A SYSTEM MODEL FOR GRID COMPUTING IN HOSPITALS

BY

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DECLARATION

DECLARATION BY THE STUDENT:

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DEDICATION

This thesis is dedicated to my husband Robin, my daughter Jazleen, my son Jayden, my parents Mr. and Mrs. Paul Kiprotich and all those who contributed in making me realize this dream.

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I would like to thank God for his guidance and provision of strength in this journey of realizing my dreams.

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ABSTRACT

Grid computing is one of the emerging information technologies that allow sharing of important ICT resources including processing power in a given network. Moi Teaching and Referral Hospital (MTRH) is faced with the challenge of inadequate Information Communication Technology (ICT) facilities due to inadequacy of funds since being a public hospital, it depends on government grants. However, the available ICTs are not optimally used. Therefore there is a need to optimize the utilization of the limited available ICT resources. Furthermore, this will also help solve the issue of disposal of ICT equipment which is an environmental concern. The aim of this study was to investigate the optimization of the use of available ICT resources in the hospital with a view to developing a system model for implementing Grid Computing. This will enable the sharing of the limited available ICT resources within the organization. The specific objectives of this study are to: establish the ICT tools and equipment used at MTRH; establish the challenges faced by the hospital in optimizing the use of ICTs; establish the suitability of implementing Grid Computing; design and develop a system model for the implementation of Grid computing in the hospital. The study adopted a layered architecture based model which is used for developing grid computing systems as a guide during system development. Qualitative research approach was adopted for requirements gathering and analysis while experimental approach was used for the prototype development. Eighteen respondents were purposively selected and interviewed from MTRH. The sample was composed of six (6) heads of departments and twelve (12) ICT specialists. They were believed to have crucial and relevant information to this study, since they are the ones involved in decision making and implementation of new technologies. The findings indicated that the hospital had taken a step in using ICTs in dispensing services. However they are faced with the challenge of inadequate ICT facilities and challenges of disposal of ICT equipment. It was also found that sometimes some of the machines were lying idle while others were overworked. The requirements obtained were used for development of a grid computing system model. The study recommends that the hospital implements this ICT solution, which will help it to overcome the challenges of inadequate ICT resources by optimizing the utilization of the available machines for better service delivery. Further, the hospital should develop policy guidelines on sharing resources. The hospital should also train staff on current and relevant ICT skills. This study concludes that there are many benefits that comes with the use of ICTs in modern hospitals. Therefore, MTRH needs to implement new ICTs for them to excel and achieve its goals. Future studies may consider the environmental impact of grid computing since it reduces the number of ICT equipment targeted for disposal.

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LIST OF ABBREVIATIONS

Saas	Software as a service
PDA	Personal Digital Assistant
CPU	Central Processing Unit
MTRH	Moi Teaching and Referral Hospital
DBR	Daily Bed Returns
SMP	Symmetric Multi-Processing
MPI	Message Passing Interface
API	Application Program Interface
LAN	Local Area Network
SQL	Structured Query Language
RAM	Read Only Memory
FR	Functional Requirements
NFR	Non Functional Requirements
HPC	High Performance Computing
VM	Virtual Machine

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.0 Introduction

The world of technology has grown tremendously. New technologies are coming up almost every day. Whatever you have today might not be what you will have tomorrow. Therefore, organizations and individuals have to always embrace the new technologies to be relevant in this world and also to benefit from the advantages that it offers. Grid computing is one of these technologies which enhance sharing of resources within a network. This chapter addresses the background of the study, statement of the problem, the aim, objectives, scope and significance of the study.

1.1 Background Information

Senthamarai and Krishnan (2008) defines Grid Computing as *" a form of distributed computing that involves coordination and sharing of computing application, data storage or network resources across dynamic and geographically dispersed organizations. "* This therefore simply means that grid computing is the sharing of resources by mutually linking them to enable a machine to use the collective resources of all other connected computers within a network. Under normal circumstance computers are restricted to the use of only its resources that is, the Central Processing Unit (CPU), Memory and Storage, but Grid computing is surpassing this limitation by going beyond the traditional operation of the machines and allowing a vast virtual environment where the resources of various machines can be shared. Therefore, an individual using a single computer to access this virtual environment means the same individual can access resources from idle computers

in the networks, thus improving its computing capabilities hence turning it into a 'supercomputer'. Grid computing can be applied in so many areas e.g. Education system, Companies, industries, military and health sector, (White et al, 2000)

Stickland, (2008) presents the following scenarios where grid computing is relied on.

1. A scientist uses an entire network of computers by logging into one computer in the network to analyze data on proteins.
2. A business man uses his Personal Digital Assistant (PDA) to access his company in a network.
3. An Amy official uses different networks to access computer resources to generate a battle strategy

Grids technologies can also be applied in provision of health care due to its vast advantages. This will lead to improving e-health which is a quicker way of administering health services across the world.

Advantages of Grid Computing

Chaudhary (2011) presents the following advantages in two categories: business benefits and technological benefits. The business benefits are as follows: 1) Improves efficiency i.e. the organization will have access to cumulative computational capability of all their computing devices. 2) Integrates IT and human resources. 3) Enables widely dispersed departments and businesses to create virtual organizations to share data and resources. 4) Create flexible, fault tolerant computing infrastructures. 5) Adapts to the ever changing customer requirements.

The technological benefits discussed by Chaudhary (2011) are as follows; 1) Enables the resources to be optimally used and caters for applications that have been prioritized. 2) Vets data that is to be transmitted globally. 3) Support collaboration across the organizations. 4) Enables the organization to run large computing applications on the grid. 5) Reduces data delivery delay.

Malhotra (2007) discusses the following reason as to why Grid Computing is important. These can also be termed as the advantages of Grid Computing: *It assists in solving many small problems that are computationally costly, allows sharing of expensive resources amongst institutions and makes resources available to anybody by ensuring that the cost barrier is lowered and increasing overall bandwidth.*

Disadvantages of Grid Computing

It is almost certain that anything with advantages has disadvantages. According to Kos (2011), relative immaturity of the concept is the first disadvantage. This is because of non-defined standards, missing features and software. "*...Applications which are not designed to use Message Passing Interface (MPI) will have to revert to a SMP (Symmetric Multi-Processing)...*" The fact that the results are broadcast to all available nodes in the grid and then they are assessed collaboratively is taken as a disadvantage. This means that it is difficult to identify/define the outcome unless the final assessment is made. This is a great disadvantage since it takes a lot of time before getting the final results. In addition to that grid computing requires advanced infrastructure, in other words, it requires the use of qualified personnel, advanced software and tools to manage

and monitor the grid. This means that this technology is quite expensive. Lastly, it's a challenge especially when other people are not willing to share their resources in spite of the technology encouraging the sharing of resources.

As much as there are disadvantages, this research tries to minimize on the disadvantages by developing a grid application that will allow multi-processing and results need not to be broadcasted to all nodes but received, analyzed and stored by the server machine.

Thiga (2018), when establishing the demand for high performance computing and grid computing by Kenyan researchers, the arrears identified are: for fraud analysis, computational fluid dynamics, seismic modeling and lastly he indicates that there is potential use in education and research. Whatever is lacking in this research is the need of grid computing in Kenyan hospitals. Therefore this research will introduce the use of high performance computing in the Kenyan market since it is a new field that needs to be exposed and tapped due to its benefits. It is geared towards developing and proposing implementation of grid computing in MTRH to create high computing performance by optimal utilization of available ICTs.

1.1.1 MTRH Background Information

MTRH is situated near Eldoret town in Uasin-Gishu county of Rift Valley Province. It is the second national referral hospital in Kenya. It started in the early 1917 with a bed capacity of 60 and a few members of staff.

The health care industry all over the world is looking forward to improving quality health care because of the fast increase of diagnosed diseases and sicknesses. MTRH has embraced ICTs as a way of curbing the ever- increasing need for health care services. It is being driven by its vision which is *"to be an excellent referral and teaching center in Healthcare."* Its mission is "*to provide accessible specialized quality health care services and teaching facilities through research, training, capacity building, innovation and participation in national health planning", (http//:www.mtrh.or.ke)*

The institution has realized the enormous advantages offered by ICTs because it has implemented the use of ICT systems in some sections like at the point-of sales, registration of patients, Billing, Management of suppliers, management of pharmacy, patient number management DBR(daily bed returns) and debtors management. Although manual systems are still practiced especially in the medical department, computerized systems have helped a lot in making things faster and enhancing accountability and transparency especially in revenue collection.

According to the ICT manager, the management with the help of ICT specialist is open to new ideas which may lead to solving the challenges they are currently faced with. The researcher is proposing the implementation of grid computing because it will highly make use of the available and or few resources. This will help the organization not to spend so much on ICT tools in their quest of providing quality health care in terms of accessibility, sharing of resources (including information, processing power and equipment), accountability and transparency.

1.2 Statement of the Problem

MTRH is a public hospital, therefore it is a nonprofit making organization and its core business is provision of quality health care. Like many other organizations, MTRH has realized the need and importance of optimally using ICTs due to their massive benefits. The hospital has tried implementing the use of ICTs and is ready to embrace other new technologies to better their services, but it faces a big challenge due to lack of adequate ICT resources and challenges of disposal of these equipment. This is due to the inadequacy of finance because the institution serves all citizens regardless of their financial capabilities, so it focuses more on helping the Kenyan citizens and not necessarily making money. As much as there is inadequacy of ICTs, this research found out that the limited ICT resources are not optimally used because some computers lie idle while others are overworked. There were also old machines that they were termed as obsolete and ear marked for disposal but where to dispose them was also a challenge. It is important to note that disposal of electronic waste is a major environmental concern today not only in Kenya but across the world (Otieno and Omwenga, 2015).

The problem of this study is, therefore, lack of optimal use of available ICT resources in MTRH and the challenge of disposing e- waste emanating from low performing machines. There is therefore a need for the institution to optimize the utilization of the available ICT tools to maximize their output. For instance if the old and low performing machines which are considered for disposal are connected together and there resources shared, it will create a huge performance and there will be no need of disposing them because they are optimally used. This study, therefore, aims at finding and proposing a

solution to this problem by looking for an alternative method which will be efficient regarding service delivery, initial cost and reduce the number of electronic gadgets, which might be termed as irrelevant and needs disposal which is a big environmental concern as echoed by Bazargan et al (2012), who indicates that handling and treatment of e-waste is a topic of great concern in the future.

This research proposes the use of Grid computing. If it is implemented in MTRH, the hospital will not spend so much on ICT tools, since Grid computing will facilitate the use of affordable and or available ICT tools by enabling sharing of resources. This will lead to optimal use of all the resources instead of having some lying idle.

1.3 Aim

The aim of this study was to investigate the optimization of the use of available ICT resources in MTRH with a view to developing a system model for implementing Grid Computing.

1.4 Objectives

The objectives of the study are to:

1. Establish the ICT tools and equipment used in hospitals
2. Establish the challenges faced by the hospital in optimizing the use of ICTs
3. Establish the suitability of implementing Grid Computing
4. Design and develop a system model for the implementation of Grid computing in the hospital

1.5 Research Questions

The research questions of the study are:

1. What are the ICT tools and equipment currently used in hospitals?
2. What are the challenges faced by MTRH in adopting, implementing and using ICTs?
3. Is there a need to adopt new ICT technologies to optimize the use of ICT resources?
4. How can a system model for implementing Grid Computing be implemented based on the established requirements?

1.6 Significance of the Study

This study is important because it comes at such a time when the disposal of electronic equipment is a major environmental disaster and ICT resources are relatively expensive. Therefore, there is a need to optimize the use of the available resources to enhance cost effectiveness and reduce the number of gadgets which soon will be obsolete and will need disposal due to the dynamism of technology. Since the study is focusing on developing a grid computing system model that can be implemented in MTRH, it will help the hospital make use of the available ICT resources in enhancing health care service provision. This is very important due to the increase of diseases and sicknesses. The doctors and clinicians will be able to easily track the records of patients whenever needed, and data processing will be faster.

ICTs currently in MTRH are majorly used for revenue collection, treatment and management of diseases. This has led to accountability, transparency and improved

service delivery. This study is looking forward to enhancing these benefits by ensuring that the ICTs are optimally utilized across the entire hospital, by allowing its resources to be shared to enhance high performance.

The findings and recommendations of this study can be replicated in other institutions that are interested in optimizing the use of their computers to enhance their performance. Furthermore, the study can be useful to the planners and decision makers of these institutions when implementing ICTs.

The researcher hopes that the study will form as a basis for further research on implementation of Grid computing and other new technologies.

1.7 Scope and Limitations of the Study

1. 7.1 Scope

This study was limited to implementation of Grid computing in MTRH rather than the larger aspect of ICTs. Therefore, the study focused on the suitability of implementing Grid computing in the hospital. The actual implementation of Grid Computing in MTRH was not done, but instead the implementation of the technology was proposed.

In addition, there are many types of ICTs in MTRH that run under various platforms. For example, radiology machines, scanners and x -ray machines. This research focused on optimizing the use of computers that run on Windows operating system rather than all ICT equipment available.

The geographical scope was limited to MTRH because the researcher intended to perform an in-depth research to obtain a more efficient solution. However, with minor changes, the study can be applied to other public hospitals.

1.7.2 Limitation

The fact that open source software is not necessarily free was a limitation because some software e.g. GRIDGAIN were open source but required payments to access the entire software. This made the researcher to take a longer time in developing the Grid computing application because no open source software was adopted as anticipated at early stages of the research.

1.8 Chapter Summary

This chapter has discussed the background of the study, statement of the problem, aim, objectives, scope and limitations of the study. Significance of the study has also been clearly indicated. Implementation of grid computing will lead to optimization of ICT resources in the hospital and will also help in reducing e-waste since every machine will share its resource in the grid instead of them being irrelevant because of their low performance due to technological advancements.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter discusses relevant literature to this study. It presents the following areas on grid computing: an overview of Grid Computing, Theoretical Framework, Layered Grid Architecture, Considerations for designing, testing and pre-implementations of Grid Computing, Storage Performance in Grid, and implementing Grid Architectures in concurrence with those architectures that are not aware of Grid Processes.

