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**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**  
**SCHOOL OF INFORMATION SCIENCE**

**A CLOUD COMPUTING FRAMEWORK FOR  
ETHIOPIAN HIGHER EDUCATION INSTITUTIONS**

**BY:-**

**SEWALE BELACHEW DEMEKE**

**JUNE, 2012**

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**A Thesis Submitted in Partial Fulfillment of the  
Requirement for the Degree of  
Master of Science in Information Science**

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**Dedicated To:**

*Gasheye, Etaba, Befiker, Zelalem, Godoliyas, Brothers & Sisters I Love U All.*

*GOD Bless You*

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## List of Acronyms

ICTs	-----	Information Communication Technologies
ICT	-----	Information Communication Technology
IT	-----	Information Technology
HE	-----	Higher Education
HEI	-----	Higher Education Institution
HEIs	-----	Higher Education Institutions
EHEIs	-----	Ethiopian Higher Education Institutions
EU	-----	Ethiopian Universities
AAU	-----	Addis Ababa University
EthERNet	----	Ethiopian Education and Research Network
EUHC	-----	Ethiopian Universities Hybrid Cloud
EUPC	-----	Ethiopian Universities Private Cloud
EC2	-----	Elastic Compute Cloud
S3	-----	Simple Storage Service
CEO	-----	Chief Executive Officer
SaaS	-----	Software as a Service
PaaS	-----	Platform as a Service
IaaS	-----	Infrastructure as a Service
CSP	-----	Cloud Service Provider
AWS	-----	Amazon Web Service
SQL	-----	Structured Query Language
SOA	-----	Service Oriented Architecture
MOE	-----	Ministry of Education

ERP ----- Enterprise Resource Planning  
US ----- United States  
API ----- Application Programming Interface  
APIs ----- Application Programming Interfaces  
NASA ----- National Aeronautics and Space Administration  
IBM ----- International Business Machine  
LMS ----- Learning Mangement System  
SIS ----- Student Infomration System  
UNESCO ---- United Nations Educational, Scientific and Cultural Organization  
VLE ----- Virtual Learning Environment  
UK ----- United Kingdom  
VLC ----- Virtual Computing Lab  
DOE ----- Department of Education  
USD ----- United States Dollar  
BPM ----- Business Process Management  
OSS ----- Open Source Software  
CSM ----- Course Management System  
VM ----- Virtual Machine  
VMs ----- Virtual Machines  
AWS ----- Amazon Web Service  
VPC ----- Virtual Private Cloud  
VPN ----- Virtual Private Network  
CRM ----- Customer Relation Mangement  
DB ----- DatabaseF  
DBs ----- Database Systems

OS ----- Operating System  
CDN ----- Content Delivery Network  
SLA ----- Service Level Agreement  
QoS ----- Quality of Service  
GUI ----- Graphical User Interface  
CPU ----- Central Processing Unit  
SLA ----- Service Level Agreement

## **Abstract**

Educational institutions throughout the World have become highly dependent on information technology for their teaching-learning, service delivery and business requirements. Procuring and maintaining a wide range of hardware and software require substantial, ongoing investment and the skills to support them.

In the current financial crisis and being challenged by growing needs, universities are facing problems in providing necessary information technology (IT) support for educational, research and development activities. The objective of this paper is to find alternatives to the use of IT, while leading universities try improve agility and obtain savings.

The research methodology consisted a rigorous analysis of the latest research on Cloud Computing as an alternative to IT provision, management and security. It also took into account the best practices for Cloud Computing usage within universities, interviewing with selected ICT directors, plus the authors' experience in IT and higher education.

The research paper discuss the advantages of cloud computing for educational institutions, the limitations of current IT utilization in Ethiopian Higher Education institutions. It also discuss alternative solutions to solve the current IT utilizations limitations in Ethiopian Higher Education Institutions.

The research finding shows that Cloud Computing is the better ICT utilization mechanism for Education institutions teaching-learning and service delivery requirements, for it enables wise and strategic use of technology which significantly reduces cost. Accordingly, when the Proposed Hybrid Cloud Computing model is implemented, it will have significant contribution to the country in different aspects.

**Keywords:** Cloud Computing, Higher Education Institutions

# CHAPTER ONE

## 1. Introduction

### 1.1. Background

The use of the Internet and Information and Communication Technologies (ICTs) to deliver educational resources is considered mainstream in the 21st century, yet in Higher Education (HE) in developing countries it is often seen as a luxury. This has far reaching effects on teachers, learners and educational institutions in these countries, which often include a lack of basic ICT infrastructure and limited or no support for the training of teachers and learners in the use of digital online information sources. It is increasingly accepted that in the future most information sources and desktop applications currently used will be mainly accessed through the Internet, now increasingly referred to as 'the cloud'. This means that at higher education level ICTs should be adopted as a matter of urgency to enable teachers and learners to access this new direction in Internet technology and application delivery. Teachers and learners will no longer have to physically carry their documents and data around them; instead they will be able to access them in the 'cloud' anywhere, from any connected device. This blending of traditional teaching and learning with online applications and tools for collaborated learning via the Internet is thus a fundamental concept of cloud computing.

The term 'cloud computing', which has been described as an Internet computing model that offers unparalleled access to computing resources, began entering the public domain around 2006 when Amazon announced a limited public beta version of its Amazon Elastic Computing Cloud (EC2) system. It was only in 2006, when Google's CEO, Eric Schmidt [1], described his company's commitment to a new mode or model of computing called "cloud computing" that would be different from the "old client/server" computing business model largely invented by Oracle, that the term 'cloud computing' as a data service architecture on servers in a 'cloud somewhere' began to take off.

The term cloud computing refers to the delivery of scalable information technology (IT) resources over the internet, as opposed to hosting and operating those resources locally, such as on a business organization or university network[1]. Those resources can include applications and services, as well as the infrastructure on which they operate. By deploying IT infrastructure and services over the network, an organization can purchase these resources on an as-needed basis and avoid the capital costs of software and hardware. With cloud computing, IT capacity can be adjusted quickly and easily to accommodate changes in demand. “While remotely hosted, managed services have long been a part of the IT landscape, a heightened interest in cloud computing is being fueled by ubiquitous networks, maturing standards, the rise of hardware and software virtualization, and the push to make IT costs variable and transparent[2].

Cloud computing delivers infrastructure, platform, and software as services, which are made available as subscription-based services in a pay-as-you-go model to customers. These services in industry are respectively referred to as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

Cloud computing is an Information and Communication Technology (ICT) sourcing and delivery model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (example networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction[2].

In recent days, many research institutes are struggling to adapt Cloud Computing for solving problems that are continuously increasing computing and storage. There are three main factors that interests in Cloud Computing: [3] rapid decrease in hardware cost and increase in computing power and storage capacity, and the advent of multi-core architecture and modern supercomputers consisting of hundreds of thousands of cores; [4] the exponentially growing data size in scientific instrumentation/simulation and Internet publishing and archiving; and [5] the wide-spread adoption of Services Computing and Web 2.0 applications [8]. The Cloud Computing trend of replacing software traditionally installed on campus computers (and the computers themselves) with applications

delivered via the internet is driven by aims of reducing Higher Education Institutions (HEIs) IT complexity and cost. Cloud Computing could be a technological innovation that both reduces IT costs for the HEIs and eliminates many of the time-related constraints for students, making learning tools accessible for a larger number of students[5]. There are many benefits of cloud computing for educational institute and below are listed a few of them;

- With cloud computing, HEIs can open their technology infrastructures to businesses and industries for research advancements.
- The efficiencies of cloud computing can help HEIs keep pace with ever-growing resource requirements and energy costs.
- The extended reach of cloud computing enables institutions to teach students in new, different ways and help them manage projects and massive workloads.
- When students enter the global workforce they will better understand the value of new technologies[6]

Cloud computing allows students and teachers to use applications without installing them on their computers and also allows access to saved files from any computer with an Internet connection [7].

## **1.2. Statement of the Problem**

Across the past twenty years the use of ICT has fundamentally changed the practices and procedures of nearly all forms of endeavour within business and governance [9]. Within education, ICT has begun to have a presence but the impact has not been as extensive as in other fields. Education is a very socially oriented activity and quality education has traditionally been associated with strong teachers having high degrees of personal contact with learners. The use of ICT in education lends itself to more student-centred learning settings [10]. There have been a number of factors impeding the wholesale uptake of ICT in education across all sectors. These have included such factors as a lack of funding to support the purchase of the technology, a lack of training among established teaching practitioners, a lack of motivation and need among teachers to adopt ICT as teaching tools.

Currently as [11] indicated, different cloud computing companies are investing more on cloud computing. Some of the top cloud computing companies are: Amazon Web Service (AWS) provide Infrastructure-as-a-service (IaaS) offerings in the cloud for organizations requiring computing power, storage, and other services. [11] Google (SaaS, PaaS), Google App Engine is Google's platform-as-a-service (PaaS) offers building and hosting web applications on the Google Infrastructure. Currently Python and Java are the supported programming languages. Microsoft Azure Service Platform (PaaS) Azure Service Platform is Microsoft's PaaS offering an operating system called Windows Azure that serves as a runtime for the applications and provides a set of services such as: NET Services, SQL Services, Live Services [13].

According to [8] In Ethiopia different initiatives are working as part of a national capacity building program that includes schoolNet, WoredaNet that aims to provide connectivity and specialized applications for schools and for local governments. The Ethiopian Education and Research Network (EthERNet) was launched in 2001 to build and deliver highly interconnected and high performance networks for Universities and other Educational and Research Institutions in Ethiopia. More specifically, EthERNet was aimed to build and deliver high performance networking that connected these institutions with each other and similar institutions in the world, and by doing this to enable them to share educational resources and collaborate both within Ethiopia and globally. Since its establishment EthERNet has provided services like datacenter, video conference, e-library and technical support. Eventhough EthERNet is providing different services to Ethiopian Education and research, it still needs integration of other services, and service delivery based on the new model of computing, which cloud based computing, for a better service delivery strategy and strategic utilization of resources.

For a particular IT service, a sufficient level of aggregation for efficiency cannot be achieved within one campus but, rather, must be achieved at a higher level of aggregation, beyond a single institution. Efficiencies may be realized in aggregating personnel, expertise, licensing, business continuity, and other benefits far beyond simply joining computer hardware [12].

Hence the main concern of this study will be finding solutions for the above aforementioned factors so that HEIs can get the advantages of ICT in efficient and affordable manner. Therefore, the research will intend to get answers for the following research questions.

- Is the current EHEIs ICT service delivery strategy efficient?
- Do we need to change the way we are currently deploying and using ICT in EHEIs?
- Could cloud computing be an answer for minimizing the aforementioned problems?

### **1.3. Objective of the Study**

#### **1.3.1. General objective**

The general objective of this study is to examine existing ICT utilization strategy in EHEIs and analyze cloud computing concepts for adopting cloud computing technology in Ethiopia Higher Education Institutions and to design a prototype cloud computing framework that can be used in all Higher Education Institutions of Ethiopia.

#### **1.3.2. Specific objective**

- ✓ Examine the current ICT service delivery strategy and efficiency?
- ✓ To explore the potential benefits of Cloud Computing in Education
- ✓ To examine the necessity of Cloud Computing for EHEIs.
- ✓ To compare the cost effectiveness of using cloud computing technology in EHEIs.
- ✓ Designing a prototype cloud computing framework model that can be placed in a moderate place and can provide cloud service for all EHEIs.
- ✓ To identify and recommend future research directions for further investigation on the benefits of Cloud Computing for Ethiopian Educational Institutions.

## **1.4. Methodology of the Study**

In order to achieve the specific and general objectives of the study and answer the research questions, the following research methods are used.

### **1.4.1. Literature review**

Several previously proposed related literatures (books, articles and the Internet) are reviewed in order to have detail understanding on this research works. Different techniques and tools which are relevant for the current research are analyzed, modified and used from previous works.

### **1.4.2. Interview**

Different persons including students, researchers, developers and ICT directors from different higher education institutions have been interviewed for better understanding of the current ICT utilization strategy, Effectiveness and efficiency of service delivery, and their recommendations for better service delivery was covered by the interview. Accordingly purposive sampling technique was used. ICT directors from different universities and undergraduate and Masters level students from different departments have been randomly selected and interviewed.

### **1.4.3. Tools**

Different softwares and designing tools are used. Open source Cloud Computing implementation softwares like Opennebula, aneka and other designing tools are used.

## **1.5. Significance of the study**

This research will allow the Ethiopian Higher Education Institutions to consider alternative ways of deploying ICT infrastructures for an efficient and effective teaching-learning and service delivery. The study gives new insights to the Ministry of Education (MOE) and concerned government sectors on how to invest ICT budgets on HEIs. The Proposed Hybrid cloud computing model and the presented implementation plan can be used as a baseline

for the physical realization of the cloud. Additionally the study could be used as a baseline for further studies of this newly emerged ICT utilization strategy to be considered in different governmental and non governmental organizations of Ethiopia.

The proposed Cloud Computing framework could also be used as a baseline for EHEIs ICT managers on how the cloud computing will be implemented and used in HEIs.

### **1.6. Scope of the Study**

The main intent of the study is to examine the current ICT service delivery strategies to support EHEIs, to consider cloud computing in the field of education specifically in Ethiopian higher education institutions and propose a Cloud Computing framework that could be used as a baseline for implementation of Cloud Computing in EHEIs.

### **1.7. Organization of the Thesis**

This section describes the organization of the rest of the thesis. Chapter two discusses related works on cloud computing in general and cloud computing for education in specific.

Chapter one discusses about background information about cloud computing, the statement of problem, objectives, methodologies and related concepts are presented.

Chapter two presents the conceptual discussion about cloud computing and detailed literature review. What the trends in cloud computing tell us, Service and deployment types Cloud Computing, How is cloud computing used in education , How the future of education is affected by Cloud Computing , Who are currently using cloud computing in educational sectors, What does cloud computing look like in EHEIs , is there any research work related with it, What are the best design considerations in architectural designing of cloud computing for educational institutions and related concepts is discussed in chapter two.

In chapter three all concepts related with cloud computing design consideration is covered. What design is better for Ethiopian higher education institutions , why the specific design is

selected and basically the methodologies and sample cloud services that can be provided with the proposed cloud computing framework is discussed

Chapter four contains information about the proposed Cloud Computing Framework for EHEIs. It contains the proposed cloud computing framework architecture and its' in detail. It also contains the implementation proposal for the proposed Cloud Computing framework.

Chapter five discussess about the advantages and limitations of the proposed cloud computing framework and its implementaion proposal.

Finally in chapter six conclusions about the research and recommedations for future research direction is presented.

## CHAPTER TWO

### 2. Conceptual Discussion and Literature Review

#### 2.1. Cloud Computing

Experts in the cloud computing industry and providers give their own definition for the term cloud computing. Today there is not yet a consensus for what exactly this term means. Examining some of the existing definitions helps to clarify the term and what it involves (or might involve). Here are some of the definitions quoted from different experts and companies:

“Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” [15].

“A pool of abstracted, highly scalable, and managed computing infrastructure capable of hosting end-customer applications and billed by consumption” [16].

“A style of computing where massively scalable IT-enabled capabilities are delivered as a service to external customers using Internet technologies.” [17].

“A Cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers” [18].

