KCA UNIVERSITY

AN ACADEMIC CLOUD MODEL FOR ENHANCING OPERATIONS EFFICIENCY IN THE PUBLIC UNIVERSITIES

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DECLARATION

I hereby declare that this Research Project has not been published or submitted elsewhere for the award of a degree or any other qualification. I also do declare that this is my own original work and contains no material written or published by other persons except where due reference is made and the author is duly acknowledged.

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AND have certified that all revisions that the Research Project Panel and Examiners recommended have been adequately addressed.

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PROFESSOR DDEMBE WILLIAMS.

ABSTRACT

The cloud computing paradigm has become an acceptable and adoptable technology in today's world. Its' an advanced technology that provisions ubiquitous computing resources such as hardware and software applications in a datacenter on a utility and pay-on-the-fly basis. The growth of cloud computing has been envisioned in many economic sectors to foster productivity and efficiency in the changing global economy. In order for organizations to retain customers and offer quality services, they have to keep abreast with changing innovations which are costly and expensive to maintain. Thus, cloud computing offers a platform for these organizations to have access to these technologies at an affordable rate as they only pay for what they have consumed. The Education sector has not been left behind in the adoption of cloud computing. Funding pressures, advances in IT field, the need to accommodate and improve the academic performance of the ever increasing population are some of the major reasons that have compelled institutions of higher learning to adopt to cloud computing services.

The major objective of this research is to develop an education cloud model standard that will also make use of the existing computing infrastructure. The study also presents a review of related literature on cloud computing implementation by various research scholars who have also delved into the technology. The researcher has also explored how public cloud can be integrated with private cloud created within the institution to offer the services to the different users. The researcher has examined and analyzed the existing methodologies and highlighted how the proposed methodology will integrate all the services. If implemented, institutions will be highly reliable due to ubiquitous information that can be accessed from any location, improved data security and integrity, scalability of information and a greater return on economic value, since the institution will only pay for what it consumes.

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Finally, I shall forever remain indebted to my loving parents for their constant moral, emotional and financial support during my entire study period. I will forever remain indebted to you.

DEDICATION

This research work is dedicated to my dear father, who's constant motivation and inspiration to quality education has brought me this far.

LIST OF ABBREVIATIONS

AWS - Amazon Web Services

CC - Cluster Controller

CLC - Cloud Controller

CMP - Cloud Modelling Platform

DC - Data Center

DVD - Digital Versatile Disc

GAE - Google Apps Education

GFS - Google File Systems

HLI - Higher Learning Institutions

NC - Node Controller

NIST - National Institute of Standards and Technology

OS - Operating System

SC - Storage Controller

SLA - Service Level Agreements

VM - Virtual Machine

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

In order to gain a competitive edge in running of organizations, businesses have devised innovative ways of minimizing costs by acquiring resilient, cost-effective enterprise hardware and applications at minimal costs whilst offering quality services to the consumers (Ferriman, 2011).

Cloud computing has been viewed as a new emerging computing paradigm which offers an opportunity to deliver any computing services from any location via an internet connection. Nicholas (2008) notes that experts within the IT industry have gradually embraced cloud computing since the required resources can be purchased only when needed. This in turn reduces hardware and software implementation costs, and its corresponding administration and maintenance costs. The use of cloud computing has attracted the IT experts in institutions of higher learning institutions as they are preparing to adopt and use the cloud services. (Rob et al., 2010).

Great partnerships have been forged between the government, industry and business makers with the learning institutions so as to transform the entire society into a major world economy. Thus, higher education has been envisioned as a major pillar in the development and growth of society. (Lazowska et al., 2008). Universities in Kenya are viewed as the highest level of information dissemination body and more people are moving to them for knowledge acquisition. The introduction of FPE (Free Primary Education) in Kenya led to increased enrollment of children in our learning institutions. This in turn led to a ripple effect of student admissions in institutions of higher learning. In addition, the advent of parallel programmers coupled with double intakes by CUE (Commision for Universities Education) has led to large student populations in the universities utilizing the same resources within the institution.

The 21st century learner cannot be fully restricted to the traditional learning method by attending the physical classrooms which is teacher centered. They have diverse and enormous learning requirements which cannot be satisfied by the conventional teaching and learning modes (Singh, 2012). The modes of teaching have now evolved from the teacher being “the sage on the stage” to being “a guide by the side” thanks to the vast information explosion on the internet which is readily available. Mavodza (2012) posits that the use of cloud resource applications such as Microsoft, Salesforce, Amazon, Google among others is prevalent, thus instructors have to embrace the new teaching methods so as to utilize the diverse applications offered in the cloud.

There are three major universities in Kenya (Jomo Kenyatta University of Agriculture and Technology (JKUAT), Strathmore and Riara University) who have partnered with IBM to create a conducive and robust learning environment that will produce experts in the IT field in occupations such as analyses of business data, social data, security in the cyber space, and any such fields in the job market. The institutions of higher learning need to purchase highly scalable, robust and versatile hardware and software platforms so as to keep track of the large volume of student records as well as maintain phase in the dynamic changing digital environments. Universities have been associated with large scale data servers that are used optimally during school sessions; thus a surplus of storage and processing capacity idles when the institution is closed or during off peak hours. By implementing virtualization, the institution can achieve greater returns and ensure efficient utilization of resources. Hence purchasing cloud resources from a cloud provider or implementing a private cloud using its existing infrastructure seems to be the best approach for a university (Bansal et al., 2012).

Implementation of cloud computing in this environment can offer great flexibility in the backdrop of tight, strained financial constraints within our learning institutions. Availability of a scalable and flexible infrastructure will lead to reduction in hardware and software costs, storage costs, resource management costs such as electricity, technical maintenance personnel, cooling systems, etc.

Below is an illustration by (Sultan, 2010) on how the cloud resources that are specific to a university can be utilized and how they can be administered to the different users (i.e students, researchers, administration, lectures and the software developers). Thus, demand for the IT services is handled by the IT Department whose sole responsibility is to:

- Provision hardware (e.g. servers, PCs', networks) and software (e.g. antivirus, operating and application systems) components to the users in the institution.
- Provision processing and storage capabilities to the students and researchers
- Avail to the research large volumes of research areas and documents
- Provision web development application tools to programmers
- Provide all the stakeholders with help desk support as well as regular maintenance schedule.

The layout above can be moved to a cloud and offer the following capabilities:

- Hardware components and software applications can be accessed by the students and lecturers from any location. Through virtualization, they can acquire the necessary storage and software for running the practical sessions required. Similarly, a lecturer can access a virtual cloud specification for each student in his classroom.

- Postgraduate students and research staff can acquire any additional disk space requirement, processing power or hardware capability at any given time
- Reduced costs and down-time processing capabilities in the event of a single breakdown of a computer within a network infrastructure.

There is a great need for universities to access resources in a public cloud so as to remain relevant and competitive in the academic world. They have to keep abreast with changing technologies whose costs are prohibitive in an academic setting. Also, there is a need to move the university applications to the cloud, due to the different users who access the documents. The academic institutions need to feel secure about the sensitive data that it produces, thus information should be accessed only by the authorized persons. Increased access to database resources during peak hours while students are registering and off-peak while students are taking their exams creates a need for the university to migrate to the cloud instead of purchasing additional storage and processing capacity during the peak periods.

1.2 Definition of Terms

Cloud computing: It's a process of computing where applications and hardware components are stored on central server locations, delivered online and accessed via web browsers to the cloud consumer.

Cloud services: Refers the commodities that are availed to the cloud consumers from the cloud provider's servers.

Cloud Provider: A company that offers any of the cloud computing components (Iaas, Paas or Saas) to other individuals or companies

Cloud Consumer: An individual or company that uses any of the cloud computing components (Iaas, Paas or Saas) offered by a cloud provider.

Data Center: Is a center that houses computer systems, storage systems and telecommunications, wired with proper security, redundant power systems and data communication systems that properly secure the consumers' data.

Virtualization: The act of creating a virtual version of either computer hardware, operating systems, storage component or network resources.

Virtual classroom: An online learning environment; it can either be software based or web-based and accessed through a portal.

Digital Library: Refers to an electronic compilation of organized documents, that is stored on DVDs' or can be accessed via the internet

E-learning: A learning environment that emulates the traditional form of education by offering an equivalent, via virtual access to instructors and resources.

Web-2 technology: This is a advanced revolutionary approach of creating, editing, altering and sharing of user content over the web. Examples include mashups, wikis, blogs, video sharing and web applications.

Service Oriented Architecture (SOA): A type of architecture that helps the user to break business problems into services that can be integrated to provide a solution.

1.3 Problem Statement

Many HLI in developing countries are faced with financial constraints whilst implementing teaching and research activities, hence cloud computing will significantly reduce the ICT investment cost that is required to implement the said activities (Mtebe, 2013). Currently, Universities have become hubs of research and development and they require large scalable storage capacities to store the voluminous data and software application platforms. The advent of E-learning and web 2 technologies have revolutionized the traditional teaching methods to virtual classrooms where the student and teachers from different parts of the world become collaborators and share/access knowledge freely from any location. In order to complement face-to-face delivery of information, universities need to keep abreast with newer versions of hardware and software platforms, web interactions, emerging technologies whose costs are prohibitive. There is also the integration of mobile computing in the learning sector and this promises to have a larger impact on the students as most of them have access to one, hence can access information online. The emergence of digital libraries which require large storage capacities and should be easily accessed by researchers from any locality. Collaboration of universities consortium creates virtual universities where students can study and access instructional material at the comfort of their homes/office without having to access a physical classroom.

Institutions of higher learning may adapt the cloud computing paradigm as they are faced with tight budget constraints and challenges to sustain the existing resources and operations (Sasikala & Prema, 2010).

1.4 Objectives of the Study

The main purpose of this study is to develop a model cloud infrastructure for the Kenyan Universities, whilst making maximum utilization of existing hardware and network infrastructure.

The following specific objectives shall guide this study.

1. To identity the various cloud computing models and implementations in Higher Learning Institutions (HLI).
2. To define the requirements of an appropriate cloud model that can be implemented.
3. To design a cloud model that can be implemented in the universities.
4. Test, validate and gain operational experience with the proposed model.

1.5 Scope of the Study

The case study of this research was Dedan Kimathi University of Technology (DKUT), since it has an inclination to technology and has incorporated the use of e-learning and virtual libraries for knowledge dissemination.

1.6 Justification of the Study

Academic research institutions have necessitated access to scalable computing resources that will allow them to store large volumes of data and finish research projects in time due to diverse and innovative hardware and software applications, lower maintainance costs among other benefits (Sasikala & Prema, 2010).

Workdays (2011) affirms that educational institutions that have embraced cloud computing have the ability to easily access their records, enhanced security and privacy levels, access to diverse and innovative hardware and software applications, lower operational costs among other benefits. Cloud computing will assist the many communities and nations to revitalize and transform the education sector. An entire world of knowledge resources is readily available to the teachers, students and researcher's through cloud-based services that can be accessed anytime, anywhere, from any device. By helping countries worldwide, lowering the cost and simplifying the delivery of educational services, cloud computing enables students across the globe to acquire the 21st-century skills and training they need to compete and succeed in the emerging global information society (Masud & Huang, 2012).

1.7 Significance of the Study

There is need to deploy cloud computing in the Kenyan Universities due to the high dynamic requirements of computing processing power, storage capacities, hardware and software specifications so as to reduce economies of scale whilst offering quality elastic service on-demand to various stakeholders that rely on the university for information or a service.

The study is intended to inform the relevant stakeholders in the universities the importance of cloud computing establishment as well as assist them in choosing a favorable cloud deployment given that the technology is still young in maturity in the Kenyan market.