2.1 Overview of Grid Computing

Grid computing was first conceived by Ian Foster et al (2002). When they discovered that resources of cooperating organizations can be interconnected. According to Rajaraman (2016), most scientific instruments today are computer controlled and may be accessed remotely among various institutions. The practicability of this has not happened due to high development cost of specialized applications which also takes a longer time to develop. He goes further to differentiate grid computing and cloud computing by stating that grid computing is a collaborative model among scientist and engineers providing addition to computing power. While cloud computing provides loosely coupled servers to customers on demand.

Grid computing implementation in hospitals is essential as Leister and Skomedal (2006), posits that medical applications are the most demanding multimedia applications with huge volumes of data and high processing demands.

According to an article compiled by Stickland (2008), Grid computing is a field that is still developing and has many faces, because it is related to a number of other innovative computing systems. Some are even part or a section of grid computing. For example:

a) *Shared computing*- this is the sharing of computing power by a number of grouped computers to perform a specific task.
b) *Software- as- a- service (saas)*- it is a system which a company offers special/specific services e.g. a company may decide to provide data storage services to another company by providing a storage space in the server.
c) *Cloud computing*- is a method which software and applications are stored on a server and are made available to any client on the network.

Grid computing comprises the above technologies. In addition, it links computer resources together and allows someone to use the collective power of all connected computers.

.*Grid computing can be differentiated from almost all distributed computing paradigms by this defining characteristic: The essence of grid computing lies in the efficient and optimal utilization of a wide range of heterogeneous, loosely coupled resources in an organization tied to sophisticated workload management capabilities or information virtualization."* North (2007)

Requirements of a grid computing system according to Stickland (2008) are:

- A computer - This computer is usually a server which is responsible for allocation of resources and monitoring the network to ensure that it does not become overloaded.
- A group of networked computing nodes (desktops, laptops, smart phones) running grid computing client software.
- Grid computing management software that will aid management of the cumulative grid recourses

The researcher concurs with Stickland (2008) on requirements of grid computing because in the system model that was developed in this study the server is key for monitoring the network and performing analysis of resource utilization of the client computers which are networked. Networked computers are running the grid application client service which relays information to the server at regular intervals. This is what Stickland is referring to as middleware.

2.2 Grid Computing *Related Studies*

This subsection discusses the basis of this research in relation to other studies that have been done relating to Grid Computing technology. The gaps and how this research will address them has been discussed.

Thiga (2018), performed a research on the demand for High Performance Computing (HPC) and grid computing by Kenyan researchers. This was done under the umbrella of Kenya Education Network (Kenet). The areas established as the reasons why there is

need for HPC were: for fraud analysis, computational fluid dynamics, seismic modeling and lastly he indicates that there is potential use in education and research. He adds that there were researchers in Kenyan universities carrying out research on material science currently using HPC facility in South Africa.

In this regard, grid computing in hospitals is nowhere in the picture, this study therefore adds value to the world of knowledge and technology by arguing out that there is need for implementing grid computing in Kenyan hospitals and proposing implementation of grid computing in MTRH. The fact that Kenyan university researchers are using HPC facility in South Africa, clearly shows that there is no such facility in Kenya and this is a new field of technology which should be explored. This research aids in the exploration part and also geared towards solving the problem of underutilized computing resources.

Saini and Yadav (2015), indicates that lack of communication facilities in the current health service operations makes the services inadequate. The researchers points out that there is unavailability of current data and information due to lack of well computing facilities. They further established that there is a need of developing modern computing systems to reduce cost and wastage of resources. This study is therefore making Saini and Yadavs' recommendation come to pass by developing a better grid computing application that can facilitate communication for the purpose of resource sharing. Thus reducing cost and wastage of resources.

Zhou, et al (2008), in there study developed grid computing and performed evaluation on its performance. The results established indicated that a local Grid with ten CPUs

provided much faster execution than in remote Grid with thirty seven CPUs because of less communication and competition for job execution. This research is in agreement that first Grid computing works and has been tested. Secondly, that use of locally available resources in Grid technology is better and faster in job execution than using remote Grids.

However the Grid technology developed by Zhou and his fellow researcher, used virtualization technology. It allows the user to decide whether to avail its resources to be shared / donated or not. This study is therefore geared towards developing a solution where by the user is not at liberty to make a decision on whether to donate its resources or not, but instead developing a client service application which will require every client node on the Grid to communicate utilization of its resources to the server for job allocation consideration.

In addition, this research developed grid computing application without using virtualization because virtualization technology suffers from the following disadvantages discussed by Paula, (2013), which the study is trying to avoid: it increases security management burden because it adds layers of technology which may require additional security controls, virtualization sometimes makes it easy to share information between systems. This flexibility can be taken advantage by attackers looking for confidential information, virtualized environments are quite dynamic. Hence complicating the creation and maintainability of the necessary security boundaries.

Zhao, et al (2009), also indicates that hardware cost may be a challenge since Virtual Machine (VM) performs better when a lot of resources are assigned to each VM. Virtualization is therefore not an option in this study since it is looking forward to solving a problem of inadequacy of ICT resources and finance. Therefore the study disagrees on using virtualization and develops an application which will be installed direct to the machines on the grid.

2.3 Theoretical Framework

Since this study is looking forward to designing and developing a system that will lead to implementation of Grid computing in MTRH, the researcher hopes that this technology will be accepted and implemented by the institution. Therefore, the study was guided by an architecture based model which was used for implementing grid computing systems. The researcher settled on a layered grid architecture developed by Senthamarai & Krishnan (2008), after studying grid architectures developed by other researchers. This is because this layered architecture has been widely discussed and is considered to be more comprehensive compared to other grid architecture. The Layered Grid Architecture is as illustrated below:

2.3.1 Layered Grid Architecture

Senthamarai & Krishnan, (2008), present a layered grid architecture which contains the components necessary for a grid to be sufficient. This architecture was used by researchers in their study on a proposed *Grid computing based model for monitoring energy flow in power distribution systems*. The following diagram shows the layered grid architecture.

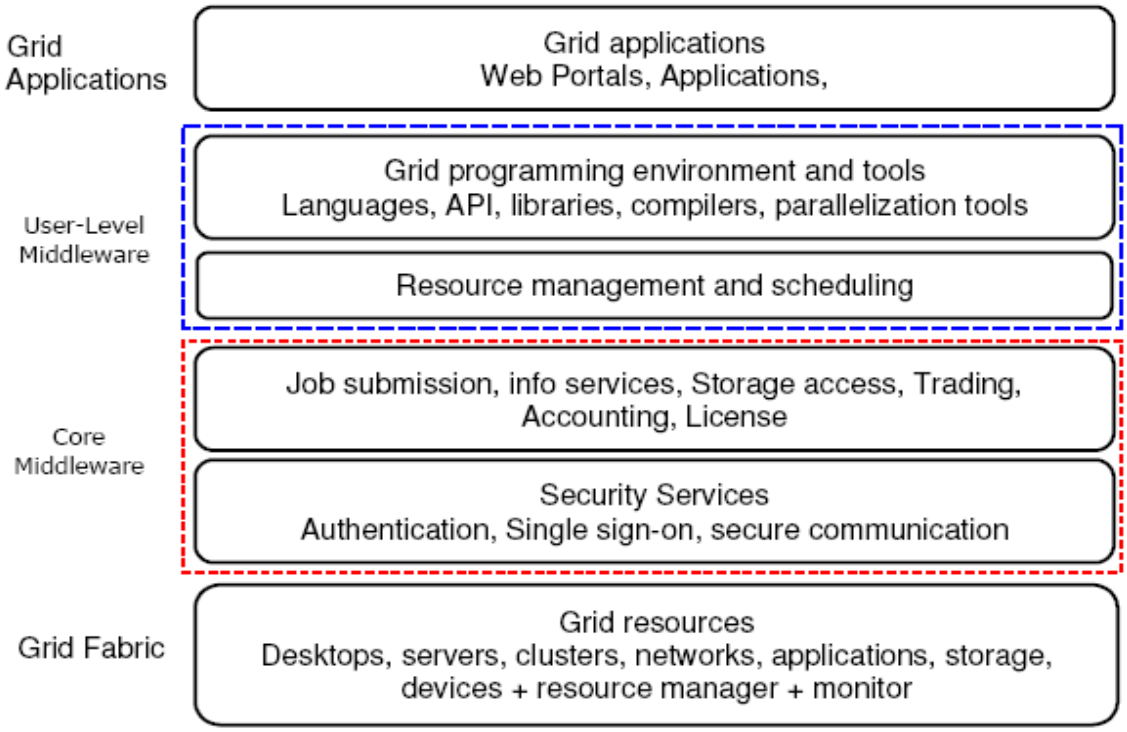

Figure 2.4: Layered Grid Architecture (Source: Senthamarai & Krishnan, 2008)

Explanation of the layers:-

Grid Fabric layer: this layer manages recourses and execution environment which runs a range of operating system like windows, UNIX etc. At this level resources are made available by *local resource managers* which have the capability to monitor the available resources.

Core Grid middleware layer: this is the second layer which provides the following services: storage access, accounting, information services, job submission. Due to the dynamic nature of any grid, it is important to consider security services to address authentication, confidentiality, accountability and integrity.

User-level middleware layer: This is where user applications are created. This allows for the selection of appropriate resources depending on the different applications. Suitable programming languages and tools e.g. C, C++, JAVA, API among others can be used as platforms to facilitate the creation of different user applications.

Grid application layer: this is the layer which enables the end -users to utilize services offered by the Grid. Therefore, grid applications have to be a user friendly for the end users to find it easy to use. They should also be dynamic in their functions and run on various operating systems for users to be able to access them with no difficulties.

2.4.2 How the Layered Architecture was employed

As indicated earlier, the layered grid Architectures chosen for adoption in this study was considered to be comprehensive compared to other architectures discussed in this study. It shows what is expected in a full functional grid computing application. However not all layers were implemented fully because this research involved developing a prototype for demonstration purposes. This may need to be enriched further if it is considered for implementation.

The grid fabric layer which presents the grid resources, enabled the researcher to develop a client service application which compelled the clients in the grid to communicate there resource utilization. Another application which enabled the server to perform analysis of the information received and establish underutilized resources for allocation of tasks was developed. The user level middleware layer which requires selection of appropriate

software, led to the selection of Visual Studio. Net for the development of the Grid and SQL software for database creation.

The necessity of security presented in the second layer (core middle layer), was not adhered to since this research intended to develop a prototype and the actual implementation of the application was not part of the scope. Hence that can be considered at a later stage of implementation. The last layer was also helpful because it presented the need of a user friendly software which ensured the development of the interface having all the modules of the Grid application for easy navigation.

2.5 Other Grid Architectures

An architecture is a plan or design (mostly inform of a framework) that shows step by step instructions undertaken when performing a certain task. It is important therefore to look at grid architecture used by other researchers as they studied Grid Computing. The architectures presented below were considered not to be as detailed as the one adopted by this study though they were also presented in a layered form.

a) Grid Protocol Architecture

According to Ian Foster et al, (2009) grid protocol architecture is made up of fabric, resource, collective, application layers as shown in the diagram below:

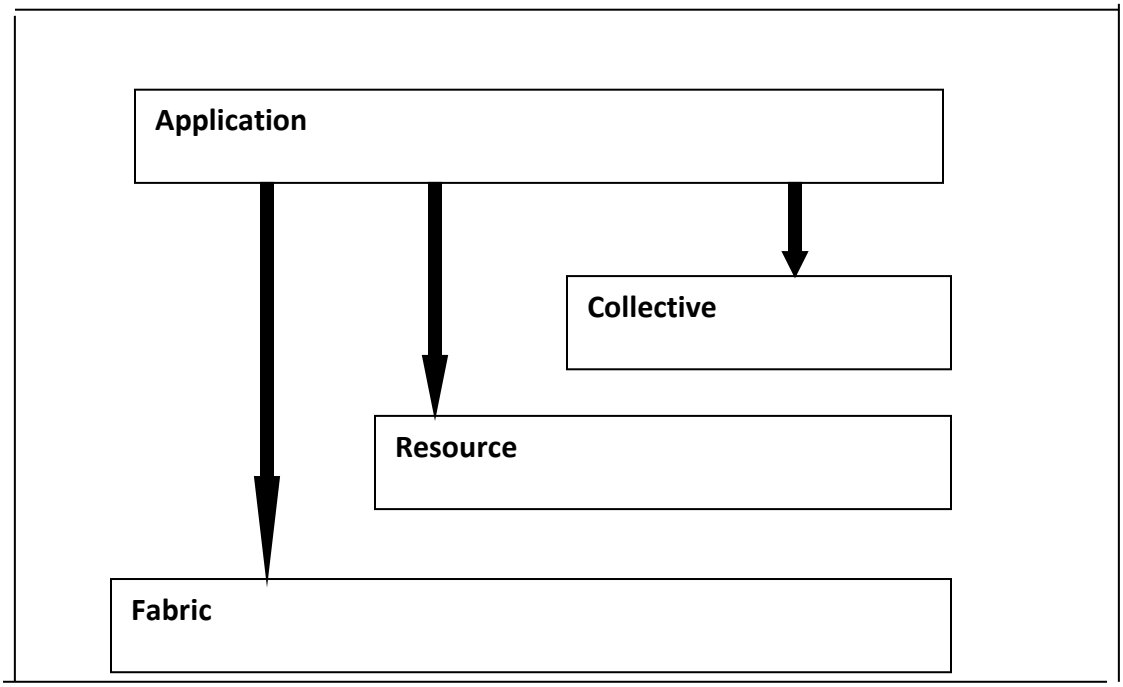

Figure 2.5: Grid Protocol Architecture (Ian Foster et al, 2009)

Fabric layer- it is the first layer which makes resources within the network available e.g. data/information, processing power, software and hardware. It brings the existing components which participate in the environment of sharing the available resources together.