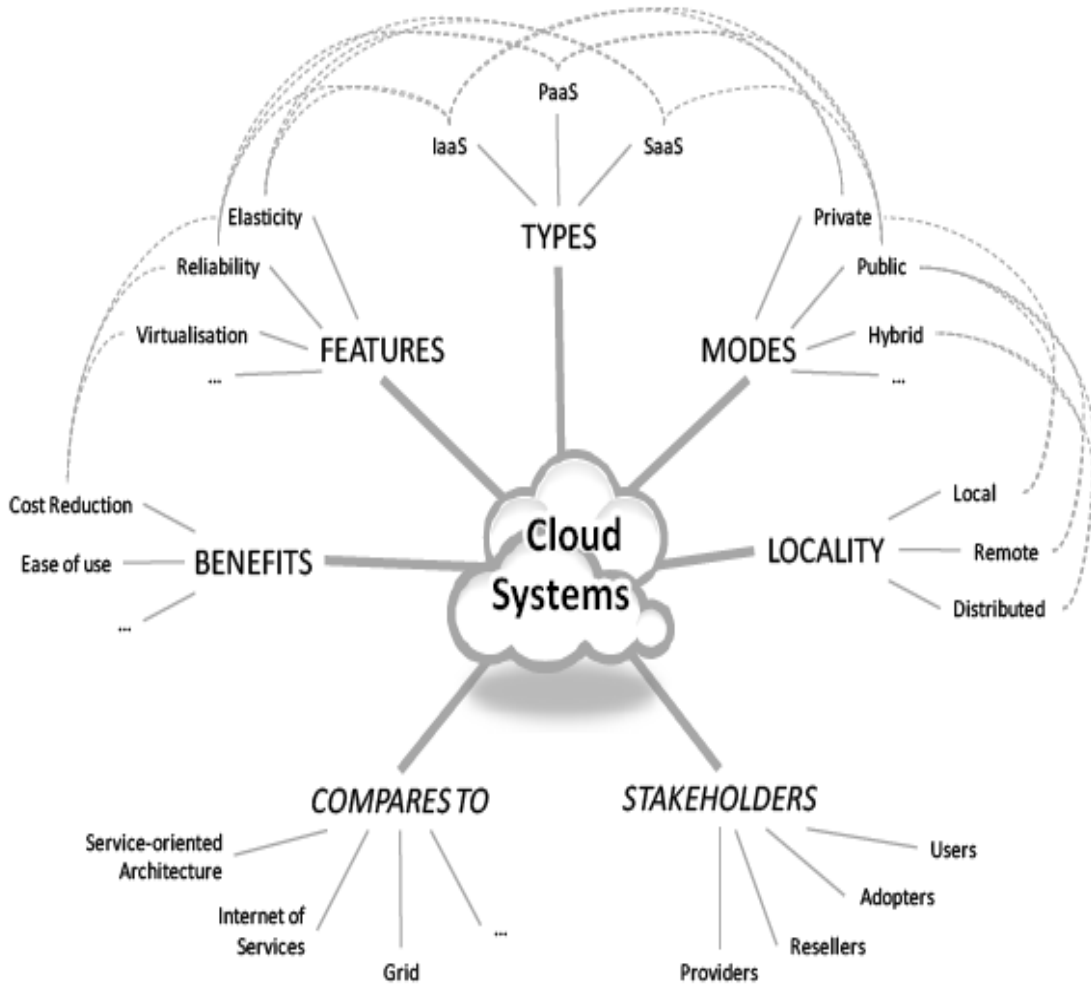


Figure 1. Main Aspects Forming a Cloud System

As it is defined above, and will be explained later in more detail, the definitions of cloud computing include different classes of services. For example cloud computing can supply remote storage space; but could also supply processing power to supply applications as a service over the internet. Reading these definitions there is a noticeable pattern, this pattern enables us to extract the main features of a cloud computing system. These features are described in the following subsections.

## **2.2. Cloud Computing Features**

### **2.2.1. On demand**

A basic condition that a cloud computing provider must fulfill is the ability to deliver computing resources whenever the customer needs them. From the customer's point of view the available computing resources are nearly infinite (i.e., the customer is not limited to the set of servers located at one site and it is the responsibility of the cloud computing provider to have sufficient resources to satisfy the requirements of all their customers).

Utilizing computing resources on-demand is one of the most desired capabilities for a large number of enterprises because it eliminates the need for planning ahead, purchasing, and installing the resources they will require at some point in the future. This enables the customer to avoid making an unnecessary upfront investment in servers and computing resources. This enables the customer to avoid making an unnecessary upfront investment in servers. Furthermore, when comparing cloud computing with the traditional model of owning the servers, cloud computing will help to avoid the costs of having underused resources. Effectively the cloud computing vendor is doing what firms such as EDS did when it started to run service bureaus by combining the needs of multiple firms the service bureau is able to take advantages of the effects of resource pooling.

Consequences of this feature of on-demand computing resources are a lowering of the entry barriers to some business models, as software vendors can develop applications without worrying beforehand of provisioning for a specific number of customers and then bearing with the risk of greater success than planned, leading to the service not being available or, worse, having very few users and a large capital expense caused by purchasing resources that are very underutilized.

### **2.2.2. Pay-Per use**

Another new aspect of cloud computing is application of usage based billing model. Customers simply pay for the services they use while providers bear the costs of

hardware and software provision. Pricing may vary depending on the time of day due to peaks in demand or varying electricity costs and institutions may therefore carry out certain activities when costs are cheaper. However distributed cloud networks may enable providers to smooth out demand globally and offer uniform pricing strategies not dependent on timing.

### **2.2.3. Rapid elasticity**

Based upon the specific of a service level agreement, the cloud provider scales up or down the resources that are provided to meet the customer's changing needs. This service level agreement must define the response time for the cloud provider to adapt to the customer's needs. Such an agreement is needed by the cloud provider, because the cloud provider does not in fact have infinite resources, so depending upon the service level agreement the cloud provider has to find a set of allocations of resources that satisfy the current demands of the aggregate of their users while meeting the various service level agreements of these customers - otherwise the service level agreement may specify a penalty that the cloud provider has to pay to each customer for not meeting the relevant service level agreement.

### **2.2.4. Maintenance and upgrading**

Because the cloud provider rather than the customer maintains the computing resource, there is an effective outsourcing of maintenance tasks. Thus the cloud provider maintains and updates the resources, whether the resource is hardware or software. Therefore all repairs and replacement of the underlying hardware resources are transparent to the customer, as they do not affect the customer's experience. While this might be true in the ideal case, there may be short intervals when a customer's image is migrated from one hardware platform to another in order to perform maintenance or repair of a given physical platform, during this period of time the customer might not have any of the resources associated with this image available.

## 2.3. Cloud Computing Service Models

The U.S. National Institute of Standards and Technology Laboratory definition of cloud computing describes three service layers [15]:

- Software as a Service (SaaS)
- Platform as a Service (PaaS) and
- Infrastructure as a Service (IaaS).

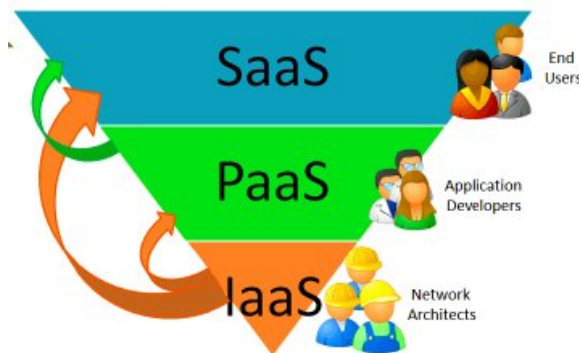


Figure 2. Cloud Computing Service Models

### 2.3.1. SaaS (Software as a Service)

The SaaS customer is an end-user of complete applications running on a cloud infrastructure and offered on a platform on-demand. The applications are typically accessible through a thin client interface, such as a web browser. The customer does not control either the underlying infrastructure or platform, other than application parameters for specific user settings.

### 2.3.2. PaaS (Platform as a Service)

In the case of PaaS, the cloud provider not only provides the hardware, but they also provide a toolkit and a number of supported programming languages to build higher level services (i.e. software applications that are made available as part of a specific platform).

The users of PaaS are typically software developers who host their applications on the platform and provide these applications to the end-users. Programming platforms and tools (such as .NET, java or python) and APIs for building cloud-based applications and services are exposed to developers who can create applications for testing or for commercial purposes for a minute fraction of the cost of provisioning server infrastructure for themselves. Google's App Engine allows developers to write programs to run on Google's infrastructure or platform. Other examples include Amazon Simple Storage Service (S3), Azure Storage, and Force.com.

### **2.3.3. IaaS (Infrastructure as a Service)**

The capability provided to the customer of IaaS is raw storage space, computing, or network resources with which the customer can run and execute an operating system, applications, or any software that they choose. The cloud customer is not able to control the distribution of the software to a specific hardware platform or change parameters of the underlying infrastructure, but the customer can manage the software deployed (generally from the boot level upward).

## **2.4. Cloud Computing Deployment Models**

Clouds can also be classified based upon the underlying infrastructure deployment model as Public, Private, Community, or Hybrid clouds. The different infrastructure deployment models are distinguishing by their architecture, the location of the datacenter where the cloud is realized, and the needs of the cloud provider's customers (for example, due to regulatory, legal, or other requirements).

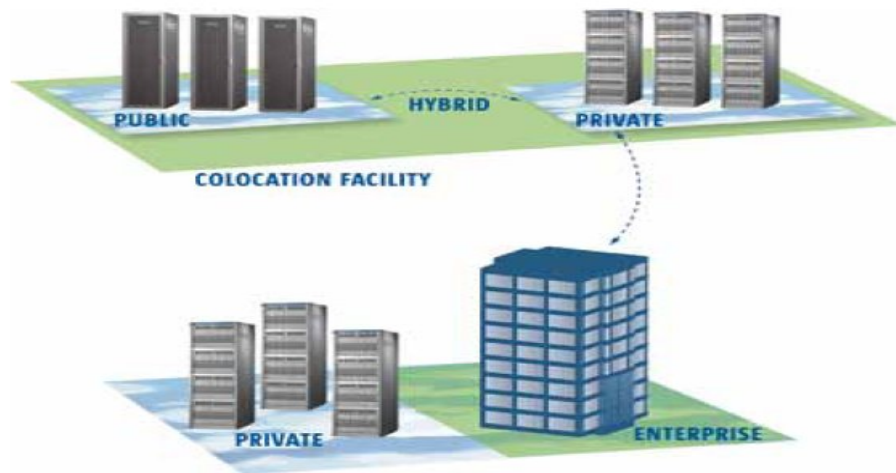


Figure 3. Cloud Deployment Models

### 2.4.1. Public clouds

A public cloud's physical infrastructure is owned by a cloud service provider. Such a cloud runs applications from different customers who share this infrastructure and pay for their resource utilization on a utility computing basis. Public clouds are most often hosted away from customer premises, and they provide a way to reduce customer risk and cost by providing a flexible, even temporary extension to enterprise infrastructure.

If a public cloud is implemented with performance, security, and data locality in mind, the existence of other applications running in the cloud should be transparent to both cloud architects and end users. Indeed, one of the benefits of public clouds is that they can be much larger than a company's private cloud might be, offering the ability to scale up and down on demand, and shifting infrastructure risks from the enterprise to the cloud provider, if even just temporarily.

Portions of a public cloud can be carved out for the exclusive use of a single client, creating a virtual private datacenter. Rather than being limited to deploying virtual machine images in a public cloud, a virtual private datacenter gives customers greater visibility into its infrastructure. Now customers can manipulate not just virtual machine images, but also servers, storage systems, network devices, and network topology. Creating a virtual private datacenter with all components located in the same facility helps to lessen the issue of data

locality because bandwidth is abundant and typically free when connecting resources within the same facility.

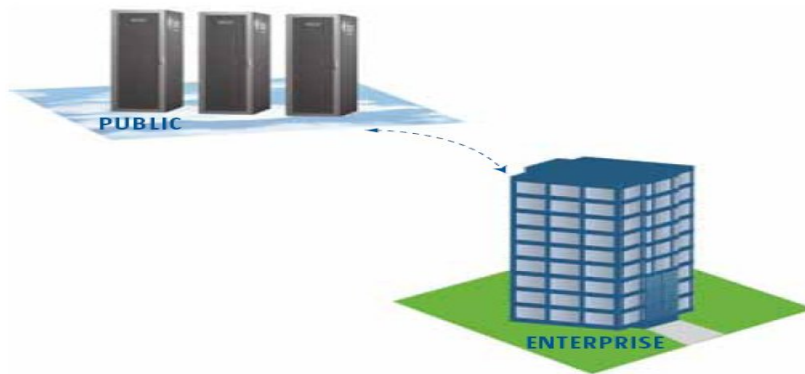


Figure 4. A public cloud provides services to multiple customers.

#### **2.4.2. Private clouds**

A pure private is the Cloud which operates dedicatedly for a single organization. Private cloud infrastructure may be set-up On-Premise or off-premise and may be managed either internally or by third-party service providers. Private clouds offer highest level of security and control but are expensive. A private cloud is built for the exclusive use of one customer, who owns and fully controls this cloud. Additionally, there are variations of this in terms of ownership, operation, etc. The fact that the cloud is used by a specific customer is the distinguishing feature of any private cloud. A private cloud might be owned by the customer, but built, installed, and managed by a third party rather than the customer. The physical servers might be located at the customer's premises or sited in a collocation facility. A recently introduced alternative to a private cloud is a 'virtual private cloud'. In such a virtual private cloud a customer is allocated a private cloud within the physical infrastructure of a public cloud. Due to the allocation of specific resources within the cloud the customer can be assured that their data stored on and processing is done only on dedicated servers (i.e., these servers are not shared with any other customer of the cloud provider). An example would be the NASA's Nebula Private Cloud which is an infrastructure-as-a-service implementation for scientific data and Web-based applications



Figure 5. Private clouds may be hosted at a colocation facility or in an enterprise

### **2.4.3. Community clouds**

Community cloud is the Cloud whose infrastructure is shared by several organizations and supports a specific community that has shared concerns. The community Cloud may be managed by organizations collectively or by a third-party Cloud services provider. An example would be the Community Cloud being built by the Mount Sinai Hospital in Toronto, Canada that will give 14 area hospitals shared access to a fetal ultrasound application and data storage for patient information

Typically cloud systems are restricted to the local infrastructure, i.e. providers of public clouds offer their own infrastructure to customers. Though the provider could actually resell the infrastructure of another provider, clouds do not aggregate infrastructures to build up larger, cross-boundary structures. When several customers have similar requirements, they can share an infrastructure and might share the configuration and management of the cloud. This management might be done by themselves or by third parties.

### **2.4.4. Hybrid clouds**

Though public clouds allow enterprises to outsource parts of their infrastructure to cloud providers, they at the same time would lose control over the resources and the

distribution / management of code and data. In some cases, this is not desired by the respective enterprise.

Hybrid clouds consist of a mixed deployment of private and public cloud infrastructures so as to achieve the maximum cost reduction through outsourcing whilst maintaining the desired degree of control over e.g. sensitive data by employing local private clouds.

There are not many hybrid clouds actually in use today, though initial initiatives such as the one by IBM and Juniper already introduce base technologies for their realization [18].

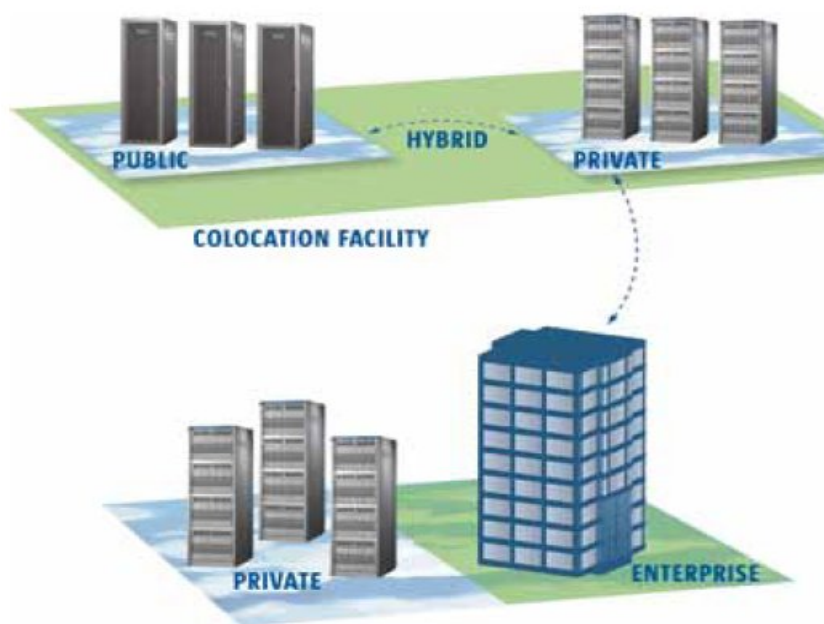


Figure 6. Hybrid clouds combine both public and private cloud models.

## 2.5. Cloud Computing and Education

### 2.5.1. Education

The education sector is one of the cornerstones of socio-economic development. It is widely accepted that education contributes to poverty reduction and increased economic growth, which in turn leads to an improved standard of living. It also enables the

individual to participate in wealth generating activities, leads to the creation of employment, and the overall development of society.

Like other sectors, the education sector has also felt the effects of the meltdown, with some countries reducing their budget for education. However, with governments making concentrated efforts to ensure that education remains a top priority, the sector is on an upswing. This is primarily because education is considered to be a linchpin in economic turnaround. Both the Ethiopian government and private players are investing in the education sector to leverage opportunities in the sector.

The Ethiopian government has taken several initiatives to promote Education in Ethiopia. Some of these initiatives are:

#### **Teachers Training:**

- Restructuring teacher training programmes towards creating good quality teachers
- Constantly upgrading the capability of teachers through short and long term courses
- Expansion of research programmes/projects and creating incentives for growth in research facilities through publicly funded projects/research

#### **Macro Considerations**

- Provide quality education in urban and rural areas focusing on skill development by encompassing many students every year and making them industry ready
- Plans on reducing the drop out rates and increase literacy rates.