CHAPTER TWO: LITERATURE REVIEW

2.0 INTRODUCTION

The Literature Review focuses on the state of art in the cloud computing environment in regards to learning and academic institutions. The study shall also review cloud models in established academic centers and learning institutions. Further review shall be done on cloud computing essentials and characteristics, types, service models, infrastructure and service implementation.

2.1 State of the Art In Cloud Computing

The State-of-the-art implementations of cloud computing are described as below:

Architectural Design of a Data Center

Ahmed et al., (2012) outlines a data center as a facility used to house powerful servers, storage and processing systems and telecommunications systems. It includes, redundant data communications connections, backup power supplies, environmental controls (e.g., air condition facilities, fire suppression) and security devices to protect the clients data. A robust data center should offer maximum performance, available, scalable, provide maximum security to applications, provide free VM migration and offer backward compatibility. The data center consists of three major basic layers: The access layer is where the servers in racks physically connect to the network. The aggregation layer provides for functions such as location service, load balancing in the server, and domain service . The core layer offers connectivity to the multiple aggregation switches and provides a resilient routed fabric with no single point of failure.

Distributed application framework over cloud

The application framework enables developers to write programs that are processed across a number of distributed cluster of servers which are used for computation and data intensive tasks. Ghemawat and Dean (2004) underlines MapReduce which is an entire framework introduced by Google to enhance distribution of computations across a number of similar nodes. To ensure efficient synchronization and distribution of a given data that is needed by an application, MapReduce requires the use of a distributed file system known as GFS (Google File System) .In this framework, the map and reduce operations are written by the developers and they implement them according to their needs. The Map reduce system consists of a single Master that transparently distributes computations across all the nodes within the data center, making every effort to keep a task as close as possible to a specific node. The Master treats all the issues relating to individual node communication, fault tolerance and load balancing across the computation infrastructure. This helps improve throughput across the main backbone as the workload is distributed across nodes. If the Master goes down, all the operations taking place on the client nodes are lost. When it comes up again, it looks up for any pending tasks and resumes from where it last left.

Distributed File System over Cloud

Ghemawat and Leung (2003) asserts that a distributed file system over the cloud provides for an efficient and reliable way of accessing data from storage servers. A classic example is the proprietary GFS was developed by Google, to enforce fault tolerance and built auto-recovery into low-latency and data centers that have high throughput applications. The GFS consists of a single master and multiple chunk servers which are accessed by multiple clients. Each file is divided into fixed chunks of 64 megabytes , and the chunk handle specifies if it is a read or write file (Ahmed et al., 2012).

2.1.1 Cloud Service Models

There exists three basic service models that can be provisioned on the cloud. The difference between the models is the type of service offered and the level of customer-vendor control engagement. It is also worthwhile to note that the services do not mutually reinforce each other. Different organizations usually employ different models depending on the type of departmental needs and functions (Massadeh & Mesleh, 2013).

In the Cloud Software as a Service (SaaS), model, the users' applications software is installed on the servers of the cloud provider and the user accesses the application via the internet. Thus, the end users do not have to worry about installing and maintaining specific software applications on their workstations in order to access computing services. Classic examples of Saas models include Twitter and Facebook, Google applications such as Gmail, Youtube, MyErp.com, Workday.com (Babar & Chauhan, 2011). Since the applications are available at limited or no cost at all, HLI can use Gmail for their email needs instead of the current university e-mail system (Khmelvsky & Voytenko, 2010).

In the Cloud Platform as a Service (Paas) model, The cloud provider manages and controls the physical infrastructure apart from the applications which are controlled by the cloud consumer. The vendor will provision resources such as programming languages, API's, web development tools that allow the consumer to develop applications that meet their specific needs. Some classic examples of PaaS include Heroku, Wolf Frameworks. Microsoft's Azure and the Google Apps Engine.

The Cloud Infrastructure as a Service (IaaS) model allows the cloud provider to manage and control the underlying cloud infrastructure. The consumer only has control of the infrastructure by provisioning on demand, computing resources such as storage, processing, networks, or any other applications or operating systems that he may need to use (Mell & Grance, 2011). Mokhtar et al., (2013) reiterates the benefits of this model to the consumer is the cost of purchasing the current technology while reducing software maintenance costs and licenses. It can also provide an experimental lab to the research scholars, who need to test their own research work (algorithms) using different operating systems, processors etc. (Madhumati & Ganapathy, 2013).

2.1.2 Cloud Deployment Models

There exists four kinds of deployment models, of the cloud. (Dustin et al., 2010; Mell & Grance, 2009a,). These deployment models, as defined by NIST are clearly defined by the type of service offered and the type of community that utilizes the services.

a) Public cloud: The cloud provider solely owns the underlying cloud infrastructure, and the cloud resources are sold and availed to the consumer(may be an organization or public) who access these resources via a web interface. The consumers usually select the most appropriate security level and SLA that will suit their needs. The first and most used type of this offering is the Amazon Web Services EC2.

b) Private cloud: The basic cloud infrastructure is owned by an individual organization, but is managed by the organization (on premise), or a third party organization(off premise). The cloud resources are solely specific to a community that have shared interests and values (e.g. government institutions, NGO's, churches, schools), hence the resources cannot be accessed by unknown third party.

c) Community cloud: The cloud infrastructure is shared by several organizations and institutions . It supports a specific community/ organization that have shared concerns, interests and values (e.g., government institutions, NGOs' churches, schools etc). It may be managed by the organizations or a third party, and may exist on premise or off premise.

d) Hybrid cloud: The underlying cloud infrastructure is made up of two or more unique models i.e. (the public or private cloud) that retain their own individual preferences, but are joined together by proprietary technology that allows them to share applications and data across the boundaries of the cloud.(e.g. cloud bursting technology that allows the clouds to share the load resources during peak season)

An academic cloud infrastructure can be owned and managed by the university (exist within the premise) or by a third party organization (outside the premise) and the cloud resources be provisioned to a university that is made of different departments (Baniwal, 2013). An institute can implement a private cloud by utilizing its own existing resources and infrastructure.

It is worth noting that the deployment models, service models and the five essential characteristics of a cloud computing environment do not run independent of each other. The illustration below by (Bishop, 2011) depicts a sample of the interrelationships between the characteristics and cloud models. Organizations may decide to take any form of strategy (e.g. employ different cloud deployment models depending on the various services/departments they have, employ a single service model and then scale up if the implementation is a success or utilize a single deployment model for all their services.

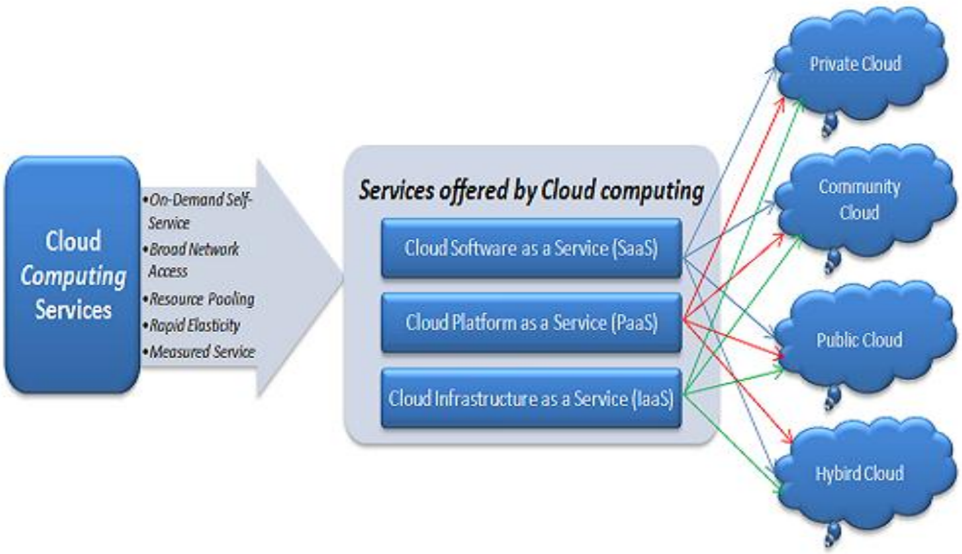

Figure 2.1: Sample of services that can be offered on the cloud. Source: Bishop, J. (2011)

2.1.3 Cloud Computing Application Areas

According to Jangra and Bala (2011) the main implication of cloud computing is to have data centers that are distributed all over the world where one can store data, access services, run your applications and programs without having to bother the about the locality of the programs and services.

Gartner (2010) asserts that the cloud computing paradigm has already attained its peak, and is moving to a more mature and stable state for maximum utilization and productivity in its' use.

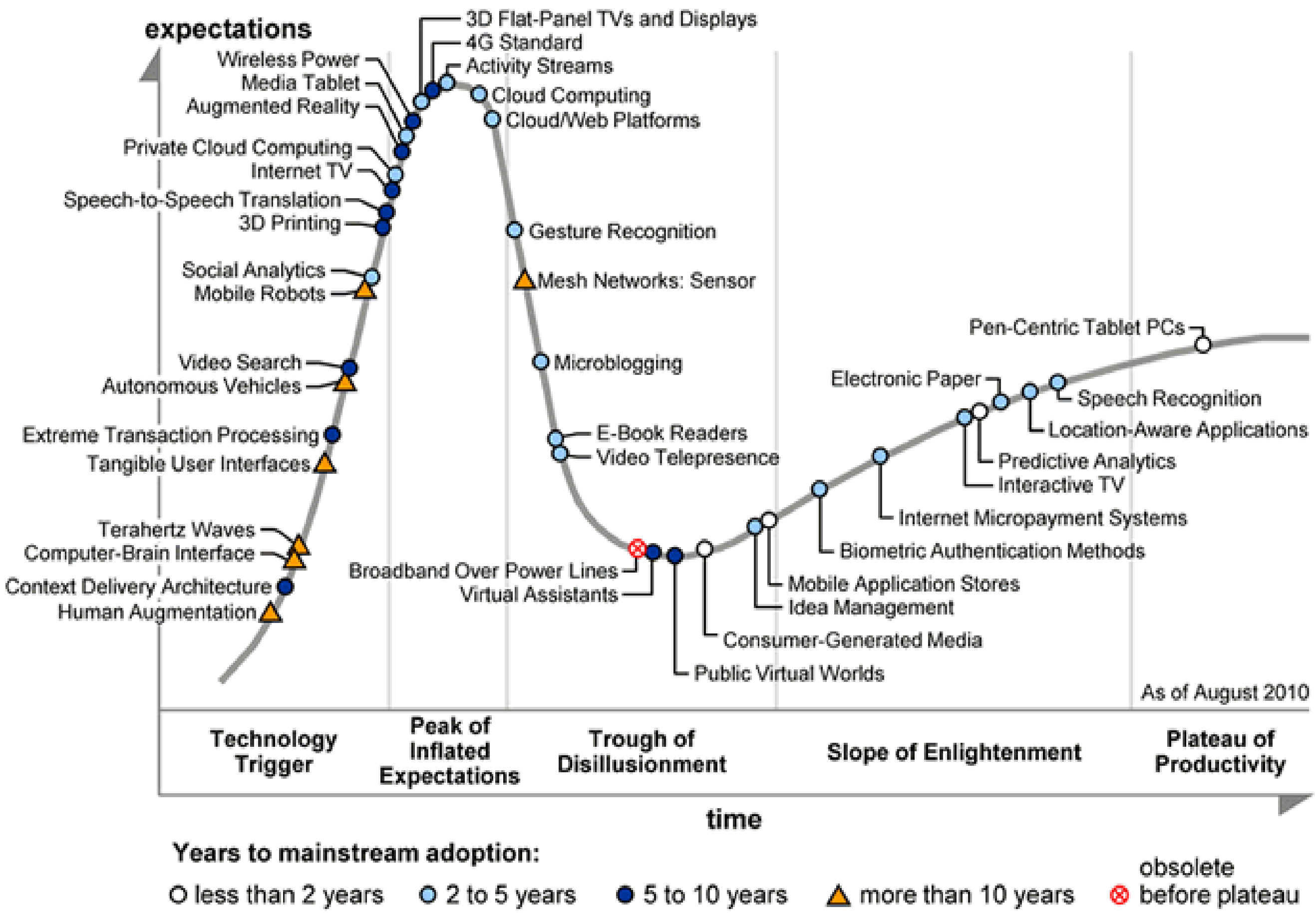

Figure 2.2: Progressive growth of Cloud Computing over time: Source: Gartner (2010)