The connectivity layer- this layer provides authentication protocols to guide communication. This ensures that the network transaction is secure and communication is made easy.

The resource layer- according to the author resource layer defines the protocols that will be used for making publications, monitoring, negotiations, payment and accounting of

shared operations of various resources. In other words, this layer provides protocols that will aid the allocation and monitoring of the resources shared in a network.

The collective layer- this layer is responsible for monitoring how the collections of resources within the network are interacting with one another.

The application layer- this presents a platform where user requests are being presented and responses are received. It is therefore the user applications which have been built on top of all those other protocols since it is found at the topmost.

b) Grid computing layered architecture

Maarten et al (2016), presents the following layered architecture

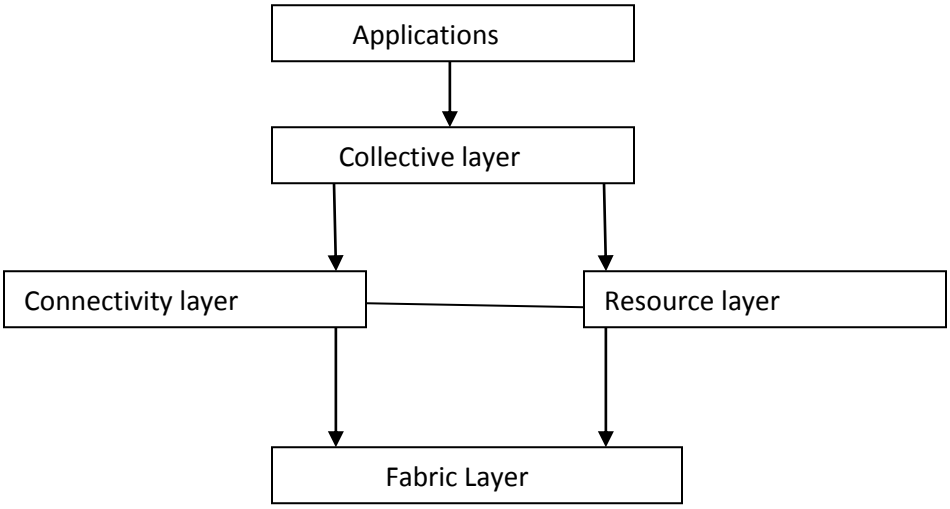

Figure 2.6: A layered architecture for grid computing (Source: Maarten, 2016)

2.6 Designing, Testing and Pre-Implementations of Grid Computing

System Architecture and Administration (SAS) Institute (2010), presents a list of items that have been assembled as considerations for designing, testing and pre-implementations of a distributed environment which in this case is termed as grid computing. Once you have established whether your software can be distributed, then you are required to perform the following:

- Draw a data flow diagram

  This will help the researcher understand the data flows in the application. The researcher is required to include the amounts of data (e.g. volume of data that can be accessed) and throughput requirements.

- Sketch a comprehensive drawing of the Grid

  This will help in identifying the required hardware, software and network. It is also essential to label all the storage and network connections.

- Identify the location of your application's temporary storage. In a distributed environment, it is good practice to ensure that there is a temporary storage that holds frequently used resources in the environment to ease access to the resources. The temporary storage can either be on the individual computer (grid node), or on the nodes within the network.

- Keep it simple

  It is important to keep the application simple and not over designing it and making it complex.

- Analyze the diagram to ensure that all aspects have been captured accordingly and design the hardware architecture
- Design testing- it is essential to test your design before the actual deploy of the final product. This helps in the realization of the problems present and allows solutions to be generated at an early stage. The Design can be tested by comparing it to existing architecture.
- Once the design has been tested and the designer/researcher is satisfied, it is good practice to implement the application and evaluate it.

SAS institute, (2010) presents the following questions which the researcher can use in the evaluation process:

> *"….What is the I/O requirement per process? How many users in each class and what are the response time requirements? What are the data volumes that each user needs to access and what are the typical throughput requirements in MB per second? If applicable, what is the bandwidth of the connection to the database and or other data resources? Are there user groups that could be isolated to different grid nodes in order to improve response time? Are there priority users? (Grid scheduling can help with this.)"*

This research concurs with the above considerations for designing, testing and pre implementations of Grid applications. However it depends on the grid applications being developed and considerations made from the above discussion is captured in the

methodology used in developing the system model which is prototyping. The methodology has been discussed in detail in chapter three.

2.7 Storage Performance in Grid

One of the most critical things in a Grid environment is storage performance. This is because in a grid there are volumes of data that needs to be processed. Information that has been obtained needs to be stored properly since it will help in an organization's decision making. Broberg et al, (2009) .This information will be retrieved a number of times as required, therefore its storage is essential. Thus any one intending to develop a grid has to seriously consider the kind of storage that will be efficient. According to SAS Institute Inc (2010), there are three types of shared file systems (storage facilities), these are:

- *Network Attached Storage(NAS)*
- *Clustered / Shared File Systems*
- *Hybrid File Systems*

Network Attached Storage (NAS)

According to the author, this type of storage allows one to influence the sharing of storage space with remote clients by implementing network sharing protocols. These protocols can be Network File System which is built on a UNIX and/or LINUX operating systems or Common Internet File System (CIFS) which is built on windows. These two protocols are network file systems used for sharing data across a Local Area Network (LAN). The following table shows the advantages, challenges and best practices of NAS.

Table 2.1: Advantages, Challenges and Best Practices of NAS (source: SAS Institute Inc (2010).

Advantages	***Challenges***	***Best practices***
Easy to deploy and administer.	*Less scalability than SAN based CFS.*	*Use a dedicated Ethernet interface(s) on storage clients for storage traffic.*
Low cost shared file system option.	*Poorer performance due to packetized network traffic (but newer 10 GB Ethernets could help).*	*Use more than one Ethernet per storage client for availability.*
Can be configured for high availability.	*Does not support load balance across multiple Ethernet interfaces easily (extra software and hardware or manual load balancing required)*	*Use high speed networks like 10 GB Ethernet when possible.*
		Ensure NFS server can meet server throughput requirements of storage clients (NFS servers typically don't provide the throughput capability of standard storage devices)

Clustered / Shared File Systems

CFS is a storage architecture which makes use of available standard storage devices to be shared in storage area network architecture. CFS is installed on all of the clients used for storage. This allows the control of synchronized access when sharing of metadata is considered. The table below shows the advantages, challenges and best practices of CFS.

Table 2.2: Advantages, Challenges and Best Practices of CFS (Source: SAS Institute Inc (2010).

Advantages	***Challenges***	***Best practices***
Typically the best performing shared file system architecture	*Not all products support multiple operating systems*	*Understand the metadata requirement for the CFS.*
Typically the best performing shared file system architecture	*More expensive than NAS*	*Dedicated server and storage might be required to store metadata. Metadata server response time can be critical to overall CFS performance.*
	Harder to administer than NAS	*Monitor throughput performance from storage client all the way to the disk Volumes in the storage device.*
	Requires dedicated storage network (typically fiber channel)	

Hybrid File Systems (HFS)

This kind of file system is a combination of both NAS and Storage Area Network (SAN). However it shares the same capability as CFS. Internet or IP based Storage Protocol and Multi-Protocol File Systems are examples of hybrid file system. Ethernet cables are used

to connect the storage nodes that get access to the file system which are also connected to storage devices that are connected to the network.

The table below shows the advantages, challenges and best practices of HFS.

Table 2.3: Advantages, Challenges and Best Practices of HFS (source: SAS Institute Inc (2010).

Advantages	***Challenges***	***Best practices***
Faster throughput than pure IP based storage due to use of storage protocols	*More complex to administer and monitor*	*Use a dedicated Ethernet interface(s) on storage clients*
Strong failover and load balancing capability with multiple Ethernet interfaces	*More expensive than NAS solution*	*Use more than one Ethernet per storage client for availability and performance*
		Monitor throughput capability at all layers of the architecture
		Seek design help from the vendor to ensure throughput requirements can be met

Having discussed the three types of storage file systems which can be used in a grid environment, the researcher advocates the use of CFS since it is the best performing storage system and less expensive compared to HFS. CFS can be used when the storage devices are connected using a fiber cable hence internet connectivity is not a requirement.

2.8 Implementing Grid Architectures in Concurrence with those Architectures that are not aware of Grid Processes

It is important to know how to implement grid structure for effective functionality of the grid.

According to Nasuti et al (2011), grid nodes sometimes run other grids which are not aware of grid processes together with those grids which are aware of the processes. Therefore a grid manager is employed to provide controls that will govern all the resources in the grid environment and ensure that there is no inefficiency what so ever. Use of grid managers in any grid environment ensures that organizations are able to make the most use of their hardware resources efficiently. This is because it provides plentiful functional tools that enhance the resource utilization and performance of grid programs and applications. The grid manager technology can be utilized in the following ways:

- ***Multi-User Workload Balancing-*** this is a case where by workloads/tasks are shared among available resources. It ensures that the customers are optimally using the underlying resources. The grid manager does this by submitting the workloads to the grid and not to individual machines. This means that some machines will not be loaded since the workloads are evenly distributed depending

on the resource requirements. It allows priorities to be assigned based on either applications or users and also allows job interrupt (suspending and or preempting jobs during processing).

- ***Parallelized Workloads Balancing–*** this is dividing larger tasks into smaller pieces which are processed in parallel. Instead of one large task being processed serially_ this means that a single processor is used to process this task_ then it is divided into smaller tasks and these tasks are distributed over the available processors. This technology therefore enables larger tasks to be processed easily and very fast compared to serial processing.
- ***Distributed Enterprise Scheduling-*** There are jobs which are scheduled to run regularly and mostly these jobs are scheduled to be executed when there are less jobs requiring the resources. This ensures that resources are effectively utilized even at off pick hours.
- ***Scalability/Maintainability-*** grid manager technology enables expansion by allowing the sharing of configurations and binary directories. Therefore adding more grid nodes to the existing one is simple. Since grid nodes can be easily added or removed, maintainability is not complex.

If all these concepts are considered during implementation of grid computing in any given environment, then there is an assurance of quality services/performance in any organization due to the advantages obtained from full utilization of resources.

In an architecture that has both grid aware and those that are not aware of grid processes, there is a need to consider an architecture which consist of two subsets of nodes i.e. those

running in a grid environment in conjunction with non-grid awareness and those purely running on a grid environment. These two subsets are configured exclusively according to their awareness of grids.

The first set of nodes (grid nodes and non-grid nodes) can be scheduled to run processes that are non-grid aware, non-interactive and less prioritized. While the second subset (purely grid nodes) can be configured to run high priority tasks. The interaction of the nodes is governed by grid manager.

This research considered running grid nodes that are aware of the grid environment by enabling the clients to run a service that communicates the utilization of its resources to the server and also running a non-grid node. A comparison was made on the time taken by the two environments to process a task as demonstrated in chapter three.

2.9 Chapter Summary

This chapter has discussed the works of other researchers in relation to grid computing. The theoretical framework presents a layered Grid Architecture by Senthamarai& Krishnan, (2008), which was adapted to guide the development of the Grid application which is the main focus of this study. The ways of implementing Grid architectures have also been discussed and the researcher concurs with Nasuti et al, (2011) that a grid manager is important to govern all the resources in a grid environment to ensure efficiency. Storage performance in a Grid is also critical and there is need to ensure that data and information obtained need to be stored properly for further referencing.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the procedures that were followed in conducting the study. It covers the following key areas that were adopted in designing and developing the system model: research design, sampling technique and procedure, data collection, data analysis and methodology.

3.1 Research Design

According to Kombo and Tromp (2006), research design is defined as the structure of research. It can be referred to as a "glue" that holds together all the elements in a research project. This study was conducted using experimental research design. Oso and Onen (2005), states that experimental method is a type of design that entails "systematic manipulation of some characteristics and examination of the outcome".

A grid computing system that was able to share resources among connected computers was developed. Three tasks were loaded to a grid node with two other computers on the grid and a non-grid node. The time taken to complete each task (in the two environments) was recorded in three attempts and an average performed to obtain the most accurate time estimation in milliseconds. It was established that the grid node connected to two other nodes on the grid was appropriate for processing complex tasks within a shorter period due to the ability of sharing resources.

3.2 Population and Sampling

3.2.1 Target Population

The researcher carried out this study in MTRH. The study's target population therefore included all the personnel in MTRH who are involved either directly or indirectly in decision making, concerning implementation of new technologies. The personnel considered in this population are twenty eight. These were heads of departments and ICT personnel responsible for selection, acquisition and implementation of new ICT technologies in MTRH.

3.2.2 Sampling Procedure

Purposive sampling was used to select a sample from the targeted population. Oso and Onen (2005), states that purposive sampling is a technique that the researcher decides who to include in the sample, it is used to collect focused information. Therefore this research purposely considered the management of MTRH and ICT personnel (system administrators, system implementers, computer programmers, computer technologists, system analysts, database administrators and network administrators) who were believed to be having crucial information on the challenges facing them as far as ICT implementation is concerned. The personnel in the management who were sampled from the target population are six heads of departments and twelve ICT specialists.

This sampling technique was considered the best for this study because it not only saved time but also enabled the researcher to select typical and useful information only.

3.3 Data Collection Procedure

The data collections method that was employed in this study was interviews. Interviews are face to face verbal communication in which interviewees are asked questions by an interviewer that are anticipated to prompt information and opinions, (Konthari, 2004). The researcher employed semi structured interviews. This means that some structured questions were asked alongside some open-ended questions. This was the ideal tool because it enabled the researcher to obtain a complete and detailed understanding of the issues at hand. Interviews are advantageous since they provide in-depth data, which is not possible to get with questionnaires, Kombo and Tromp (2006). The interviews schedule was guided by the objectives of the study.

