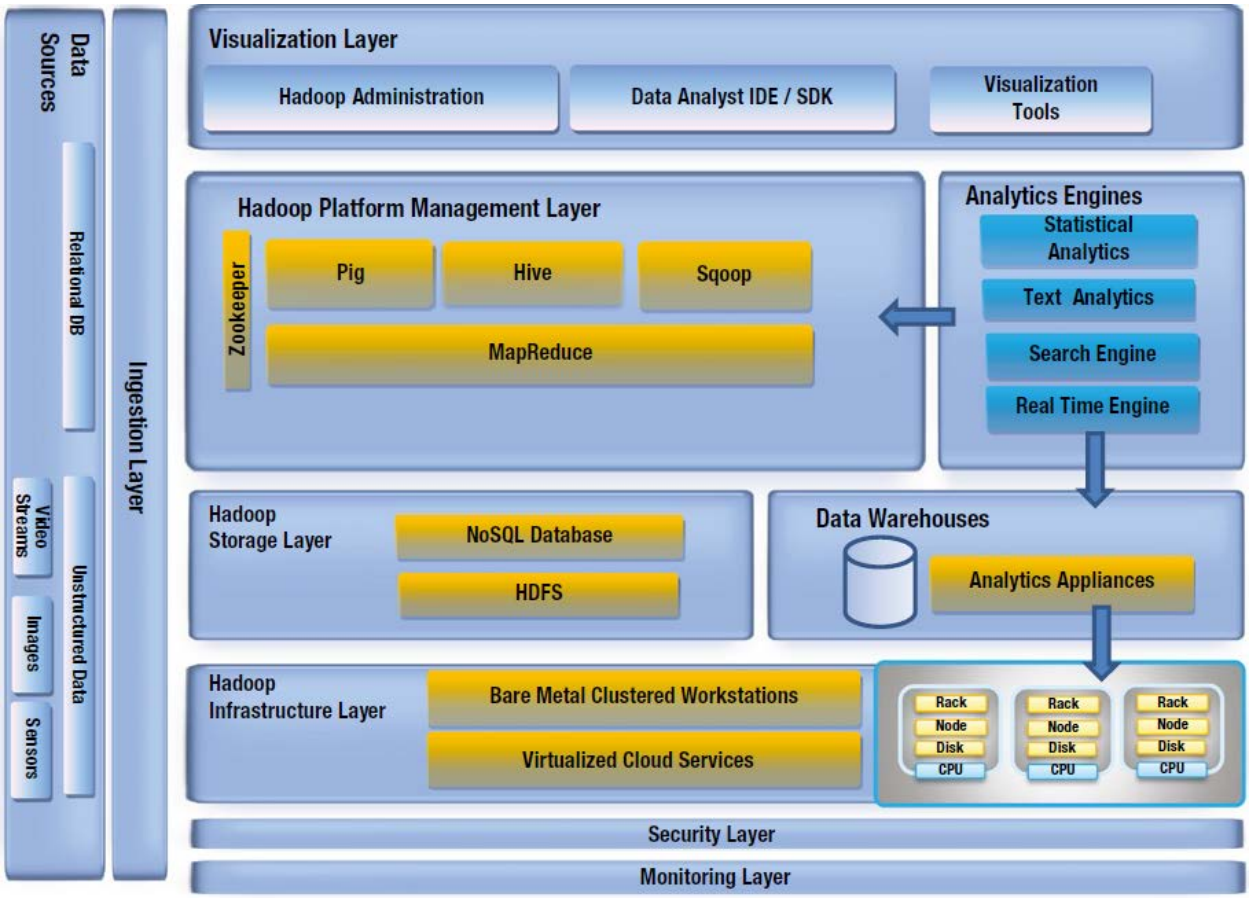


Fig. 2.6: big data architecture [1]

2.3. Related Works

As described in [10], Big Data components, challenges and opportunities is discussed to review the evolution and current state of Big Data in terms of seven dimensions, historical background, what's big data?, data collection, data analysis, data visualization, impact, human capital, and infrastructure & solutions. It surveys and distills literatures in order to know the effects of Big Data in business environment. The study is clearly showing the rewards of Big Data not only in business environments but also in everyday life activities of individuals. In general, it is conceptually indicating that Big Data and Analytics require all the seven dimensions in today's business environment.

Large scale web mining by utilizing Data Intensive Scalable Computing (DISC) System to extract information and models from web data necessitates traditional algorithms by putting power of parallelism [11]. DISC system is considered as one of powerful, fault tolerant and inexpensive to process large data sets even though it has limited computing primitive. The study has tackled three classical problems in Web mining: finding similar items from a bag of Web pages, content distribution from Web 2.0 to users through graph matching and suggesting new articles from stream in real time.

As indicated in [12], the study deals with design of conceptual Big Data adoption Model by exploring Big Data solution adoption within organizations. The methodology used is multi-case study research by interviewing practitioners of Big Data in telecommunication and energy utility sectors. Its result was a strategy development phase, a knowledge development phase, a pilot/test-case phase and a fine tuning phase are followed by organizations to implement Big Data solution.

As indicated in [3], high speed real time Big Data processing using Storm system is used instead of MapReduce which is appropriate for batch processing. Storm is distributed and fault tolerance system which achieves processing in collaboration with other tools such as Cassandra, Redis and Kafka over NoSQL. The study is also proposed system architecture that support to process Twitter and Bitly streams of data.

The research in [47] explains effects of Big Data, expressed by 3Vs, analytics on organizations' value creation. As per the study, data growth rate is becoming enormously high which has forced organizations to look for new technologies to handle it economically. Case study methodology is used to confirm value creation in organizations using Big Data analytics. The finding shows that Big Data analytics might create value in two ways: improving transaction efficiency and supporting innovation.

As explored in [48], spring of data sources are stretching limits of traditional data management so as to extract unused sources to gain more insights. To realize these values, organizations need to consider architectural expansion to accommodate new technologies on top of traditional architecture. According to the research, additional requirements have to be elicited on the basis of new data behavior to design reference architecture by combining several data management components. The reference architecture is built on traditional enterprise data warehouse architecture using evolutionary approach.

Literature review, related works and knowledge of researcher show that researches are conducted as conceptual studies in general to date. The studies indicate a real and current challenges of flood of data from a varying sources in different formats with high frequency; and they are showing potential benefits of Big Data implementation in organizations using qualitative methodology. But

the challenges are not addressed using experimental study for implementation and usage problems that are faced by all levels yet. In this study, Big Data processing and visualization particularly on unstructured data sets are conducted taking into account Volume of Big Data.

Chapter Three
Data Collection and Design

3.1. Data Collection

There are open access data for public use and research community to carry their activities without any associated fee even though now companies whose line of business (LOB) as data broker are flourishing in the data market. These companies are collecting demographic data for sale to all interested companies so as to increase their customer base.

3.1.1. Data Type/Nature

Big data is a type of diversified data that cannot be forced to align a certain format or confront standards and practice of an organization. In addition, in a big data scenario, data is short lived in terms of value that could be extracted from it for decision making or actions. Data has to be connected with other data sets to be most valuable to yield accurate insight.

Most big data research projects deal with behavioral aspect of data rather than pursuing veracity of data. This is because data creation is decentralized to individuals who are expressing their activities and whereabouts using various technologies like facebook, twitter, google+, pinterest, instagram and so on. So, truthfulness of data from individual data creator cannot be verified by any means. As a matter of fact, big data analytics projects are concentrating on behavioral aspects of data.

Categorization or sorting of data for management or manipulation is not a simple task. On the top of unstructured data sets, there are other types of data sets that are structured data which are transactional or machine generated data sets and semi structured data sets which are generated

from social media sources. Free text, for example books, is one of unstructured data sets that require high computational resources to preprocess and process with multiple steps so as to come up with final result.

In this study, unstructured data sets, free text, particularly more than five hundred eBooks of philosophy category is used for processing. The books are from a number of languages such as English, French, Chinese, Germany, Greece etc. and they are zip files that are being extracted while processing them in Hadoop framework.

3.1.2. Data Size

Current limitation of data storage and retrieval is triggering for further innovation in the form of software rather than adding more storage and processing speed for hardware. Commodity hardware machines are gaining bases in large companies instead of cutting edge super computers in order to solve complex data problems. As the size of data is sky rocketing from time to time from every direction, it is possible to say everything is generating data from every corner, about hundreds of Exabyte in a day. More importantly, the philosophy of the value of data overtime is reversed in the way that every drop of data should be tracked so as to tap its value because data is "new oil" [49].

Big data as target population can be varying size to be processed for a given analysis which depends on available sources and resources to analyzer(s). Analyzer might have hundreds of thousands clusters of commodity hardware machines which could be grouped into thousands of racks that will provide greater deep insight which shape business operations and strategy as well. Therefore, there is no upper ceiling for determining how vast data sets are good enough in order to get better or reliable insight so that business may utilize to act up on. More data, in general,

provides better and different perspective to see in depth; for instance take a sample of a population to test statistical significance of a certain treat but the sample might not yield practical significance for aforementioned test result whereas population as a whole might give real statistical significance for which the sample could not be revealed. Similarly, big data with its wealthy revelation is able to provide statistical significance regardless of practical significance.