The pie-chart, Fig. 2.3 below indicates that cloud computing is implemented more in the financial (12%), manufacturing (10%) and the business sector (10%) (Ercan, 2010)

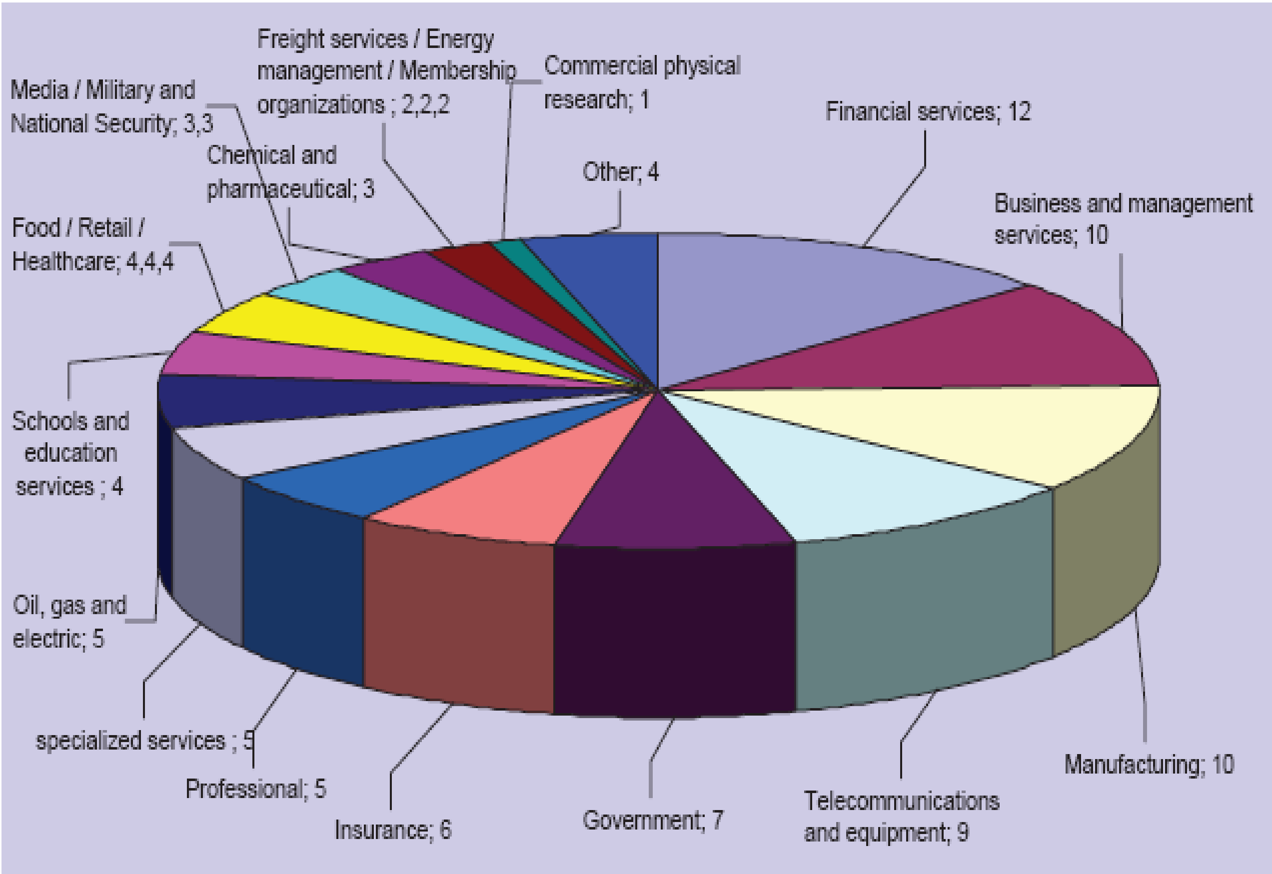

Figure 2.3: The usage (in percentages) in Cloud Computing in different industries (Ercan, 2010)

According to CDW's 2013, State of the Cloud Report survey, the Higher Education Institutions and K-12 institutions that have implemented or are maintaining the cloud computing paradigm stand at 43% and 42% respectively. The graphs below (Fig 2.4 and Fig 2.5), indicate the common services that are implemented via the cloud. The HLI use storage (31%), Conferencing and collaboration (29%) and Compute power at (25%) while K-12 institutions mainly use office and productivity (33%), Conferencing and collaboration (36%) and storage (40%).

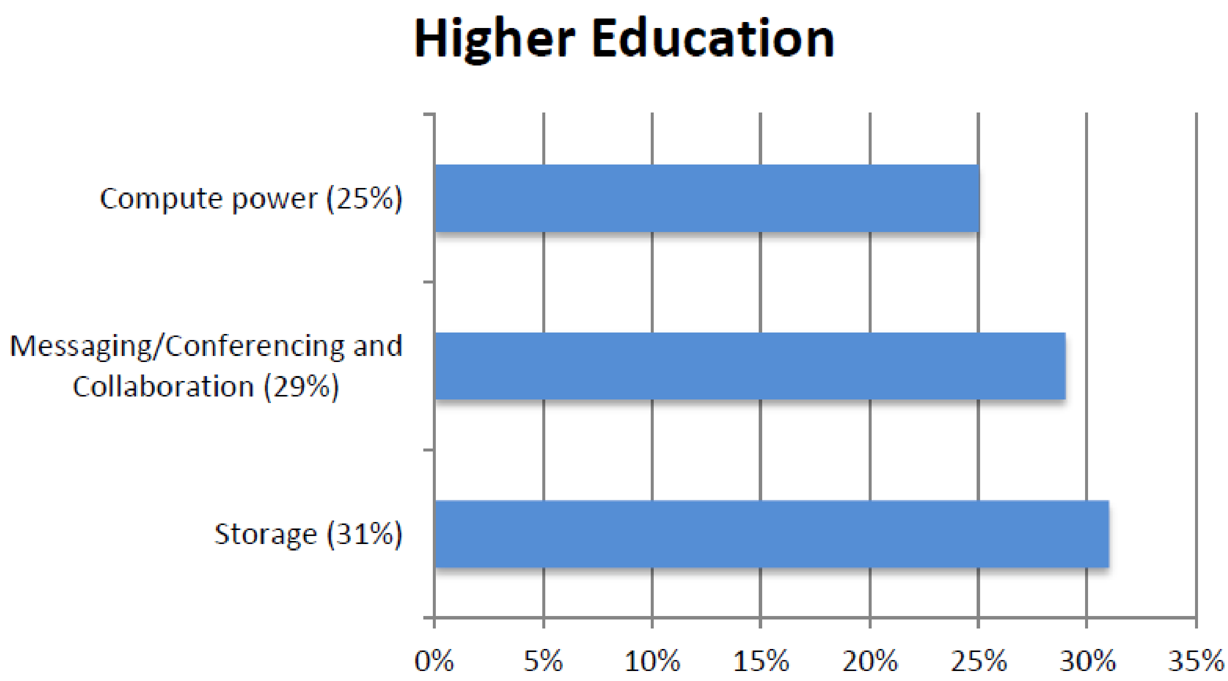

Figure 2.4: Commonly used cloud services in HLI

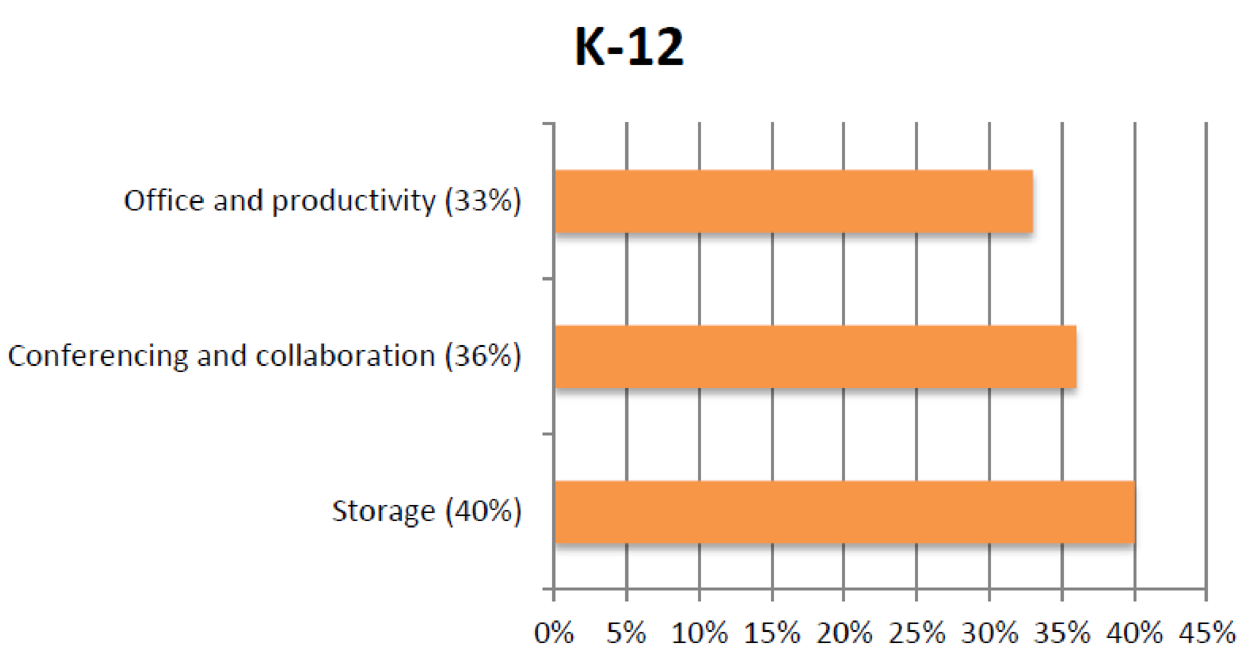

Figure 2.5: Commonly used cloud services in K-12 institutions

2.2 State of Practice In Cloud Computing

CJB and Evans (2010) acknowledges that the Cloud computing paradigm makes it easier for those in the education environment such as students, researchers, faculties and administrators to gain immediate access to a wide range of new educational application resources and research software and tools. Alshwaier et al.,(2012) affirms that the workplace is rapidly changing the desktop applications that are being used by students and researchers into applications that are combined with technical services.

However, educators prepare workforce to partner with Microsoft for example, that can give them affordable access to those tools. The Microsoft educational cloud enables researchers to flow workloads across the infrastructures and complement their existing IT assets with Web-based services (Microsoft Cloud Computing website). It offers great programs such as Microsoft Live@edu at no cost to education accounts. Some basic features include; . desktop and file sharing, website creation, resource scheduling, word processing and presentation. Additionally, all the services offer greater financial flexibility to educational institutions and enable lower costs to develop, scale, operate and migrate the systems that are distributed between the cloud and the datacenter.