These instruments were chosen because they helped the researcher gather appropriate data on the challenges faced on ICT implementation and suitability of Grid Computing in MTRH. This helped the researcher to come up with an appropriate solution for the identified problems.

3.4 Data reliability and Validity

Data collection is the determining factor of any research. This is because data collected is analyzed in order to get the results which are used in determining the solution of a given problem, Kothari (2004). Therefore the all process of collecting data should be very sufficient in order to obtain correct information.

In respect to that, a pilot study was done by visiting the ICT manager to get an overview of their opinion and expectation on this research. This enabled the researcher to formulate grounded strategies to ensure that the available time was planned and used well. Interview guides were developed and the interviewees were decided by providing a list of members to be interviewed. This ensured reliability and validity of data.

The researcher pre-tested the instruments which were used for data collection to ensure that they were meeting the stated objectives. After pre-test, the questions were restructured according to the pre-test results before the actual research was carried out. The researcher also ensured that each question presented in the instruments was specific, precise, directed to the correct respondent and without any ambiguity.

Upon completion of data analysis, an appropriate solution was developed. To ensure validity and reliability of data collected, the researcher performed a post-test analysis on the solution to ensure that this was what actually the respondents wanted and that it was meeting their needs.

3.5 Data Analysis

Data analysis is transforming collected data which is raw in to sensible data. This is done by doing comparison, finding relationships and presenting the results in the tables, charts and graphs. According to Huberman and Mile (1994) data analysis comprises of data reduction (transforming data that was noted), data display (organizing data in a certain format for presentation) and drawing conclusions.

Qualitative data analysis was used in this study. Data analysis was therefore done hand in hand with data collection. This helped the researcher to integrate any emerging issues during the data collection process. Written notes from interviews were analyzed basing on the objectives of the study, which allowed identification of the requirements/specification of the solution that was developed.

3.6 System Development

This study focused on designing and developing grid computing system model that can be implemented in MTRH. Therefore the researcher heavily relied on a system development methodology. After a thorough investigation on the available system development approaches, the researcher settled on prototyping. A prototype is a functional system model that is used to test assumptions and ideas of the system being developed. According to a survey study on system development process models (Government University at Albany, 1998), prototyping is the development of a simplified version of the proposed system which is presented to the customers for consideration as part of the development process.

Prototyping was considered appropriate for this study since it can be used to model realistic aspects of a system during each phase of the development process. (Huffaker, 1986), it allows the participation of users in system development and communication among project stakeholders; it encourages innovation and flexible designs. These assisted the researcher to understand the fundamental problem since it was necessary to avoid solving the wrong problem.

The principal use of a system prototype is to help customers and developers understand the requirements for the system (Sommerville, 2000).

3.6.1 System Development Process

This study focused on developing and designing a grid computing system. As discussed earlier in the theoretical framework, this study was guided by an architecture based model (Senthamarai and Krishnan, 2008), which can be used for implementing grid computing systems, together with a prototyping system development methodology. Therefore the researcher was directed by the following prototyping steps:

Requirements Analysis: this was the first step where, after data collection, the researcher was required to analyze the collected data and specify the detailed requirements for the new system that was to be developed.

Design: this was the process of transforming requirements specification into a logical view of the system. The logical view showed what the prototype was designed to do. Pictorial representation tools were used as illustrated in chapter four.

Prototype creation / coding: this is rolling down the information in the designing stage into the prototype. In this case the researcher developed a prototype that meets the specifications set at the design stage. Visual Studio. Net was used in coding, SQL management server and MySQL was used in database development.

Testing /Assessment: this phase involved the presentation of the prototype to the customer for review. Recommendations and suggestions were collected from the customers. This phase was very important since it helped the researcher determine

whether the objectives were achieved. If the objectives were met then the system was ready to be released for implementation else the prototype was refined.

Prototype Refinement: this was the stage where customers' recommendations were considered. They were analyzed and integrated into the prototype to make it more efficient and effective.

3.7 Ethical Considerations

"Issues of ethics are very important in research. This is because knowledge acquired through research cannot be pursued at the expense of human dignity" .Oso and Onen (2005). This study is therefore keen to observe the following ethical issues as proposed by Oso and Onen (2005).

- Informed Consent

  The researcher ensured that the respondents of this study and the institution involved (MTRH) were informed about the processes of the study which they were expected to take part in. This information includes the benefits of participants, expected duration of participation and if there were any unpredictable risks.

- Privacy and confidentiality:

  The researcher respected the right of privacy and confidentiality. The researcher ensured that the data collected will strictly be used for the purpose of the study.

- Anonymity:

  The researcher respected the right of the respondents to remain anonymous, since it did not affect the research.

- Researcher responsibility:

  The researcher observed human dignity and ensured that her intentions did not compromise any ones' dignity. Other researchers' works that were used or referred to were acknowledged and cited.

CHAPTER FOUR

RESEARCH FINDINGS, ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter presents a discussion on the research findings, data analysis and interpretations of data collected from the interviews. Data analysis is based on the objectives of the study.

The discussions of the findings are presented in tabular form to enhance reading and understanding.

4.1 Analysis and interpretation of research objectives:

Objective 1: to identify the ICT tools and equipment used at MTRH

The table below shows the ICT infrastructure available in MTRH according to the interviewed ICT specialists:

Table 4.1: ICT infrastructure in MTRH

ICT RESPONDENT	RESPONSE FINDINGS
ICT R1	Servers, Computers(approximately500), Internet(6Mbps), LAN(fiber optic and wireless)
ICT R2	Machines, switches, printers, scanner, internet (6Mbps)
ICT R3	Computers, servers, internet, printers
ICT R4	Computers, internet, servers
ICT R5	Internet (8MB), Machines (300), Servers(6)
ICT R6	Servers(6), Routers, Switches, computers(300), iPods
ICT R7	Fiber, computers(400-500), printers, Fax machine
ICT R8	Computers, LAN , internet, systems
ICT R9	Computers, servers, CISCO switches
ICT R10	LAN, computers, routers, switches
ICT R11	Computers, internet, servers
ICT R12	Computers, switches, printers

From the findings as indicated in the Table 4.1, where research was conducted to identify the ICT tools and equipment used in various departments in MTRH. Several respondents were interviewed which included the following; system administrator, system implementers (IHMIS, Clocking, PAC), Network administrators, computer technologists and computer programmers.

From the research it was found that the following ICT equipment are found within MTRH; servers, Computers (approx. 500), internet, LAN, printers, Routers, systems as well as Pads.

The several resources that MTRH currently has can be greatly optimized to ensure optimal levels. This can only be achieved through Grid computing. With about 500 computers MTRH can greatly utilize and generate a lot of Grid power.

In Mustafee (2007), grid computing is said to be different from the normally traditional computing because it focuses on huge performance, large scale resource sharing and execution of creative applications. Its main objective is having coordinated resource sharing and ability of solving problems in multidisciplinary virtual organizations. A virtual organization can be a group of organizations or individuals that have come together to perform certain tasks by sharing resources governed by clearly stated regulations. This can be emulated in the case of MTRH, by sharing resources situated in various departments to ensure optimization of the available resources.

The table below shows the responses of HODs who are considered as the Key Informants in this research on the services that are ICT enabled in their respective departments:

Table 4.2: Services that are ICT enabled

RESPONDENT (KEY INFORMANTS)	FINDINGS
R1-KI	-Registration of patients, Billing, Management of suppliers, management of pharmacy, patient number management DBR(daily bed returns),debt management
R2-KI	-Billing, Revenue collection, Credit control
R3-KI	Radiology Information System and Picture Archiving and Communication Systems (RIS/PACS). Billing and data entry
R4-KI	There is a Hospital Management Information System (HMIS), which was expected to be rolled to the department. It was geared towards handling the following areas; 1.Tendering process 2. Procurement process 3. Receiving and Issuing 4. Storage 5. Disposal of Items
R5-KI	Recording of patients/registration, billing , HMIS
R6-KI	HMIS which helps in patients records and billing

The table above shows the responses of the various head of departments on the services that are ICT enabled, it is evident that most of their services were provided by the HMIS. Some of the services offered by the HMIS are registration of patients, billing, management of suppliers, management of pharmacy, daily bed returns and debts management. Radiology Information system and Picture Archiving and Communication

System (RIS/PACS) is an independent system used in the radiology department. This means that if they implement Grid computing it will help them enhance the activities performed by the HMIS and (RIS/PACS) since there will be resource sharing which will lead to enhanced processing and retrieving of information.

The table below shows the responses of the ICT specialist on their opinion of the extent to which MTRH has implemented ICTs:

Table 4.3: The Extent to which MTRH has Implemented ICTs

RESPONDENT	RESPONCEFINDINGS
ICT R1	Automation level is 58.6% as per e-government audit carried out in April 2013
ICT R2	55% implementation. At least all departments have implemented ICTs
ICT R3	Not fully implemented e.g. data entry should be fully automated
ICT R4	All departments have computers
ICT R5	All departments have implemented. Public health has not yet implemented ICTs
ICT R6	Most departments have embraced ICTs due to the introduction of HMIS, but clerking is still lagging behind since doctors still take handwritten notes. 56% implementation
ICT R7	Every 10 staff for one computer. 60% implementation
ICT R8	According to his view ICT implementation is 55%
ICT R9	Mentioned the system in place i.e. HMIS
ICT R10	54% implementation
ICT R11	58% implementation
ICT R12	56% implementation

The table 4.3 above on the extent in which MTRH has implemented ICTs, all the interviewees acknowledged that MTRH has taken a step in automation. The figure given by the respondents on the extent of ICT implementation was 55% to 60%. It was also noted that the level of automation was at 58.6% as per e-government audit carried out in April 2013.This shows that MTRH has seen the importance of embracing ICTs. New technologies like Grid computing will enhance their functionalities and services.

Objective 2: to establish the challenges faced by the hospital in optimizing the use of ICTs

The table below shows the responses of the HODs on the challenges faced in their areas concerning optimization of ICTs:

Table 4.4: HODs Response on Challenges faced by MTRH in Optimizing the use of ICTs

RESPONDENT(KEY INFORMANTS)	CHALLENGES	SUGGESTED SOLUTIONS
R1-KI	• Inadequacy of finance • There is no dynamisms in the Human resource sector • Inadequacy of ICT equipment • No appreciation of customer and business adoption	Better financing from government Embrace new technology Retrain the staff to appreciate new technologies
R2-KI	• Lack of enough ICTs • Processing speed of computers	Embracing new technologies

	is too slow especially when the system is overloaded • Some computers are obsolete but still in work stations	Disposing the obsolete machines
R3-KI	• Lack of skills on ICT • Shortage of staff • There is no full networking that enables transmitting of information from the department	Good networking is recommended. Acquisition of modern computers
R4-KI	• Capacity of servers are limited • There is no diversification of the employees • Difficulties in disposing electronic machines e.g. computers	Acquiring more servers that are effective Ensuring that proper disposal mechanisms are put in place
R5-KI	• Lack of adequate number of computers • Lack of expertise to link up information among users • Slowdown of the system especially when there is much work to be done	Purchase of more computers Close working of ICT personnel Ensuring the system is always effective
R6-KI	• Inadequacy of finance • Inadequacy of ICT equipment • Inability of sharing the available ICT resources	Establish ways of cutting down cost and utilizing fully the available once

According to table 4.4 above: Most respondents brought out the issue of urging the government to increase funding to finance more ICT equipment in health facilities. Respondent No. 1 further explained the need for retraining of the staff to appreciate and to adapt newer technologies such as Grid systems which were reiterated by Respondent No.2, Respondent No. 3, Respondent No. 4 and Respondent No. 6 in this category. Inadequacy of computers has been mentioned across this category as well. Respondent No. 4 stressed the need to increase the capacity of the server, which is currently limited as well as the facility lacks full networking which hinders the transmission of information from one department to another. Respondent No. 4 and Respondent No. 2 mentioned that they were facing challenges in disposing electronic machines especially computers and there was a need to establish proper disposal mechanisms.

According to Arviansyah (2009), there has been a decline in global economy and this has affected the justification of allocation of funds to ICT during the creation of budgets in organizations. Before venturing into the implementation of ICTs, there is a need to perform effective evaluation of ICT investments which depends on the organizations ability to determine the business value of ICT investments. Existing literature majorly focus on the utilization of ICT's in hospitals without majorly looking at its full optimization perspective.

Based on this research, there is a need to determine the usability of the available ICTs in MTRH, which will lead to budgetary implications on whether to invest more on ICTs or

optimally use the available ones to improve health care provision. This will help the processes to work together, share information and communicate to each other.