#### **Budgetary Expansion**

- Increased the budget for expansion of higher education facilities.
- Setting up new universities

- Expanding and upgrading Technical and vocational Institutes

### **Admission and Curriculum Assessment**

- Create a common platform for admission through a common entrance test and/or other relevant criteria for professional courses under central universities
- Adopting of semester system across institutes
- Changing method of assessment from annual examination to internal and continuous evaluation

### **Accreditation and rating**

- Introduction of mandatory accreditation system for all education institutions
- Creation of multiple rating agencies with a body to rate these ratings
- Department-wise rating in addition to institutional rating

However, as the sector struggles with rising demand and limited budgets, it becomes necessary to budget / manage in a lean and cost-efficient manner. The use of technology does not only help provide education in a lean and cost-efficient manner but also address concerns centered on quality of education. Technology plays an integral role in today's educational ecosystem. It has become medium and facilitator of interaction between learners, educators and the school administration. Many schools have an in-house IT staff or third party vendors to provide support for their IT systems.

#### **2.5.2. Role of technology in the education ecosystem**

The education sector has historically shared a symbiotic relationship with technology. While on one hand, the sector has been a cradle for many technological innovations, on the other technology has played a pivotal role in the evolution of education and academia. IT has, in particular, played a catalytic role in making education a more collaborative and

interactive process. In today's education system, students and educators are using technology in many areas like:

- Class room teaching
- Online examinations
- Online books and journals
- Online forums for information.

Similarly, educational institutes are using technology for

- managing education content and scheduling
- recording student information
- communications
- Managing the admission process.

Apart from the obvious use of technology in the organized segment of the education sector, technology has also penetrated into the unorganized segment. Training programs, private tuitions and vocational training programs are some of the services that are being provided through the use of technology in the unorganized segment.

In the absence of regulations, this sector has had a non-uniform usage of technology. Some of the technology tools that are being / could be availed by this sector are:

- Hosting programs
- Content management systems
- Interactive learning systems
- Automated enrollment processes

Technology, especially ICT has impacted several aspects of the education sector in the last decade. Some of the impacts of technology on various aspects of education are:

### **Tools and Methodologies**

- E-books and netbooks
- Virtual Learning Environment (VLE)
- Desktops/laptops/Supercomputers
- Knowledge management systems

### **Collaboration**

- Emails
- Epals
- Social networking tools

### **Distribution**

- Online programs
- Virtual Classes
- Tele-education

### **Administration**

- Learning Management Systems (LMS)
- Student Information System (SIS)
- Admission System

Some of the benefits of using technology in the education sector are given as below:

#### ➤ **Standardized Tools:**

Traditionally, the tools like knowledge management systems, virtual learning environments, etc used by the education sector were proprietary in nature and limited to being used in select institutes or countries. Modern tools are more standardized, cheaper, and universal in nature.

➤ **Environment of collaboration:**

Globalization has highlighted the advantages of collaboration between people across geographies. Schools are increasingly in favor of using collaborative tools to prepare students for a future where common goals are achieved through interactions between people sitting across geographies

➤ **New modes for providing education:**

Dependence on the brick-and-mortar infrastructure and traditional teaching methods was inhibiting the reach of education. New modes of providing education such as virtual learning environment, tele-schools and online education programs have enabled providers of education to cut across geographical boundaries. This has the potential to help governments boost literacy rates, especially in smaller cities and rural areas

➤ **Administrative efficiency:**

New age education systems, regulations and guidelines of governing bodies require educational institutes to function as corporate firms do. Technology has provided management systems such as Learning Management System (LMS) and Student Information System (SIS) to enable better administration of schools and universities.

### **2.5.3. Challenges in the Present Education Ecosystem**

#### **2.5.3.1. Socio-Economic challenges:**

➤ **Increasing cost of Education:**

One of the key issues confronting the sector is the rising cost of education across the globe. Due to inflation and increasing share of private players in education sector, cost of education has experienced a historic rise in Ethiopia. As number of students increase from time to time, Government schools are not able to handle all of the students and these forces parents to send their childrens to private schools, which asks unaffordable

price for attending education. Major reasons for increase in the cost of education are the labor intensive nature of delivering education and the increasing cost of technology.

➤ **Cut down in Education budgets due to recession:**

The economic crisis has been most precarious for the education sector of developing nations. It had temporarily impacted not only its progress but also reversed the gains achieved over past years.

➤ **Limited reach of education:**

In developing nations, lack of infrastructure has been a major hindrance to the reach of education in urban and rural areas. Infrastructure facilities such as buildings, power and telecommunications require significant investment from both public and private players.

➤ **Poor quality of education in developing nations:**

Along with making education accessible to all, it is equally important to create conditions conducive to the development of skills. In many parts of the world, a significant gap exists between the number of students graduating from school and those among them who master a minimum set of cognitive skills. In Ethiopia, the government is trying to deliver basic literacy instructions as “free and compulsory education” that is dispensed by barely qualified teachers. The poor quality of education and rudimentary physical infrastructure leads to high drop-out rate.

### **2.5.3.2. Technology challenges**

➤ **High start-up cost of adoption of new technologies:**

High start-up costs in the implementation and deployment of new technologies enabling a Virtual Learning Environment (VLE) and online education have inhibited schools and universities from investing in them. These tools, in fact, are most needed in developing countries where the quality of education needs improvement. Moreover, regular

maintenance and periodic upgrade of technology resources require these institutions to budget for an in-house IT department.

➤ Complexity in maintenance of technologies:

As technology evolves, the IT Infrastructure employed becomes increasingly complex and at the same time requires periodic upgrades and uninterrupted support. Therefore there is a need for dedicated in-house or third party IT teams. The complexity and cost of employing and maintaining IT departments and outsourcing services has been a major concern for schools. Rapidly changing technologies pressurize schools to switch to the most recent technology in order to take advantage of the benefits they offer. Moreover, apart from the huge capital investments that are required, managing changing technologies would be cumbersome.

➤ Underutilization of technology resources:

Present day technology needs resources – software and hardware - that can support peak load. Inconsistent usage patterns in smaller schools and programs like online education result in large expenditure on resources and the relative underutilization of resources. Deploying and maintaining present day technology for small groups is often cost prohibitive.

Further, the overall infrastructure - reliable power supply, telecommunication, cooling systems, etc. - required for supporting these technologies are scarcely available in many lower and higher level educational institutions.

#### **2.5.4. Cloud computing in the education sector**

Cloud Computing is based on a collection of many old and few new concepts in several research fields like Service-Oriented Architectures (SOA), distributed and grid computing as well as virtualization, it has created much interest in the last few years. This was a result of its huge potential for substantiating other technological advances while presenting a

superior utilitarian advantage over the currently under- utilized resources deployed at data centers.

In this sense, cloud computing can be considered a new computing paradigm that allows users to temporarily utilize computing infrastructure over the network, supplied as a service by the cloud-provider at possibly one or more levels of abstraction.

The education sector has traditionally been cautious to embrace new technology due to factors such as cost and risk. But the 21st century presents new financial, demographic and industrial pressures to the education sector that are making it imperative for schools and universities to align themselves to the latest technology. In such a scenario, the Cloud could offer a highly acceptable solution to the education sector, helping it adopt evolving technologies without the burden of excessive cost and complexity.

The Cloud has already started making its presence felt in the education sector globally. Schools have started leveraging the Cloud for student e-Mails, collaboration tools and virtual desktops. The Cloud is also providing cost effective and low maintenance solutions to online programs and distance education programs. Affirmative feedback from the early adopters of the Cloud promises extensive use of this technology in the education sector.

The potential and efficiency of using Cloud Computing in higher education has been recognized by many universities among which, University of California, Washington State University's School of Electrical Engineering and Computer Science, higher education institutions from UK, Africa, U.S and others [20]. Cloud Computing offers to universities the possibility of concentrating more on teaching and research activities rather than on complex IT configuration and software systems [20], through a fast IT implementation. In addition, cloud solutions can be used to support cooperative learning and socially oriented theories of learning, using computer technologies to support collaborative methods of instruction [20].

Cloud computing offers many benefits to e-learning solutions by providing the infrastructure, platform and educational services directly through cloud providers and by

using virtualization, centralized data storage and facilities for data access monitoring [20].

#### **2.5.4.1. The Cloud offers an opportunity to reduce IT costs**

Increasing spends on technology and shrinking grants to the education sector are some of the key pain points of the education sector. Spending on technology is eating into a substantial part of a schools budget. One of the significant benefits of adopting the Cloud is the reduction in costs incurred on IT.

The Cloud offers software, platforms and infrastructure at a much lower cost:

- The Cloud enables schools to avail administrative software such as Learning Management Systems (LMS) and Student Information Systems (SIS) as service instead of paying hefty license fees for products. The SaaS model also helps schools reduce the capital costs of deploying software.
- The Cloud also offers IaaS to educational institutes. Research and Development departments of schools are now gravitating to the Cloud as the model has proven cost benefits – campuses do not need to maintain on-site IT infrastructure such as high-end data servers and application servers. It has also removed many restrictions prevalent on existing computer networks.
- The private Cloud for e.g. can also play an increasingly important role in teaching and learning. The school or university applications, documents, content, data, and services once plugged into the private Cloud can be accessed with just an internet connection and a web browser, from anywhere, inside the classroom or out, by the entire school community

[22] Virtual Computing Lab (VLC) is an example of a private cloud at North Carolina State University. The VCL has been in production for six years and serves 30,000-plus users and over 100,000 reservations per semester. Images that integrate software applications, operating systems, and other utility and network-based access tools are loaded on blades — high-end personal computers clustered in a centralized system. Upkeep of the

automated blade clusters takes less than one-tenth of the lab personnel's time and effort that would be required to install and maintain hundreds of computing lab machines.

#### **2.5.4.2. The cloud reduces management burden for schools**

- In the Cloud, the deployment and maintenance of software, and IT infrastructure would be the responsibility of the Cloud services provider. Hence, schools that use LMSs or SISs as SaaS need not worry about annual upgrades of software.
- Schools offering online distance education programs need to be concerned only about the content of the programs. Technical issues related to the hosting and maintenance of online portals would be the responsibility of the Cloud services provider.
- Schools that encourage research and development activities need dedicated IT teams for maintaining data centers and server farms. With The Cloud offering PaaS and IaaS, maintenance of IT infrastructure is taken up by the Cloud service providers.

[23] In 2007, UC Berkeley began a pilot project class focused on developing and deploying SaaS. In 2008, the university moved the course from Berkeley-owned servers to the Cloud. According to Berkeley, they wanted undergraduates to gain exposure to the Cloud technologies as they believe they will be in demand. They also found the Cloud made it easier to fulfill assignments, such as saturating large database servers.

#### **2.5.4.3. The cloud offers collaboration in education**

The Cloud offers solutions for cost effective and easy collaboration for researchers, students, teachers and parents. Schools have been trying to set up their own eMail systems, and there's been a big push towards using online platforms for learning and communicating with students and parents.

[23] The New York City Department of Education (DOE)—the largest system of public schools in the United States, serving about 1.1 million students in more than 1,600

schools—chose ePals, a Cloud solution. EPals offers a cost-effective, secure, and private space where students easily could communicate and collaborate as part of their learning. The Cloud solution is expected to save the district from spending up to USD 5 million annually on infrastructure needed to host e-Mail for students, teachers, and parents. City students also will be able to communicate with classrooms across the world as part of ePals' global community, which reaches 600,000 educators who teach 25 million students worldwide. This will enable parents to interact with teachers and school staff in almost any language. Parents will be able to receive e-Mail regarding school events and their children's progress in class.

#### **2.5.4.4. E-books replacing textbooks thus reducing Students' burden**

With textbooks getting dearer with time, education has become fairly expensive for students with respect to the costs associated with buying textbooks. The contents of textbooks also require periodic revisions. With technology all the books can be put online and accessed through personal computers, tablets, laptops, cell phones, etc. Instead of buying a number of books over the entire course duration, students would be required to only invest in just one of these devices to access the Cloud.

#### **2.5.4.5. Opening up research options**

One of the prominent features of technology is 'resource pooling', as it allows users to share common resources. This feature opens up new opportunities for research. The Cloud can support schools encouraging research and development by reducing the costs involved with computation, as most of the research requires capacity computing, with systems that share their computing power with several users.

[23] Governor Arnold Schwarzenegger has called for California schools to shift to digital textbooks to save much of the USD 350 million that the state annually budgets for textbooks and instructional materials. Moreover, textbooks are hardly interactive and are isolated from the computing resources with which we have provisioned our schools at great expense.

### **2.5.5. Challenges of adopting the cloud in the education sector**

Despite various advantages that the Cloud has to offer to the education sector, there are still challenges that need to be overcome to leverage its complete potential in education sector.

#### **2.5.5.1. Privacy and risk of identity theft:**

These issues are raised by legal officers and senior administrators more than the end users – students, as they are not aware of issue of privacy. Educators and research communities are concerned about sensitive research data being stored beyond the bounds of their university. Further, high-end usage of the Cloud such as admission process and online assessment have issues related to validation, information, and identity theft.

#### **Piracy:**

Another challenge of adoption of the Cloud by research institutes is the protection of intellectual property. Researchers and school administrations are hesitant to store confidential data on servers which are out of the university's boundaries. They are even more reluctant to store such information on shared facilities offered by the public Cloud.

#### **Risk and nonperformance:**

Along with risk, strategies to deal with aspects such as unexpected service stalls from the Cloud need to be deployed. Another important aspect of risk associated with privacy and data, is to correctly classify and value the intellectual property of the data that is being moved to the Cloud, and then to build appropriate indemnity into the contractual arrangements. Doing so, not only ensures that Cloud service providers will correctly understand and value the data but also financially compensate the college or university in the event of a leak.

[24] Victoria University is developing a strategy to re-architect its internal infrastructure so that integration with the Cloud can be done in a more seamless and elastic manner. In this environment, data and processing can move transparently between the university infrastructure and the Cloud provider. The university can then readily address and control performance issues by adjusting, in real time, how much of the service sits in the Cloud and how much stays on the university infrastructure.

### **Unsolicited advertisement**

Another risk is that cloud providers will target users with unsolicited email or advertising. This is illegal in areas such as the European Union, and institutions must take steps to ensure this does not happen as there are high penalties for breaches. In addition the accumulation of usage data by the providers may be of value for onward selling to third parties, though it may be anonymised. The inclusion of appropriate clauses in the contract may minimize the risk of abuse.

### **2.5.6. Future of education with cloud technologies**

Though the education sector has historically been hesitant to embrace new technologies, it has been quick to begin the process of evaluation and adoption of the Cloud. The Cloud can prove to be catalyst to achieving some of the long desired social goals of the education sector such as “education for all” and “affordable education”.

#### **2.5.6.1. Meta-universities**

The concept of “meta university” may be realized sooner than envisaged across the globe. A meta-university is a conglomeration of several universities that give access to scholarly publications, scientific works in progress, tele-operation of experiments, and worldwide collaborations, thereby achieving economic efficiencies and raising the quality of education through a global endeavor. A metauniversity would have a global network for high learning, focusing on collaborative learning and knowledge, while operating on web-based platform. The Cloud could prove to be an ideal platform that can support such a concept.

Collaborative learning could become the norm as the Cloud takes care of the technological challenges. Meta-universities could enable developing countries to contribute to the global intelligentsia. Research and innovation would no longer be limited to the laboratories of developed nations, as developing nations could also have equal participation. Commercial clouds will have a pivotal role in realizing the goal of meta-universities. To support IT infrastructure of this scale, outsourcing will see an innovative pricing model, new governance models and novel partnerships.

#### **2.5.6.2. Advent of mobile education:**

The education sector could leverage the development in telecom to make it more mobile. Technology has moved classrooms from brick-and-mortar rooms to desktops and laptops. SaaS solutions could be adapted to enable members of the Education ecosystem to access study material on mobile phones.

The foundation for providing such services already exists: however, in order to realize its full potential there would be the need for collaboration between educational institutes, Cloud providers, software vendors and telecom providers.

### **2.6. Cloud computing for Ethiopian Higher Education Institutions**

#### **2.6.1. Higher education in Ethiopia**

Ethiopia possesses a 1,700 year tradition of elite education linked to the Orthodox Church. But secular higher education was initiated only in 1950 with the founding of the University College of Addis Ababa. During the following two decades half a dozen specialized technical colleges were established. The nation's new HEIs strived, with considerable early success, to maintain international standards. But the cost was high. Awareness of the need for reform began to grow. Unfortunately, these incipient reforms were truncated by political events. As the 20<sup>th</sup> century drew to a close, Ethiopia found itself with a higher education system that was regimented in its management, conservative in its intellectual orientation, limited in its autonomy, short of experienced doctorates among academic staff,

concerned about declining educational quality, weak in its research output, and poorly connected with the intellectual currents of the international higher education community.