Google Apps Education (GAE) offers cloud computing capabilities at no cost to colleges, universities and educationally focused groups. The google apps suite is scalable and offers compatibility across different platforms. The suite contains the following products such as : Google Mail, Google Sites, Google Video for education, Google Calendar, Google Talk and Google Docs Package (Documents, Spreadsheets and Presentations) that allows workflow to proceed seamlessly among different types of documents. The apps are designed to interoperate within the Google suite. Each of these applications is entirely web-based, although there are client applications that supply additional functionality (Herrick, 2009).

Amazon Web Services (AWS) cloud provides highly scalable virtual storage platforms for universities, which enable the students, researchers and faculty to build a wide range of applications. Students can provision on demand compute power, storage and other capabilities thus getting access to a wide range of IT elastic resources for their educational purposes. Some of its' basic services Amazon Elastic Compute Cloud (Amazon EC2) and Amazon Simple Storage Service (Amazon S3). The users have the flexibility to select whichever development service or model of programming makes the most sense for finding the solutions for any problem. (Alshwaier et al., 2012; Amazon Web Services).

The Saleforce.com platform offer educational institutions with the tools required for comprehensive operations thus enabling the students, instructors and researchers to store, analyze and manage each and every aspect within the institution. The platform can assist the instructors manage their services effectively from when a student is admitted to completion whilst tracking personalized details such as individual class performance, participation in study groups or any other activities that might have taken place. These products allows the users within a learning institution to effectively organize their work so as to carry on with their day to day activities. (Alshwaier et al., 2012; Salesforce.com website).

Zmanda is an open source software that is built to provide backup and disaster recovery functionality such as Amanda Open Source Backup and Archiving software with low cost subscription fees to schools. Some of its main products include Zmanda Recovery Manager for MySQL, Amanda Enterprise, and Zmanda Internet Backup. It has also launched Amazon S3 backup solutions for educational institutions. One of its' biggest offering is that it uses standard formats and tools that are beneficial to students since it prevents vendor lock-in. One of the most famous internet photo-sharing sites that have been acquired by Amanda Enterprise is SmugMug.

The IBM Cloud Academy is an online resource collaborative global community forum that is composed of the IBM community IT professionals, educators, researchers, organizations for K-12 schools and HLI. It offers a broad range of IBM products and services that are modeled for the learning institutions. It's main objective is to provide a forum to exchange best practices to assist academic institutions with computing initiatives that create innovative cloud technologies that will accelerate gainful cloud deployment. This will enable the HLIs' share best practices and to develop cloud initiatives that are cost-effective and improve the overall quality of education to the educators (CJB & Evans, 2010).

The HP Cloud System is a platform system of the HP experience that offers a wide range of scalable cloud services from different sources. It is renowned for automating industry and education based tasks and for converging the much needed infrastructure to the consumers. It is in charge of controlling and delivering computing resources such as a DC, external web services from a proprietary cloud or its own HP cloud. This enables the cloud consumers (the teachers, researchers, students) to seamlessly provision and consume cloud resources without having to worry about the location of the resource that could be either a private, public, basic traditional IT systems or HPs own cloud system (Alshwaier et al., 2012).

2.2.1 Benefits of Cloud Computing

One of the major benefits of cloud adoption is cost reduction. The cloud reduces operation, management and maintenance costs as it is based on utility pricing. The organization does not need to purchase additional hardware or software infrastructure when its' need grows (Erol et al; 2012, Leavit, 2009, Farrell, 2010 Goodburn & Hill, 2010 and Geelan et al. 2008). The academic researchers can focus more on their research reports rather than the complexities of installing and managing the IT infrastructure. Massadeh and Mesleh (2013) asserts that a great proportion of the costs of running an IT infrastructure comes from electricity consumption (needed to power the hardware e.g., PCs, servers, switches, backup drives, etc.), air-conditioning systems(needed to reduce the heating generated by the hardware) and labor related costs (needed to maintain infrastructure e.g., technicians, administrators etc). Hence, the cloud will effectively reduce this cost as organizations will move away from perpetual capital expenditure to operational expenditure. Less power and people shall be required to run the cloud IT infrastructure.

Miller (2009) affirms that the cloud services can effectively lower software costs. Most software applications that are used in organizations have exorbitant prices with frequent updates. An organizations can save on this costs by installing a software application on the cloud which can be accesses by all the employees instead of a single user license on each individual machine. Moreover, cloud computing technology is actually able to improve compatibility between operating systems (OS). The user's OS can be connected to the cloud and still share documents with other users who have a different type of OS (Aljabre, 2012).

The cloud includes support and maintenance services. Mtebe (2013) points out that in order to implement the various e-learning courses, institutions have to invest resources to provide reliable support and maintain computer servers, associated accessories, and software. These include regular hardware and software upgrades, virus protection, and performance maintenance which are carried out by internally employed technical staff. However, institutions will be able to reduce the recurrent support and maintenance costs by hosting their services on the cloud. Additionally, the burden of hiring staff, and management of hardware with its accessories will be moved to cloud service provider.

The cloud also offers a great opportunity to many third-world countries that are trying to keep up with the IT revolution. Many computing providers are offering IT services via the cloud platform to countries that have lacked adequate resources for the deployment of IT resources. It dramatically lowers the cost of entry for smaller firms trying to benefit from compute-intensive business analytics that were hither to available only to the largest of corporations. These computational exercises typically involve large amounts of computing power for relatively short amounts of time, and cloud computing makes such dynamic provisioning of resources possible. (Avram, 2013).

Cloud computing can lower IT barriers to innovation, as can be witnessed from the many promising startups, from the ubiquitous social online applications such as Facebook, Twitter and Youtube to the more focused applications like TripIt (for managing one's travel) or Mint (for managing one's personal finances). (Avram, 2013).

Cloud computing makes it easier for enterprises to dynamically scale their services either up down – which are increasingly reliant on accurate information – depending to the client demand with minimum service provider interaction. Since the computing resources are managed through software, they can be deployed very fast as new requirements arise (Dubey, 2007).

Al-Zoube et al., (2010) affirms that the cloud enables the student/researcher to work from any location(home, office, library) to access, modify and edit his applications so long as there is a robust internet connection. It also allows multiple users to access and collaborate on projects or documents in the cloud. This may come as a relief for the forgetful employee that left his/her document in work or for companies that require employees to travel by giving him/her access to these documents from the cloud. The employees only require a computer and an Internet connection. If these requirements are available for the user, documents can be easily accessed from anywhere (Miller, 2008).

Since the cloud represents a single point of entry, supervision and monitoring of data is made easy, as compared to thousands of users who are scattered across diverse geographical regions. Also, security applications can be implemented and effectively monitored from the cloud source (Wheeler & Waggenner, 2009).

Ouf et al., (2011) asserts that the student does not need to back up everything to an external drive and transferring it from one device to another since the cloud offers a repository of all his documents. It also means students can create a repository of information that stays with them and keeps growing as long as he wants them. Also if the student computer crashes, there is no need for crash recovery since all the data is stored on the cloud.

Cloud computing enhances traceability and efficient audit trail within the operations of an organization. The ability to trace the history, location, or application of an item through recorded documentation is vital for ensuring that companies conform with internal and external constraints. Internally, compliance rules may require companies to audit the use of their data from other parts of the world (Iyer & Henderson, 2010).

2.2.2 Issues and Challenges in the Cloud Environment

According to (Yaser Ghanam et al., 2012) security and privacy of data spans issues such as authentication, encryption, intrusion, detection of malware, side communication channel attacks and other kinds of attack- both internal and external to an enterprise or organization. This area refers to the technical and organizational issues related to keeping cloud services at an acceptable level of security and privacy.

Despite the use of SLA between the cloud provider and the potential users, there are no defined and established safety standards that can protect the information contained in the cloud (J. Wang & S.Mu., 2011). There is a lot data accumulation from the users and these can be sold off to third parties by the cloud providers which will then lead to lots of unsolicited advertising from the consumer to other persons. Zhang and Zhang (2012) argue that fault tolerant mechanisms for backing up data are required when there are failures in the infrastructure, such as network outages and the consumer can hardly access the services on the cloud. Tsai et al., (2010) also point out that the integrity, confidentiality, and non-repudiation of the data is at risk due to the cloud being a multi-tenancy environment. Solutions that segregate user data, manage identity, and governance and regulatory compliance have been investigated to address this (Srinivasan, 2012).

Most research on issues and challenges with cloud computing recognize interoperability as a major adoption barrier because of the risk of a vendor lock-in (Cardoso, 2012). There is the lack of common standard interfaces and deployment interfaces and this creates a problem on the integration of services from different cloud providers and the cloud resources. Thus a user becomes dependent on a single cloud provider for all their service needs.

Infrastructure entails the quality attributes of the hardware specifications (reliability, availability, scalability and sustainability); the software and application capabilities (actual provision and scaling) and network infrastructure (reliability, ubiquitous computing, traffic balancing, speed) that need to operate on the cloud environment. As cloud computing is enabling more data-intensive applications at the extreme scale, the demand is increasing for effective data management systems (Zhang et al., 2010). Data storage brings about the issue of data federation (the storage of data across various platforms); data backup and archival; data processing; data retrieval; data placement (data is spread across various data centers); data fragmentation and duplication (data is replicated across various servers for redundancy); data segmentation and recovery and all related issues to data management.

Use of cloud resources has brought legal issues pertaining to data placement in different regions. Laws and regulations of different countries and jurisdiction vary widely as to the how and where the data in the cloud should be used, stored, processed and disseminated. Compliance requirements in relation to the disclosure of sensitive data to the Government or any other regulatory body usually vary from region or country. The cloud also lacks a solid comprehensive liability on the users who access the cloud and the cloud providers.

Economic issues address at the cost-benefit aspect of cloud implementation of the cloud from a financial perspective. Other issues include predicting the potential cost of administering the business aspects that are hosted remotely, upgrading the existing network infrastructure and bandwidth to achieve practical performance while utilizing the cloud. For cloud providers, the cost of the hardware infrastructure and the administrative costs associated with it are key to understanding the economic viability and sustainability of the business (Forell et al., 2011). Thus the cloud provider has to work on effective monetary strategies in order to ensure effective return on the investments made for the cloud services. This in turns makes financial benchmarking difficult in respect to the quality and availability of services due to the different pricing models by the cloud providers.

There is an urgent need for the automation of service provisioning and automation of services. Managing longer-standing service workflows is a challenge given the impact of service failures of complex applications onto which the service is integrated. There is also a challenge in managing the entire service lifecycle for which the user has subscribed to the cloud provider.

Lack of SLA between the cloud provider and the consumer lower the confidentiality and the adoption/ acceptance of cloud services by many stakeholders. According to (Dillon et al., 2012) the preparation of SLAs requires careful considerations such as quality at different layers (i.e., infra-structure, platform, software), the tradeoff between complicatedness and expressiveness in the agreement, and the evaluation and feedback mechanisms that keep the SLA relevant and up-to-date. The absence of a standard set of service level objectives and quality of service metrics makes negotiation difficult as there are no quantifiable benchmarks.

Trust is being viewed as a major obstacle to the adoption of the cloud. Khorshed et al., (2011) identified trust as a barrier to pro-viding effective remedies against cyber-attacks in the cloud. Lack of transparency between service providers, malicious insiders, and vulnerable shared technologies are some of the trust issues that need to be addressed.

2.3 Technological Advancements in the Cloud

Grimes et al., (2009) asserts that cloud computing applications will become the future of the academic learning and research activities. Educational cloud computing is quickly taking the education community by storm as more platforms, applications and services are being developed for academic cloud computing. Some students and researchers are already using a type of cloud computing based applications and services such as Gmail and Youtube.