Lower limit of data, on the other hand, in terms of size might be impossible to determine however either the composition of 3Vs [7] or Terabyte of transactional data that traditional data processing technology such as RDBMS [33] or data warehouse tools are incapable to store as well as process effectively rather their upper limit is bounded in the range of Gigabytes. It is not all about the size that determine minimum amount of data to be considered in order to be called big data, it is also important to know variety of data that determine its fate as big data as well. Another major factor that influence shift of technology in addition to volume and variety is velocity – the rate at which data creation takes place and its pouring into global data accumulation which brings challenge to traditional technology stack to tackle speed of data processing.

For purpose of this research, one data type, unstructured data sets, is used with size of 210MB as experimentation point of implementation for processing words in more than five hundred documents in a category of philosophy, Africa, Language Education, Wars and Science Fiction. It is final testing and to make it presentable through visualization.

3.1.3. Data Sources

There are plenty of data sources for public use which have been availed by different bodies like governments, non-governmental organizations, corporations and the like. Even world number one companies whose business totally dependent on data especially social data are selling data to other

companies who are interested in 360 degree view of their customers. One of these companies is providing free data set but it is limited set in terms of size and completeness. For instance in [50], Twitter has provided application programing interface (API) so that the research communities are able to ingest to their specific task. In Ethiopia, there is no such practice of availing open sources standard data access provisioning which might encourage more and better innovation among research communities.

From free available data sources for public use, mainly one data source will be used to conduct this research work as indicated in section 1.6.2. It consists of thousands of free books in a number of formats but text format book is appropriate for words in a document processing task. As a matter of fact words in a document processing for large sized books are not simple task which could be very difficult to handle by a single individual that might take longer time to finish it.

Individual book with plenty of pages that may require a series of steps to process in order to generate indexes for all words accordingly. However, HDFS file structure and MapReduce framework provides a means to manipulate in speed. In the first place, Map function distributes data to nodes by chunking a file into preset block size. And then Reduce function will sort and shuffle all words by individual word category after that Reduce function summarizes as a final single result.

3.2. Planning of Technology Stacks

The technology stacks that are used to demonstrate this research experiments based on available limited resources. Actually, big data projects implementation demands huge investment in terms of human resources, fund, space and other resources. For instance [51], Facebook is one of heavy implementer of big data technologies for its data processing activity. As depicted in Fig. 3.1, it has

hundreds of thousands of clusters of machines in its data centers which are managed by highly skilled experts. It processes petabytes of data every single day which is indeed collected from Facebook users who are uploading images, videos, sharing events, comments and the likes so that Facebook Company is able to use this information to advertise targeting, suggesting friends of friends to be connected and so forth.

Implementation of required components such as Hadoop single node cluster and its related java SDK to experiment is carried out in single machine. At the same time, external hard disk with 1TB has been used to install Hadoop framework and store experimental data so that data can be replicated to DataNodes and then processed locally. Furthermore, NameNode and JobTracker nodes are used to submit, control and monitor job execution.

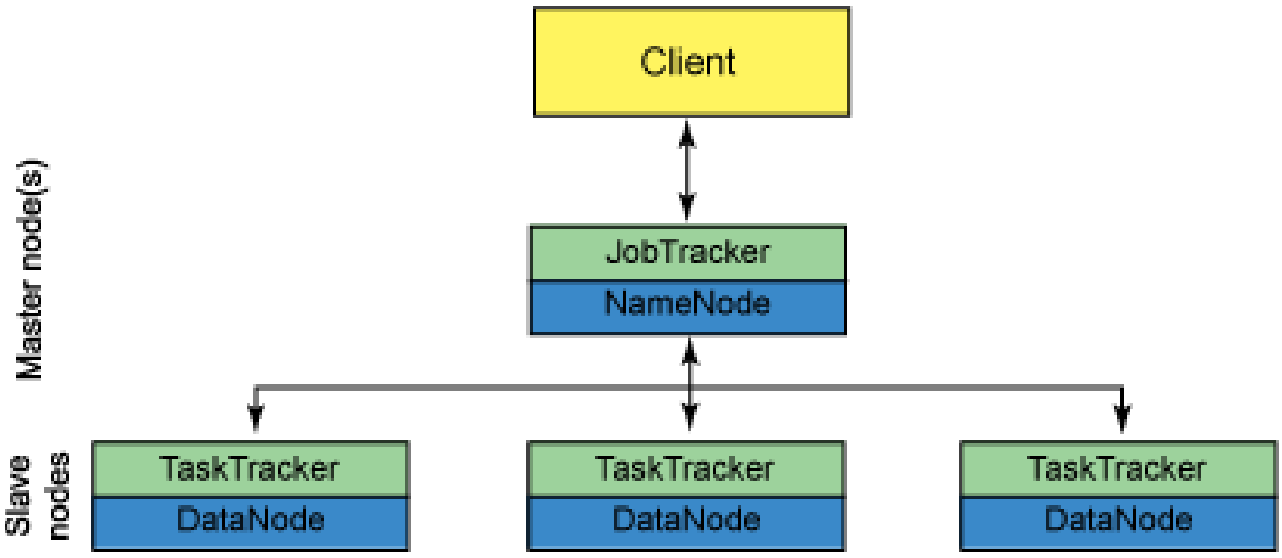


Fig. 3.1: General Architecture of Hadoop Framework [52]

3.3. Architecture of the System

The major components of the system comprise Hadoop framework and MapReduce framework. Hadoop framework library has been implemented as a bed platform so that other tools are able to

run on top of it. MapReduce framework, on top of Hadoop framework, utilizes classes to execute its functions.

As shown in Fig. 3.2, the architecture of this research implementation bases on single node cluster of Apache Hadoop 2.6.1 framework which encompasses two nodes; namely, NameNode which takes command from client and assigns task to DataNode, and DataNode where actual data processing takes place. In addition, it integrates with projects like Pig and Hive so that it has a capability to analyze and present data in a way that easily understandable.

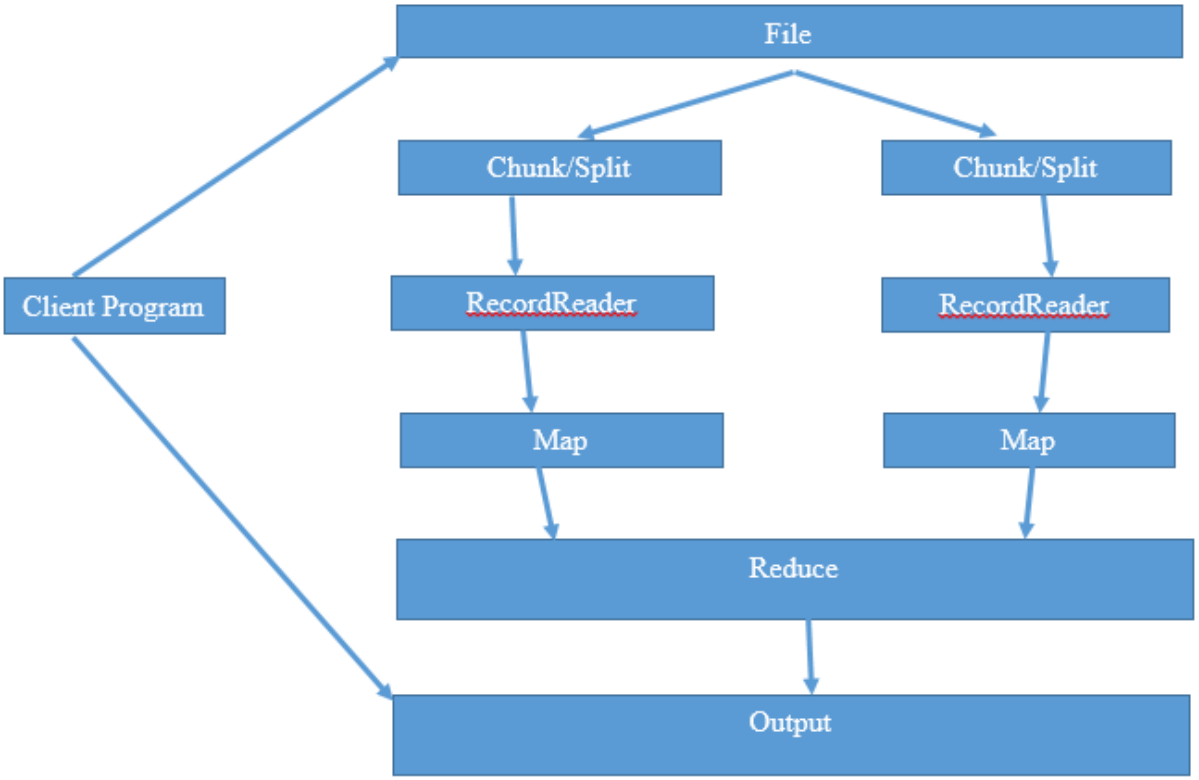


Fig. 3.2: Single node cluster architecture

3.4. Design

Implementing big data technology stacks require careful planning and management works to be executed. As number of clusters increases, clusters is organized into racks and number of nodes in a cluster depends on file size and storage space of each node. Complexity of design for Hadoop ecosystem is directly proportional to file size to be stored, storage space of nodes, size of clusters and number of racks to group number of clusters. Even though Master nodes and Jobtracker nodes are not part of clusters as well as racks, they play a major role in controlling, managing, scheduling jobs etc. of all clusters and racks being outside of both clusters and racks.