Ethiopia is engaged in a highly ambitious effort to re-align its higher education system in more direct support of its national strategy for economic growth and poverty reduction [21]. Its achievements over the past ten years have been impressive. The reforms have targeted all levels: the overall system, the institutions, and the academic programs. At the system level, 31 public universities and many more private colleges now stand in place of the previous two-university system. An aggressive expansion policy designed to raise the country's insignificant tertiary enrollment ratio to more respectable levels is producing results. Private provision of tertiary education has been permitted by government as a key component of this expansion strategy. At the institution level, the newly developed Proclamations awards substantial autonomy to universities. Strategic planning, income diversification, and information and communications technology (ICT) development are being encouraged to meet the fiscal, space and instructional requirements of the on-going expansion.

Any national tertiary system would be hard pressed to substantially expand enrolments while maintaining levels of educational quality. Ethiopia faces a double challenge in that it seeks to accomplish this while also introducing major reforms in institutional governance, management and curriculum. If the bold vision contained stated in the Higher Education Proclamation is to have any chance of success, the solution to this double challenge will have to be found in the financing strategy that underpins these reforms.

It is commendable that public higher education is growing and access to education by citizens is expanding . While growth in the number of institutions and enrollment figures are remarkable, an emphasis remains to be equally placed on quality. Quality in teaching and research must be emphasized as much as expansion. Higher education is an expensive enterprise. Maintaining good quality teaching and research comes with a heavy price tag—for it requires the mobilization of large resources. Laboratories need to be equipped with up-to-date equipments and chemicals; a large sum of expensive journals, periodicals and books as well as effective library and information systems maintained; moreover high-level

experts, who are the cornerstone of any academic and research enterprise, need to be appropriately compensated and effectively mobilized. As much as the magnitude of funds that flows into a system is critical, the effectiveness in which these resources are utilized also matters significantly.

For economically challenged countries like Ethiopia, there is a pressing need to utilize the meager resources very wisely and strategically while at the same time, exploring and tapping external resources vigorously. It is important that the first approach thus should be creating an effective networking mechanism among HEIs across the nation in sharing resources and expertise. Second, and most importantly, it is my opinion that while research is carried out in all public universities—new and old, and also a very few aspiring private university/colleges—Ethiopia must seriously invest in building a few select research institutions, programs and initiatives with an unwavering determination to foster and nurture its strategic position and international competitiveness.

### **2.6.2. Cloud Computing for Ethiopian Higher Education**

As previously discussed literatures indicate, many organizations including education sector are shifting their ICT paradigm from traditional data centers to cloud based services for the improvement of services with lower costs and better efficiency. Ethiopia as a developing nation has suffered by limitation of educational budgets. HEIs are being built in very high speed. Currently there are around 31 government owned universities and many private colleges. Without quality education establishing educational institutions by itself can not give the solution we seek for economic development and poverty reduction through education. Education should be supported through up-to-date technologies and services. Ethiopian government has been investing millions of dollars every year to support education in higher education institutions with technology. However due to struggling economy it is not able to supply full ICT infrastructure requirements of all universities. As it has been discussed in the previous sections this infrastructure requirements can be solved using cloud computing strategy .i.e. implementing a central Hybrid Cloud Computing infrastructure that can be used by all HEIs of Ethiopia. The proposed Ethiopian Universities Hybrid Cloud combines private and public clouds. The

private cloud is implemented and managed by Ethiopian MOE in collaboration with higher education institutions. Every resource that can be shared by multiple universities will be placed at EUHC and then it will be available to all hosted universities. Example, it is true that Registrar System is required by every university, this means there is a need to buy the system for all 31 universities. If the registrar system for one university costs 4 million, as one of the interviewed ICT director told to the researcher then we can imagine how much cost we invest to deploy the system in all the 31 universities. But this cost can be significantly reduced by deploying a single copy of the Registrar System into the proposed EUHC cloud. The proposed EUHC has an interface from its Ethiopia Universities Private Cloud (EUPC) to public Cloud Service Providers. Whenever some resources can't be deployed into EUPC due to different factors then through the public interface it is possible to access the resource from other CSPs. By deploying Hybrid cloud computing model, the fear of privacy and other related security issues can be avoided, since critical and sensitive data could be owned by university members and responsible bodies from Ethiopian Ministry of Education.

## **2.7. A Cloud Computing Adoption Strategy for Higher Education**

Migrating towards cloud needs a well defined strategy that supports Cloud Computing capabilities. Representing an important part of the organization IT strategy [25], migration must be aligned to this strategy. The success of the strategy implementation depends on the existence of a service-oriented architecture at the level of the institution that offers the necessary infrastructure for cloud implementation.

Without SOA and BPM (Business Process Management), migrating towards cloud has no sense from the financial point of view because it leads to high costs with reengineering of existent systems [26]. Also, in order to have success, the cloud strategy must be aligned with the university strategy. Starting from the recent researches related to the transition to Cloud Computing and the experience of universities in using it, the researcher suggests a migrating strategy towards cloud, having the following phases (figure 7):

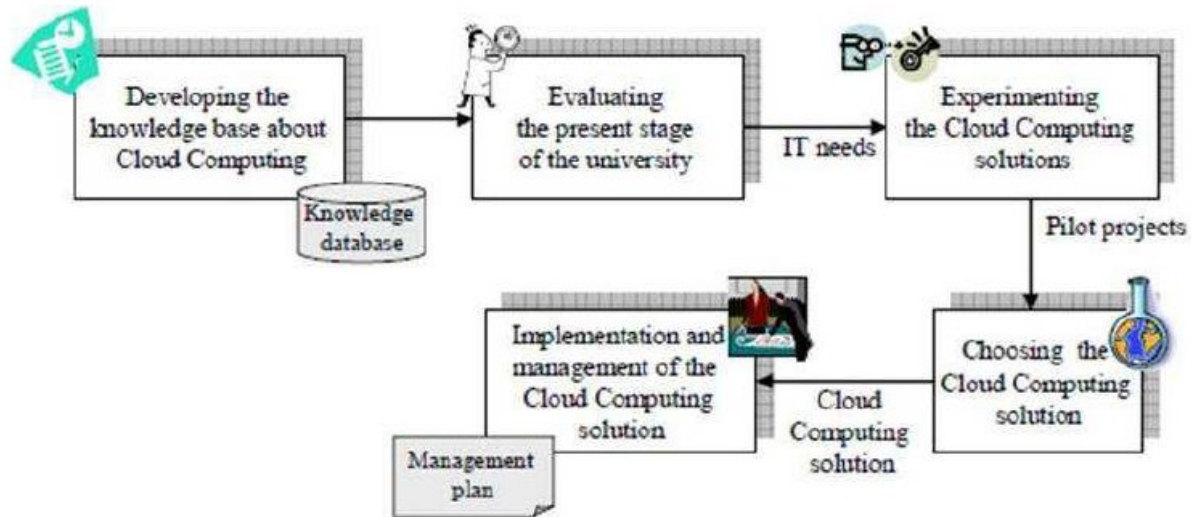


Figure 7. A Cloud Computing Adoption Strategy for Higher Education

a) Developing the knowledge base about Cloud Computing; The first step consists in developing the knowledge base by participating at seminars, conferences, discussions with the suppliers and consulting the most recent researches in the field. The success of the phase depends on the allocation of sufficient resources for research, for understanding how Cloud Computing functions in different organizational structures from universities and between institutions [26], the benefits and risks, policies and the best usage practices of Cloud Computing. The research is conducted by a team formed mainly of IT staff who permanently communicates with the users of the solution regarding the objectives, the progress, costs and benefits of the Cloud Computing solution.

b) Evaluating the present stage of the university from the point of view of the IT needs, structure and usage. The first step consists in understanding the university IT infrastructure. The service oriented architecture represents the base for understanding the data, services, processes and applications that may be migrated or need to be maintained within the university, so as to observe the security policy. With respect to the IT needs, their structure and usage, the analysis may start from the categories of users who interact with the present IT infrastructure and their necessities.

c) Experimenting the Cloud Computing solutions; by developing pilot projects test the project in cloud computing models.

d) Choosing the Cloud Computing solution; after having experimented results of cloud computing solution in the previous phase, selection and of the right cloud computing solution is identified and used in this phase.

e) Implementation and management of the Cloud Computing solution; finally implementation and management of the cloud computing solution are performed in this phase.

## **2.7. Related Works**

Regarding benefits and challenges of adapting Cloud Computing for the universities, [27] discussed the possible offerings that Cloud Computing could deliver, especially in Malaysian Universities. The 21st century students are not satisfied with the traditional learning process; thus, the researcher used Cloud Computing to enhance the learning environment by using Cloud Computing benefits in cooperation with the multimedia contents, and made the learning process highly interactive to meet student expectations. [27] Discussed more than ten Cloud computing offerings, pointing out that the Cloud Computing users gain the illusion of resource availability as an infinite on-demand resource, which enables storage and huge amounts of information on the Cloud. In addition, the researcher stated that introducing the students to Cloud technology will prepare them to work in the industry since they gained the skill of dealing with new technology. Cloud Computing offers cost-effective solutions for Universities, staff, and students since all of the needed hardware and software are available via the Cloud, which makes their files highly portable, easy to share while computing power is easy to manage. Additionally, [27] claimed using Cloud Computing would improve collaboration and communication in the learning environments. On the other hand, he clearly stated that the Cloud Computing has some drawbacks: need for Internet connection and trust in the CSP service availability, privacy of the data, and security.

[29] Built Open-source software (OSS) for e-learning based on Cloud Computing in China. The researchers proposed the EduCloud platform to launch their e-learning environment on a public Cloud, using IaaS and SaaS to overcome resource limitation and lack of e-learning scalability. The researchers constructed their solution using Hadoop with two interfaces which were mapper and reducer. EduCloud consists of a set of tools and technologies to build a virtual and personal learning environment; thus, it focuses on migration of the current application to a Cloud based one via the SaaS level, especially interactive and collaborative applications, such as Sakai and Moodle which are Course Management Systems (CMS).

Research by [32] focused on the effectiveness of using IaaS and PaaS in educational fields, specifically in teaching advanced Computer Science courses. The researcher selected eighty four students and four professors to perform advanced network courses on probing with routing algorithms assignments and then evaluated which way of teaching was easier—the traditional system setup, IaaS, or PaaS—through a survey. The author claimed that there was no comprehensive evaluation of the Cloud's usage advantages. In addition, the author mentioned the lack of identifying the appropriate service level of the Cloud abstraction which is the most effective and useful in educational fields. In this research, the researcher presented how the Cloud utilization enhanced students' outcomes, and the researcher also identified the most appropriate service in education. As a conclusion, the researcher highlighted that using Cloud Computing helps students to focus on the giving tasks with saving their time from dealing with non-related issues. PaaS is easy to learn, and it is prevalent choice for the high level courses which the students do not need to deal with the hardware level; otherwise, IaaS is appropriate for the medium level courses, such as Operating System, Software configuration in which we need to touch on the details of VM level.

[33] Discussed the suitable Cloud application used to construct a collaborative learning environment. They illustrated benefits of using Cloud Computing, such as solving the network storage when dealing with massive resources. Additionally, the researchers have focused on reasonable construction of the learning environment to utilize all the needed

educational tools accessible via Cloud Computing. To achieve such construction, the researchers proposed four basic principles, to take full advantage of Cloud Computing in the learning environment. The basic principles illustrated are learner centered which secured an exclusive analysis to apply the appropriate content, resources, and activity design that satisfied the learners' requirements, the rationality of navigation settings by unified interface structure, collaborative and sharing of E-learning by designing around the sharing principle, and the effectiveness of teaching resources by updating the resources continually. The researchers proposed a "Collaborative Learning platform" using Google's Cloud Computing; since the collaboration is a Google-centric platform, it enhanced collaboration and sharing principles in the proposed platform.

## **CHAPTER THREE**

### **3. Cloud Service and Cloud Service Provider Selectoin**

#### **3.1. Identifying the type of Services the Cloud Provides**

To identify the potential cloud services that can be provided to university community, the researcher started by analyzing the requirements of universities by means of interview and looking at companies and universities with best cloud service practices. The analysis process was based on interviewing ICT directors from selected universities, reviewing best cloud service practices of business companies and universities around the world. Accordingly the proposed cloud computing framework .i.e. Ethiopian Universities Hybrid Cloud (EUHC) provides the following services for EHEIs after implementation.

##### **3.1.1. Software as a Service (SaaS)**

SaaS is one of the service deployment mechanisms which enable user's access different softwares from the cloud wherever they are, and whenever they need without installing it on their machine. In SaaS users can access different software from the cloud:

- Office applications
- Simulation softwares
- Enterprise Resource Planning
- Information system applications for different offices, like registrar systems, finance systems, Classroom management system.

##### **3.1.2. Platform as a Service (PaaS)**

PaaS is a virtualized platform that comprises one or more servers (virtualized over the set of physical servers), operating systems, programming languages, and specific applications (such as Apache and MySQL for Web-based applications). In some cases, It can provide a VM image that contains all the necessary user-specific applications. Platform as a service comprise a layer of software and provides it as a service that can be used to build higher-

level services. There are at least two perspectives on PaaS depending on the perspective of the producer or consumer of the services:

- The person producing PaaS might produce a platform by integrating an OS, middleware, application software, and even a development environment that is then provided to a customer as a service.
- The person (users in Universities) using PaaS would see an encapsulated service that is presented to them through an interface. The customer interacts only with the platform through the interface, and the platform does what is necessary to manage and scale it to provide a given level of service. The Virtual appliances can be classified as instances of PaaS.

Using the cloud, Students and developers do not need to physically install any specific services, solution stacks or databases on their machine. It provides the images to students where they can simply select these images and use them on a machine provided in a cloud.

- Services
- Solution Stacks
  - Java
  - PHP
  - .NET
- Storage
  - Databases
  - File Storage

### **3.1.3. Infrastructure as a Service (IaaS)**

IaaS is the delivery of computer infrastructure as a service. Infrastructure as a service offers computing capabilities and basic storage as standardized services over the network. Servers, storage systems, switches, routers, and other systems are reserved and made available to handle workloads. IaaS clouds make it very affordable way to provision

resources such as servers, connections, storage, and related tools necessary to build an application environment from scratch on-demand.

The benefits of IaaS include rapid provisioning, ability to scale and pay only for what you use. By moving your infrastructure to the cloud, you have the provision to scale as if you owned your own hardware and data center (which is not realistic with a traditional hosting provider) but you keep the upfront costs to a minimum.

EUHC delivers different infrastructure at one place. It provides a platform (internally no physical infrastructure) virtualization environment in the Universities. Using this, student and other users need not to set up any specific physical infrastructure for their project, assignment and related work. EUHC provides the following services for infrastructure as a service.

- Compute
  - Physical Machines
  - Virtual Machines
  - OS-level virtualization
- Network
- Storage

### **3.2. Selecting Cloud Service Providers**

Identification and selection of clouds is started by analyzing the cloud service provider (CSP) that can best provide Platform as a Service since it is the most appropriate layer to deploy the framework .

Afterward, the researcher includes those clouds that afford a great amount of service. At the last stage, CSP selection was depending on the ease of the use and the existence of ongoing technical support services. Our cloud candidates are Amazon clouds, IBM clouds and Windows Azure. In the following sub sections, there are some details about each CSP's candidates.

### 3.2.1. Amazon Cloud Services

Amazon is one of the leading companies in the field of Cloud Computing. Amazon announced Amazon's Elastic Compute Cloud (EC2) in 2006 [25]; [26].

It delivers services through Amazon Web Services (AWS) considered mainly as an IaaS layer. AWS provides flexibility, cost-effectiveness, scalability, elasticity, and security [27]; [28] services which allow the user to manipulate the VMs sitting and configuration with a highly scalable platform.

It also supports queuing, scheduling, and caching details to deal with operating systems and networking issues. Amazon Cloud provides a PaaS layer, where the user can develop and deploy their Linux-based applications with high availability to assure the customer's trust [30]. Moreover, AWS provides a platform to deal with the database, SimpleDB. This service provides tools of relational database functionalities [30]. AWS provides scalable, elastic, and reliable resources [31], and it offers infrastructure as a service which include:

- Servers: Amazon Elastic Compute Cloud (Amazon EC2) is one of the AWS that offers resizable compute power. Using EC2, the user will be able to build one, hundreds, or even thousands of servers within minutes.
- Storage: Amazon Simple Storage Service (Amazon S3) is a web interface. It provides a storage service which can store and retrieve stored data on the web.
- Operating Systems: AWS permits the user to choose from a wide variety of available operating systems already built in AWS. In addition, it allows the user to use different OS for one application.
- Networking: Different services provide diverse networking services, such as Amazon Virtual Private Cloud (Amazon VPC) which uses a Virtual Private Network (VPN) connection to isolate the IT infrastructure and the AWS infrastructure and Amazon CloudFront which delivers the content base on the client location to improve the response time.

In Amazon Cloud, the security starts from attaining different certifications which present the efficiency of AWS internal control, such as SAS-70 Type II certification. Besides the achieved certifications, AWS is looking to acquire the strictest certifications in the industry world to guarantee the security of Cloud Computing environment which is still questionable. The second step is to guarantee that the security in AWS has the highest level of restrictions on the physical data centers access. Adding to data center security, backup services store Amazon Simple Storage Service (S3), Amazon SimpleDB, and Amazon Elastic Block Storage automatically in multiple physical locations repeatedly.