Moving web servers, management and analytic tools to the cloud is essential as this will reduce maintenance costs and reliance on subscription models as well as improve rapidness of deployment. Due to the accrued benefits of cloud computing in the industry, the cloud has been successfully adopted in HLI as it offers quality education, creates an enabling environment to share new trends and opportunities, reduce ICT investment costs and create an efficient teaching and learning environment among other benefits. Some of the successful deployments of the cloud in the education sector include:

In the U.S, the Colorado State University, Washington State University, North Carolina State University and the University of California. In the U.K , The University of Alamorgan, Leeds Metropolitan University, The University of Aberdeen and the University of Westminster have implemented the cloud.

African Institutions also have not been left behind. Google has partnered with over 30 institutions across the Africa continent to offer cloud services (Obi, 2012). These partnerships are inclusive of grants, consultancy and training services as well as technical support. Some of the institutions include University of Ibadan (Nigeria), University of Ghana (Ghana), University of Pretoria (South Africa) and the University of Mauritius (Mauritius).

The East African educational market as highlighted by (Wanjiku, 2009) focuses on a number of educational establishments (e.g., the National University of Rwanda, the Kigali Institute of Education, the Kigali Institute for Science and Technology, the University of Nairobi, the United States International University, the Kenyan Methodist University and Makerere University Business School(MUBS)) that were offered internet subsidy by a World Bank grant in order to provide Google cloud services (e.g., Gmail, GoogleCalendar, Google Talk and Google Docs and Spreadsheets) to their students. The servers act as a reservoir of management software for the universities' administration, digital instructional materials, online videos, audios and pictures for the use by the students and researchers within the learning facility.

2.4 Critique of Literature

From the literature above, the academic clouds are proprietary with the exception of Google and Microsoft cloud computing models. Though the models are offered for free to academic institutions, they limit the users only to the applications and services offered by the cloud companies. The clouds do not allow for the storage of the core applications and data that is essential to the users in the university, such as learning resources, research facilities, library resources, students data and any other essential resources.

Also, free virtual hard disk space offered to the end users is also limited to some extent and the user will have to foot the cost of any additional storage required. Hence, a private cloud could make use of the existing hardware infrastructure within the institution, to create an elastic technology to accommodate peak periods when the HLI requires additional infrastructure. An institute can implement a private cloud by utilizing its own existing resources (Mathew, 2012). From the cloud user's perspective, there is the high cost of migration from legacy systems to cloud-based systems especially when huge investments have gone into building the existing legacy systems.

Another important component is the hypervisor which manages all the incoming jobs as well as the VMs where these jobs shall be executed by provisioning the required compute, network and storage capabilities. The existing clouds do not offer redundancy and backup in the event an on-going process goes down due to failure on the cloud front end.

Issues surrounding trust and confidentiality on the consumers' end such as trusting that stored data will not vanish or get corrupted as a result of a vendor going bankrupt or getting acquired. This is especially so if the consumer relies on an external cloud provider to provision cloud services to the consumer.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the current methodologies applied as well as a proposed model that will be implemented in HLI so as to achieve the maximum utilization of the available resources and reach a wider scope of learners within the institution. The research will analyze the appropriate research design, the sampling technique, the data collection methods and instruments that shall be suitable to the afore mentioned study.

3.1 Current Methodological Approaches

Educational cloud computing is being adopted by education community as more platforms, applications and services are being developed for academic cloud computing. Educational institutions are making an effort to find the best methodologies for making web-based learning more efficient and effective in their institutions. Different forms of web-based learning such as distance learning classes, multimedia, CD, interactive entertainment activities, etc., are readily available to the data users as long as there is an existing internet connection.Due to the increased growth in cloud computing, listed below are open source solutions that have a focus on the Iaas service model.

Enomaly Elastic Computing Platform

Enomaly ECP Community Edition under the AGPL license [Enomaly 2009] is the open source cloud solution offered by Enomaly Inc. This version focuses on virtual machine administration in small clouds environments. Compared with the Enomaly commercial solution (called Service Provider Edition), the Enomaly open source edition suffers from many restrictions, such as limited scalability, no capacity control mechanism, no support for accounting and metering, and so on.

Eucalyptus Platform

Eucalyptus is an open source cloud computing framework focused on academic research. It provides resources for experimental instrumentation and study. Eucalyptus users are able to start, control, access and terminate entire virtual machines. It also supports VMs that run atop the Xen supervisor. The Eucalyptus architecture is hierarchical in nature each component is implemented as a stand-alone web service. [Nurmi et al 2009]. This architecture allows the users to add, edit, control and delete the VMs.

Nimbus

Nimbus [Keahey 2009] is an open source solution (licensed under the terms of the Apache License) to turn clusters into an Infrastructure as a Service (IaaS) for Cloud Computing focusing mainly on scientific applications. This solution gives to users the possibility to allocate and configure remote resources by deploying VMs – known as Virtual Workspace Service (VWS). It offers a cloud configuration consisting of a cloud manager service hosting and an image repository.

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3.2 Evaluation of the Methodology Approaches

The models are not limited to the three above, there are other proprietary models in the market. Despite the models above being open-source, they do not have an inclination to the academic infrastructure and applications. Also the models, do not offer any authentication module to authenticate the users in the cloud. Also, there is no permanent storage location for the running VMs once there is a network failure on the cloud front-end.

3.2.1 The Research Design

The researcher shall employ the exploratory research approach. This is due to the fact that the area under study has few studies to reference to. The focus will be to gain insights and familiarity for later investigation or when a problem is in a preliminary stage of investigation in order to solve an emerging problem.

3.3 The Proposed Model

Cloud Computing in universities may be described starting from the development and supply of Cloud Computing services and the resources offered to the university. The Eucalyptus model can be modified since it focuses more on academic and research institutions. The model also allows for interchangeability between different organizations.

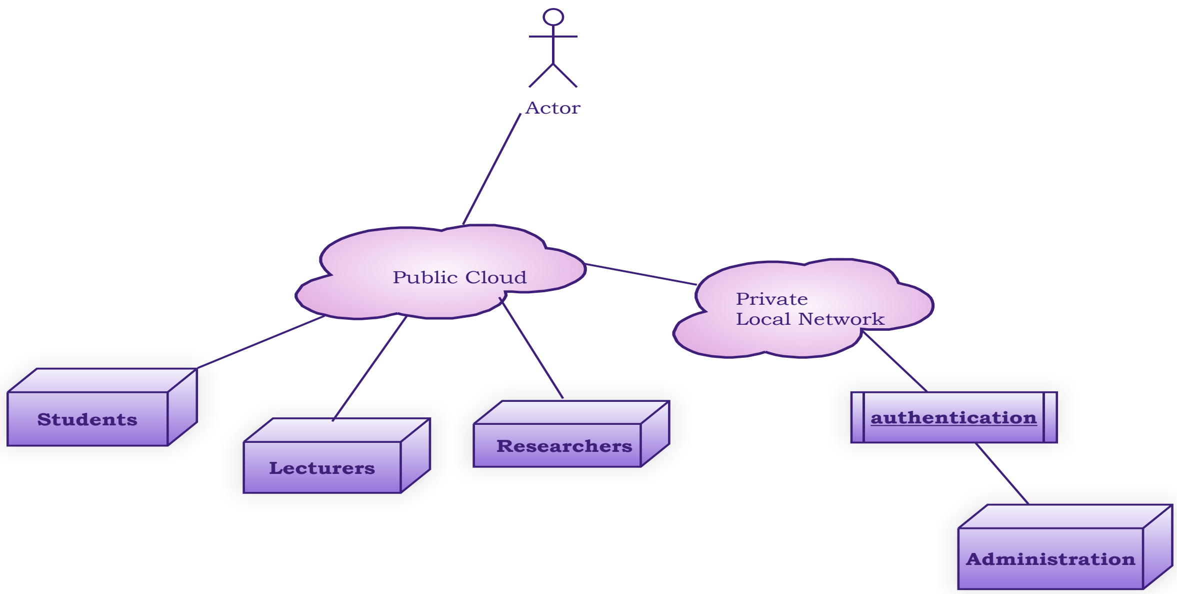


Fig 3: Proposed Conceptual Design

3.4 Characteristics of the Proposed Model

The proposed standard is appropriate for academic institutions since it allows for interchangeability between different organizations. It has the following distinct characteristics that make it unique from the other cloud computing frameworks:

i. Network: Network services provide addressing and packet delivery for the provider's physical infrastructure and the consumer's VMs. Network capability includes physical and virtual network switches, routers, firewalls, and Virtual Local Area Network (VLAN).

ii. Compute: Compute services supply the physical resources such as CPU processing power, Random Access Memory (RAM), NIC, Video, and Storage used by the provider to deliver VMs to consumers. It contains the physical server hardware and parent OS.

iii. Storage: Storage provides physical storage devices to the provider, which exposes these services to consumers as virtual disks. To ensure VM portability from one location to another, the storage module should be connected to the network.

iv. Hypervisor: The hypervisor provides VM services by partitioning and presenting processing, network, and storage services.

v. Clients: Represents the different kind of users who will interact with the cloud setting. I.e. The teacher, student, researcher, administrator. The end-users communicate with the academic cloud using the browser enabled devices such as (laptop, desktop, mobile phone, iphone, ipad) by means of the protocols such as RDP (Remote Desktop Protocol), SSH (Secure Shell),Http/Https (Hypertext Transfer Protocol) and LDAP (Lightweight Directory access Protocol)

vi. Authentication mode: This authenticates the users who need to use the resources/data that only belongs to the university i.e. gives access to the database records to the authentic users only.

CHAPTER FOUR: CONCEPTUAL DESIGN

4.1 Introduction

In the proposed cloud model, the users/consumers within the university setting are categorized into separate groups since they have different needs. All the commercialized software is stored at the public cloud. The private cloud utilizes the existing hardware and network infrastructure within the university. There is an authentication module that is used by the administrators due to the nature of information they interact with.

The conceptual design is built on the eucalyptus cloud computing platform, since it provides learning resources and any other tools needed for performing experiments. From the web interface, the cloud user can manipulate VMs (start, control and terminate the VMs.)

The hierarchical architecture encompasses four level components. Each component is viewed as an independent web service. The components include:

i. Node Controller: The NC executes on each UEC node that has been designated for hosting the VM instances. The NC queries and controls the corresponding hypervisor and system software on a given node (i.e availability of resources, number of VM instances that are running) in response to queries by the CC.

ii. Cluster Controller : The CC manages a given cluster. It's functions include receiving and instantiating requests on the NCs' that it has chosen, co-ordinate the underlying virtual network overlay that is used by the instances and gather information on the NCs and report the same to the CLC.

iii. Walrus Storage Controller: It offers simples storage service for the serviced files. It implements the put storage model i.e create/remove objects in created buckets.

iv. Storage Controller: All instances at the cluster level are stored at the SC. It also allows for attaching, detaching and creation of snapshots storage allocations.

v. Cloud Controller: The CLC manages and connects /exposes the web users to the underlying resources that encompass the Eucalyptus cloud. It usually monitors all the running instances in the NC and the available resources on the cloud, so that it can arbitrary allocate the cloud resources to the available active VMs.