The larger file size that reduces the number of nodes in a cluster which directly affects the efficiency of Map task processing ability by slowing because total file breakdown into chunks become heavy. On the contrary, as file size becomes smaller which is least size of 64 MBs the number of nodes in a cluster will be higher. Similarly, performance of Map task becomes faster than larger file sizes; however, Reduce task gets much load in processing or aggregating data from a number of nodes.

3.4.1. Design Goal

The goal of design is developing Hadoop ecosystem environment to test big data technology stack on unstructured data sets or words in documents processing so as to differentiate from traditional relational data technology stack. In doing so, test environment will be setup using Apache Hadoop library on the top of Ubuntu Linux operating system which is native operation platform for Hadoop ecosystem. In general, the main approach that is employed to conduct this research is experimenting a set of big data technology stack by performing data processing and visualization.

3.4.2. Experimental Procedure

As starting point to conduct implementation and testing this research, the following step by step approach is taken into considerations. First, Ubuntu Linux operating system has been installed on a single machine which is used as platform for other big data technology stack to run. Second, Hadoop 2v has been downloaded, installed and configured as pseudo NameNode, JobTracker, TaskTracker and DataNode. It is pseudo nodes because whenever Hadoop framework is installed and configured on single machine, it acts as two nodes which is divided into master and slave nodes. In real scenarios, Hadoop implementation requires two or more machines in order to separate master node which comprises NameNode and JobTracker, and slave nodes that consists of DataNode and TaskTracker nodes. Third, ingesting data using client program from command line to start processing is done on MapReduce framework. Finally, appropriate visualizations tools is used to present analysis result as comprehensive as possible by reducing complexity and information overload.

3.4.3. Data Analytics Design

As presented in Algorithm 4.1, the Mapper algorithm is used to accomplish three major tasks. The first task is taking files submitted by client program(s) and then chopping into blocks of chunks according to preset size, 64MB, of chunks. The second task is creating key/value pairs of the chunks. Finally, the third task is replicating chunks to nodes where enough space is assured.

As seen in Algorithm 4.2, the Reducer algorithm, on the other hand, performs four main tasks. The first task is going to nodes where target chunks are stored and then retrieving key/value pairs, sorts these key/value pairs and aggregate them locally. The second task is collecting from all nodes aggregated key/value pairs after that shuffles and sorts, and aggregates them as intermediate result

to the next level of processing. The third task is taking intermediate key/value pairs to produce final result by shuffling, sorting and aggregating, and the fourth task is responding to client program final result.

Algorithm 4.1 Map function [31]
The mapper emits an intermediate key-value pair for each word in a document. 1: class Mapper 2: method Map(docid a, doc d) 3: for all term t ∈ doc d do 4: Emit(term t, count 1)

Map (k1, v1) → list (k2, v2) ---------- mapper algorithm stores chunks in the form of key/value pairs.

Algorithm 4.2 Reduce function [31]
The reducer sums up all counts for each word. 1: class Reducer 2: method Reduce(term t, counts [c1, c2, . . .]) 3: sum ← 0 4: for all count c ∈ counts [c1, c2, . . .] do 5: sum ← sum + c 6: Emit(term t, count sum)

Reduce (k2, list (v2)) → list (v2) ---------- reducer algorithm processes data locally to merge intermediate result.

As point of start, the experiment deals with words of all books by counting individual word throughout the books and summing up their total number. The books have been chopped into chunks to be stored in DataNodes using Mapper function which provides key/value pairs of words.

That means every word is mapped its name as a ‘key’ and ‘one (or 1)’ as value at time of split process. After splitting is done, TaskTracker starts placing these chunks to designed memory addresses in the format of Hadoop Distributed File System (HDFS). In the return, NameNode registers the address of all chunks which is actually metadata of chunks that explains detail about each chunk. In addition, TaskTracker reports back to JobTracker about its accomplishment and any failure if there is any.

On the other hand, whenever there is job submission to MapReduce framework to process stored files, Reducer function brings required result by aggregating from a number of nodes. NameNode and JobTracker coordinate the processing of submitted jobs into Hadoop platform by assigning tasks to TaskTracker which in return facilitates Reducer function to sort, shuffle and aggregate locally and then return result to next level. TaskTracker is required to update status of tasks in specified time interval; for instance, as heartbeat messages to JobTracker which is responsible to scheduling and coordinating tasks across nodes. Reducer function performs activities locally, which means process to data paradigm where data resides, such as reading blocks of data, combining similar key/value pairs and sorting.

3.4.4. Data Visualization Design

Even if huge set of data yields immerse knowledge to make decisions, without data visualizations tools the values of data would be difficult to be realized [53]. The difficulty of snatching out meaning or insight from big data will increase by many folds without data visualization tools in place. So, the importance of data visualization is like hand and glove for big data scenarios because it does not make sense just long processing data for the sake of analysis.

Data visualization is dependent on a number of factors to be effective which could hinders its utilization as well as applicability for desired purpose unless properly considered in detail at the time of design [54]. The major ingredients of data visualization elements are screen size, screen resolution, data nature and machine capacity. Screen size creates a room to accommodate more data elements and at the time it creates comfort to explore as well as navigate. Screen resolution, on the other hand, provides an ability to see or visualize clearly all data sets in terms of inter data elements and intra data elements as well. Data nature puts burden for visualization tools as it is more unstructured, variety in type and huge in amount. Finally, machine capacity plays major role in processing and presenting to end user. In a nut shell, data visualization constraints can be expressed in terms of a formula below.

Data Visualization = screen size + screen resolution + data nature + machine capacity

In this study, data visualization is considering all the above factors to ensure data presentation through smart devices (mobiles and tablets) as well as computers (desktop and laptop). As it is well known that smart devices have limited capabilities in terms of screen size and machine capacity; however, data visualization is encompassing this limitation by adding interactivity by hovering cursor over data elements. On the other hand, computers are de facto standards for any data visualization design so the design data first targets computers and then smart devices become part of it.

3.5. Algorithms

Although Hadoop framework provides foundational functionalities that are consumed by MapReduce libraries to accomplish big data processing, the major algorithms that are required to ingest data sets into Hadoop Distributed File System are Mapper and Reducer functionalities to be implemented for specific problems. As a matter of fact, problems for different context and purpose

of the business demands the choice of approaches as well as unique implementation or application of algorithms for specific situation. For instance, two completely unrelated data natures such as data of IoT and social network data need separate treatment of them.

3.5.1. Mapper Algorithm

Every data set which could be structured, semi-structured or unstructured data has to be split into preset size of chunks by default 64MB for which HDFS minimum support is 64MB or 128MB. Mapper algorithm makes use of a number of libraries from Hadoop Distributed File System, e.g. RecordReader function in one to one alignment, which provides input file split so that Map function will use it to produce intermediate result for the next level of processing. Actually, Map function produces key/value pairs of a given chunk according to algorithm designed as per nature of data set to be processed. A file can be spilt into a number of splits or chunks and one split is directly processed by one Map function.

In this research, we make use of four Mapper algorithms to experiment words in all documents processing from the documents. In the case of words in documenst processing problem, Map algorithm breaks every line of statements of a document as key and its line numbers as value and then subsequently each line of statements will be broken down into words which is taken as key and its value is assigned to '1' (one). In general, all Map functions that are assigned data set processing task run in parallel which is monitored and controlled by JobTracker and TaskTracker in cascading. If there are failed tasks, MapReduce framework reinitiates tasks again to ensure fault-tolerance.

The mapper algorithm follows the following step by step procedure:

1: Hadoop reads files

2: files are chopped as per preset size into chunks

3: chunk is allocated to specific DataNode

4: individual chunk/split is read by RecordReader a line of statement with corresponding line number at a time

5: a line of statement is tokenized by Map function into a word and 1 (one) as a value

6: output key/value pair to intermediate result set

3.5.2. Reducer Algorithm

On the other hand, Reducer algorithm plays a great role in aggregating values of a key by summing or combining set of values from a single or multiple Map functions. Reduce function depends on two major libraries from Hadoop are shuffle and sort functions which take intermediate output from Map function as input to shuffle and sort the same keys together so that Reduce function can easily combine or aggregate values of each key. A single Reduce function, most of the time, is implemented for all Map functions output aggregation.

The implementation of Reducer algorithm in this research considers single Reduce function in order to aggregate outputs of Map functions. Intermediate outputs from shuffle and sort functions, these functions are libraries of the framework, is directly processed by Reduce function. The single file output which is generated by Reduce function will be taken to visualization to present result in convenient for human interpretation.

The reducer algorithm follows the following step by step procedure:

1: MapReduce library shuffles and sorts intermediate result

2: For each word, its value is aggregated

3: Hadoop writes key/values of aggregated word to Hadoop Distributed File System file

4: Output file is saved to local file system

3.6. Visual Components

The results of huge data sets processing might not be comprehensible in the way as traditional data visualization tools and practice does. It needs new way of presenting information within usual screen size and pixels density as simple as easily understandable by all level of experts to accomplish their day to day activities. Data visualization gives a flavor in grasping overall trends of events and changes across horizon. Most important factors in designing visualization components in big data scenarios is knowledge of elements of data and relationship among data sets.