### **3.2.2. IBM Cloud**

IBM has multiple Cloud solutions to different problems, starting from simple SaaS applications such as Customer Relation Management (CRM) systems to complicated DB servers with different security tools. One of its Clouds called “SmartCloud” was developed for education purposes. SmartCloud provides services to design educational systems for schools and higher education without devoted staff or infrastructure. The IBM SmartCloud consists of a set of Cloud services for educators to follow and analyze student performance. In addition, it offers more effective research tools by maximizing resource availability; thus, it overcomes resource limitation in the local institutions' infrastructure. IBM SmartCloud provides the following solutions:

- SPSS Decision Management for Education: It is a Cloud based solution to analyze student information with different tools to identify students who will be enrolled in their institution by helping them maintain and succeed in their educational life and giving them appropriate information toward the right findings.
- Virtual Computing Lab (VCL): It provides different services and tools via the Cloud for students and staff research. VCL [32]; [34] Virtual Computing Lab, 2011 is simple to implement and maintain compared to other available solutions, flexibility, cost effective solution, and wide resources. VCL offers all of the three Cloud services: IaaS, PaaS, and SaaS. On the top is the infrastructure service which prevents students and staff from setting up any software or hardware on their compute while

doing their assignment or research. VCL provides the following services for infrastructure:

- ✓ Compute resources, such as physical machines, virtual machines, and OS in the virtualization layer.
  - ✓ Network.
  - ✓ Storage
- Cloud Academy: This service provides the needed support to customers who wish to move to a Cloud and share their knowledge. It supports technical and business projects by allowing access to resources with the funding possibilities.

IBM assists the institutions and companies in their process of moving to the Cloud by helping to build strategies, developing architecture, selecting the right workloads, determining a suitable deployment model—whether private, public, or hybrid Cloud—and managing their Cloud [35].

### **3.2.3. Windows Azure cloud**

Windows Azure platform [36] provides friendly interfaces to deal with the heart of PaaS in developing and deploying differently .NET applications start from very simple Hello World applications to distributed relational databases. One of Windows Azure's services is SQL Azure, which presents DB services from building the DB to deploy it and scale it through Microsoft data centers. SQL Azure includes relational database services, such as reporting, querying, and data synchronizing. Windows Azure offers several features including computing resources, storage, database, Virtual Machines (VMs), access control, Content Delivery Network (CDN), caching, virtual network, service bus, business intelligence, and market place. Windows Azure was built to help developers succeed in their application, especially for the developers who build remote data center applications by providing different tools. Windows Azure provides a platform service which includes operating systems, a set of developer tools, and different levels on network controls to develop, host, scale, and manage developed applications on web and non-web environments [30]. Thus,

students will focus on developing the assignment without any pre-configurations for specific software or hardware.

In addition, the Windows Azure platform offers prebuilt sub-programs which often represent reuse functionalities to save the developers' time and let them focus more on their projects. By using Windows Azure, the institutes and universities do not need special equipment or infrastructure; all they need is Internet connection.

### **3.3. Pilot Proposed Services of the Cloud**

#### **3.3.1. Database Development Service**

Using the cloud, database developers can create databases; link different databases from diverse locations implement and maintain relational databases, and retrieve information using Structured Query Language (SQL) with PHP to connect the databases in the Internet.

IBM Clouds offers a database solution by providing DB2 images in their available instances which represents the OS. Students and developers need to create their databases by adding DB2 images [37] as shown in the next figure:



Figure 8. Select a DB2 image from IBM's Clouds to setup the operating system

After naming the image, students and developers should be aware of the security of their databases by creating private and public keys with configuring the DB2 image shown in the next figure:

**IBM** Close [x]

## Add instance

Step 2 of 4: configure image

**You selected: DB2 Enterprise Developer Edition 9.7.1 64bit**  
 This image contains DB2 Enterprise component of IBM Database Enterprise Developer Edition (DEDE) and is built on RHEL 5.4 64bit. Use this image to design, prototype, develop, and test database applications (non-production use). Build 3.2.sby

Complete the fields below to configure your instance selection. Required fields are indicated with an asterisk (\*).

<b>Request Name:*</b>	<input type="text" value="dW DB2 data server"/>
<b>Quantity:*</b>	<input type="text" value="1"/>
<b>Server Size:*</b>	<input type="text" value="Bronze 64 bit"/>
<b>Expires on:*</b>	<input type="text" value="10/9/10"/>
<b>Key:*</b>	<input type="text" value="dW key (default)"/> <span>+ Add Key</span>
<b>Select IP:*</b>	<input type="text" value="system generated"/> <a href="#">How do I add an IP?</a>
<b>Mount Storage:</b>	<input type="text" value="Choose one"/> <a href="#">How do I add Storage?</a>
<b>Image ID:</b>	<input type="text" value="10010275"/>

← Previous    Next →    × Cancel

Figure 9. Configure the DB2 image from IBM's Clouds to deploy SQL and PHP example [37].

The access permissions must be identified. DB2 images give the ability to set three different access levels: the owner, administrator, and user. The password should be entered for each access level. Then, students can start to write the PHP and SQL codes using their user name and password on the Cloud interface.

Windows Azure also has another solution which provides a database solution with a user friendly interface as shown in the next figure:

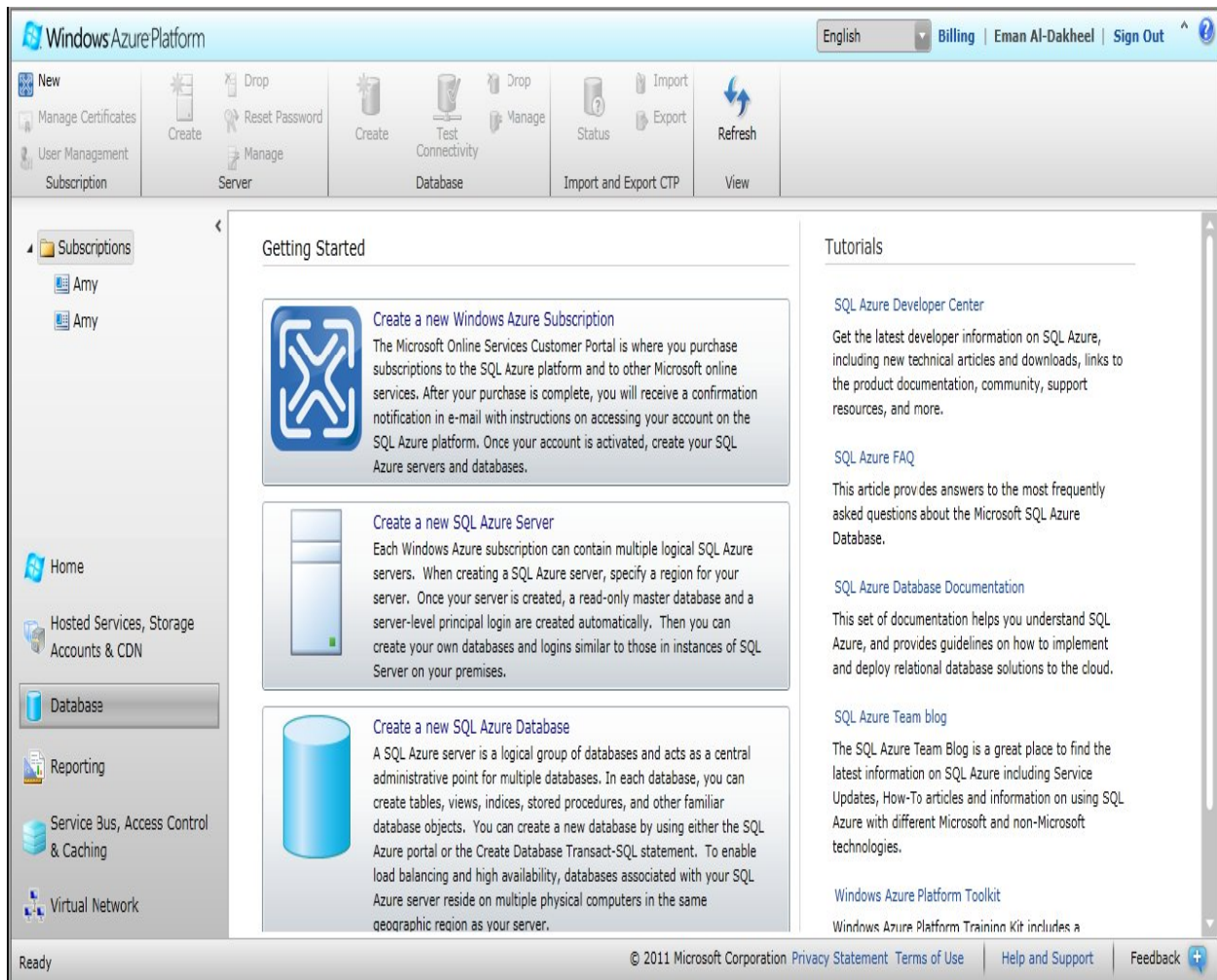


Figure 10. Windows Azure database solution interface snapshot

Building a database using Windows Azure is started with creation of a subscription followed by creating the server with the access levels and their passwords. Then the databases are created using a .NET framework after connection of the .NET to the created server.

### 3.3.2. Operating Systems Service

Operating Systems is one of the most beneficial service from Cloud Computing since most of CSPs who provide platform as a service (PaaS) are providing a variety of operating systems in image form; the students and other cloud users can perform multiple exercises and programming assignments on the available operating system images. Doing so will expose the students to in-depth knowledge in different operating systems and their performances and compatibility.

Without the Cloud, students simulate the behaviors of different scheduling algorithms using any programming language, virtual memory, or device management, and so on, but using Cloud Computing, students will experience building and testing a real algorithms which perform on any local or distributed systems.

To start programming with Amazon, the service selection comes first. Each service is presented in the AWS interface as shown in the next figure:

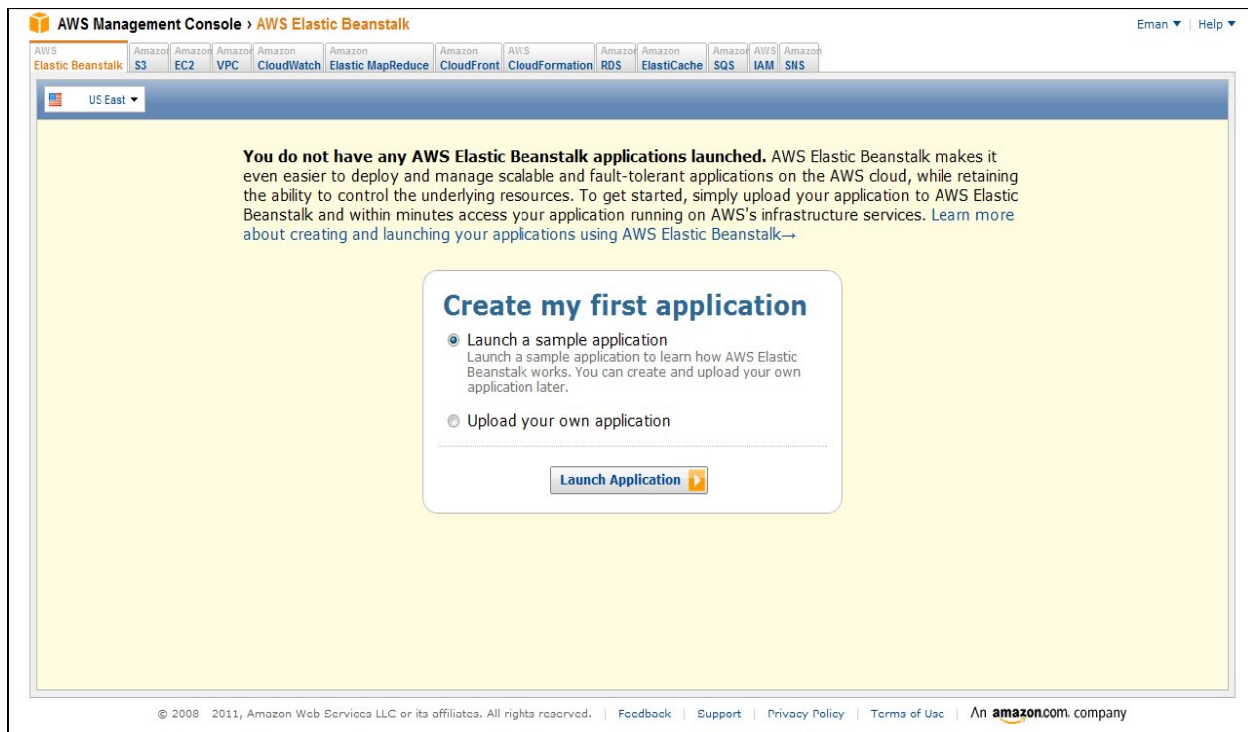


Figure 11. AWS interface with the selection of Elastic Beanstalk tap

Followed by the service selection, the user has to choose an appropriate Amazon Machine Image as illustrated in the next figure or the user can upload a specific created image from his/her local device to AWS. Then they need to specify the number of needed instances with the availability zone and type. After finishing, the entire wizard provides the details report about the selected instances given.

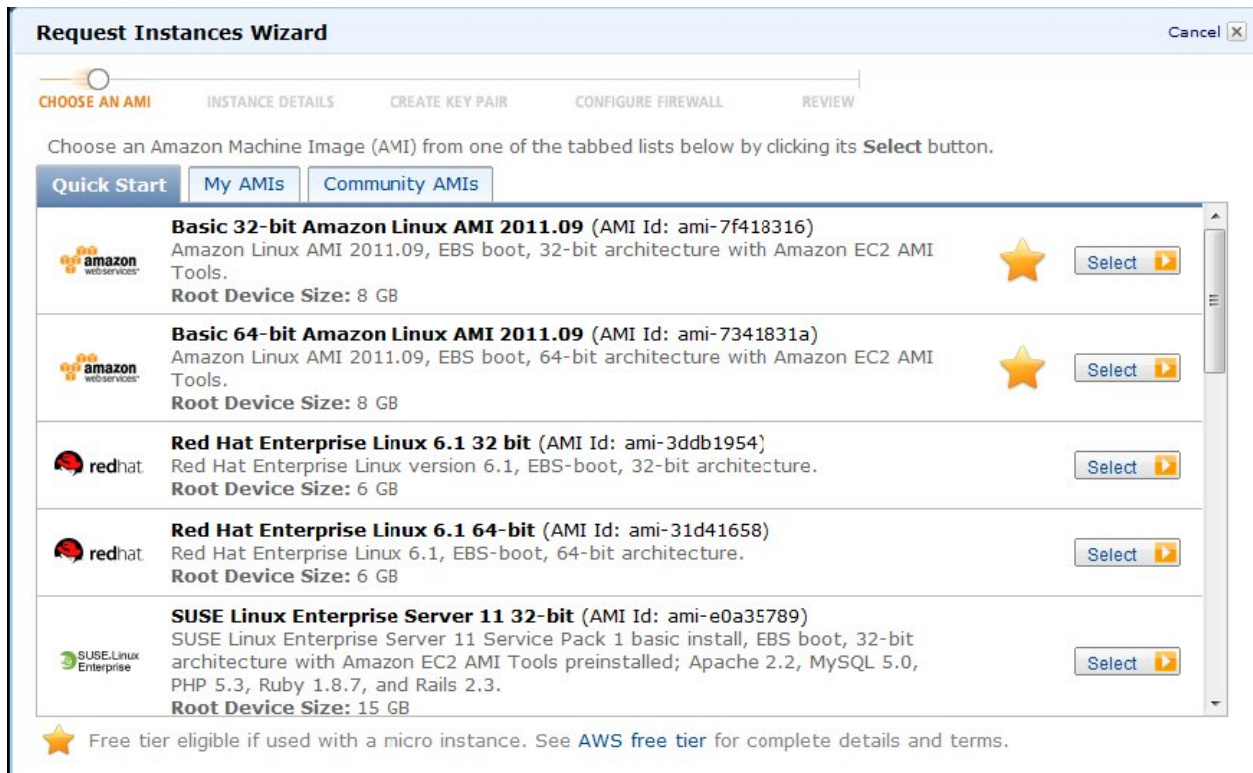


Figure 12. Operating system instance to choose from available virtual machine

### 3.3.3. Data Communication and Network Services

Amazon [38] is a rich environment to train students and professionals on practical applications for building networks since they are providing the service of building virtual networks, allowing students to apply many of the practical examples:

1. Routing
2. Scheduling
3. Network Topology

4. Security and network protection
5. Arrangement and distribution of IPs

Some of these services are shown in the next figure which represents available services on the Amazon Virtual Private Cloud (VPC).