The table below shows the responses of the ICT specialist on the challenges faced in their areas concerning ICTs and possible solutions to the challenges:

Table 4.5: Responses of the ICT Specialist on the Challenges faced in their areas concerning ICTs

ICT RESPONDENT	CHALLENGES	SOLUTIONS
ICT R1	• Insufficient funds • Wanting basic computer skills • Complexity of medical operations in the hospital	Allocating more funds to ICTs Providing in house training on basic computer skills Embracing new technologies that will help simplify operations and cut down the cost
ICT R2	• Training of users is a challenge • Challenges in disposing old computers • Inadequate infrastructure	Procurement of more machines Establish ways of disposing old computers Implementation of Grid Computing
ICT R3	• Inadequate funds • Machines are still being shared in other sections (the machines are not enough)	Embracing technologies that can help cut down the cost e.g. Grid Computing
ICT R4	• Lack of enough funds	Optimizing the cost

	• Lack of better equipment e.g. network infrastructure • The current server is not powerful enough hence sometimes slowing down the HMIS • Lack of proper mechanisms for disposing worn out machines	Embracing new technologies that help cut down the cost e.g Grid Computing Create proper mechanisms of disposing worn out machines
ICT R5	• Provision of ICT recourses is expensive hence implementation of ICTs is negatively affected. • When there are many clients to be served processing is slow • Training personnel on ICTs is weighty due to resistance to changes	To cut down the cost on resources Implementation of Grid Computing Make ICTs mandatory as people grow up to avoid resistance to change
ICT R6	• Clerking is still lagging behind in using ICT, because doctors still take handwritten notes • Lack of a fully structured network infrastructure • Presence of old machines	Allocation of more funds to ICTs Procurement of more computers Disposing old machines
ICT R7	• Acquiring machines is very expensive • Insufficient finance	Government to add more funds Implementation of Grid

	• Training of staff is challenging	Computing Management to create more motivational avenues to train staff
ICT R8	• Ratio of staff to ICT equipment is low • Insufficient Finances	Implementation of Grid Computing Finding donors to fund ICTs
ICT R9	• Insufficient computers • Training is a challenge • Old machines still in place	Allocation of funds for training Implementing Grid Computing to help in disposing the obsolete once
ICT R10	• Inadequate finance • Lack of enough machines • Challenges in disposing ICTs	Provision of more funds Embracing new technologies that will help in cutting down cost of ICTs
ICT R11	• Staff do not have the necessary ICT skills	Motivating the staff and training on the relevant skills
ICT R12	• Inability of sharing the available machines	Provision of ways of utilizing the available machines

From the finding indicated in table 4.5, it shows that the challenges concerning the use of ICTs for service delivery in MTRH revolves around the following issues: inadequacy of finance and the fact that ICTs are relatively expensive, lack of enough ICT equipment, inadequacy of relevant computer skills by staff, challenges in resource sharing and challenges in disposing worn out computers. Therefore the solutions suggested by the

ICT specialist are: allocation of more funds to purchase ICT equipment, training of staff on necessary skills, embrace new technologies that will help cut down on the cost of purchasing ICTs due to their expensive nature e.g., Grid computing, improve the network to enable sharing of information, provision of ways that will enhance utilization of available ICT resources, establish proper disposal mechanisms of worn out computers and improve system efficiency at all times.

Information and Communication Technologies are becoming more integrated into our lives, and healthcare has proved no exception. For clinicians, researchers and patients, ICT's is making healthcare more efficient, accessible and personalized. Grid computing allows users to share computing power and data storage capacity over a network. It will therefore help in cutting down on initial cost and or enhancing cost effectiveness. (Buetow, 2009).

Objective 3: to establish the suitability of implementing Grid Computing

The table below shows the responses of ICT specialist on their opinion concerning implementing Grid Computing in MTRH.

Table 4.6: Responses of ICT specialist on their opinion concerning implementing Grid Computing in MTRH.

ICT RESPONDENT	RESPONSE
ICT R1	• It is very viable • It will enhance effectiveness and efficiency of processing • Helps in cost cutting
ICT R2	• It is a good idea
ICT R3	• It is a good idea for it will help in sharing resources in areas that use less power e.g help desk and making use of them in areas that are very busy e.g Finance and Records departments
ICT R4	• It could be helpful
ICT R5	• Help cut down the cost of supplements • Will make service delivery better • Fasten the processing especially in departments which have a lot of work load e.g. Nursing and Finance NB. Public health and Transport have low work load
ICT R6	• It can help in cutting down cost
ICT R7	• It is a good idea to subsidies affected areas. • Help in increasing performance
ICT R8	• It will help to maximize the use of available resources • Will help in cutting down the cost
ICT R9	• Can help increase performance. • Can help in making service delivery better by

	enhancing processing power and access of information
ICT R10	• It can help in sharing information that is already in HMIS
ICT R11	• Will curb the challenge of inadequacy of finance
ICT R12	• Will help optimize the use of available resources

According to the responses shown in table 4.6 above, all the ICT specialist interviewed indicated that implementing grid computing in MTRH is a very good idea and suitable for their organization. They indicated that it will help in the following areas, enhance effectiveness and efficiency in processing, cutting down cost, sharing resources to optimize the use of ICTs especially in areas that use less power, make service delivery better and increase performance.

The following findings were obtained from the HODs to establish the suitability and possibility of implementing Grid computing in MTRH.

According to Respondent No. 1, there were four main projects that the organization was focusing as their future plans, i.e. implementation of IP PBX; Digitization of medical records, electronic medicine project and computer based radiology equipment-PACS (Picture Archival and Communication System). He reiterated that grid computing is very suitable and worth consideration as a future plan. This is because it will help them optimize the available ICTs. There is money set aside for ICT implementation, but to the opinion of Respondent No.1, No.2, No.3 and No.4 in the category of key informants, the money set aside is not sufficient. This is because; according to all the respondents MTRH

does not make profit and depends on grants from the government which is not sufficient. Therefore, as a way of solving this challenge all the Heads of Departments, recommended implementation of new technologies that would help cut down the cost of acquiring ICTs.

When ICT Manager, was asked on his views about implementing Grid Computing, he said that it will help in optimizing utilization of all the computers. He gave an example of the servers which are overworked and indicated that the solution proposed will enable the servers borrow the resources of the underutilized computers e.g. computers of the users who uses 10% of processing power in their respective work places. This will help in load balancing.

Norman (2005) states that modern computing is facing technological improvements in the conventional computing power i.e. processing ability and memory whose demands continues to grow. In spite of these advancements, sometimes these computational resources still fail to meet the duties allocated to them. Such situation creates the need to share complex computational resources in an organization both internally and external. Grid computing forms as the basis for grid computing which helps in optimization of all the resources regardless of their geographical location.

MTRH servers are over utilized. The stand-alone desktops in the various offices and departments are underutilized in the other end, with these underutilized resources, MTRH can greatly benefit in the implementation of Grid computing. The servers will acquire

high processing power as well as memory from the underutilized desktops. This will lead to improvement of services.

4.2 Prototype Results Presentation

It was established that there was a need of developing a grid computing application. A prototype was developed and subjected into a test to compare its performance with a non-grid node. A set up was done to establish the performance of a single node verses a grid node with two clients. This was done by loading a task that generates a password list in the two environments i.e. non-grid node and a grid node with two clients. All the machines had the same specifications that is 4GB RAM, processor (intel Pentium (R) CPU B950 @ 2.1GHz) OS 64 bit windows 10, Hard disk-1TB .

The study established that the most appropriate method of measuring the difference of the two environments was measuring the time taken to complete the task as was employed by Zhou et al, (2009). In order to get the most accurate estimate of the time taken, three observations were made and an average time obtained. Each of the two environments were loaded with four tasks i.e. generating a password list with one character, two characters, three characters and four characters respectively. Each subsequent task was computationally more demanding than its predecessor. The results were as shown in the table below:

Table 4.7: Results of the Experiment Performed on the Prototype

Task (Generate a password list)	**Non Grid Node**		**Grid Node**	
	No Attempt	Time Taken(in Milliseconds)	No Attempt	Time Taken (in Milliseconds)
with one character each	1	76	1	98
	2	74	2	104
	3	79	3	119
Average		**76.3**		**107**
with two character each	1	4456	1	2987
	2	4544	2	3214
	3	4647	3	2771
Average		**4549**		**2990.7**
with three character each	1	324963	1	234654
	2	334854	2	217554
	3	327789	3	254852
Average		**329202**		**235686.7**
with four character each	1	24545233	1	15798955
	2	22815545	2	16245452
	3	21588455	3	15665585
Average		**22983077.7**		**15903330.7**

Explanation of results shown on table

The task of generating one character favored non-Grid node since the grid node had an additional task of breaking down the task into small chunks and relaying them to other nodes in the grid which took more time. The second, third and fourth tasks favored the grid node because the grid node was able to process the tasks faster because of the resource sharing they had amongst them. On the other hand, the non-grid node took a lot of time to process the task due to its complexity. This agrees with Rajaraman (2016), who stated that grids are mainly meant for high performance numerical computing.

Grid systems that support the execution of grid applications typically contain software components that handle application scheduling. Scheduling software is responsible for locating the appropriate machines on which to run applications. A simple scheduler queues requests to execute an application and schedules these requests in the order of arrival. A more advanced scheduler would support application priority. An advanced scheduler might react to grid workload, using information about machine utilization, by scheduling applications to less utilized machines. Other advanced features include detecting and re-submitting applications upon failure and a reservation system which guarantees that an application is able to execute at a specified date and time. (Foster, 2001)

Norman (2005) asserts that monitoring software is responsible for monitoring the "health" of the grid. It is sometimes referred to as "sensor" software. Grids contain tools and components that monitor the load and activity on each of its machines. Load information is used to discover usage patterns and to make intelligent scheduling and resource utilization decisions. Information received from monitoring software can also be used for accounting purposes, for recording application profiles, and many other things.

4.3 Chapter Summary

This chapter has discussed the findings and its analysis. The findings were obtained from the head of departments and ICT specialist because they were believed to have information that would help execute this research. From the findings, it was evident that MTRH has put measures to enforce ICT integration in their services. This was further

proved by an audit report which rated their automation level at 58.6% that was by e-government in April 2013.

However, some of the challenges that were obtained include: inadequacy of finance and the fact that ICTs are relatively expensive, lack of enough ICT equipment, challenges in information sharing. It was also established that some machines were underutilized and some were over utilized. This means that there is need to optimize the use of all ICTs available to curb the challenges that are stated above. Therefore, the solution proposed by this research_ implementation of grid computing_ will help in optimizing the utilization of machines, which means there will be no need of acquiring more machines. The developed Grid computing system model proofed to be more efficient than the performance of non-grid nodes.

CHAPTER FIVE

SYSTEM MODELING AND IMPLEMENTATION

5.0 Introduction

This chapter discusses how the last objective which is to design and develop a system model for the implementation of Grid computing in MTRH was achieved. It presents the system modeling and design, system coding, system testing and system implementation. This system has been designed through the use of Data flow diagrams and use case diagrams. Software requirements analysis for the developed system has also been discussed.

Prototyping methodology was used for software modeling development. It details the various stages involved in the design which includes requirements analysis (detailing requirements specifications that is, software, hardware and functional requirements), system design and modeling, system coding, testing of the system and implementation.

5.1 Software Requirements Analysis

Requirements analysis encompasses designing of activities that would give the overall goals and more specific requirements for the design of the Grid Computing system. It is also known as system specifications (Moseti, 2013). This stage presents a precise description of how the system operates and its capabilities.

5.1.1 Requirements Elicitation

This research found it necessary to find out the user expectations of the Grid Computing system that was to be developed. Therefore elicitation of this information was carried out

by interviewing the staff of MTRH as illustrated in chapter four. The staff had no experience of how grid computing applications operate. What they were sure of is that they had a challenge of inadequacy of ICTs and some of the available ones are sometimes underutilized and some over utilized. So they need a system that will help them use their computers optimally.

5.1.2 Requirements Specification

Requirements specification presents the detailed requirements of the new system. They are divided into software requirement, hardware requirements, functional requirements and non-functional requirements.

5.1.2.1 Software Requirements

Operating system: Windows NT (includes windows 2007, 2008, XP)

Framework: Dot net 4.0 frameworks

SQL Server 2012-this was installed in the server to be used for report generation

MySQL 4.0 – to be used by remote clients to send their resource utilization information to the server

Apache

5.1.2.2 Hardware Requirements

Any computer that can run windows

Ethernet Switch

Cat 6 internet cables

5.1.2.3 Functional Requirements (FR)

This section describes processing activities and the expected output of the system. This helped in identifying the boundaries of the anticipated system. Functional requirements therefore enabled the system developer to come up with a system design that meets the needs at hand. The following are the functional requirements of the Grid Computing system:

FR1: The system should be able to identify the computers that are connected to the network. These computers should be running the grid application client service. The role of the service is to monitor the client computer's resources utilization and relay this information to the server at regular intervals.

FR2: The server analyzes the resource utilization of the clients that are connected based on the CPU, RAM and Disk usage and saves their usage status in the database. This analysis is done and recorded at intervals of ten seconds. This helps to get the latest information on resource utilization as soon as possible.

FR3: The server then identifies the clients with the least percentage workload based on the CPU, RAM and Disk usage for task allocation.

FR4: The system generates a report based on utilization of resources by client computers. This allows the system admin to establish a trend of how each client utilizes its resources and also know the peak and off peak times of each client. This can make provision of alternative task allocation criteria if required.

5.1.2.4 Non Functional Requirements (NFR)

Non-functional requirements present the features of the system that support the functions of a new system. According to (Jun, 2004) NFR are related to the quality of the system and it is so had to measure and one cannot easily judge if a system meets the NFR or not. The following are Non-functional requirements of the Grid Computing system:

NFR1: the system must have a good and easy to use interface. This is to ensure the administrator and other system users familiarize easily with how the system operates. It also helps in ensuring the system is used as expected.

NFR2: the system should be able to adapt to similar working environments e.g. companies and organizations with huge tasks to be processed.

NRF3: there should be provisions for upgrading the system to support additional uses for example, the actual task allocation after the underutilized resources have been identified

5.2 System Design

This research is geared towards developing a grid computing application that would enable MTRH to share its computing resources. During data collection it was established that some computers were very busy while others were underutilized. Hence the need to optimize the use of all computers. The system developed will therefore be able to monitor and establish the machines that have a lot of workload and those which are lying idle. This information will be useful in determining the machines that needs to be allocated

workloads to enhance load balancing. The items that this study focused for the purpose of sharing are the Hard disk, Memory and the processor.

The system design has been achieved through the use of the following activity diagrams:-

5.2.1 Use Case Diagrams

A use case analysis diagram is one of the commonly used techniques to represent system design of a tool by showing the main actors in the developed system. It outlines the overall structure of the overall use of the redesign process.