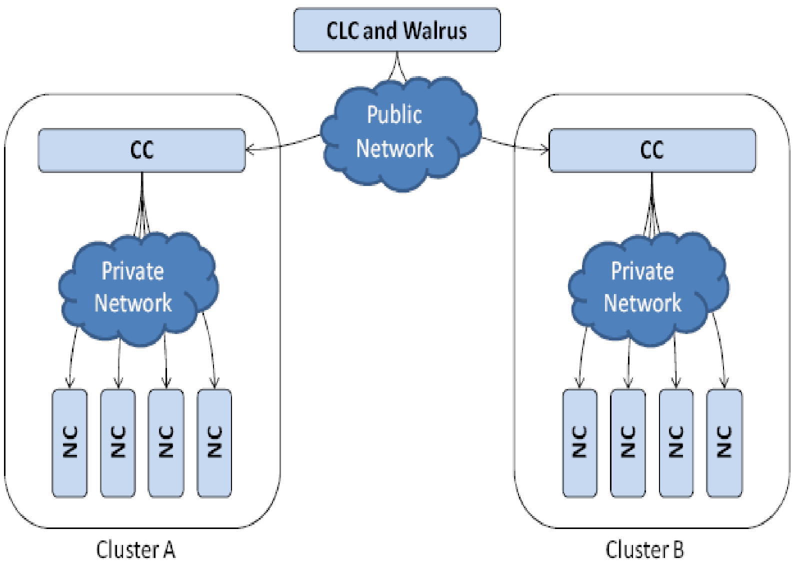


Fig 4.1: The Eucalyptus Architecture (Nurmi et.al 2009)

4.2 Field Studies

Today's networked world demands a working workforce that embraces technology as a tool to increase productivity and creativity. The cloud creates an enabling environment for IT processes to take place and enable the institutions of higher learning to focus on their primary objectives of offering quality education services to the learners. Any implementation of cloud services by any organization is faced with the major challenge of privacy/security and data protection of their data that is saved in the cloud. Also, the issue of vendor lock-in and failures are due to emerge since all the cloud providers are proprietary.

4.2.1 Educational Cloud Applications

Alshwaier et al., (2012) posits that there has been an adoption trend of cloud computing in the industries as well as the learning institutions. Jones and Scalter (2010) asserts that institutions of higher learning do greatly benefit from cloud based platforms such as office productivity application tools (used to create, edit and save a document), collaboration tools(used for creating calendars), message creation tools (used for creating mails) and platform application tools (used for supporting learning management systems, moodle applications etc).

The Google Apps Engine encompasses web-based programs that run on a web browser and allows for intercloud interoperability; i.e each app has been designed to operate with other applications within the suite. Some of the cloud based platforms that are provided at no cost services include platform applications, office applications, mail and messaging tools.

The Microsoft educational cloud provides a set of hosted collaboration services to learning institutions, as well as data storage capabilities. A service such as Microsoft Live@edu is provisioned at no cost to educational institutions or at flexible rates that will allow an institution to migrate to another level. Other services provided include collaboration services, communication tools, web based applications and tools to run on mobile and desktop machines.

Amazon Web Services (AWS) provides educational institutions with an elastic IT infrastructure service to cater for the various needs of the users in the faculty. AWS enables the students /users to requisition for infrastructure services such as storage, power, development tools and models on demand (Alshwaier et al., 2012).

The IBM Cloud Academy offers a portfolio of computing projects and services that are tailored for the education environment. Users on the cloud can effectively collaborate with each other and also with the IBM research and development faculty to develop new strategies for the education community.

4.2.2 The Private Cloud Computing Reference Model

The Private Cloud Reference Model provides a reference to architects who would want to construct and deploy a private cloud architecture.

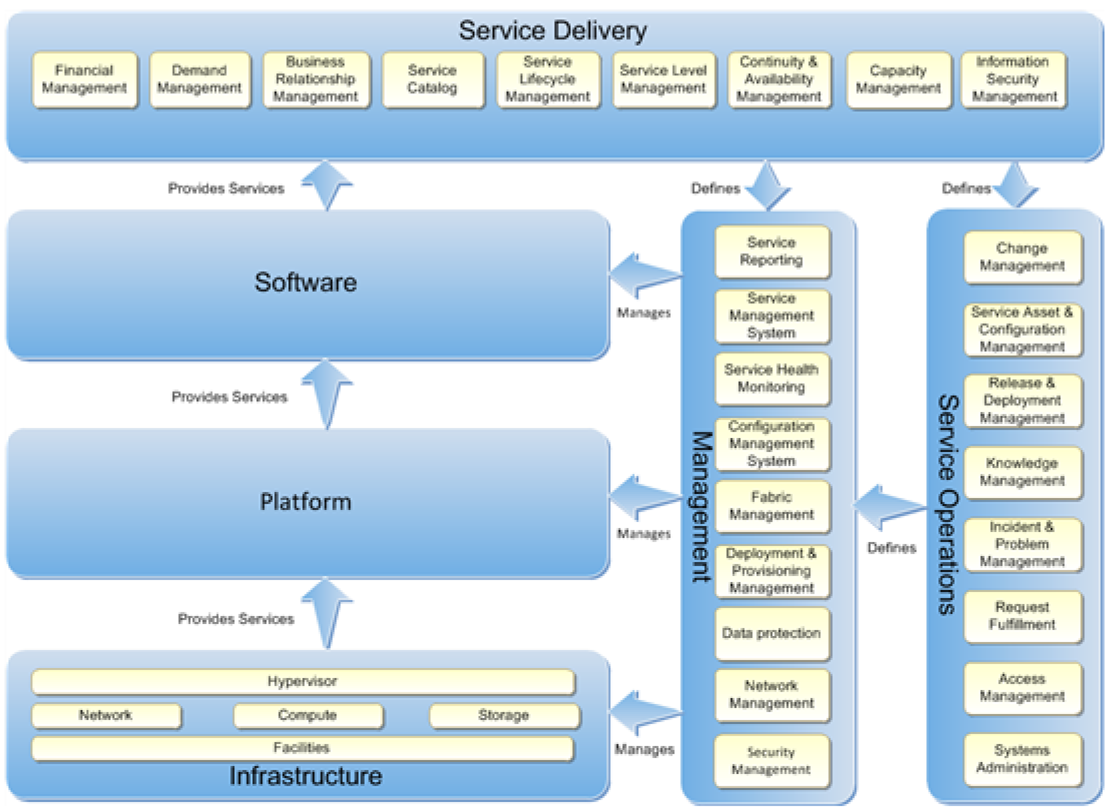


Fig 4.2: The Private Cloud Reference Model

The Reference Model above depicts a number of layers, which include:

- The First layer which represents the technology stack. It comprises the Infrastructure, Platform and Software Layers; and each layer offers a service to the layer above it.
- The Second layer comprises of the Management and Service Operation Layers; it represents the different business perspectives as well as the implementation tools required to manage these processes.
- The Third Layer provides an association between the technology and business processes

4.3 Data Inputs and Expected Outputs

The proposed CMP will be CloudAnalyst Simulator. CloudAnalyst is a graphical simulation tool built on top of the CloudSim toolkit developed by the Cloud Computing and Distributed Systems (CLOUDS) laboratory to model and analyze the behavior of large social network applications. The Internet traffic routing between the user bases located at varied geographic locations and the datacenters, is controlled in CloudAnalyst by a service broker that decides which datacenter should serve the requests from an individual user base based on the different routing policies that will be specified (Wickremasinghe et.al., 2010).

- The simulation toolkit enables the modeller to focus only on the simulation exercise and intricacies; since the simulation interface separates and hides the programming complexities from the user. This allows even for novice users in programming to easily use the simulator.

- Enables the modeller to perform repetitive simulations on the same interface ; allowing the user to make slight variations on the parameters defined in a user friendly approach in order to achieve the various results.

The simulator is expected to perform the following functions and capabilities:

i. Region: The simulator interface is divided into six major regions.

ii. UserBase. This component models a group of users that is considered as a single unit. Its main function is to generate the simulation traffic. It also specifies the number and size of virtual machines that can be allocated to each data center. The maximum allowable bandwidth of the data is specified.

iii. Internet: Represents the real world internet. Its main function is to define the basic internet characteristics such as the available bandwidth, latency, allowable traffic levels and the performance level between the data centers.

iv. DataCenterController. This component co-ordinates the activities of a data center i.e. creates the physical data centers available and the hardware specifications of a given data center and the available VMs.

v. VmLoadBalancer: This component is used by the DataCenterController to assign a request to a given VM. The common load balancing policy is the round robin load balance which uses the round robin algorithm to allocate a given request. The peak load balancing policy spreads a request across all the available VMs, thus maintaining equal workloads.

4.4 UML of Proposed Model

Fig 4.3: Class Activity diagram of the proposed Model

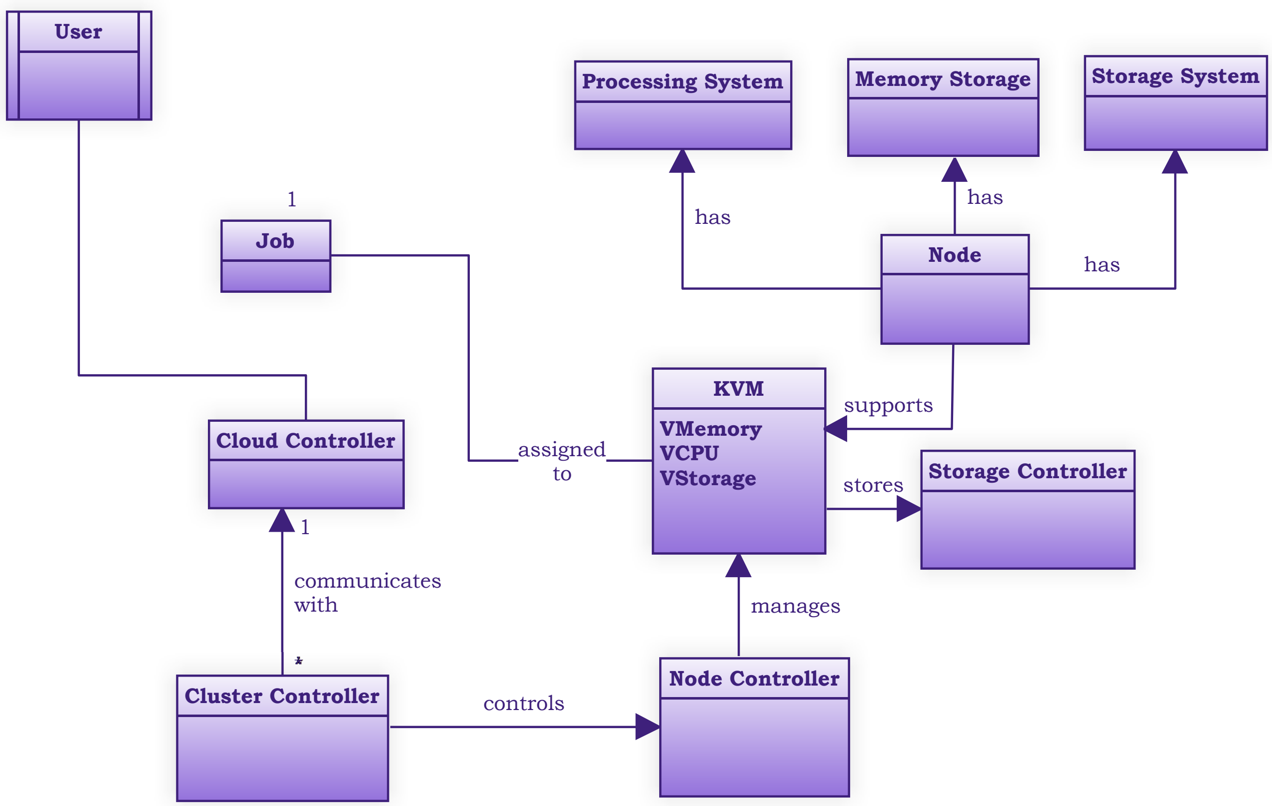
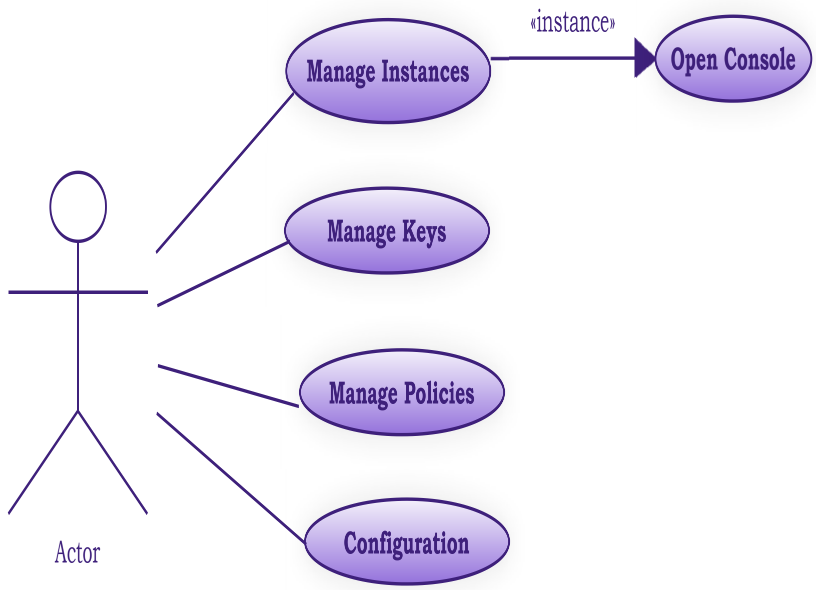