The output of Reduce function is raw result by itself which requires appropriate data formatting and arrangement so as to be consumable by target audiences. So, it is necessary to select suitable visualization tools for specific data type. The chosen visualization tool to this research is Tableau Big Data Visualization tool which is highly powerful in the area of Business Intelligence and now big data visualization is incorporated as a service into a Public Edition Tableau Desktop Version 9.3 [55].

Chapter Four
Experimentation and Results

The experiment of this research is applied on unstructured data set which is to show application of big data technology stacks in scenarios of Single Hadoop Node Setup. The setup of Single Hadoop Node but it is pseudo distributed Hadoop framework which acts as fully distributed cluster of nodes which comprises all nodes; such as NameNode, DataNode, Secondary DataNode, JobTracker and TaskTracker that are important to process experimental data sets.

4.1. Experimentation

All documents are chopped into four chunks so that one of chunks or splits is being processed on each of DataNodes. Totally, four DataNodes are used to process the data sets; however, the reducer is aggregating output of mappers using single node, one of four DataNodes, in order to return final result to specified location. Mapper firstly ingests a split using RecordReader library which provides every single line of statements as key/value pairs.

Hadoop ecosystem is coming up with great advantages for current limitation of computation by enhancing processing speed and storage capacity. As shown in Fig. 4.1, it just took four minutes and eighteen seconds which is totally 278 seconds to process more than five hundred sixty books of 205MB with total of greater than 40 million words.

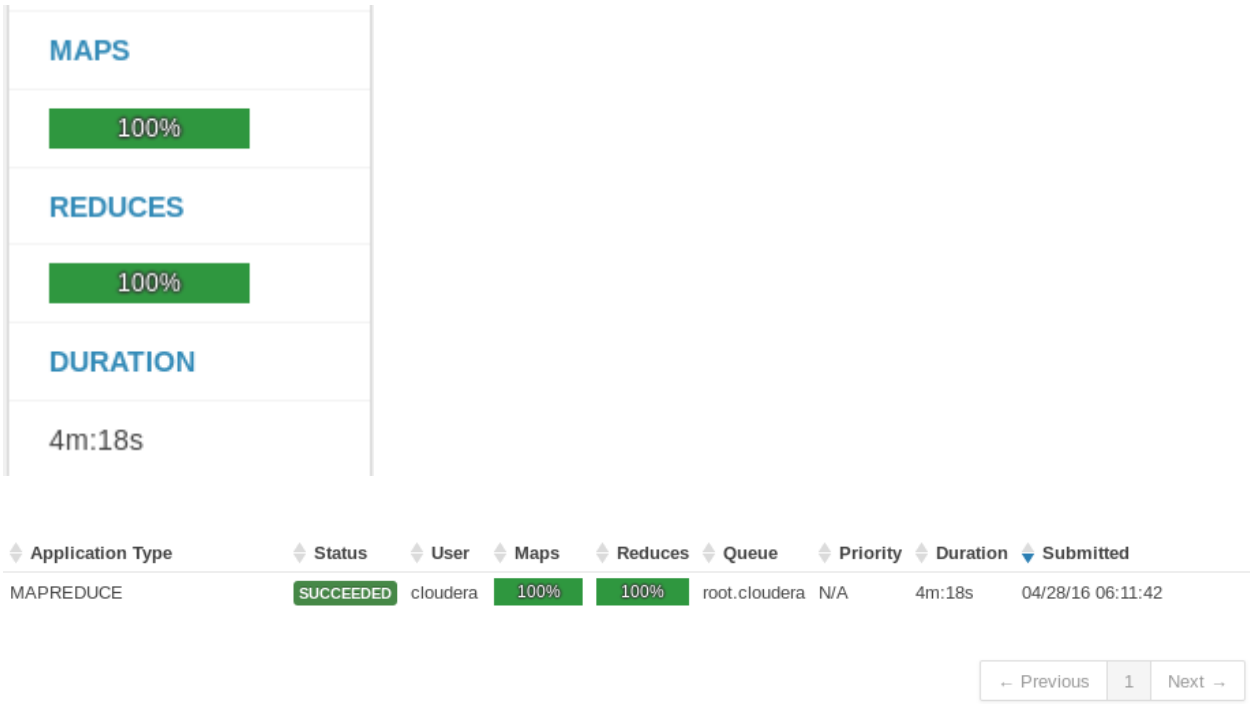


Fig. 4.1: MapReduce execution duration

The documents processing functions of MapReduce framework was running in three separate modes such as Mappers and Reducer functions mainly; in addition, sort and shuffle functions play critical role in facilitating huge data set to be shuffled and sorted within short period of time. The following Table 4.1 shows the role of JobTracker, TaskTrackers, Mappers and Reducer.

Name	**Maps Total**	**Reduces Total**	**Total**
File Bytes Read	477411456	477411366	954822822
File Bytes Written	955269776	477523045	1432792821
File Large Read Ops	0	0	0
File Read Ops	0	0	0
File Write Ops	0	0	0
Hdfs Bytes Read	214732711	0	214732711
Hdfs Bytes Written	0	3106396	3106396

Hdfs Large Read Ops	0	0	0
Hdfs Read Ops	12	3	15
Hdfs Write Ops	0	2	2

Table 4.1: MapReduce file system

As it is seen in Table 4.1, 477411456 Bytes (455 MB) and 477411366 Bytes (455 MB) of regular file data are read by Mapper and Reducer function respectively, totally 954822822 Bytes (911 MB). And 955269776 Bytes (911 MB) and 477523045 Bytes (455 MB) of regular file data are written by Mapper and Reducer functions respectively, totally 1432792821 Bytes (1 GB). On the other hand, 214732711 Bytes (205 MB) of HDFS data are read by Mapper function and 3106396 Bytes (3 MB) of HDFS data are written by Reducer function. There are 12 and 3 HDFS read operations of Mapper and Reducer functions respectively. There are also 2 HDFS write operations of Reducer function.

Name	**Total**
Data Local Maps	4
Total Launched Maps	4
Total Launched Reduces	1

Table 4.2: MapReduce Job

As shown in Table 4.2, JobTracker, TaskTracker, Shuffle and Sort, InputFormat and OutputFormat, a set of execution and parameters have been taken place with respect to Mapper and Reducer functions. For instance in JobTracker, there are four Data Local Maps, four Total Launched Maps and one Total Launched Reduce. In TaskTracker as shown in Table 4.4, there are four Merged Maps and four Shuffled Maps for Reduce. As shown in Table 4.3, Input and Output

format have been 214732211 Bytes (205 MB) read and 3106396 Bytes (3 MB) written Map and Reduce respectively.

Name	Maps Total	Reduces Total	Total
Bytes Read	214732211	0	214732211
Bytes Written	0	3106396	3106396

Table 4.3: Input and Output Format

4.2. Results

4.2.1. Data Processing

The results of experimentation show in Table 4.4 that CPU milliseconds for Maps function is 158960, Reduce function is 140000 and it is totally 298960; GC milliseconds for Maps function is 5175, for Reduce function 748 and it is totally 5923; Physical Memory Bytes for Maps function is 2006507520 (~2 GB), for Reduce function is 807206912 (~1 GB) and it is totally 2813714432 (~3 GB); and Virtual Memory Bytes for Maps function is 6229786624 (~6 GB), for Reduce function is 1566797824 (~1.5 GB) and it is totally 7796584448 (~7.5 GB) which indicate big data processing requires least resource utilization in terms of time and computation as it is compared to resource requirements of transactional data warehouse data set processing. Hadoop ecosystem has provided tremendous capabilities to ingest and process huge data sets with a least resource requirements. As shown in Table 4.4, the time and memory to compute for specified data set were manifested by its execution and generated result.

Name	Maps Total	Reduces Total	Total
Cpu Milliseconds	158960	140000	298960

Gc Time Millis	5175	748	5923
Map Output Bytes	389234094	0	389234094
Map Output Records	44088633	0	44088633
Merged Map Outputs	0	4	4
Physical Memory Bytes	2006507520	807206912	2813714432
Reduce Shuffle Bytes	0	477411384	477411384
Shuffled Maps	0	4	4
Virtual Memory Bytes	6229786624	1566797824	7796584448

Table 4.4: MapReduce Task

In particular, the result of experiment is manifesting that Hadoop ecosystem is processing unstructured data sets of Big Data in inexpensive and with high throughput. As shown in Table 4.5, IO Error, Wrong Length, Wrong Map and Wrong Reduce are all zero; so, the Big Data processing using Hadoop ecosystem is fault tolerant and reliable.

Name	**Maps Total**	**Reduces Total**	**Total**
Bad Id	0	0	0
Connection	0	0	0
Io Error	0	0	0
Wrong Length	0	0	0
Wrong Map	0	0	0
Wrong Reduce	0	0	0

Table 4.5: Shuffle Errors

4.2.2. Data Visualization

Even though experimentation has generated a single raw file which is output of Reduce function, the need of data visualization of the same file is a must so that the result of processing could easily be understood to grasp the information in appropriate and consumable format. However, the availability of visualization platforms for big data is just handful, i.e., there are very few companies as providers of visualization components. Actually, big data technology sets are now emerging on the top of traditional business intelligence technologies so big data visualization toolsets are at their infant stage. As shown below charts, the output file of MapReduce framework processing is converted into interactive charts using Tableau visualization platform. Tableau is one of few great visualization tools that embraces whole output of big data processing result without breaking down into a set of files so as to visualize. In addition, its charts are consumable through all devices regardless of their screen size or pixel density because it provides interactivity by allowing to hover mouse cursor in order to spot value of an element of interest.