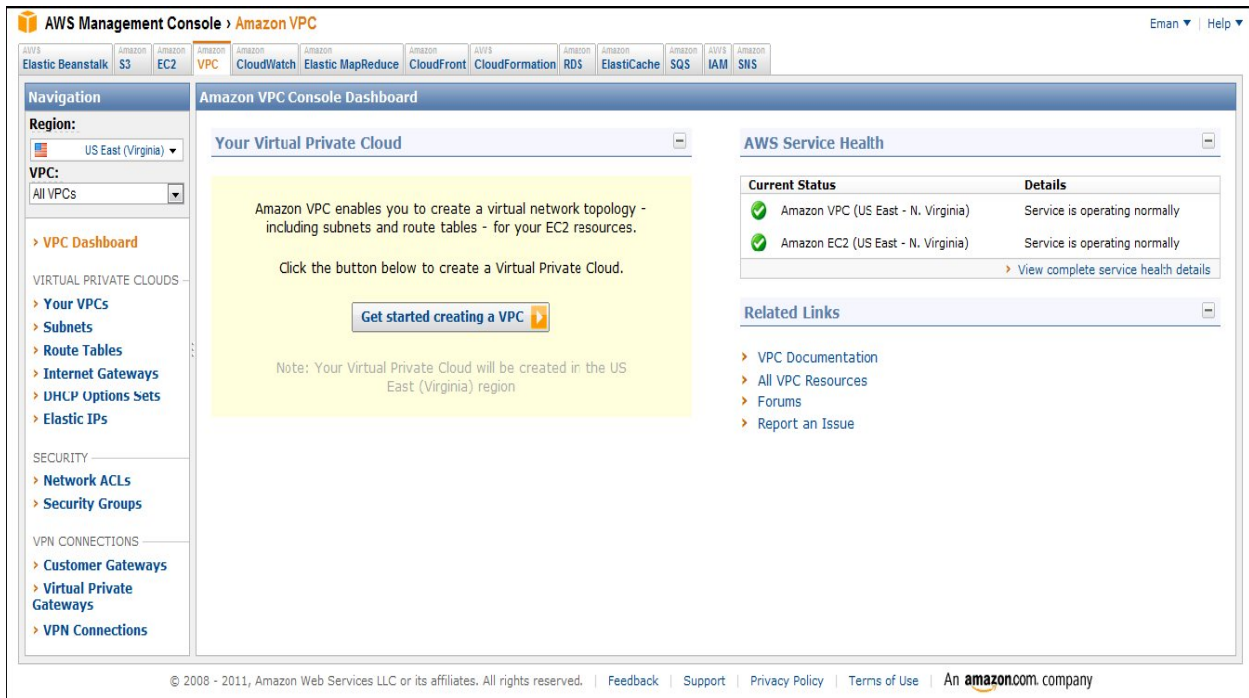


Figure 13. Amazon Virtual Private Cloud (VPC) service interface snapshot

Furthermore, there are several different deployment scenarios for creating VPC which mix and match Amazon public Cloud and private Cloud (local institution's IT) as shown in the following figure:

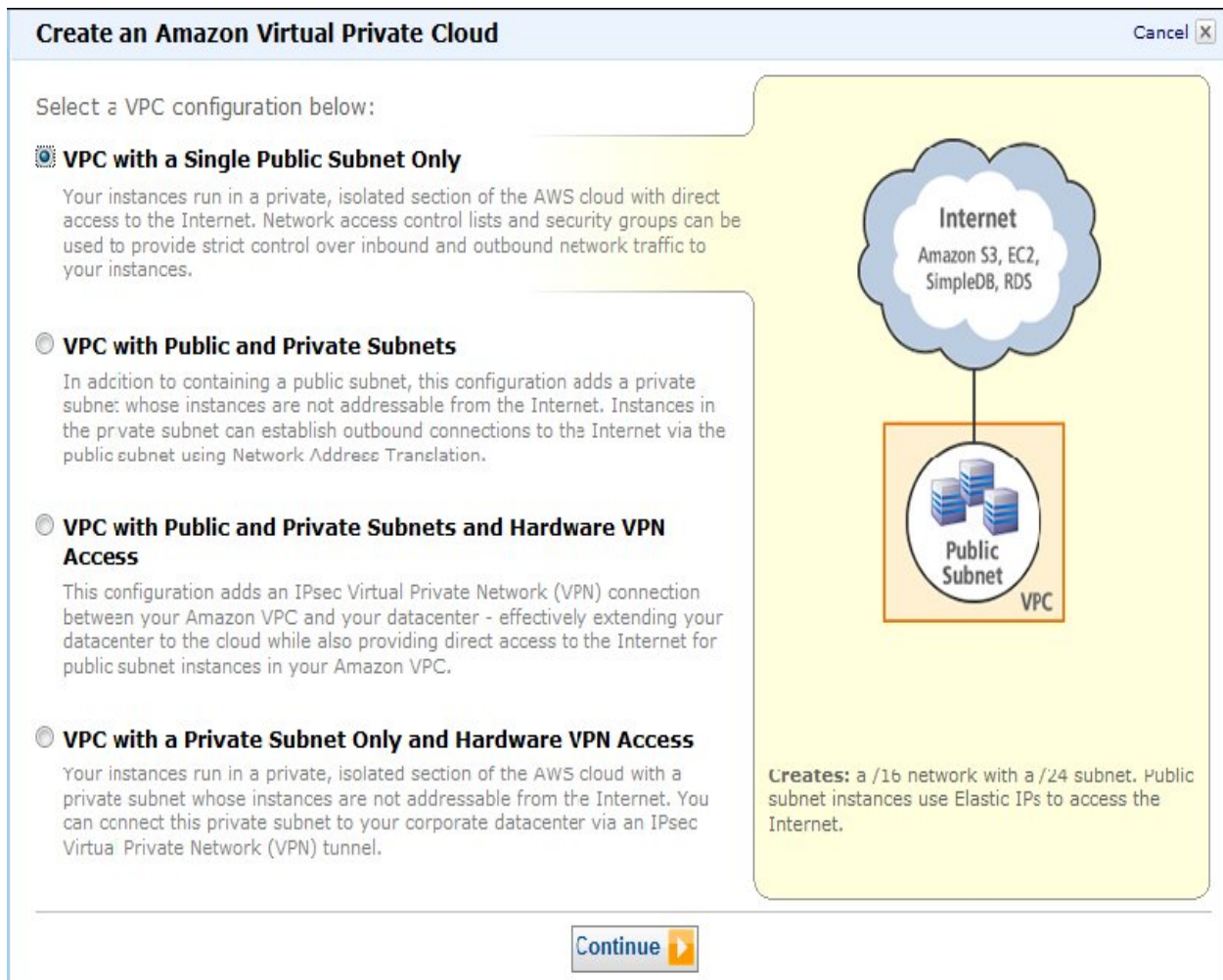


Figure 14. Select deployment methodology of the virtual private Cloud snapshot

### 3.3.4. Information Management Systems

Various information systems (e.g. Registrar Systems, Enterprise Resource Planning systems, Classroom Management Systems) will be deployed and used by cloud users. Relevant Information Systems will be placed in the cloud and users from Higher Education Institutions would access it, instead of deploying the information system for each institution that costs the no of institutions times unit price of the system.

## **3.4. Toolkits/Frameworks For Simulate Cloud Computing**

### **3.4.1. CloudSim**

It is a toolkit for a novel framework to simulate the infrastructures and the Cloud Computing management services. CloudSim is an open source and extendible simulation, allowing users and developers to do experimental studies on Cloud Computing infrastructure for different data center models, scheduling, and allocations policies [39]. In addition, it allows use of either the time sharing or space sharing allocation. CloudSim simulates the creation and deploys the VMs on a simulated node of any virtual data center which can be used to ensure the Service Level Agreement (SLA) and the Quality of Service (QoS) for user requirements [40]. Furthermore, it allows the migration of VMs to guarantee reliability in keeping the automatic scaling feature and the bottleneck discovery.

### **3.4.2. GreenCloud**

GreenCloud is a simulator built to reduce the power consumption in Cloud Computing data centers which the Cloud's infrastructure designer can use to direct them. It is a tool to reduce the power consumption [41] by applying different typologies until it finds a suitable one with an acceptable level of energy consumption with accepted QoS. GreenCloud intends to indicate the consumed energy by the data center components, such as servers and switches. It allows utilizing the power by voltage and frequency scaling, and dynamic shutdown on all data centers' components, especially the computing and networking components which consume the power primarily [42]. The energy consumption analysis is visualized [43] in Graphical User Interface (GUI).

### **3.4.3. OpenNebula**

OpenNebula is the open-source industry standard for data center virtualization, offering the most feature-rich, flexible solution for the comprehensive, complete management of virtualized data centers to enable on-premise IaaS clouds in existing infrastructures. OpenNebula interoperability makes cloud an evolution by leveraging existing IT assets, protecting your investments, and avoiding vendor lock-in.

OpenNebula can be primarily used as a virtualization tool to manage your virtualized infrastructure in the data center or cluster, which is usually referred as Private Cloud. OpenNebula supports Hybrid Cloud to combine local infrastructure with public cloud-based infrastructure, enabling highly scalable hosting environments. OpenNebula also supports Public Clouds by providing Cloud interfaces to expose its functionality for virtual machine, storage and network management.

#### **3.4.4. Aneka**

Aneka is a platform for deploying Clouds developing applications on top of it. It provides a runtime environment and a set of APIs that allow developers to build .NET applications that leverage their computation on either public or private clouds. One of the key features of Aneka is the ability of supporting multiple programming models that are ways of expressing the execution logic of applications by using specific abstractions. This is accomplished by creating a customizable and extensible service oriented runtime environment represented by a collection of software containers connected together. By leveraging on these architecture advanced services including resource reservation, persistence, storage management, security, and performance monitoring have been implemented. On top of this infrastructure different programming models can be plugged to provide support for different scenarios as demonstrated by the engineering, life science, and industry applications.

## CHAPTER FOUR

### 4. Cloud-Based Services in Ethiopian Higher Education Institutions

#### 4.1. Building the Framework

Due to different factors, it is true that ICT usage in Ethiopian Higher Education Institutions in its current situation is very primitive, as discussed in previous sections. Harnessing the Cloud Computing technology for delivering different services such as e-learning environment, Class Room Management Systems, Enterprise Resource Planning Systems, researching and similar services will give more flexibilities and dynamic resource utilization which solves the scalability issues. Then the Virtual University Services on top of Cloud Computing layer helps to solve limitations of the current IT service deployment scenario. The next figure shows a general layout of the new Ethiopian Universities Cloud Ecosystem based on the cloud computing with an interface layer to control the user's access to different services.

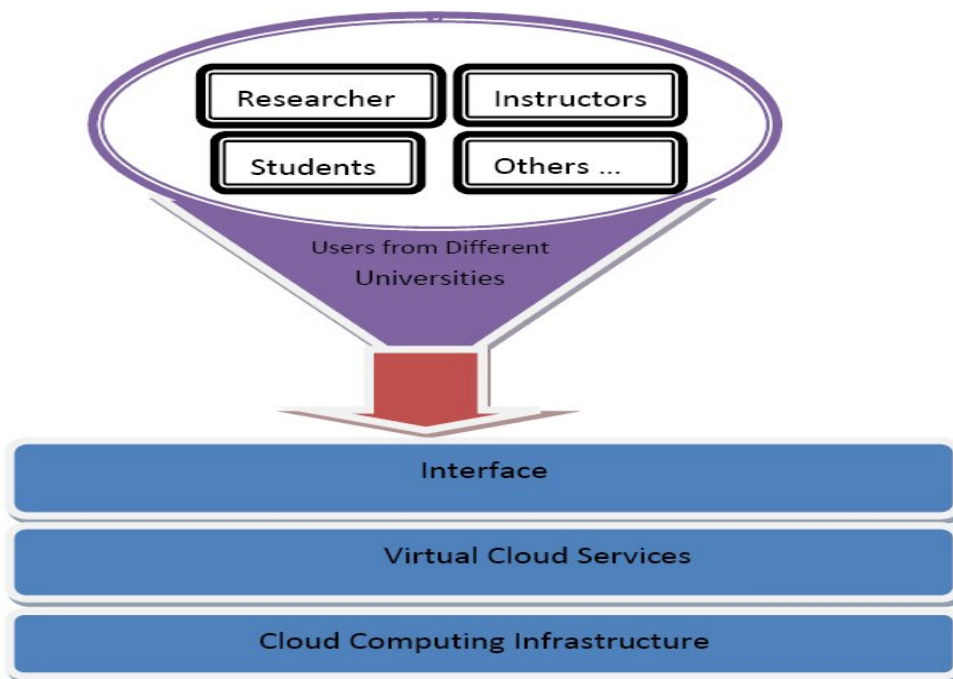


Figure 15. Cloud-Based Virtual Services Architecture

Applying the Cloud based architecture deployment of ICT infrastructure to Education System will result in adding the required service in the appropriate layer through the interface. Using this architecture will enhance the QoS for adding more students and more multimedia content. In addition, video streaming will be performed better when utilizing the Cloud infrastructure [44]. Using Cloud-Based Service for Users not only demonstrates the benefit of the underlying infrastructure [45]; [46]; [47]; [48], but also gains more and more solid base real world practical experiences and management skills by utilizing Cloud services.

Based on the identified services and selected Clouds, the researcher proposed a Cloud Computing framework Ecosystem for EHEIs. The teaching-learning components, infrastructure, and their Learning Management System (LMS) are called the “Virtual Teaching - Learning ecosystem” [49]. The following figure shows the Ethiopian Universities Cloud framework.

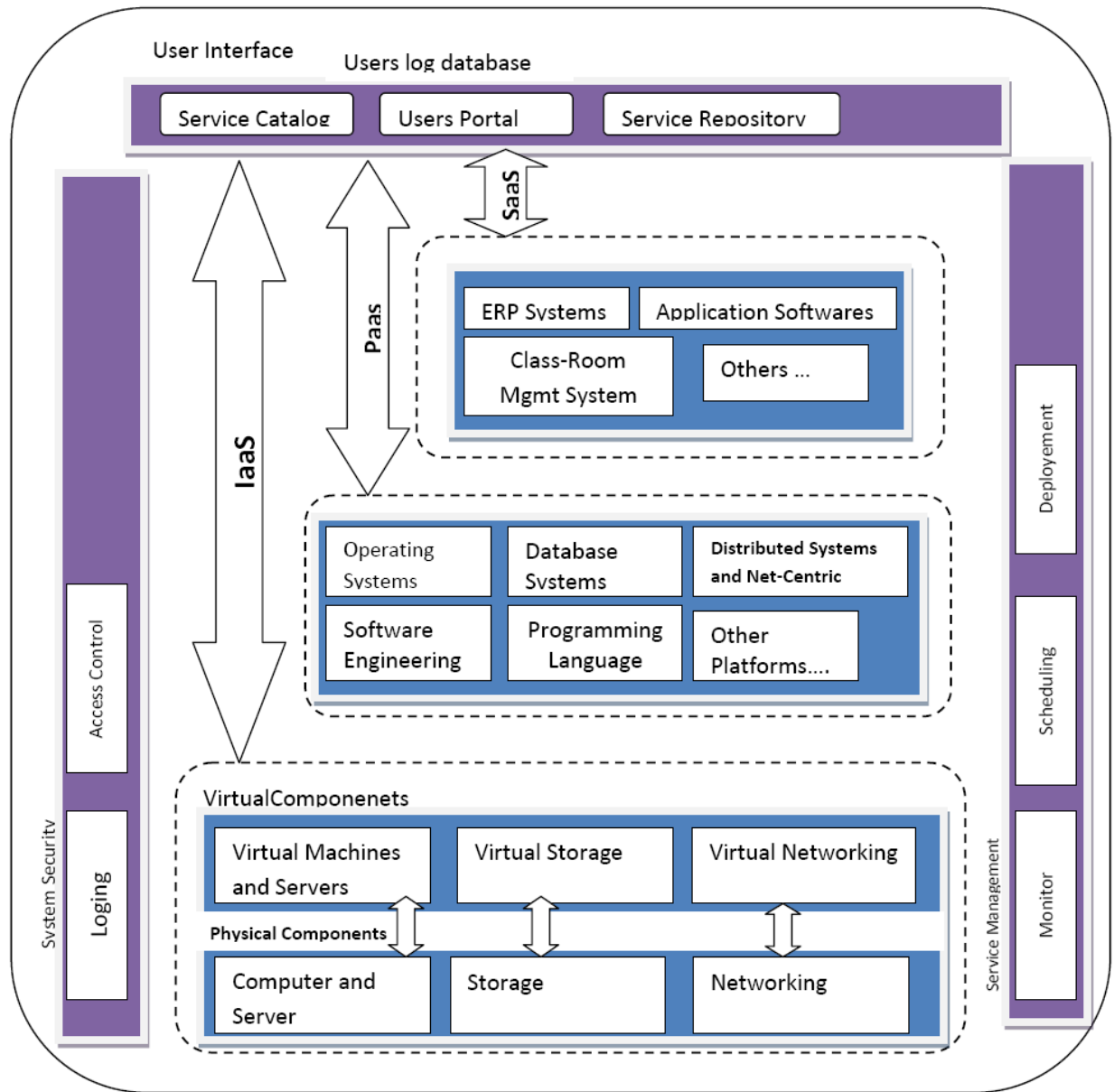


Figure 16. Virtual Higher Education Services Ecosystem for Users on Cloud Computing

The presented framework namely Ethiopian Universities Hybrid Cloud (EUHC) contains four layers (User Interface, SaaS, PaaS, and IaaS) and three modules (User log database, system security, and service management):

#### 4.1.1. User Interface Layer:

A user Interface represents Learning and system interaction Management System since it

acts as an interface between the user and the Cloud content. The User Interface layer contains three important components:

- User Portals: provide an access path to specific web applications or services since everything is located on the web and can be accessed using a network connection.
- Service Catalog: contains different types of services with detailed information about the additional access information, such as what layer the service is located and who can access this specific service.
- Service Repository: composed of different services like softwares, courses content, etc. categorized and arranged depending on the service name and access level which may be in one of the three other layers (SaaS, PaaS, or IaaS).