Fig 4.4: Use-Case diagram of the proposed Model



The figure indicates 4 different main use cases for each process of the system. As There is only one actor in this system. He can interact with the system getting information about the available images on the system and the instances running on them. The actor can create and delete keys; specify and manage all the policies of accessing to these instances and specify the configuration of the program. Also there's a special use case, open console is included inside the instance management.

CHAPTER FIVE: IMPLEMENTATION

5.1 Implementation

5.1.1 Distribution of different Data Centers and Virtual Machines

A data center is a facility used to house computers, telecommunications, and storage systems. Most data centers have redundant power systems and data communications connections, proper ventilation, and proper security to protect the equipment and the clients' data. By renting these data center resources, clients can reduce their hardware expenditure as well as the need for technical staff to handle any IT crisis, and increase the amount of time and energy expended on their core business and operations.

Virtualization makes the servers, workstations, storage and other components purely independent of the underlying physical layer. Some benefits of server virtualization include managing multiple systems since multiple applications or OS for those applications can be managed securely from a centralized environment, where redundant systems can be deployed for secure backup and additional reliability in the event of a network outage. Centralized server environments can run multi-user systems software such as Citrix XenApp, Microsoft Remote Desktop Services, or VMware View to deliver popular applications such as MS Office and PC-based learning software from a spectrum of providers to virtual desktops. Updates, new applications and specialized services can be centrally provisioned rapidly by network administrators via a central location. Applications run simultaneously, and can be accessed on demand via a web interface from any secure cloud client regardless of the application OS. Access to applications is centrally controlled and can be based on the different users in the learning environment i.e. lecturers, researcher, student, or administrator.

5.2 Testing

5.2.1 CloudAnalyst Simulation Analysis

The CloudAnalyst simulation tool provides for a repeatable and controlled environment to setup the data center configuration, Cloud configuration and Internet characteristics for the cloud tasks that you intend to simulate. It provides an interface that enables the researcher to generate information about response time of requests, processing time of requests, and other metrics. By using CloudAnalyst, the researcher can determine the best strategy for allocation of resources among available data centers, strategies for selecting data centers to serve specific requests, and costs related to such operations.

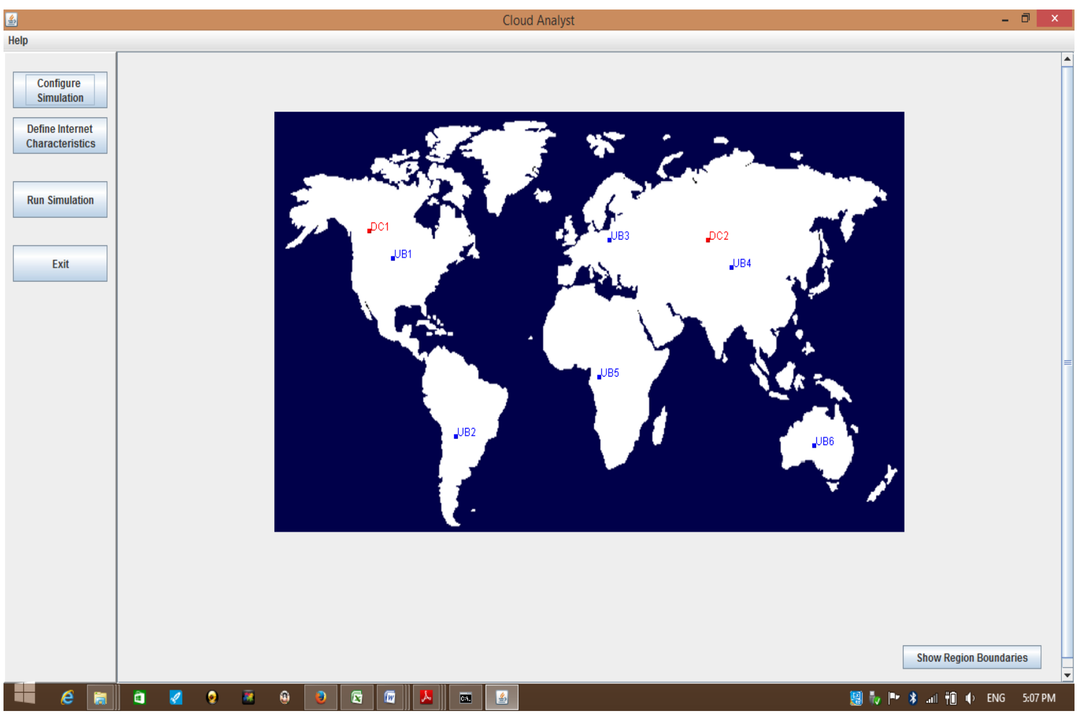


Fig 5.1: The Cloud Analyst Simulator Interface

In the context of the researchers aim, the researcher was able to perform the following tasks during the simulation process:

i. Define Internet characteristics in relation to the available bandwidth (Mbps) and transmission delay(ms) between the different regions
ii. Configure a DC with its corresponding physical hardware specifications.
iii. Specify the number of users from a single base/location. Also specify the number of simultaneous requests a single application server instance support. An appropriate load balancing policy that runs across the VMs is selected i.e. round robin or peak load sharing policy.
iv. Select the number of VMs that can be allocated within a single DC. Specify the size, memory and corresponding bandwidth of the VMs that have been instantiated.

Configuration Details

Size of virtual machines used to host applications in the experiment is 100MB. Virtual machines have 512MB of RAM memory and have 10MB of available bandwidth. Simulated hosts are built on the x86 architecture, virtual machine monitor Xen and Linux operating system.

Each simulated data center hosts a specific number of virtual machines as indicated in Table1 below. Machines have 2 GB of RAM and 100GB of storage. Each machine has 4 CPUs, and each CPU has a capacity power of 10000 MIPS. A time-shared policy is used to schedule resources to VMs. Users are grouped by a factor of 1000, and requests are grouped by a factor of 100. Each user request requires 250 instructions to be executed.

Cloud Configuration Type	**No. Of Virtual Machines**	**Type of simulation algorithm to implement**
1 Data Center	50VMs	Round Robin
2 Data Centers	25VMs for each	Round Robin
2 Data Centers	50VMs each	Round Robin
2 Data Centers	50VMs for each	Peak load sharing balancing policy
3 Data Centers	25, 50 75VM for each	Peak load sharing balancing policy