All charts or graphs show results of processing in different forms but they are conveying the same information by accommodating capability to figure out the content or value of a single element of data. Horizontal Bar chart, Treemap, Pie Chart, Highlight Table, Stacked Bar Chart, Circle Views Chart, Bubble Chart, Box-and-Whisker plot, Heat Map and Packed Bubbles Chart are used to present MapReduce framework processing results. Each of them has given interactivity as well as elegant format of information presentation capabilities by enhancing information consumption for all audiences. More importantly, such information presentation for advanced users creates a room for further exploration and analysis.

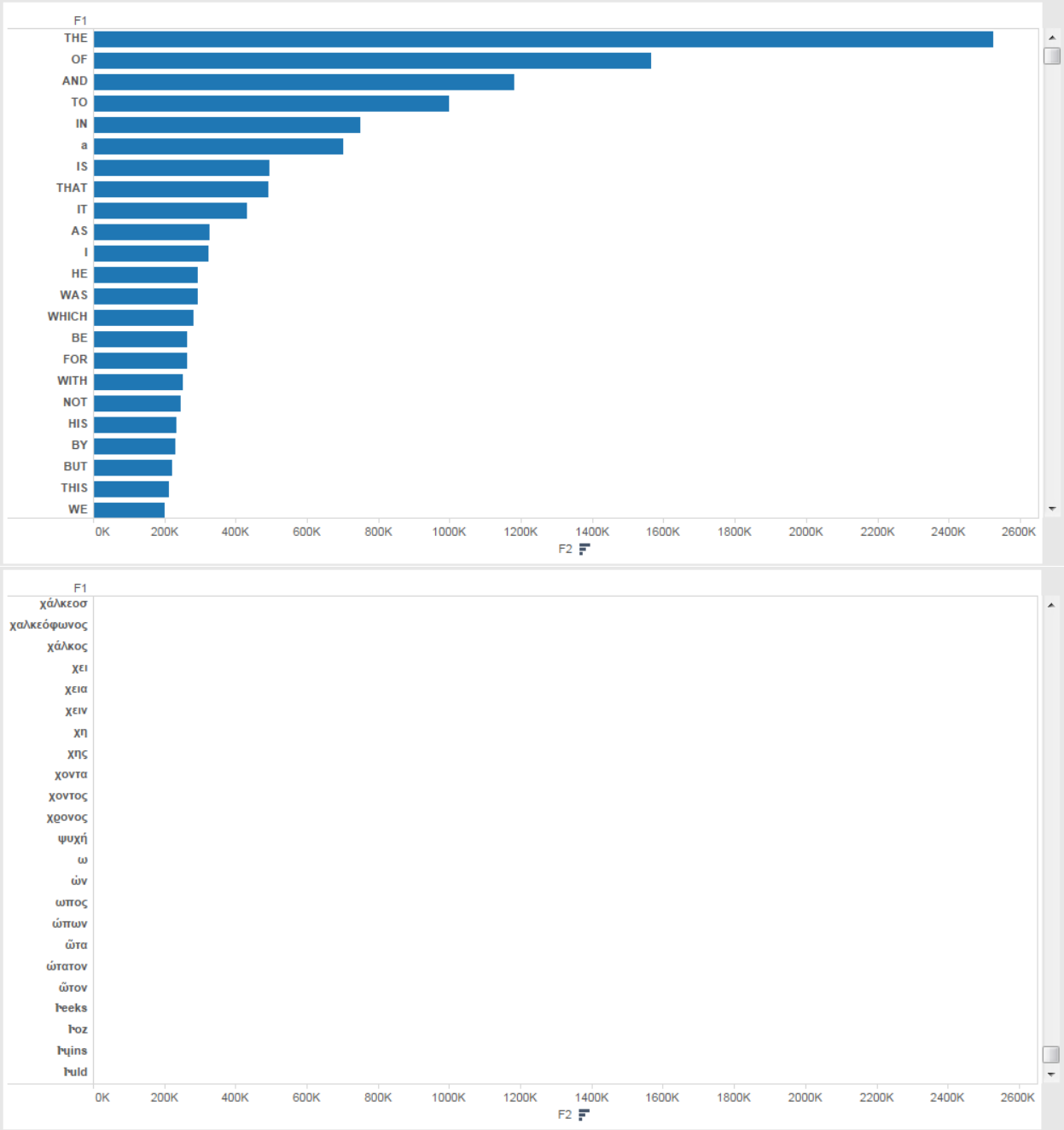


Fig. 4.2: Horizontal Bar chart

As Horizontal Bar chart indicates, the count of a word is shown by length of a bar by demonstrating its relative value from other words. For instance, words are listed on vertical axis and values of each word is placed on horizontal axis and the graph is interactive enough to display specific value of a word by hovering over it.

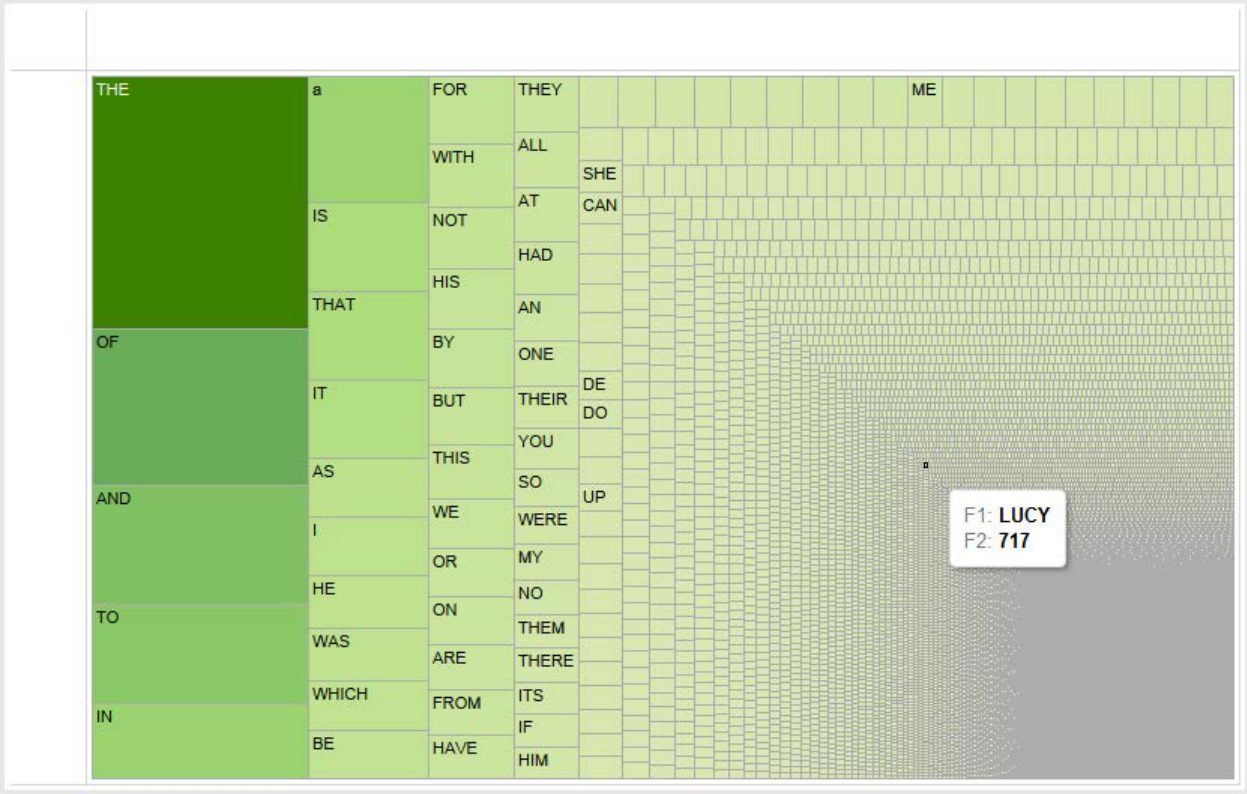


Fig. 4.3: Treemap

In the Teemap chart, the size of a block and its color intensity shows that word's count relative value, i.e., as the count of a word increases its block size becomes larger and color intensity becomes brighter. Word 'LUCY' is counted 717 times which is indicated with small black square box that is found hovering over in the area.