#### **4.1.2. SaaS Layer**

This layer provides access to hosted programs–applications or tools on the Cloud. ERP systems, Class room Management Systems, and other Application Softwares can be hosted at this layer. Using Microsoft Word or Microsoft Access, for example, as a hosted application on the Cloud by SkyDrive [50] or Google Apps [51] is considered as a component for this layer.

#### **4.1.3. PaaS Layer:**

This layer provides access to different platforms- programming language, distributed systems, netcentric systems and similar platforms. For example for students taking Distributed Systems, Building a distributed system or simulation needs control of the number and the IPs for the VMs with a platform to host the developed application. For the Information Systems Management and DB systems, they are able to build more sophisticated systems and distributed DBs using different tools to manage these systems and DBs. They can use different programming languages to build an application or system on the provided platform for the PaaS level. In the PaaS level, the user can access the VM level with some limitations, and with this access, they are able to control part of the networking issues, such as IPs and routing mechanism which help in teaching Net-Centric

Computing courses for the beginner. For the Computational Science course, they can build a temporary multiprocessing system using multiple VMs to solve an existing problem quickly and efficiently. Researchers and developers use SaaS for their work simply by connecting to the cloud.

#### **4.1.4. IaaS Layer:**

The IaaS level gives more flexibility when dealing with the Hardware layer but through the virtualization. Now, we have reached the point where we have to build the servers and set up their configurations. Additionally, the user can deal with the fine details of the virtualization with some limitation which makes the virtualization step set in this level.

Additionally the proposed framework has system security module for maintaining the security of the cloud, ASrvice management module for monitoring, scheduling and deployment of services and users log database module for tracking users access to the cloud.

## **4.2. Implementation Proposal**

The proposed framework will utilize the existing IT infrastructure for institutions which would adapt the framework namely, Ethiopian Universities Hybrid Cloud (EUHC) as illustrated above. In such a situation, the framework needs to deploy a hybrid Cloud model which combines the local infrastructure as a private Cloud with selected public Clouds [52]. This mashup process combines multiple services [53] from different CSPs to serve students and other users from different universities to enhance the teaching-learning and service delivery.

Hybrid Cloud is one of the Cloud Computing deployment models. It provides the ability to access, manage, and use third-party (vendors) resources from multiple CSPs and combines them within in-house infrastructure (private Cloud). Using such a model allowed us to avoid lock-in and was blocked with one CSP by allowing mix and match services from

different CSPs. In addition, it will give us the ability to secure the institution's critical application and data by hosting them on the private Cloud without having to expose them to a third-party. With a hybrid Cloud model, the institution has more control of their system since part of the infrastructure is under their control. For this model, the research needs software which manages the complexities and the heterogeneity of this distributed data centers. The framework's candidate is an open-source project called OpenNebula which can support on-demand VMs provisioning, pre- configured, and manage groups of interconnected VMs; thus, OpenNebula enhances the integration of external providers (CSPs) to enable the selected model of deployment.

Managing Cloud's infrastructure is one of the top concerns in IaaS; consequently, the need for a virtual infrastructure manager was raised. Using OpenNebula gives the ability to manage the local infrastructure and establish the first step toward hybrid Cloud solution by interfacing with a remote Cloud site. OpenNebula's main role is to manage the VMs [55]. This management creates a life cycle for each VM [56]. The life cycle starts from the resource selection stage which results in a feasible placement on the selected VM by the scheduler. The VM is placed on the target physical resource which is considered as resource preparation in the second stage. After the VM placement, the VM creation stage boots the VM by the resource hypervisor. In the middle of the process, for example, the VM could be migrated to more suitable resources in the VM migration to optimize power consumption. The Final stage is VM termination which shuts down the VM image. The following figure shows the architecture of OpenNebula:

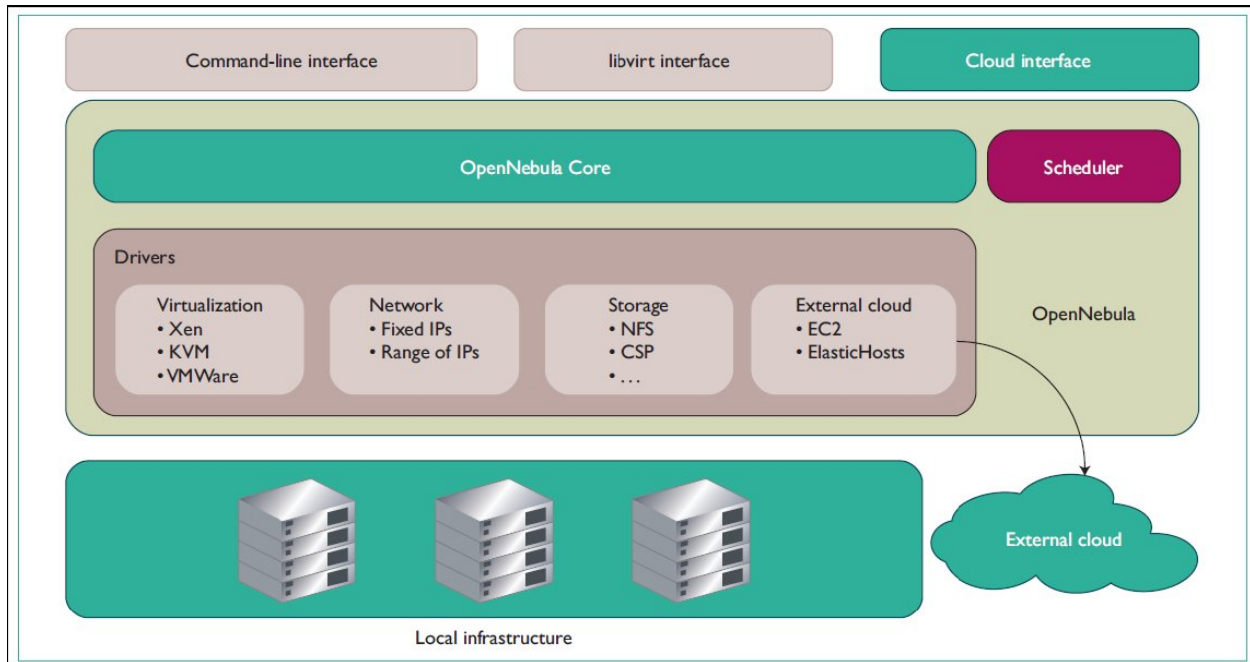


Figure 17. OpenNebula virtual infrastructure engine components [57]

The framework places as its base the hybrid Cloud. On top of OpenNebula, Aneka [58], Which is a platform for managing and programming applications that are built and deployed on the Cloud PaaS implementation solution, as the implementation model for the PaaS layer. Aneka provides software infrastructure for scaling applications using broad collection of APIs for the developers to design and implement applications. Aneka gives developers the ability to run their application on a local or remote distributed infrastructure which supports the hybrid Cloud deployment model. Transferring the current system or platform to be managed and accessible within Cloud technology is a very hard task. Therefore, it needs lots of planning, preparing, testing, and changing of the current layers and architecture of the platform to be compatible with the Cloud- based educational environment; furthermore, the need for a flexible, extensible, and accessible solution for developing and deploying the proposed framework is raised. The Aneka platform met the listed requirements mentioned above which made it one of the best solutions in our case. The Aneka platform [58] provides a flexible and configurable platform which supports multiple programming languages and gives the ability to develop and deploy the applications either on private or public Clouds as the following figure

shows:

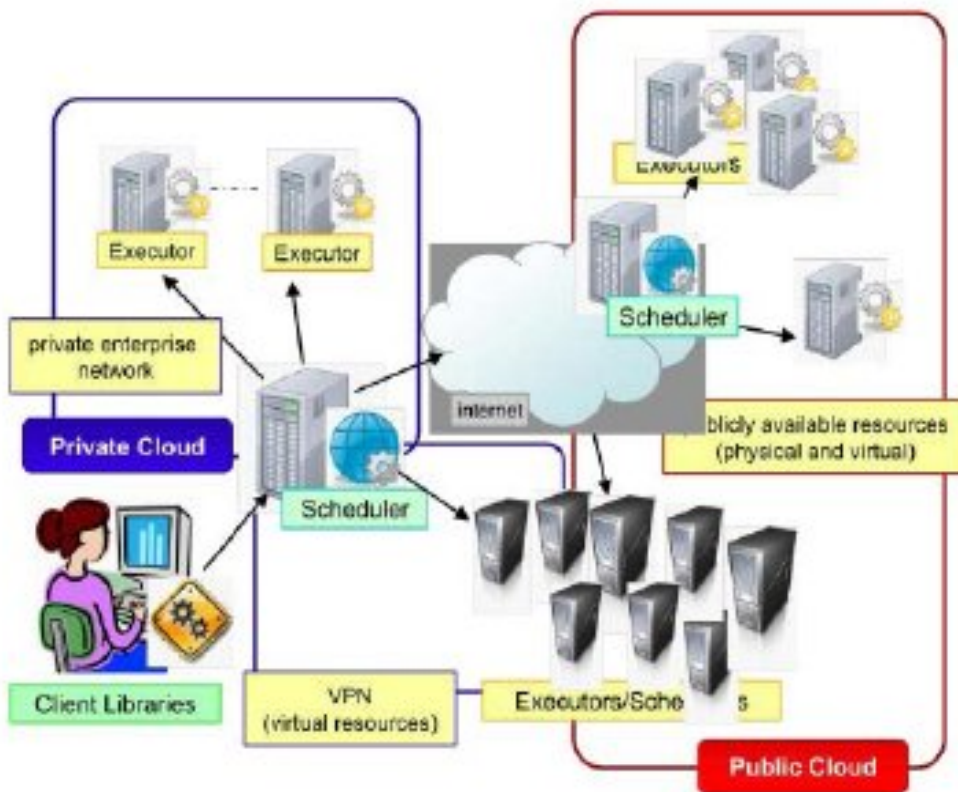


Figure 18. Typical Aneka Cloud deployment [58]

Since Ethiopian Universities IT infrastructure is heterogeneous including their workstations and servers, Aneka [58] is suitable to deal with such heterogeneity to maximize resource utilization in powerful manner as the following figure shows. Aneka was built on the service-oriented architecture which gave Aneka its extensibility to integrate different types of Clouds. The aneka framework architecture is shown below:

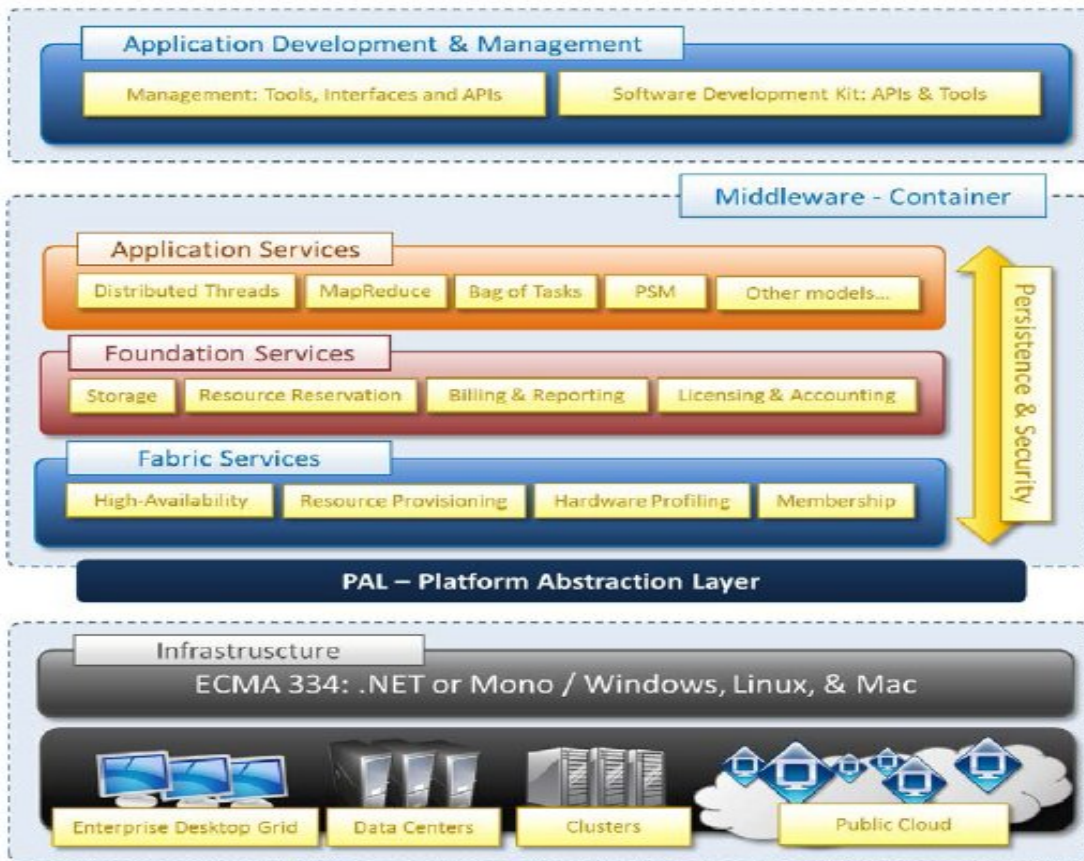


Figure 19. Aneka framework architecture [59]

As shown in the above layers corresponding to the basic service layers of the Cloud Computing easily integrated with the external Cloud. Aneka enables the execution of the application on its runtime environment by using the underlying Cloud infrastructure for either private or public Clouds. It provides management tools; administrators can easily start, stop, and deploy any application. The Aneka platform contains three classes of services which characterize its middleware layer:

1. Execution Services: Their primary responsibility is scheduling and executing deployed applications.
2. Foundation Services: They represent the collection set of management services, such as metering applications and resource allocation and updating the service registry whenever needed.

- Fabric Services: They present the lowest level of middleware services classes. They provide access to Cloud resource management to enable resource provisioning which will scale the allocated resources to the applications to achieve the required QoS.

The next figure shows an overview of the proposed Hybrid Cloud Computing model for Ethiopian Higher Education Institutions.