Table 5.1: Cloud Configuration Type Summary

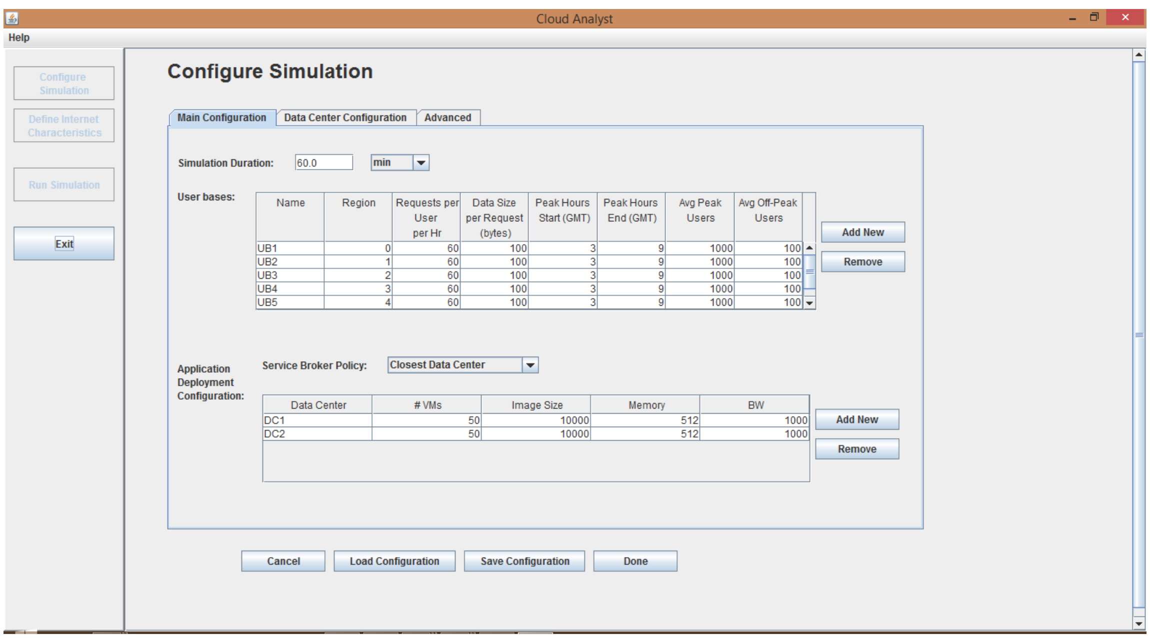


Fig 5.2: The VM Configuration Interface

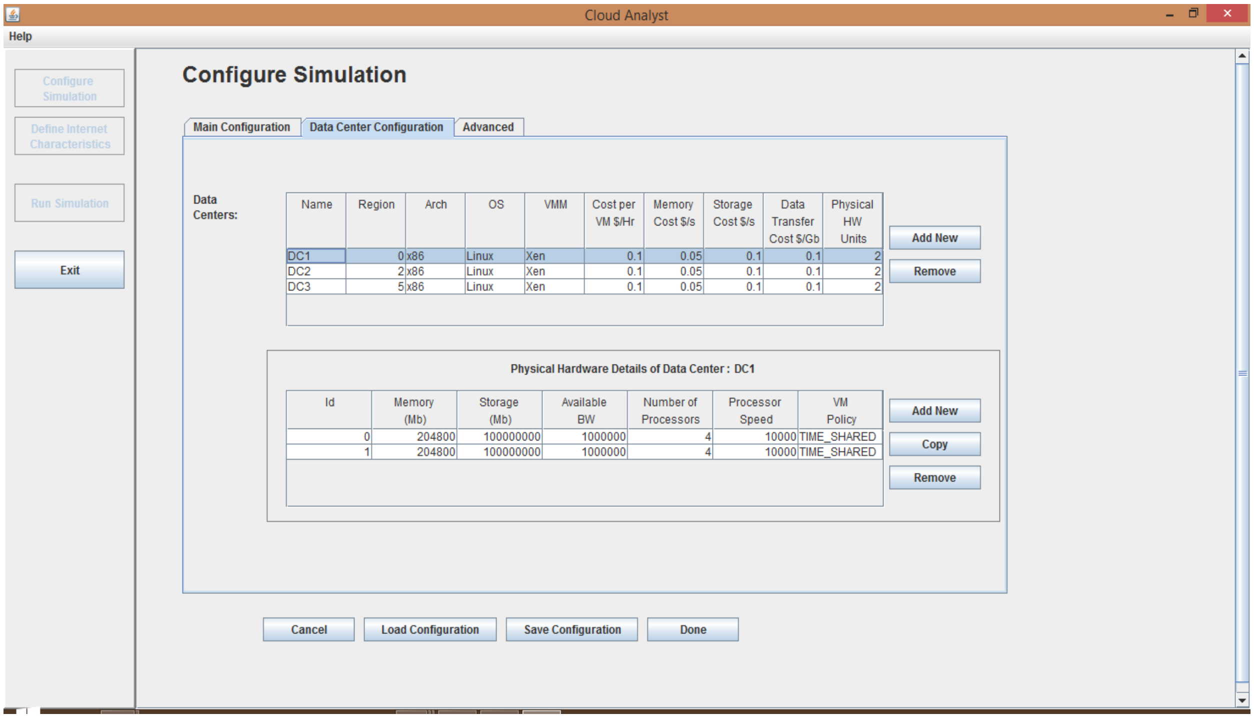


Fig 5.3: The DC Configuration Interface

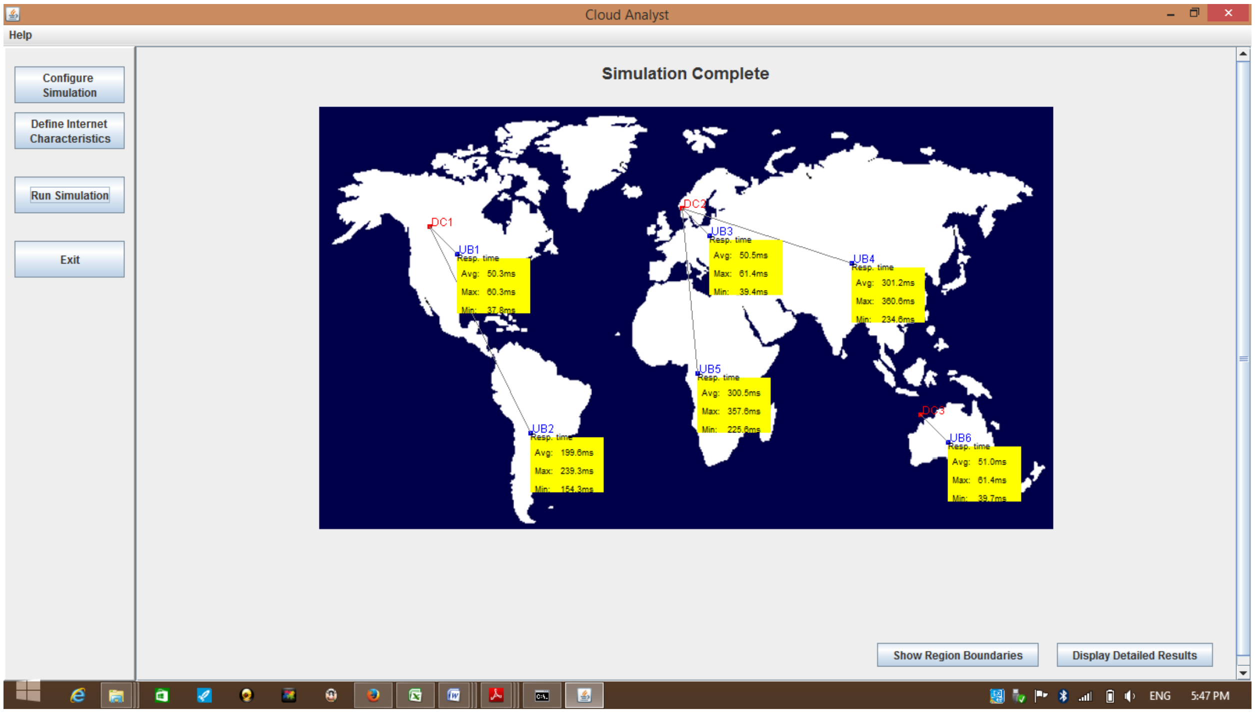


Fig 5.4: Complete simulation (Cloud Configuration Type 5)

Cloud Configuration Type	Overall average response time (milliseconds)	Overall average time spent for processing a request by a data center (milliseconds)
1 Data Center with 50VMs	292.04	28
2 Data Centers with 25VMs each	266.89	103
2 Data Centers with 50VMs each	218.37	39.66
2 Data Centers with 50VMs each but with load sharing policy	220.32	39.5
3 Data Centers with 25, 50 75VM each but with load sharing policy	159.93	15

Table 5.2 : The Cloud Configuration vs. Response time and Time spent to process a request.

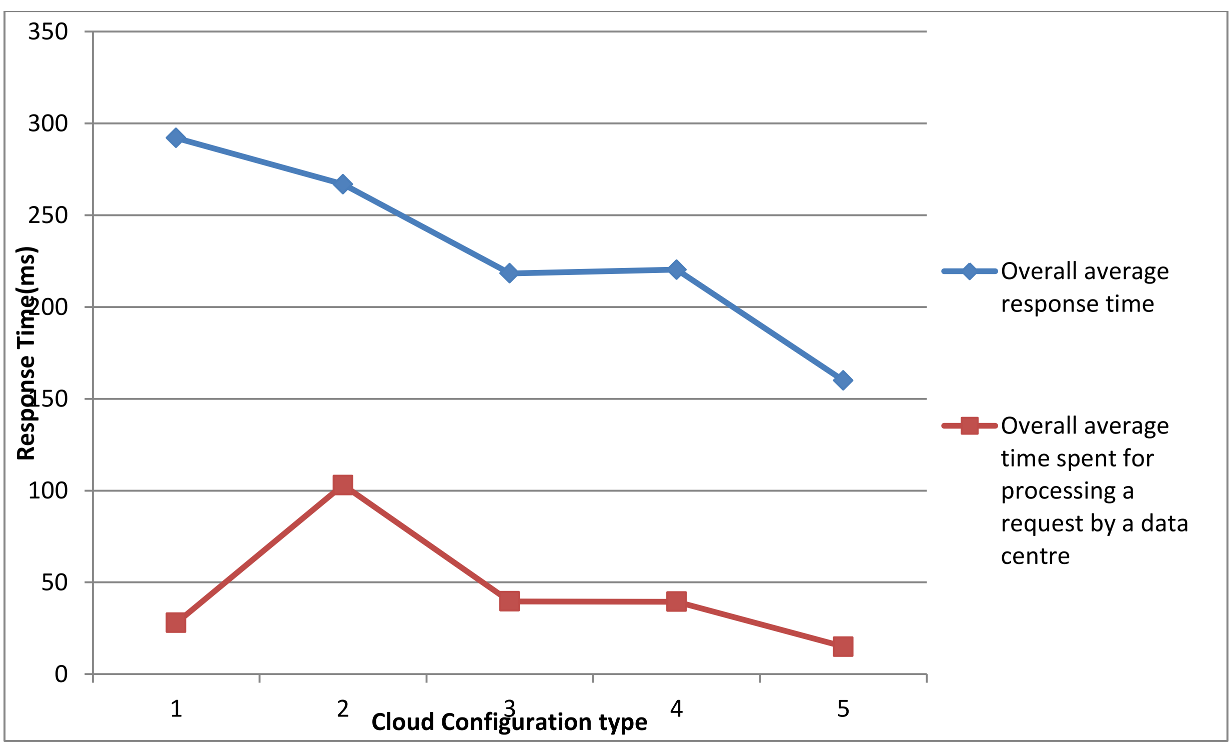


Fig 11: Final Simulation graph of cloud configuration type vs. response time

The simulation experimental results are summarized in Table 5.2 and Fig 5.5. The final simulations results obtained will assist in cloud performance analysis for a given cloud configuration.

CHAPTER SIX: DISCUSSION OF FINDINGS

6.1 Discussion of Findings/Conclusions

From the findings above the response time and data center processing time act as a performance evaluation parameter for the aforementioned study.

The analysis indicates that bringing the service closer to the users improves the quality of service (response request time). It is an expected effect, because users experiments have less effect from internet issues when they are geographically closer to the application server or computing server.

It is quite clear from above results, that when we increase the number of cloud resources(data centers) near to the user base, then overall quality of service (response time) is improved i.e. we should deploy our application using more cloud resources at different geographical locations using minimum performance evaluation parameter so that our users can enjoy faster response while interacting with an application. This is clear in cloud configuration 2 which has 2DC (which are geographically distributed) and 25VMs as compared to cloud configuration 1 which has 1DC with 50VMs.

An addition of load balancing policy across the data centers can also improve the response time and time taken to process a request by a data center, this can be clearly illustrated by cloud configuration 4, which has 2DC with 50VMs each with the load sharing policy; as compared to cloud configuration 3.

Overall average response time and Overall average time spent for processing request by a datacenter is minimum in the case of cloud configuration 5 with 3 data centers with 25, 50 and 75VM configurations. This is due to the fact that the services (data centers) are geographically distributed in 3 different regions. It also indicates that high quality of service is achieved when the peak load balancing policy is applied across the virtual machine in each cloud resource (data center).

6.2 Critical Review and Reflections

The institutions of higher learning have not yet adopted the cloud computing model for managing their activities, thus it was not possible to actively apply the simulation analysis across the universities processes and infrastructure. Despite the shortcoming, the researcher was able to deduce the following in view of the simulation results:

The cloud enhances accessibility of records/information irrespective of the user location i.e. any user can access the records stored on the cloud via a web interface as long as there is an existing network connection. The cloud will support and deliver a wide-range of course materials and academic support tools to the students, instructors, researchers and any other educators seamlessly on demand.

Also the distribution of the data centers across different geographical locations will ensure quick accessibility and response to a given user as compared to having a single data center that is located on a central location.

Regular hardware and software updates can be deployed easily, since all the applications run on the data centers. This in turn lowers the cost of purchasing the regular updates of every single client machine and ensures that the university keeps abreast with the changing dynamics of technology.

Monitoring of applications and data is enhanced since the major applications are stored on data centers alone; as compared to having the applications installed on singular user machines which can make the monitoring process almost impossible.

The researcher may not have exhausted the simulation process not only because of the complexity of the scenarios, but because of limitations of the cloud simulator software and hardware specifications; For example, the DC hardware specifications, are limited to the x86 architecture, Linux OS and the Xen hypervisor.

6.3 Future Studies

Data centers consume unprecedented amounts of electricity; thus incurring lots of capital expenditure to manage the day-to-day operations of a data center. Thus, future work would be to investigate on any new models and allocation strategies of applications that are energy efficient whilst maintaining maximum threshold of operations.

Another future work is to design a single, flexible model that will integrate all the universities applications and operations; since their main objective of offering quality and effective training and information resources that are dynamic in this information age, cuts across the mission of all learning institutions.

There is a need to design a model that shares some of the cloud resources with small to medium business and start-ups which may have similar computational needs that are flexible in terms of computational schedules such as payroll applications, human resource applications etc.

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