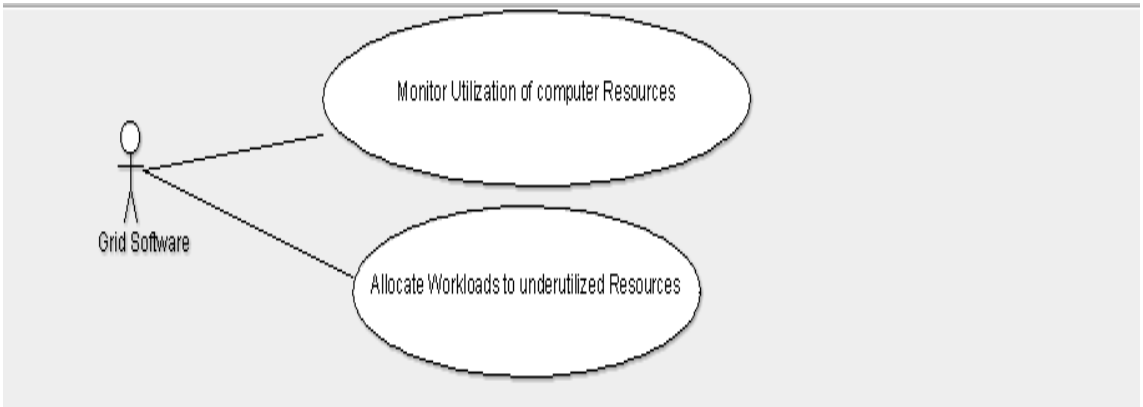

Figure 5.1: Use case representation of the Grid Software.

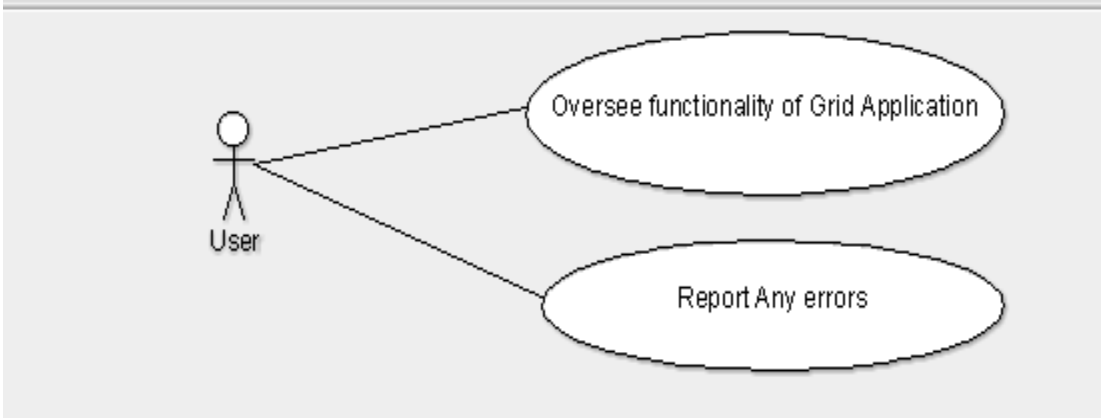

Figure 5.2: Use case representation of the User.

5.2.2 Data Flow Diagrams

An algorithm is a step by step approach of solving a problem basing on the findings from the analysis and requirements specifications. This can be designed using a data flow diagram, a flow chart or pseudo code. A data flow diagram uses four symbols: rectangle showing process, eclipse/oval represents external entities, arrow representing data flow and open ended rectangle representing data store. On the other hand pseudo code uses English like statements that may use programming language syntax to present a step by step approach. The design phase enables the programmer to come up with models of the expected program. The models show the flow of events and data throughout the entire system. Therefore two modules were considered during the design that is, the monitoring module and the allocation module. Once the logical steps have been designed, it is then presented to the customer for deliberation as part of the development process. Feedback from the customer is given to the developer who intern goes back and refines the system requirements to include the new information from the customer. The following data flow diagram was designed:

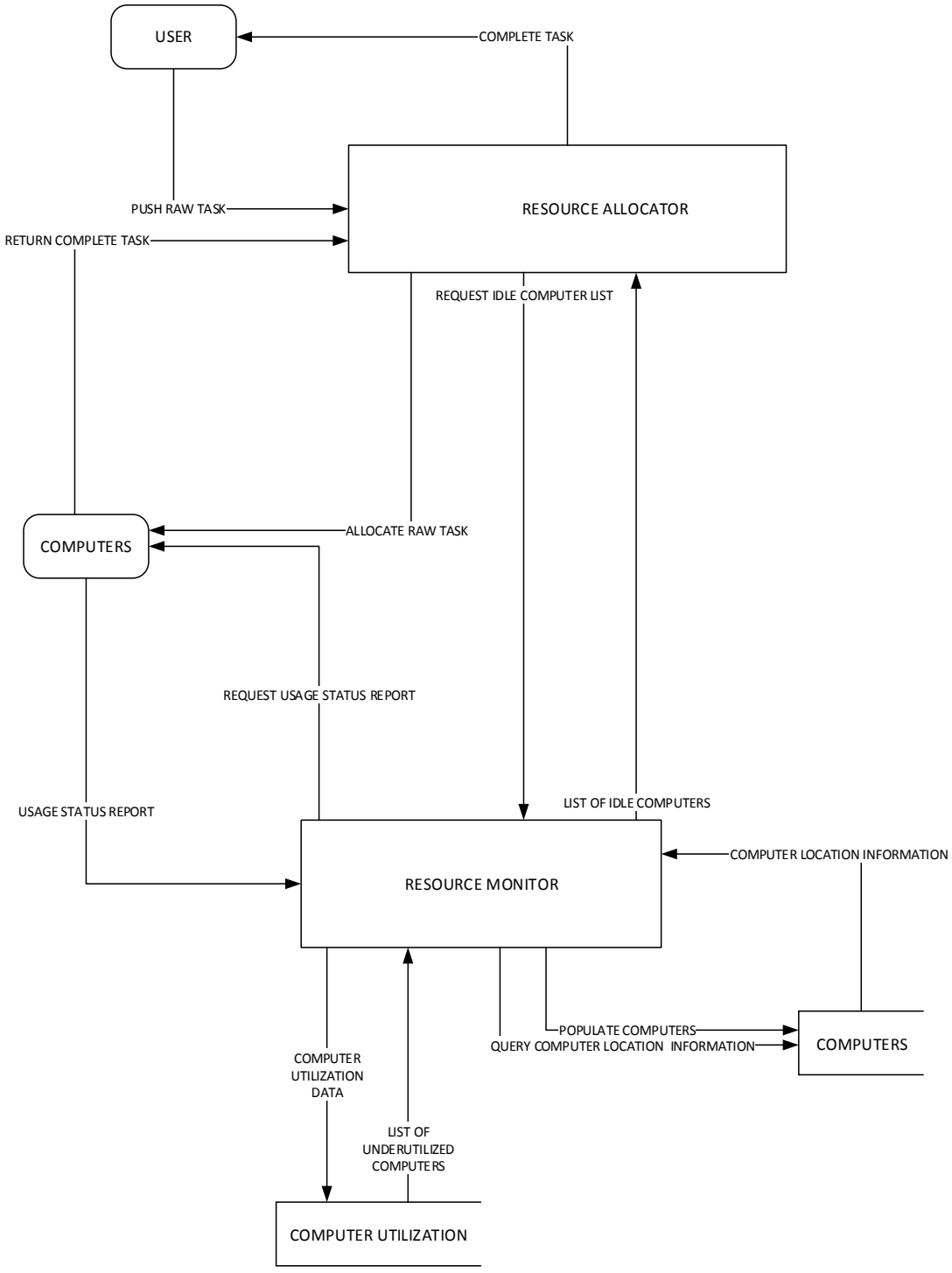

Figure 5.3: Data Flow Diagram Developed during System Design

5.3 System Coding

System coding is the actual processes of converting a design model into its equivalent program. This is done by creating a system using a particular programming language. The end result of this stage is a program which can be translated to machine language.

The programming language used to develop the Grid computing system model is Visual Studio. Net which was considered convenient by the researcher. It was important for the programmer to choose a programming language that she is well conversant with for smooth coding, to help in minimizing the errors that can be encountered while coding. The application was connected to the database for storage of established results and generating reports on resource utilization. The software used in developing the database was SQL Management studio and MySQL.

Steps taken while coding:

Step 1: created the environment for implementing what had been designed to actual coding by acquiring the tools necessary for the development of the system. These were Visual Studio. Net 2013, SQL management studio and MySQL (which was the platform used to develop the database).

Step 2: created the system setup portion of the application. The role of the system setup was to identify the computers in the network, their Names, IP Addresses and Status

The sample code that implemented the objective of this step was as shown below:

```
ImportsMySql.Data.MySqlClient' reference mysqllibrary
PublicClassfrmSetup

PrivateSubfrmSetup_Load(sender AsObject, e AsEventArgs) HandlesMyBase.Load

EndSub


1`r                  u8ok89i88886544
PrivateSubfillActive_Systems()

DimadptAsMySqlDataAdapter'create mysql data adapter
DimstrgAsString
Dim dst1 AsNewDataSet'create dataset
Call connect()     ' initializing the connection as set in the module
strg = "Select colComputerName,colCompID,colStatus  from
TblCOMPUTERUTILIZATION"'sql query to retrieve list of systems from tblutilization
Try
cnn.Open()
adpt = NewMySqlDataAdapter(strg, cnn)
adpt.Fill(dst1) 'filling the dataset
cnn.Close()
            DataGridView1.DataSource = dst1.Tables(0) 'transfering data from the
dataset to the datagrid
Catch ex As Exception
MsgBox(ex.ToString) 'capturing exceptions or errors in the above block
EndTry
EndSub

PrivateSub DataGridView1_CellContentClick(sender AsObject, e
AsDataGridViewCellEventArgs) Handles DataGridView1.CellContentClick

EndSub

PrivateSub Timer1_Tick(sender AsObject, e AsEventArgs) Handles Timer1.Tick
fillActive_Systems() 'timed event fires after some 1 second refreshes the
procedure above
EndSub
EndClass
```

The code above populates the data grid with the contents of a table which contains the status of various computers in the network. This table is created at the application startup module.

Step 3: this step involved the creation of the utilization monitor module which was responsible for retrieving the status of utilization of resources for networked computers.

Afterwards, three computers were connected together and the utilization of their resources (CPU, RAM, and Disk) retrieved and stored in the utilization table. To obtain resource utilization readings the researcher used the following codes which employed the system. diagnostics library.

```
Privatem_CPUAsNew_
       System.Diagnostics.PerformanceCounter("Processor", "% Processor Time",
"_Total")
Privatem_RamAsNew_
       System.Diagnostics.PerformanceCounter( "Memory", "Available MBytes")
Privatem_NetworkAsNew_
       System.Diagnostics.PerformanceCounter( "Processor", "% Processor Time",
"_Total")
Privatem_DiskAsNew _
       System.Diagnostics.PerformanceCounter("Processor", "% Processor Time",
"_Total")
```

Once the readings were obtained, the results were stored in the computer utilization table using

the following codes:

```
PrivateSubsaveReadings(ByValconnectionStringAsString)
DimqueryStringAsString
If (checkExist(mComputerName) = 0) Then'checkexist procedure checks if a computer
already exists in the table if it doesnt it returns 0 else 1
queryString = _
"INSERT INTO tblCOMPUTERUTILIZATION
(colCompID,colStatus,colCPU,colRAM,colNetwork,colDisk,colTime,colDate,colComputerN
ame)"
queryString = queryString&"
Values('"&mCompID&"','"&mStatus&"',"&mCPU&","&mRAM&","&mNetwork&","&mDisk _
&",'"&Date.Parse(Now.ToShortTimeString())
&"','"&Date.Parse(Now.ToShortDateString()) &"','"&mComputerName&"')"' Inserts new
system
Else
queryString = _
"UPDATE tblCOMPUTERUTILIZATION SET
colCompID='"&mCompID&"',colStatus='"&mStatus&"',colCPU="&mCPU&",colRAM="&mRAM _
&",colNetwork="&mNetwork&",colDisk="&mDisk&",colTime='"&Date.Parse(Now.ToShortTime
String()) &"',colDate='" _
&Date.Parse(Now.ToShortDateString()) &"' WHERE
colComputerName='"&mComputerName&"'"'updates the stauts of an existing system
EndIf
Callconnect ()
cmd.Connection = cnn
cmd.Connection.Open()
```

```
Try
cmd.CommandText = queryString
cmd.ExecuteNonQuery()
Catch ex As Exception
MsgBox(ex.Message)
EndTry
EndSub
```

The results stored above were retrieved using the following codes. This table was updated once

every 10 seconds using a timer. Hence the table was up to date.

```
PrivateSubgetReadings(ByValconnectionStringAsString)

DimqueryStringAsString = _
"SELECT * FROM vwResourceAllocation"' WHERE colDate='"
&mDate.ToString("dd/MM/yyyy") & "'"
Dim command AsNewOdbcCommand(queryString)

Using connection AsNewOdbcConnection(connectionString)
command.Connection = connection
connection.Open()
'command.ExecuteNonQuery()
Dim reader AsOdbcDataReader = command.ExecuteReader()
Dim row AsListViewItem
            ListView1.Items.Clear()
Whilereader.Read()

                row = NewListViewItem(reader("colComputerName").ToString())
'row.SubItems.Add(reader("colComputerName").ToString())
row.SubItems.Add(reader("colCompID").ToString())
row.SubItems.Add(reader("colStatus").ToString())
row.SubItems.Add(reader("colCPU").ToString())
row.SubItems.Add(reader("colRAM").ToString())
row.SubItems.Add(reader("colNetwork").ToString())
row.SubItems.Add(reader("colDisk").ToString())
                ListView1.Items.Add(row)
EndWhile
'Release resources
reader.Close()
connection.Close()
EndUsing
EndSub
```