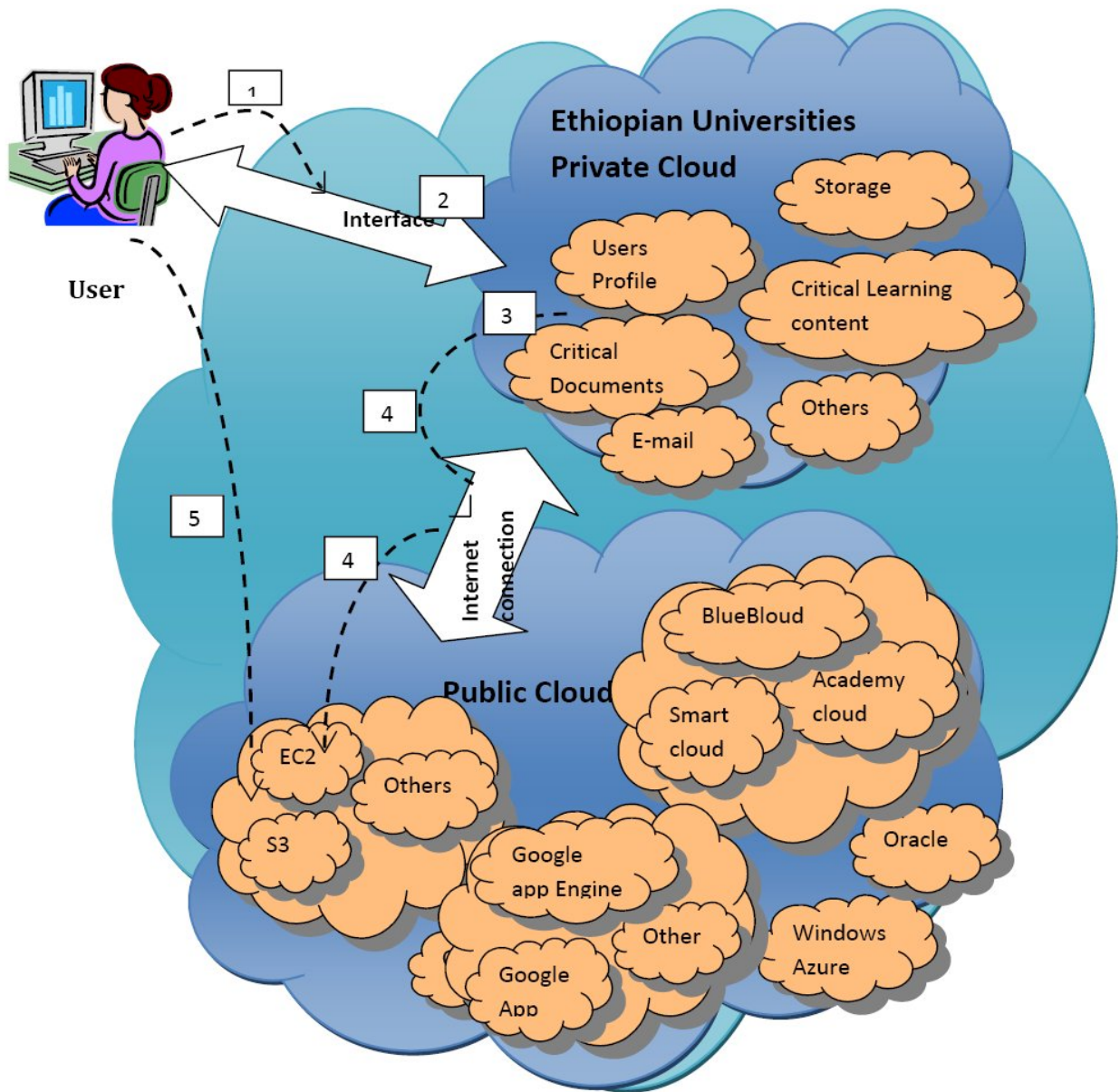


Figure 20. An overview of a hybrid Cloud for Ethiopian HEIs

The figure above shows an overview of the selected Cloud and how the content could be arranged in the private Cloud. Within six steps, the user can use a resource and then release it; these steps are illustrated in the following points:

- 1- The user sends a request using the EUHC interface
- 2- The verification of the authorization level will be checked using the user profile private Cloud.
- 3- If the user is unauthorized to request such services, the system will reject the user's request; otherwise, the request will be sent to the virtual infrastructure manager (OpenNebula) to redirect the request to the appropriate location for either public or private Clouds.
- 4- The system will establish a connection between the requested service from the Cloud and the user.
- 5- As long as the user needs the resource and does not exceed the maximum usage period, the system synchronizes the service delivery between the user and the resource.
- 6- When the user is done and no longer needs the requested resource, the system will terminate the session and disconnect the user from the target Cloud.

To build a powerful hybrid Cloud solution [59] which utilizes the current Ethiopian Universities IT infrastructure (private Cloud), the researcher proposed to use Aneka middleware on top of OpenNebula. The combination of these two open-sources provided a manageable hybrid Cloud for the institutions. This approach will utilize the universities IT infrastructure more efficiently, and it provided additional resources when the Universities's IT infrastructure was at the peak time and could not provide all the requested resources, such as storage and computing power. The additional resources will be brought from the available public Clouds. Ethiopian Universities's hybrid Cloud contains several components to deliver the requested service. There are three layers made up for the private EUHC with two modules to manage the user's access and the content delivery. EUHC's private Cloud will have the ability to be connected to public Cloud at the peak time. In addition, the user can request any needed service from the public Cloud at any time, which results in EUHC hybrid Cloud. The following list describes EUHC hybrid Cloud

components:

- 1- Infrastructure layer: The Ethiopian Universities IT Infrastructure will be placed at the bottom of this layer since Ethiopian Universities's private Cloud would be built on top of the available infrastructure. Furthermore, these physical infrastructures will be virtualized using OpenNebula which plays a critical role in the infrastructure layer.
- 2- Platform layer: This layer will contain the Aneka platform which will work and manage the platform to enable development and deployment of applications and programs with the ability to access public Clouds resources and platforms. Moreover, it is would be connected to the Service Repository module to integrate the Aneka platform service with different services.
- 3- User Interface layer: This layer controls and is managed by the EUHC's hybrid Cloud, identifying the access model which could be students, faculty, administrator, researchers or others which can be created by the system's administrator. The authorization and identification process will be done using the Users Logs module to verify the entered information. Then it forwards the users' request to the appropriate component in the same layer. Furthermore, this layer has three other components: IaaS, PaaS, and SaaS. IaaS provides a resource from the Infrastructure layer. A middleware container is used to develop applications and give learners and educators the access to PaaS services provided by the PaaS component in the user Interface layer which provides an access to the Platform layer that contains the Aneka platform. Lastly is the SaaS component which provides access to either the Platform layer so as to use one of the deployed applications or to public Clouds which may host an application used by system users, such as e-mail. There is a certain level of QoS which is granted by the provided SLA which includes detailed information about the services and available levels of resources to be accessed. This multi-layer in the EUHC hybrid Cloud architecture offers additional levels of security for the presented system.
- 4- Service Repository module: This consists of different services, e-learning systems content, such as database systems, Web file system, and so on. This module could

contain specific details about services.

- 5- Users Logs module: This is mainly responsible for checking the track of the authorizations users and its access mode which is selected in the User Interface layer. Users' information is stored in the Users Logs module, such as access modes, user account name, password, user type, and so on. Moreover, this module manages and supports resource utilization by recording the resource requirements and their status. The following figure is the proposed EUHC hybrid Cloud implementation architecture:

# Ethiopian Universities Hybrid Cloud

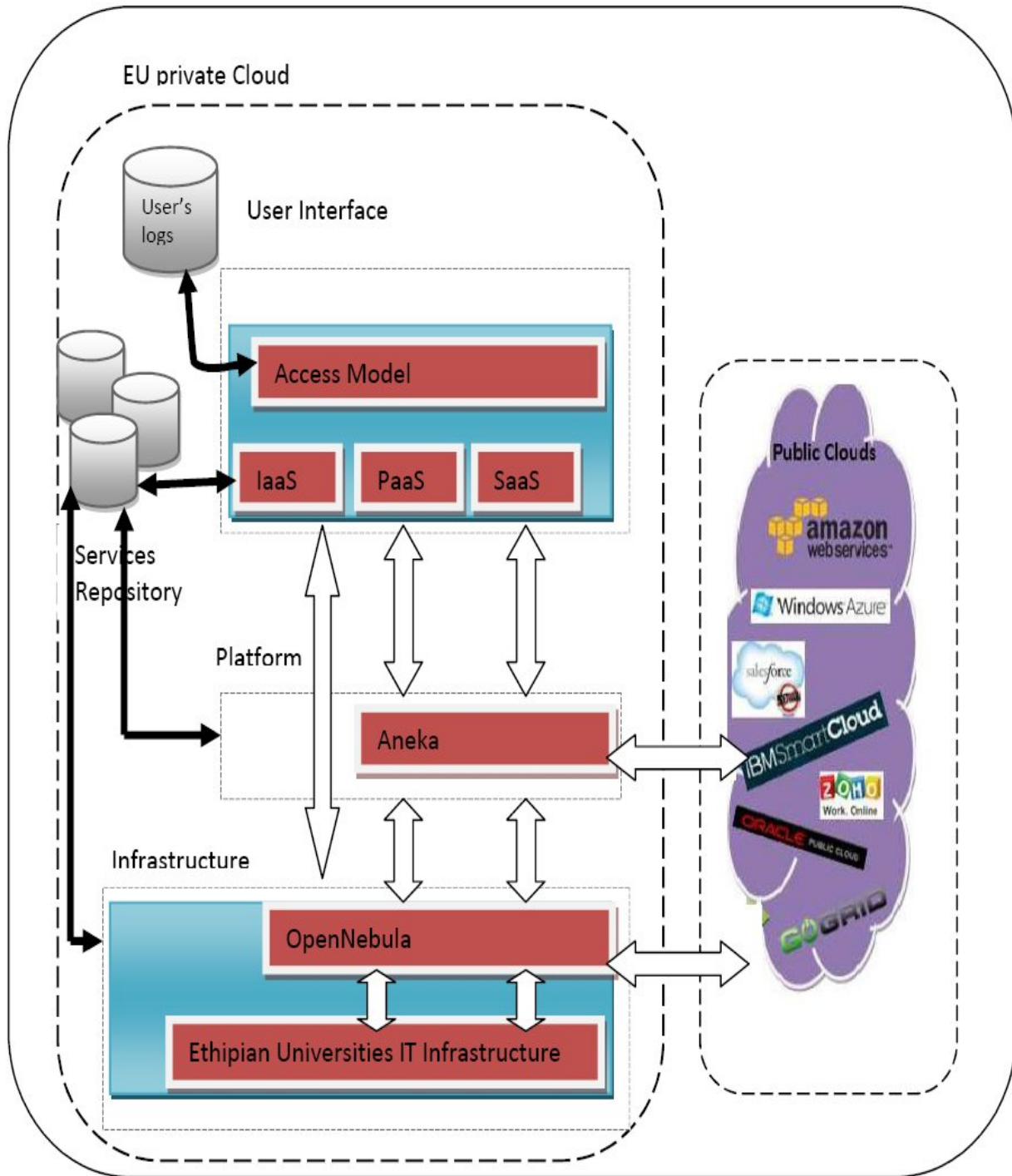


Figure 21. Ethiopian Universities proposed Hybrid Cloud Implementation Architecture

## CHAPTER FIVE

### 5. Discussion and Findings

In this research, the current status of ICT usage in Ethiopian Higher Education Institutions, limitations of the current ICT service delivery in the institutions, and identification of better ICT service delivery technologies has been studied. After identifying the challenges and limitations, the research showed that Cloud Computing can overcome most of these limitations [61]; [62]; [63]; [64] to improve the Teaching-Learning Environment ; thus, the idea of harnessing the Cloud Computing service at Higher education institutions by utilizing Infrastructure as a Service (IaaS) to overcome the resource limitations [27]; [66]; and SaaS to enhance the learning environment by adding more interactive and valuable tools [67]; [68] seems feasible. The primary focus of this research is to develop a Cloud Computing Framework that can be used by Ethiopian Higher Education Institutions, which would enable service delivery much more efficient and effective than the current system.

Examples of pilot cloud services have been given. The pilot services are Enterprise Resource Planning Systems, Database Development systems, Operating Systems, and Data Communication and Network. The proposed Hybrid Cloud Computing and its components have been discussed. An open source Cloud Computing tools, OpenNebula and Aneka has been proposed for the implementation and testing of the proposed framework.

A Hybrid Cloud Computing Model is chosen, because this cloud deployment scenario enables HEIs to use private cloud in collaboration with other public cloud service providers in case if it is difficult to deploy the service in private clouds. This framework is designed to be implemented and managed by the collaboration of MOE and EHEIs.

The interview responses from ICT directorates of HEIs and Ethiopian MOE shows that the ICT usage maturity level in HEIs is at its primitive stage. The respondent also told the researcher, the reasons for being in primitive stage are high cost of technology, lack of skilled professionals in the area, unorganized work between HEIs and related factors. The respondents also give recommendations to improve ICT usage. One of the recommended

solution given by the respondents is if there is a means to share resources between HEIs, the cost of technology will reduce significantly. As Addis Ababa University ICT director, Dr. Dereje Teferi told to the researcher AAU is contracted with third party vendor to develop Registrar System with a cost of 4 Million birr. It is true that all of the 31 Public universities need this Registrar System and the total cost of this system to be implemented to all 31 universities in the current system costs around 121 million birr. This shows inefficient resource utilization by the government. But if the government implemented the proposed cloud computing framework then deploying only one copy of this Registrar system in the cloud could enable not only 31 universities but also the new institutions which are under construction.

In addition the interviewed students told the researcher the current ICT service delivery in the institutions is not satisfactory. The students also responded that there is scarcity of resources for their course and research works. Using the Cloud would allow EHEIs provide educational resources to their students and researchers by simply providing end devices that can enable them connect to the cloud. By using the Cloud Computing which overcomes most challenges of the current Teaching-learning systems, the researcher proposed a much better learning environment for students and improved job opportunities because of the hands-on training, background, and knowledge of the Cloud Computing. With the proposed hybrid cloud, IT managers can decide on what data and applications should reside within and be run in the internal private cloud and which should be moved to the public cloud. Minimizing resource overcapacity and balancing critical applications and data within the private cloud while moving peak-loads and less critical apps/data to the public cloud should be the goal.

A Cloud-based framework has been presented which combines the existing public Clouds and EU's private Cloud to host different services. The proposed framework has been validated by ICT directors from different universities and it gets positive feedback for its implementation.

## **CHAPTER SIX**

### **6. Conclusion and Future Research Direction**

Despite its critics and drawbacks, it seems that Cloud Computing is here to stay. Present economic situation will force more and more organizations to at least consider adopting a cloud solution. Universities have begun to adhere to this initiative and there are proofs that indicate significant decreasing of expenses due to the implementation of cloud solutions. The aim of this work was to identify the particularities of using Cloud Computing within Higher Education in Ethiopia. Mainly, we have considered the risks and benefits of cloud architecture and proposed a Cloud Computing framework for EHEIs. And also the study presents a cloud adoption strategy proper for universities. This research discusses different cloud topics like cloud deployment types, service delivery models and related concepts. It also discusses the benefits and limitations of cloud computing to higher education institutions. This research investigated the potential benefits of using Cloud Computing in teaching-learning environments to overcome the current learning and service delivery system limitations. The research shows that hybrid cloud computing is a better choice for deployment in the universities since it gives the combined benefit of private and public clouds. The proposed hybrid Cloud Computing would be used as a road map for further studies on the topic. As it is discussed in previous sections Cloud Computing would be the next major break-through in IT revolution so it is time to wake up and start cloud laboratories in Ethiopian higher education institutions.

The proposed framework is just the road map for the implementation of a whole virtual cloud based teaching-learning and service delivery ecosystem. After the system is ready to use an independent study comparing the teaching-learning process and service delivery using the proposed framework with the original teaching-learning process and service delivery environment should be conducted. This framework can be tested in departmental level before fully implemented for all universities.

The research possibilities regarding Cloud Computing for educational purposes are immense since the technology is relatively new. Research in the education fields has much to be examined, but there is not yet a clear definition and standard for such technology. The movement will be rapid after the standardization. Here is a list of some of the future work to be done:

- 1) The proposed framework should be implemented at departmental level and tested with iterative feedback reflection from the users so that the proposed framework will be modified based on the feedback before the framework's full implementation for all universities.
- 2) Implement the framework and measure the framework's effectiveness by having different users. One group of users should use the cloud for every service and the other group of users without using the cloud for their work. Example take two classes who study the same course, the first should use the cloud for course materials, assignments and related course work, and the other class without Cloud-based applications.
- 3) Compare the implementation of the framework on the public Cloud, private Cloud, and hybrid Cloud by highlighting the strengths and weaknesses of each Cloud architecture while considering the performance and security issues. In addition the comparison study may consider the cost, ease of learning, network latency, ease of use, and any other important measurements.

In addition, all the opening questions can be considered as opportunities for future work. More questions would be regarding whether the Cloud augments the learning process, whether the Cloud is superior to traditional server farms, how good Cloud-based teaching-learning and other service delivery would be, and whether Cloud-based education is superior to traditional classroom education.

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## **Appendix;**

### **Interview Questions:**

- 1) What are the ICT services and supports that are provided to the university community by your office :
  - a. For Teaching learning process, students, lecturers and researchers?
  - b. For Administrative Staffs like, Registrar offices, finance offices, human resource offices and related offices in the university?
  - c. For cooperating with business partners, graduated student employeemnet, on student on job training, giving support for developers and researchers from outside the university?
- 2) Do you think these services are enough to achieve your mission and vision, supporting quality education, and creating qualified professionals?
- 3) What are the limitations in providing the above discussed services?
- 4) What is the yearly budget for the ICT office of the university?
- 5) What is your suggestion in formulating a new paradigm for providing ICT services and supports in the university? And if possible suggest your own solution from the current technology trends?
- 6) As an ICT director, what do you think is best strategy to provide ICT services for Higher education institutions all over the country to support with the current economic level of Ethiopia ?
- 7) If a central cloud computing infrastructure is to be built in Ethiopia that could be used by all higher education institutions of the country including your university to provide ICT services, what will be your reaction to this strategy, what kind of services your university need from the cloud?