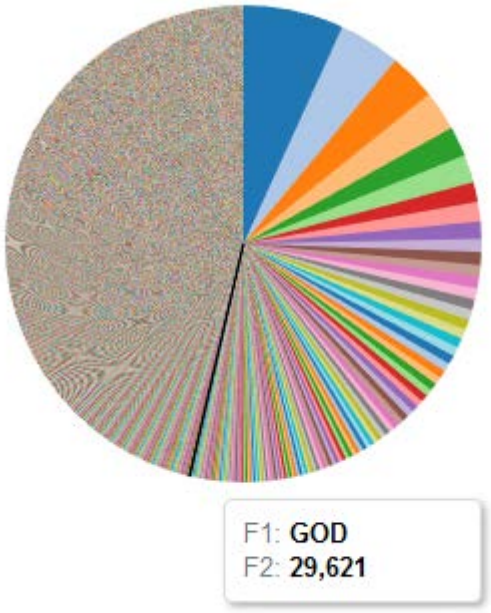
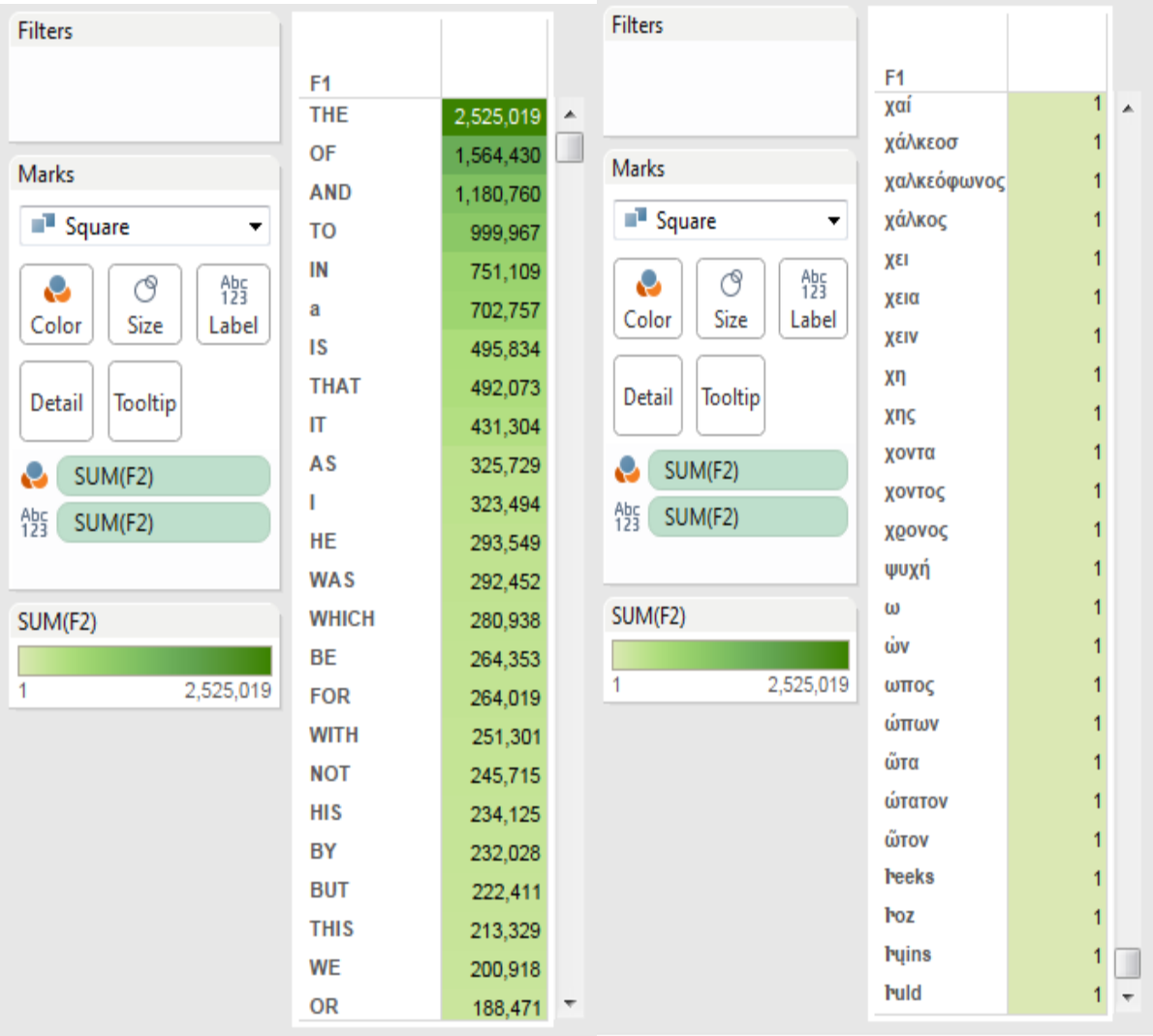


Fig. 4.4: Pie Chart

Similarly, Pie chart displays value of each word using different coloring schema composition to indicate relative value of a word. As shown word ‘GOD’ is counted 29,621 times as indicated by black strip from center of the circle to down circumference.



Graph a. high value words Graph b. low value words

Fig. 4.5: Highlight Table

In Highlight Table, values or counts of words along with color intensity but there is no distinct demarcation between two consecutive values. As shown in graph a & b, the value of words are exhaustively listed in descending order.

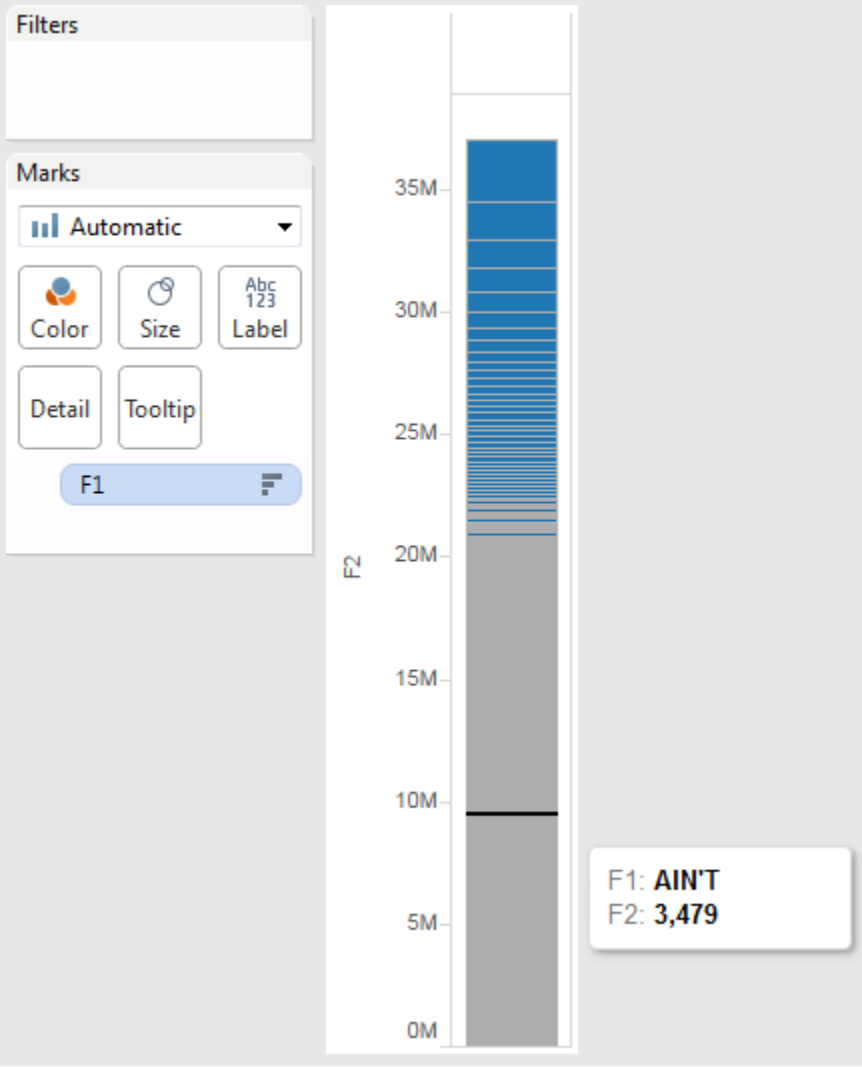


Fig. 4.6: Stacked Bar Chart

In Stacked Bar chart, there is differentiation of values of word count using color intensity and height of bars except its width. Only vertical axis is used to show size of word count and shade of size of the color indicates the word itself. For instance, the value of word 'AIN'T' is 3,479.