Step 4: this step involved the creation of the resource allocation module. The resources of the three computers used in the experiment are retrieved and stored in variables. Analysis

is done to determine the underutilized resources. Thereafter the most appropriate computer is selected based on the utilization of its resources. The criteria used was the lower the resource use, the higher the computer rank so computers whose resources are lower in utilization are called to be considered for task allocation . This was implemented using the following sample code:

```
...
Whilereader.Read()
                i = i + 1
                row = NewListViewItem(reader("colComputerName").ToString())
'row.SubItems.Add(reader("colComputerName").ToString())
row.SubItems.Add(reader("colCompID").ToString())
' row.SubItems.Add(reader("colStatus").ToString())
row.SubItems.Add(reader("colCPU").ToString())
row.SubItems.Add(reader("colRAM").ToString())
row.SubItems.Add(reader("colNetwork").ToString())
row.SubItems.Add(reader("colDisk").ToString())
                ListView1.Items.Add(row)
If i = 1 Then
mCPUn = reader("colComputerName").ToString()
mCPU = reader("colCPU")
mRAMn = reader("colComputerName").ToString()
mRAM = reader("colRAM")
mNetworkn = reader("colComputerName").ToString()
mNetwork = reader("colNetwork")
mDiskn = reader("colComputerName").ToString()
mDisk = reader("colDisk")
Else
       'if mCPUnew>mCPUinit then ignore else swap
If reader("colCPU") <mCPUThen
mCPUn = reader("colComputerName").ToString()
mCPU = reader("colCPU")
EndIf
If reader("colRAM") <mRAMThen
mRAMn = reader("colComputerName").ToString()
mRAM = reader("colRAM")
EndIf
If reader("colNetwork") <mNetworkThen
mNetworkn = reader("colComputerName").ToString()
mNetwork = reader("colNetwork")
EndIf
If reader("colDisk") <mDiskThen
mDiskn = reader("colComputerName").ToString()
mDisk = reader("colDisk")
EndIf
EndIf

EndWhile
lblCPU.Text = mCPUn
```

```
lblRam.Text = mRAMn
lblDisk.Text = mDiskn
'Release resources
reader.Close()
connection.Close()
EndUsing
        ...
```

Step 5: this step involved the creation of Client Service.

The researcher developed a service that was able to allow connected devices relay their status and percentage usage of their resources to the server. This was implemented through the following source code;

```
ImportsMySql.Data.MySqlClient
PublicClassResource_monitor_Service
Privatem_CPUAsNew  _
System.Diagnostics.PerformanceCounter( _
"Processor", "% Processor Time", "_Total")
Privatem_RamAsNew  _
System.Diagnostics.PerformanceCounter( _
"Memory", "Available MBytes")
Privatem_NetworkAsNew  _
System.Diagnostics.PerformanceCounter( _
"Processor", "% Processor Time", "_Total")
Privatem_DiskAsNew  _
System.Diagnostics.PerformanceCounter( _
"Processor", "% Processor Time", "_Total")

PrivatemCompIDAsString = ""
PrivatemStatusAsString = ""
PrivatemCPUAsDouble = 0.0
PrivatemRAMAsDouble = 0.0
PrivatemNetworkAsDouble = 0.0
PrivatemDiskAsDouble = 0.0
PrivatemTimeAsDate
PrivatemDateAsDate
PrivatemComputerNameAsString

PubliccnnAsNewMySqlConnection
PubliccmdAsNewMySqlCommand
PublicconstringAsString = "server='192.168.0.200';user id='resource';
pwd='bQ37mXchdEW9WAYy';  database='resourcedb'"

PublicSub Connect()
Try
If (cnn.State = ConnectionState.ConnectingOrConnectionState.Open) Then
cnn.Close()
cnn.ConnectionString = constring
```

```
Else
cnn = NewMySqlConnection
cnn.ConnectionString = constring
EndIf
Catch ex As Exception
MsgBox(ex.Message)
EndTry
EndSub

PrivateSubrefreshTimer_Tick(sender AsObject, e AsEventArgs)
Handlesrefreshtimer.Tick
DimcpuValAsSingle = m_CPU.NextValue
DimramValAsSingle = m_Ram.NextValue
DimnetValAsSingle = m_Network.NextValue
DimdiskValAsLong = 0

DimtMAsULong = My.Computer.Info.TotalPhysicalMemory
        DimpRamAsLong = (((tM / (1024 * 1024)) - ramVal) / (tM / (1024 * 1024))) *
100
DimpDiskAsLong = 0
ForEachcurDriveAsSystem.IO.DriveInfoInMy.Computer.FileSystem.Drives
IfcurDrive.DriveType = System.IO.DriveType.FixedAndcurDrive.Name = "C:\"Then
DimtheFreeSpaceAsLong = curDrive.TotalFreeSpace
DimtheTotalSpaceAsLong = curDrive.TotalSize
diskVal = diskVal + theTotalSpace
pDisk = pDisk + theFreeSpace
EndIf
Next
IfdiskVal> 0 Then
diskVal = ((diskVal - pDisk) / diskVal) * 100
EndIf

DimstrHostNameAsString
DimstrIPAddressAsString
strHostName = System.Net.Dns.GetHostName()
strIPAddress = System.Net.Dns.GetHostEntry(strHostName).AddressList(0).ToString()

mCompID = strIPAddress
mStatus = "WORKING"
mComputerName = strHostName
IfDateDiff(DateInterval.Second, mDate, Date.Now) > 4 Then
mCPU = CDbl(cpuVal)
mRAM = CDbl(pRam)
mNetwork = 0.0
mDisk = CDbl(diskVal)
mTime = TimeOfDay
mDate = Date.Now
saveReadings()
EndIf
EndSub

PrivateFunctioncheckExist(ByValComputernameAsString) AsInteger
Dim Result AsInteger

Try
```

```
start:

DimnewpermcmdAsNewMySqlCommand
Dim check AsObject
newpermcmd.Connection = cnn

cnn.Close()
Call connect()
cnn.Open()
newpermcmd.Connection = cnn
newpermcmd.CommandText = "SELECT count(colID) FROM `tblcomputerutilization` WHERE
colcomputername='"&Computername&"'"

            check = newpermcmd.ExecuteScalar()
If check = 0 Then
                Result = 0
Else
                Result = 1
EndIf
Catch ex As Exception
MsgBox(ex.Message)

EndTry
Return Result
EndFunction

PrivateSubsaveReadings()

DimqueryStringAsString
If (checkExist(mComputerName) = 0) Then
queryString = _
"INSERT INTO tblCOMPUTERUTILIZATION
(colCompID,colStatus,colCPU,colRAM,colNetwork,colDisk,colTime,colDate,colComputerN
ame)"
queryString = queryString&"
Values('"&mCompID&"','"&mStatus&"',"&mCPU&","&mRAM&","&mNetwork&","&mDisk _
&",'"&Date.Parse(Now.ToShortTimeString())
&"','"&Date.Parse(Now.ToShortDateString()) &"','"&mComputerName&"')"
Else
queryString = _
"UPDATE tblCOMPUTERUTILIZATION SET
colCompID='"&mCompID&"',colStatus='"&mStatus&"',colCPU="&mCPU&",colRAM="&mRAM&",co
lNetwork="&mNetwork&",colDisk="&mDisk&",colTime='"&Date.Parse(Now.ToShortTimeStrin
g()) &"',colDate='"&Date.Parse(Now.ToShortDateString()) &"' WHERE
colComputerName='"&mComputerName&"'"
EndIf
Call connect()
cmd.Connection = cnn
cmd.Connection.Open()
' MsgBox(queryString)

Try
cmd.CommandText = queryString
cmd.ExecuteNonQuery()
' MsgBox("Readings Saved")
```

```
Catch ex As Exception
'MsgBox(ex.Message)
EndTry
cnn.Close()

EndSub


EndClass
```

5.4 System Implementation

System implementation is the process of delivering the system for use in operating environment. The tested system model was implemented using three machines as a pilot to experiment on the functionality of the grid system model as shown in the figures below:

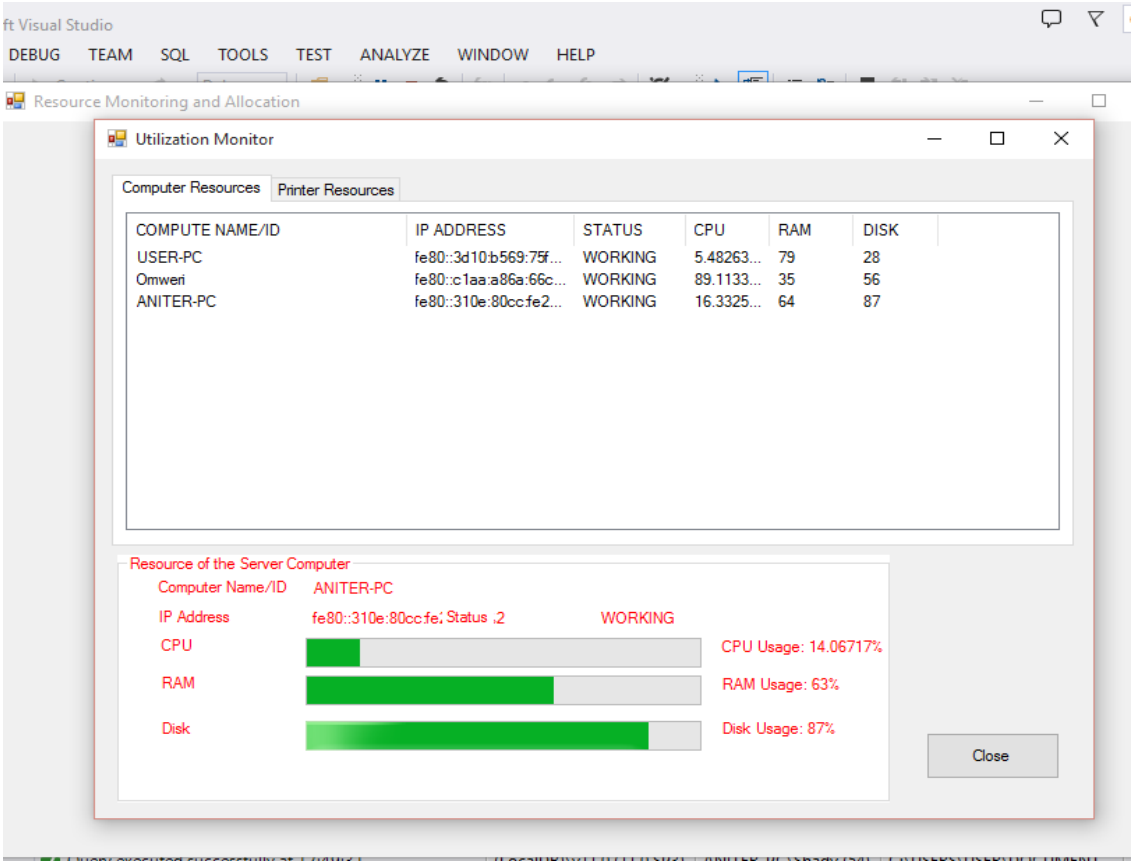

Figure: 5.4.1: Resource Utilization

The figure shown above shows the monitoring of resource utilization. CPU, RAM and hard disk of three machines that were used for piloting. During testing all the three computers were working and within the network, as indicated in their status. The resource utilization was presented in percentage form. For instance,

ANITER-PC's utilization was: CPU 14%, RAM 63% and Disk Usage 87%.

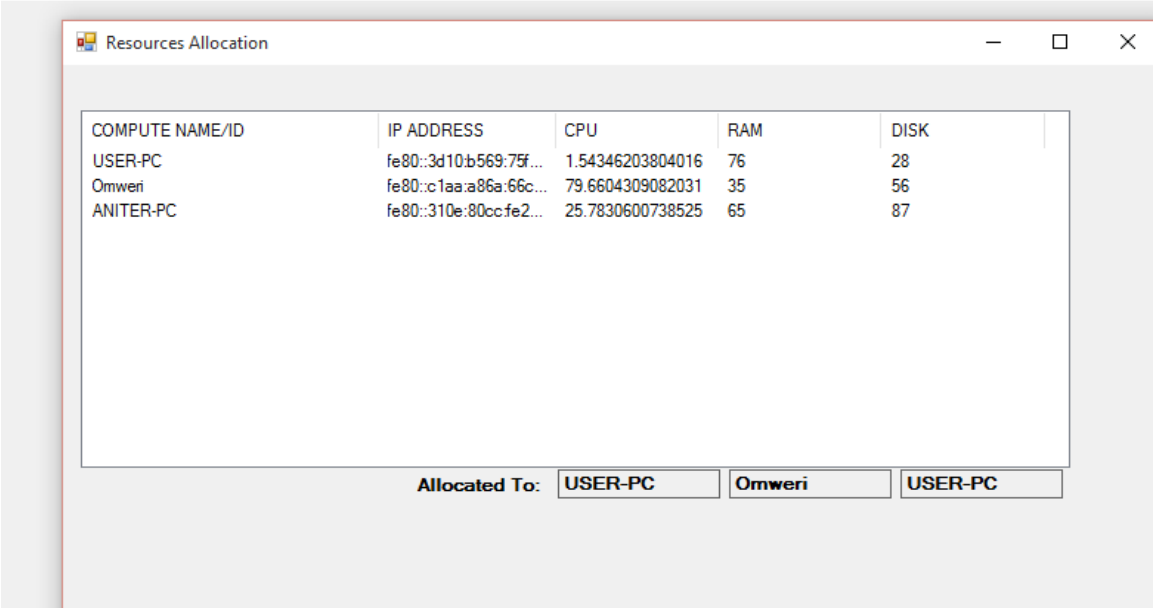

Figure: 5.7.2: Resource Allocation

Figure 5.7.2, shows resource allocation where tasks are to be allocated to the resources which have the lowest workload. For instance at that time, USER-PC had the lowest usage of the CPU (1.5%) and the hard disk (28%), while the 2nd machine called omweri, had the lowest usage of the RAM (35%).

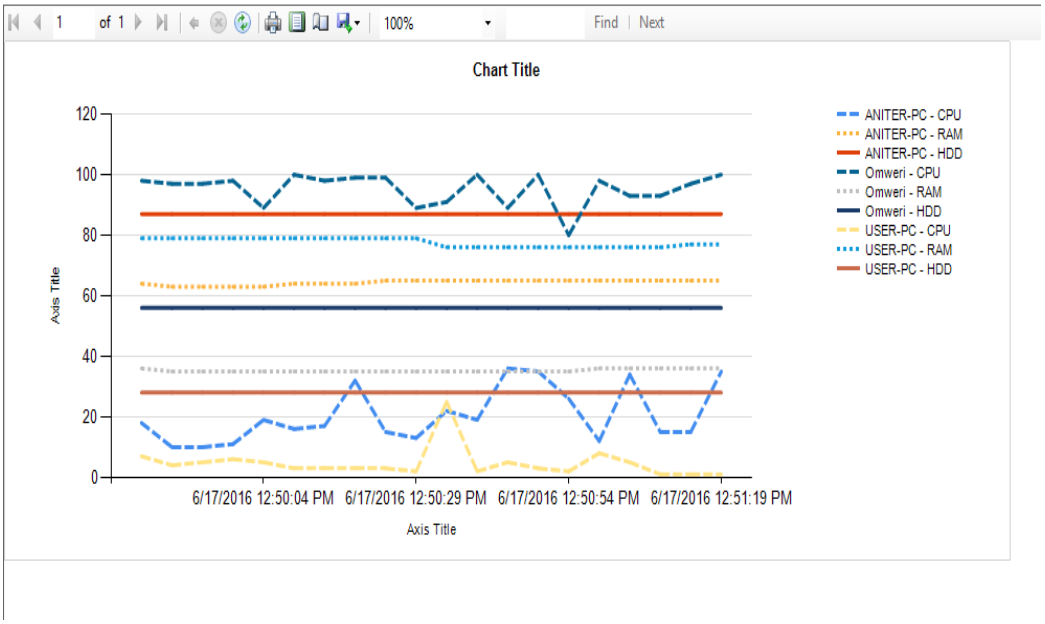

Figure 5.7.3: Resource utilization Report

The figure above shows a report on resource utilization, the x axis shows the time that the reading was done and y axis indicates the utilization of the resources in percentage form. Reports can therefore be used to show some trend of resource utilization.

5.5 Experimentation Program

A program containing four tasks i.e. generating a password list with one character, two characters, three characters and four characters was developed. This program was used to compare the performance of the grid system developed and non-grid node as indicated in chapter four. The codes used are attached at the appendix section.

5.6 Chapter Summary

This chapter has presented the system development approach describing how the system model was developed. It was evident that the success of one phase depends on the success of the previous phase. For instance, system development was done basing on requirement analysis. Therefore if requirement analysis was not properly done, then system development would not have been successful. This means every phase discussed in this chapter was very important in developing the system. The system model developed will help MTRH in optimizing the use of computers that are available.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION

6.0 Introduction

This chapter presents the summary of findings, conclusions and recommendations. The chapter is divided into five sections which include: a summary of the study, summary of findings, conclusions, recommendations and suggestions for further studies.

6.1 Summary of the Study

The aim of this study was to investigate the optimization of the use of available ICT resources in MTRH with a view to developing a system model for implementing Grid Computing. The specific objectives of this study are to: establish the ICT tools and equipment used at MTRH; establish the challenges faced by the hospital in optimizing the use of ICTs; establish the suitability of implementing Grid Computing; design and develop a system model for the implementation of Grid computing in the hospital The research adapted experimental research design where the system model developed was tested severally to ensure the objectives were met. Purposive sampling was used to select the key informants out of the targeted group. The top managers and ICT specialist were sampled because they were believed to have the relevant information for this research.

6.2 Summary of Findings

The basis of this summary presented below is obtained from the findings presented in chapter four and in line with the following objectives of the study:

1. **Based on objective one which was: to establish the ICT tools and equipment used at MTRH**

It is evident that MTRH has taken a step in embracing the use of ICTs in service delivery, some of the ICT infrastructure the institution has are: servers, Computers, internet, LAN, printers, Routers. This research is proposing the optimization of some of this equipment. It was also found that they have a hospital management system which is helping them in service delivery and the respondents gave a range of 55% to 60% as the extent at which MTRH has implemented ICTs.

2. **Based on objective two which was: to establish the challenges faced by the hospital in optimizing the use of ICTs**

It was evident that, there was lack of enough ICTs and inadequacy of funds to acquire more ICTs due to their expensive nature. Another challenge established was the challenge of disposing worn out computers. The solutions suggested by the interviewees to curb the challenges was to source for more funds and embrace technologies that would help cut down the cost and reduce the problem of disposing e-waste.

3. **Based on objective three which was: to establish the suitability of implementing Grid Computing**

It was clear that MTRH was willing to adapt new technologies that will enhance their service delivery. According to interviewees there is money set aside for implementation of ICT but in their view, the funds allocated is not enough. This means that it has the capacity of implementing Grid computing if they find it important, as a way of cutting down the cost of buying more ICT equipment by optimizing the once available, and

reducing the challenge of computer disposal since computers termed as irrelevant will be optimally used by sharing their resources. It was also evident that grid computing was more efficient in processing complex tasks compared to non-grid nodes agreeing with Rajaraman (2016), who stated that grids are mainly meant for high performance numerical computing.

4. **Based on objective 4 which was: to design and develop a system model for the implementation of Grid computing in the hospital**

The methodology used while developing the grid computing system was prototyping. Therefore the system modeling, system development, system design, system testing and system implementation were steps followed in achieving this objective.

6.3 Conclusion

MTRH is the second biggest referral hospital that serves the whole of western region. It is therefore very important for the institution to always look for means to continue improving their services due to the massive number of patients, who expect quality services. Adapting new technologies is one of the efficient ways of improving service quality.

Lekan (2013) states that Use of ICTs has brought about many benefits in modern day businesses, including hospitals. Every institution needs ICT in their undertakings for them to excel and achieve its goals. Therefore, with the stated problems above, MTRH needs to adopt and implement Grid computing which is a lasting approach that will help them optimize the use of ICT's that are currently in place. This means all the computers

will be optimally used which reduces the need of acquiring more computers which will lead to reduction of these electronic gadgets hence, reducing the problem of e-waste which is a worldwide environmental concern.

6.4 Recommendation

The study recommends the following based on the findings and conclusions of the study:

- The management of MTRH should allocate more funds to ICT department is encouraged due to the massive benefits the institution can get on implementing new technologies.
- MTRH through the help of ICT department should implement Grid computing since it will enable them optimize the available ICTs by enabling sharing of recourses and therefore will not only lead to cutting down cost of acquiring more machines and equipment but reduce the problem of electronic disposal. Resources will be available in a way that they can be called into action any legible user/ machine at any time agreeing with Muramba and Mucheni (2017).
- If need be, hospitals should consider buying brand new computers instead of the second hand ones which have a short life span to help solve the menace that comes with e-waste. This concurs with Otieno & Omwenga (2015), on their study on e-waste management in Kenya: Challenges and opportunities.
- The hospital management should develop policy guidelines on sharing information. This is because as much as sharing of information is important; there must be guidelines on who should access what for confidentiality, accountability and integrity purposes.

- MTRH ICT department should facilitate the establishment of ICT training programs to enable the staff to acquire current and relevant skills on new computing technology and be more confident on using ICTs in service delivery**.**

6.5 Areas for Further Research

This research concentrated on the sharing of three resources of a computer i.e. the RAM, CPU and the hard disk. Computers use windows operating system. Other machines which run on different platforms were not considered. Therefore, it is important for this research to be advanced to ensure the development of a fully functional grid application that will incorporate all the machines of a given institution irrespective of the operating system running them. There is also a need for research on strategies for reducing the effects of e-waste disposal. Future studies may also consider the environmental impact of grid computing since it reduces the number of ICT equipment targeted for disposal.

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APPENDIX I: INTERVIEW GUIDE FOR KEY INFORMANTS

A: Personal identification and job description.

1. Name of interviewee …….(optional)
2. Date of interview……..
3. What is your current position……
4. What are your roles?
5. For how long have you been working?

B: ICT related issues

1. Which services are ICT enabled in your department?

   ---

2. Are there any future plans for embracing new ICT technologies as far as your department is concerned?

   Yes ☐ No ☐ Not sure ☐

3. If the answer in question 3 is yes, briefly describe the plans your department has.

   ---

4. In your knowledge is there any amount of money set aside for ICT inmplimentation?

   Yes ☐ No ☐ Don't know ☐

5. If the answer in question 4 is yes, then how much?

---

6. In your opinion is the money allocated enough to meet the future plans?

Yes ☐ No ☐

7. In your informed view, does your organization make profit from the services it provides?

---

8. If answer in question 7 is yes, then what do you think should be done to ensure quality health care despite inadequacy of finance

---

C: Conclusion

9. What are the challenges currently faced by your department?

---

10. In your own view how can the stated challenges be solved?

---

11. Is there any general comment you would like to share with me?

APPENDIX II: INTERVIEW GUIDE FOR ICT SPECIALIST

A: Personal identification and job description.

1. Name of interviewee …….(optional)
2. Date of interview……..
3. What is your current position……
4. What are your duties and roles?

---

5. For how long have you been working?

B: ICT related issues.

1. What ICT infrastructure do you have?

---

2. To what extent has MTRH implemented ICTs?

---

3. What are the technologies used in MTRH?

---

4. How were the technologies installed?

---

5. Is there a Hospital Management Information System?----------

---

---

6. If quiz 5 is yes, then name the modules in the system and there functions?

---

7. Which programming language was used to develop the HMIS?

---

8. Is the usage of ICTs optimized in MTRH?

---

9. If yes how?

---

10. If no, is there a need to consider optimizing the use of ICTs in MTRH?

---

11. What is your opinion concerning implementation of grid computing in MTRH?

C: Conclusion

1. Are there any challenges faced in MTRH concerning ICTs?

   ---

2. In your own view how can the above challenges be solved?

   ---

3. Is there any general comment you would like to share with me?

APPENDIX III: CODE FOR THE EXPERIMENT JOB

```
Private Sub btnExecuteJob(sender As Object, e As EventArgs) Handles Button1.Click
    Dim numberofchars As Integer, i As Integer, j As Integer, k As Integer
    Dim Execution_Start As New Stopwatch
    Dim characters() As String = {"a", "b", "c", "d", "e", "f", "g", "h", "i", "j", "k", & _
                "l", "m", "n", "o", "p", "q", "r", "s", "t", "u", "v", "w", "x", "y", "z", & _
      "A", "B", "C", "D", "E", "F", "G", "H", "I", "J", "K", "L", "M", "N", "O", "P", "Q", "R", & _
      "S", "T", "U", "V", "W", "X", "Y", "Z", "1", "2", "3", "4", "5", "6", "7", "8", "9", "0", "!",& _
       "@", "#", "$", "%", "^", "&", "*", "(", ")", "_", "+", "=", "-", "|", "\", "]", "}", "[", "{", & _
                "'", ":", ";", "?", "/", ",", "}", "]"}

    numberofchars = Val(InputBox("Enter Number of Chars per Pass"))

    Execution_Start.Start()
    Select Case numberofchars
      Case 1
        For i = 0 To UBound(characters) - 1
            PasswordList.Rows.Add(characters(i))
        Next i
      Case 2
        For i = 0 To UBound(characters) - 1
          For j = 0 To UBound(characters) - 1
              PasswordList.Rows.Add(characters(i) & characters(j))
```

```
            Next j

        Next i


    Case 3

        For i = 0 To UBound(characters) - 1

            For j = 0 To UBound(characters) - 1

                For k = 0 To UBound(characters) - 1

                    PasswordList.Rows.Add(characters(i) & characters(j) & characters(k))

                Next k

            Next j

        Next i

End Select

Execution_Start.Stop()

Llbtmr.Text = "Time Elapsed=" & Execution_Start.ElapsedMilliseconds.ToString() & "
milliseconds"


End Sub
```

APPENDIX IV: RESEARCH AUTHORIZATION

REPUBLIC OF KENYA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telephone: 254-020-2213471,2241349
254-020-310571,2213123, 2219420
Fax: 254-020-318245,318249
when replying please quote
secretary@ncst.go.ke

P.O. Box 30623-00100
NAIROBI-KENYA
Website: www.ncst.go.ke

Our Ref: **NCST/RCD/13/012/59**

Date: **5th September 2012**

Anither Jepchirchir Rotich
Moi University
P.O.Box 3900-30100
Eldoret.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "***Development and adoption of grid computing at Moi Teaching and Referral Hospitai,***" I am pleased to inform you that you have been authorized to undertake research in **Eldoret East District** for a period ending **31st December, *2012.***

You are advised to report to **the Chief Executive Officer, Moi Teaching and Referral Hospital, Eldoret** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. M. K. RUGUTT, PhD, HSC.
DEPUTY COUNCIL SECRETARY

Copy to:

The Chief Executive Officer
Moi Teaching and Referral Hospital
Eldoret.

APPENDIX V: TIME TABLE

	Oct	Sep	Nov	Dec	Jan	Feb	March	April	June
1.									
2.									
3.									
4.									
5.									
6.									
7.									

KEY:

1. Piloting and pre-test of instruments
2. Seek research permit
3. Data collection
4. Data Analysis
5. Report Writing
6. Presentation of final thesis and defense