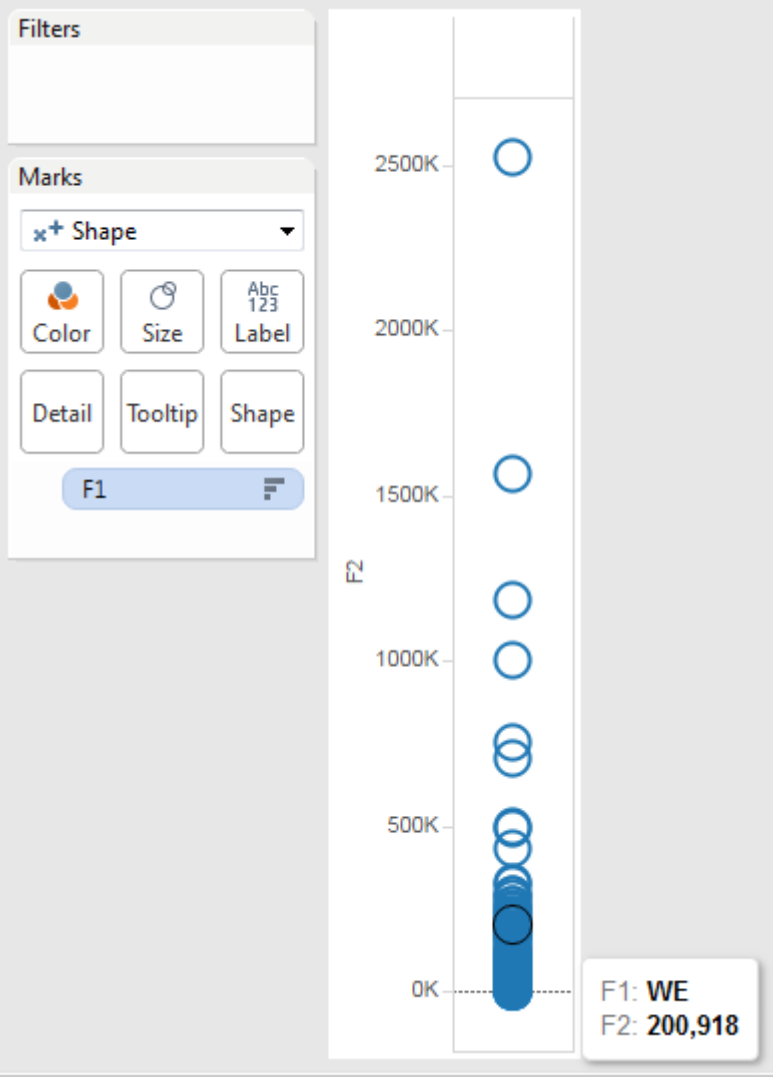


Fig. 4.7: Circle Views Chart

The Circle Views chart displays data elements in circles on vertical axis within its relative position; as shown word 'WE' is counted 200,918 times which falls in range of between 0K and 500K.

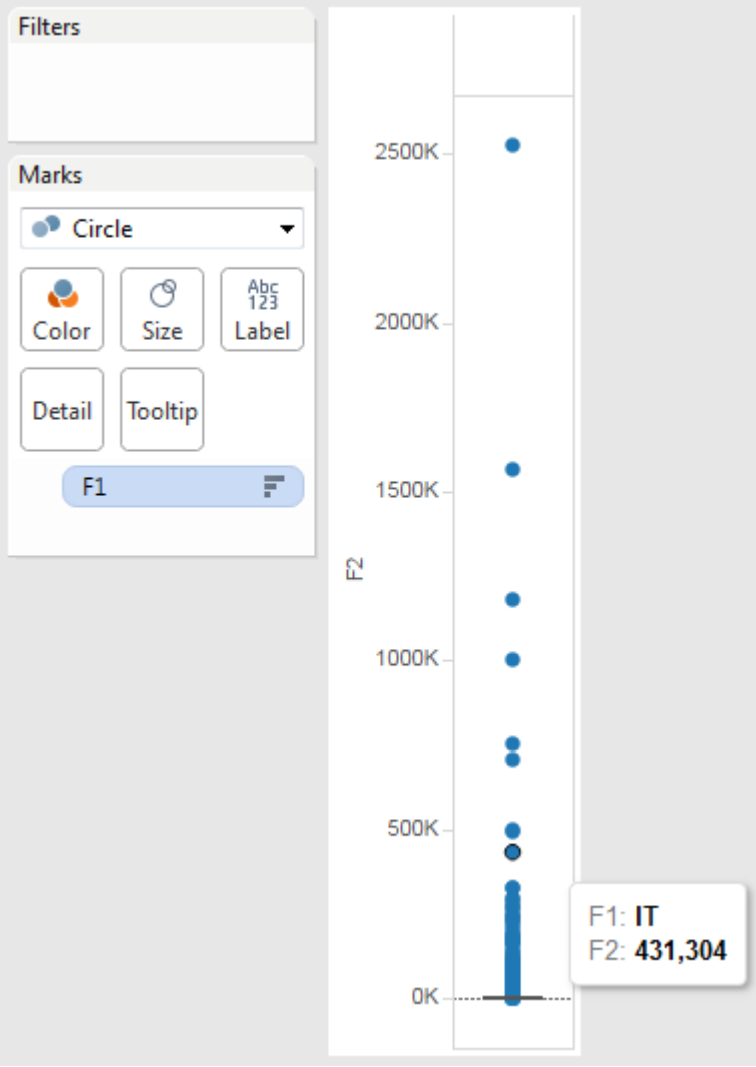
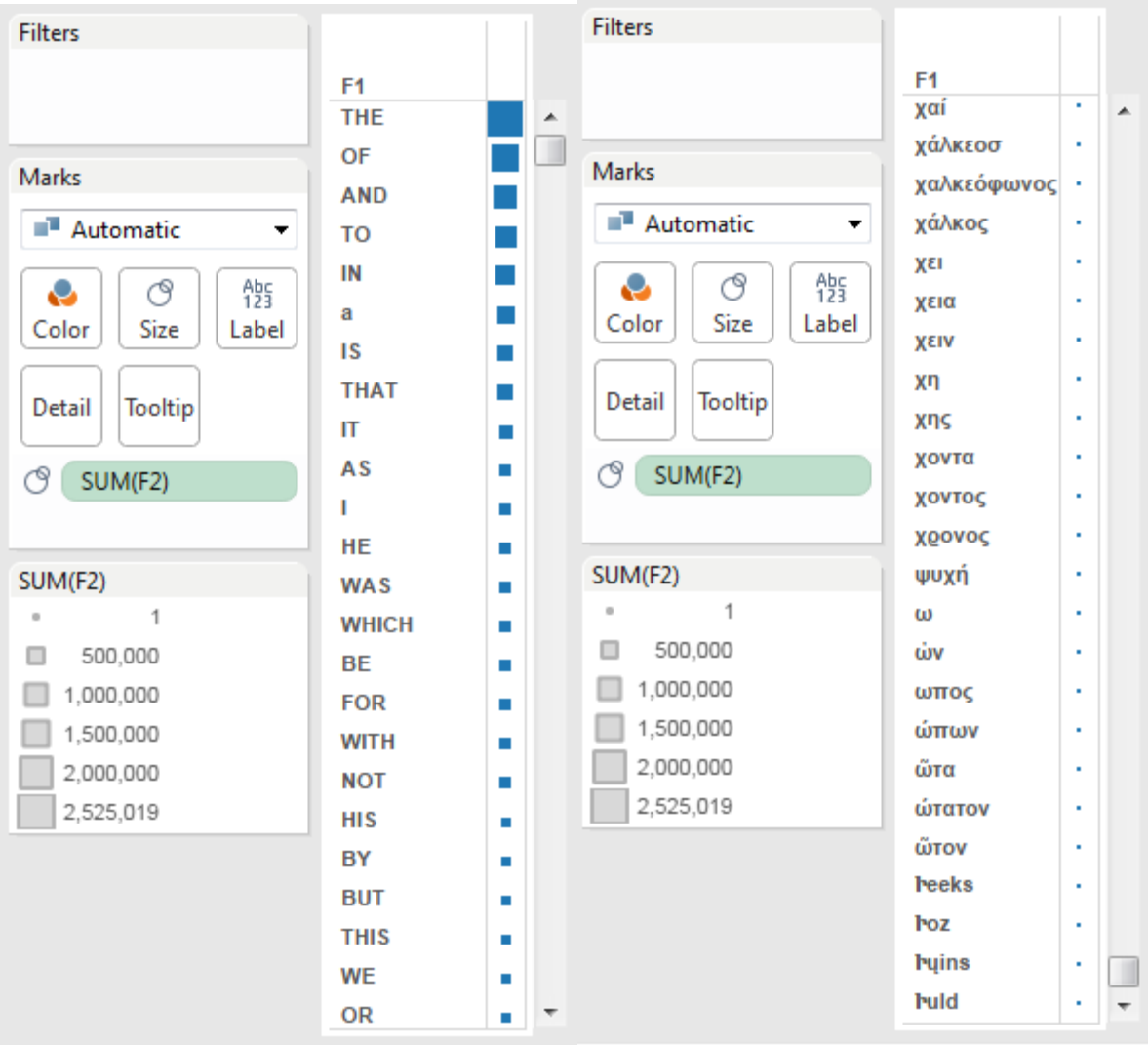


Fig. 4.9: Box-and-Whisker plot

Vertical axis is used to display value of word count but words are represented with color filled circles; for instance, word 'IT' is counted 431,304 times as highlighted with black circle in range of between 0K and 500K.



Graph a. high value words Graph b. low value words

Fig. 4.10: Heat Map

The value of a word in Heat Map is square in proportion to size of count, i.e., larger square shows bigger count of a word in opposite smaller square shows few word counts. As shown in Graph a & b, the size of a square is directly proportional to the value of word.

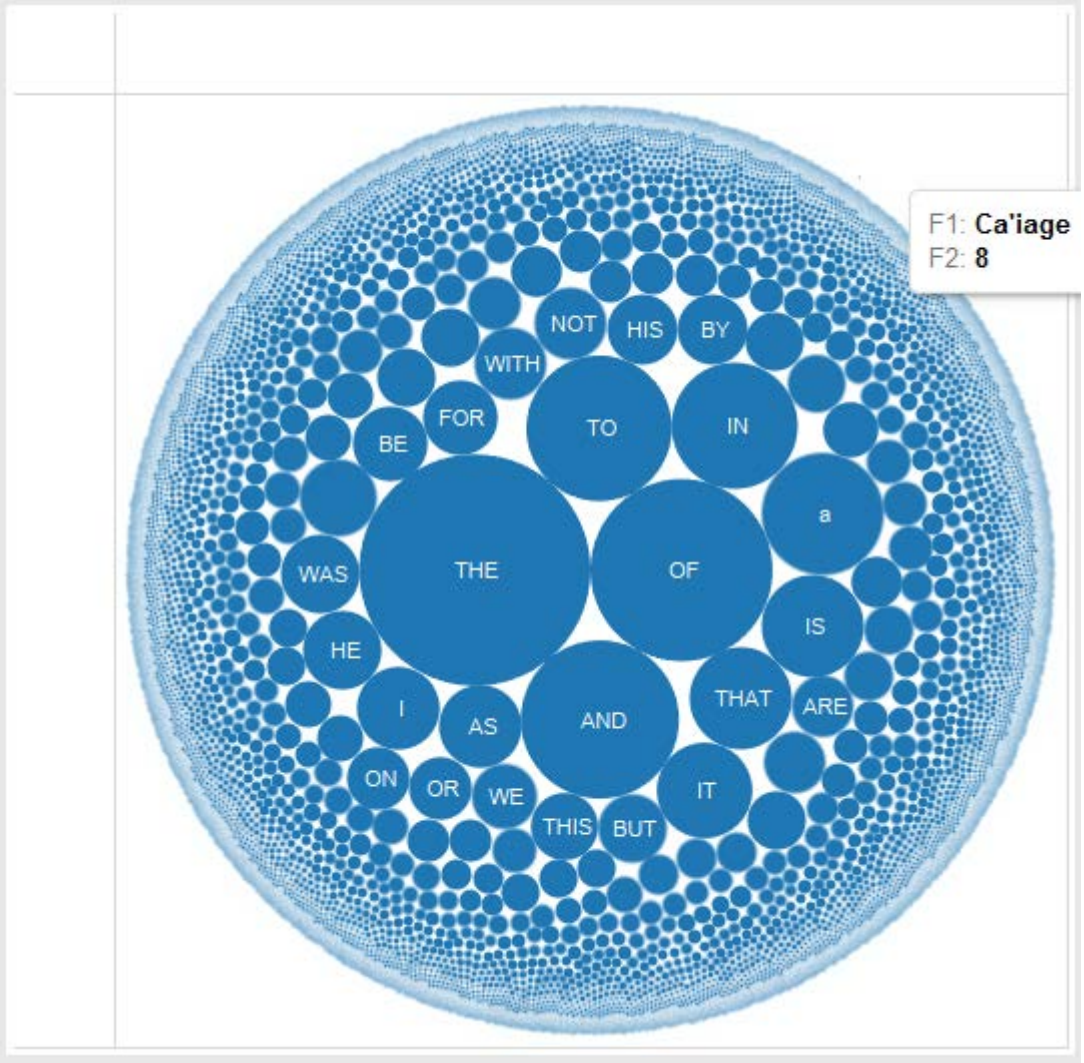


Fig. 4.11: Packed Bubbles Chart

This chart, Packed Bubbles, has the most fascinating way of presentation of word and its count in proportion to value or size of count. The bigger counts are placed in the center of the circle and few counts are scattered on circumference of the circle. For example, word 'Ca'iage' is counted 8 times and placed inside the circle near to circumference as indicated with black spot.

Chapter Five
Conclusion and Recommendation

5.1. Conclusion

Big data processing and visualization is a challenge that needs new way of tackling which is otherwise cannot be solved with current practice of data management because data deluge and data creation frequency in varieties of formats are inevitable scenarios. The approach that is employed in this study to undertake these challenges are reviewing problem areas in detail, followed by designing solution, then implementation of designed solution after that testing implemented solution using big data sets. As a result shows, Hadoop ecosystem provides platform to process unstructured data sets of Big Data in cheap, fault tolerant and high speed. The achievement of the study expounds next generation of IT in areas of data storage, processing and visualization. Especially, reliability and computational power does not need scale up in terms of hardware and processor capacities. Therefore, Big Data processing and visualization challenges are able to handle using software solutions rather than in placing specialized machines with increased hardware and processing capabilities.

This study has strong points to be raised for practical study in the area. These are data dimension and technological dimensions which indicates glimpse of light that sheds for upcoming challenges how to confront and extract insights from huge unstructured data sets. As we have seen in the study, it is possible to manage big data regardless of size and nature of data. However, full scale experimentation on all data types including multimedia have not been carried out in this study, due to time and resources constraints, which can be researched further. Apart these, the points that require further investigation and study are fully distributed environments or clustered machines to

exploit full potential by processing Terabytes and Petabytes of data sets of big data in general and its specific application for decision making by implementing revealed insights.

5.2. Recommendation

Big Data has enormous potential and benefits at every level of societies which can be considered as an eye opener to new discoveries and innovations. Now, it is not only possible to study populations as whole without looking for samples and its representativeness but also it becomes common to forecast or trend analysis of unimaginable situations. So, it is important to study further impacts of structured and semi-structured data sets by accommodating Velocity data along with power of parallelism computation in fully distributed setup.

As new area of study, it is recommended further studies in specific contexts to identify wealth of benefits and cautions. The main points to consider to dig deep wealth of Big Data are:

- Data management
- Data retrieval
- The need for well-equipped experimental lab with clusters of machines

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Appendices

Data set size

Name	Symbol	Value
Kilobyte	KB	2^{10} = 1,024
Megabyte	MB	2^{20} = 1,048,576
Gigabyte	GB	2^{30} = 1,073,741,824
Terabyte	TB	2^{40} = 1,099,511,627,776
Petabyte	PB	2^{50} = 1,125,899,906,842,624
Exabyte	EB	2^{60} = 1,152,921,504,606,846,976
Zettabyte	ZB	2^{70} = 1,180,591,620,717,411,303,424
Yottabyte	YB	2^{80} = 1,208,925,819,614,629,174,706,176

Source Code

```
import java.io.IOException;

import java.util.*;

import org.apache.hadoop.fs.Path;

import org.apache.hadoop.conf.*;

import org.apache.hadoop.io.*;

import org.apache.hadoop.mapreduce.*;

import org.apache.hadoop.mapreduce.lib.input.FileInputFormat;

import org.apache.hadoop.mapreduce.lib.input.TextInputFormat;

import org.apache.hadoop.mapreduce.lib.output.FileOutputFormat;

import org.apache.hadoop.mapreduce.lib.output.TextOutputFormat;

public class WordCount {

 public static class Map extends Mapper<LongWritable, Text, Text, IntWritable> {

    private final static IntWritable one = new IntWritable(1);

    private Text word = new Text();

    public void map(LongWritable key, Text value, Context context) throws IOException,
InterruptedException {

        String line = value.toString();

        StringTokenizer tokenizer = new StringTokenizer(line);

        while (tokenizer.hasMoreTokens()) {

            word.set(tokenizer.nextToken());

            context.write(word, one);

        }

    }

 }
```

```
public static class Reduce extends Reducer<Text, IntWritable, Text, IntWritable> {
   public void reduce(Text key, Iterator<IntWritable> values, Context context)
    throws IOException, InterruptedException {
      int count = 0;
      while (values.hasNext()) {
         count += values.next().get();
      }
      context.write(key, new IntWritable(count));
   }
}

public static void main(String[] args) throws Exception {
   Configuration conf = new Configuration();
      Job job = new Job(conf, "wordcount");
   job.setOutputKeyClass(Text.class);
   job.setOutputValueClass(IntWritable.class);
   job.setMapperClass(Map.class);
   job.setReducerClass(Reduce.class);
   job.setInputFormatClass(TextInputFormat.class);
   job.setOutputFormatClass(TextOutputFormat.class);
   FileInputFormat.addInputPath(job, new Path(args[0]));
   FileOutputFormat.setOutputPath(job, new Path(args[1]));
   job.waitForCompletion(true);
}
}
```

List of books for Experimentation

The following are lists of books are used for experimentation. The books are composed of a number of categories such as literatures or language education, science fictions, Africa, war and philosophy.

No.	Author(s)	Title	Remark
1	Frederick Douglass	The Narrative of the Life of Frederick Douglass An American Slave	
2	René Descartes	A Discourse on Method	
3	Karl Marx and Friedrich Engels	The Communist Manifesto	
4	Norman Coombs	The Black Experience in America The Immigrant Heritage of America	
5	Edgar Rice Burroughs	Tarzan of the Apes	
6	Frederick Douglass	Collected Articles of Frederick Douglass	
7	Edgar Rice Burroughs	Jungle Tales of Tarzan	
8	Frederick Douglass	My Bondage and My Freedom	
9	Harriet Beecher Stowe	Uncle Tom's Cabin	
10	Various	The Martin Luther King, Jr. Day, 1995, Memorial Issue	
11	Lao-Tse	Tao Teh King	
12	Joseph Conrad	Heart of Darkness	
13	Charles Alexander Eastman	The Soul of the Indian An Interpretation	
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