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On

A conceptual Architectural Framework of Cloud Computing for Higher Educational Institutions in the Sultanate of Oman

By

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Certificate

This is to certify that the thesis entitled **"A conceptual Architectural Framework of Cloud Computing for Higher Educational Institutions in the Sultanate of Oman "** is a bonafide record of Research work done by **Zeyana Saif Ahmed Alkindi** (11212451), demonstrator, Department of Information Systems. University of Nizwa, Sultanate of Oman under my guidance and supervision submitted to the University of Nizwa for the award of the degree of Master in Information Systems and that the thesis has not formed the basis for the award to the candidate of any Degree, Diploma, Associateship or any other similar titles.

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Declaration

I **Zeyana Saif Ahmed Alkindi (11212451**) hereby declare that the thesis entitled "**A conceptual Architectural Framework of Cloud Computing for Higher Educational Institutions in the Sultanate of Oman** " submitted to Department of Information Systems at University of Nizwa, Sultanate of Oman in partial fulfillment of the requirements for the award of the degree of Master of Science in Information Systems is a record of original research work done by me under the supervision and guidance of Prof. John Haynes, Professor, Department of Information Systems, University of Nizwa, and it has not formed the basis for the award of any other Degree / Diploma / Associateship or any other similar title to any candidate of any University.

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Date: 28/12/2014 **Zeyana Saif Alkindi**

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الإهداء

أهدي هذا الجهد المتواضع الى أبي رحمه الله و طيب ثراه فكم كان تواقاً لأن أواصل دراستي ، والى الشمعة المضيئة بالتضحية والعطاء أمي الغالية يحفظها ربي ويرعاها ، والى زوجي العزيز الذي أمدني بالعزم والتصميم ، والى إخوتي وأخواتي الأعزاء ، والى أساتذتي الكرام في جامعة نزوى ، والى كل من ساهم في إخراج هذا العمل الى حيز الوجود.

Abstract

Higher Educational Institutions worldwide have become highly dependent on Information Systems for their IT provision and service delivery. Thus, the crucial necessity for educational resources like hardware, software, study materials, teaching tools, teaching documentations etc. constantly arises. The objective of this research is to find alternatives and replace the computing machines and other peripherals that are not optimally used, by adopting Cloud Computing.

This research studies the current status of adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman. It investigates the current state by distributing online questionnaires to Faculty in IT fields and employees who are working in ICT.

Additionally, this research proposed a Higher Education Hybrid Cloud framework as a model for delivery to all Higher Educational Institutions in Oman to provide flexible means for accessing educational resources anywhere and anytime on demand. The model facilitates the innovative teaching pedagogies, enables more effective knowledge transfer and encourages lifelong learning.

The research finding shows that adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman is a better solution for learning progression and service delivery requirements. Accordingly, when the proposed Higher Education Hybrid Cloud (HEHC) framework is implemented, different users from different academic institutions can access the services provided by Cloud Providers online which moves the user from being attached to a single machine to the internet.

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LIST OF ACRONYMS

Acronym	Meaning
CSPs	Cloud Service Providers
HEHC	Higher Education Hybrid Cloud
HEIs	Higher Educational Institutions
MoHE	Ministry of Higher Education
OHEIs	Omani Higher Educational Institutions
ON	OpenNabula
QoS	Quality of Services

Chapter 1

Introduction

1.1 Preamble

In recent days, Higher Educational Institutions are struggling to adopt and adapt Cloud Computing for solving problems of computing and storage.

Cloud Computing introduces many benefits for Educational Institutions like a rapid decrease in hardware cost and an increase in computing power and storage capacity. The importance of Cloud Computing is the trend of replacing software traditionally installed on computers with applications delivered via the internet. Cloud Computing provides a set of tools to help students, faculty, researchers and developers to use applications without installing them on their computers and allows access to saved files from any computer with an internet connection which makes learning tools accessible for a large number of students.

Higher Educational institutions, however, have a clear unique mission and a strategic purpose. Many educational institutions worldwide decided to move partially or completely their infrastructure to the Cloud. This trend didn't seem to be followed in Higher Educational Institutions in the Sultanate of Oman. Hereafter, this Thesis intends to obtain answers for the following research questions: Are Omani Higher Educational Institutions (OHEIs) following this trend to move to the Cloud? Is Cloud Computing currently ready to meet the needs and requirements of Omani Higher Educational Institutions? Is it really the right time to switch the IT infrastructure of these institutions to the Cloud?

1.2 Problem Statement

The Higher Educational sector in the Sultanate of Oman is divided into five different segments namely Government University, Colleges of Applied Science, Private Universities, Private Colleges and Colleges of Technology. There are a total of one Government University, six Colleges of Applied Science, seven Private Universities, nineteen Private Colleges and seven Colleges of Technology. These academic institutions have thousands of computing machines and other peripherals that are not optimally used which create a surplus of computing capacity.

If we virtually move all the campuses into a Cloud, it will enable greater returns on data center investments. Moreover, through virtualization it will allow anytime, anywhere access to computing resources which support synchronized contents without much concern about the infrastructure limitations. The resources, when they are needed, can be rented from the Cloud. Furthermore, it will make it possible for Educational Institutions to create their own Private Cloud within their own infrastructure.

This research is intended to create an architectural framework of Cloud Computing for Higher Educational Institutions that can help the institutions to understand what capabilities they need to develop, where they are on the Cloud adoption spectrum and how much time it could take to make the move to Cloud. Additionally, it allows better utilization of the IT infrastructure for educational purposes for a learning institution which will enhance the learning progression. Furthermore, it moves the user from being attached to a single machine to the internet.

1.3 Research Hypotheses

The aim of this research is to introduce a proposed conceptual architectural framework of Cloud Computing for the Higher Educational Institutions in Oman. The hypothesis indicates that using Cloud Computing in Higher Educational Institutions will reduce the hardware cost, solve the computing problems and storage, and improve quality and access to education. All educational resources available in the Cloud can be rented when they are needed.

This research is going to answer the following questions:

1. Are the educational institutions in Oman planning to move to the Cloud?
2. Is Cloud Computing currently ready to meet the requirements of Higher Educational Institutions in Oman?
3. Has the time arrived for migrating the IT of Higher Educational Institutions in Oman?

If yes, what elements should be considered before the migration?

1.4 Research Objectives.

General Objectives:

The main objective of this research is to examine the current ICT strategy in the Higher Educational Institutions in Oman and to study the possibility of adopting a conceptual architectural framework of Cloud Computing for HEIs. A proposed conceptual framework will be provided.

Specific Objectives:

- Observe the current ICT service delivery strategy and effectiveness in Higher Educational Institutions
- Identify the benefits of Cloud Computing in Higher Educational Institutions
- Identify the requirements of adopting Cloud Computing in Higher Educational Institutions in Oman
- Design a Conceptual Architectural Framework of Cloud Computing that can provide Cloud services for all Higher Educational Institutions in Oman

1.5 Research Motivations

- To make a linkage between Higher Educational Institutions in Oman
- To enhance the power for the Ministry of Higher Education in overseeing all Higher Educational Institutions
- To enable Higher Educational Institutions to teach students in new and different ways
- To improve the learning trends from the legacy system which is physically carrying the documents and data to access them in the Cloud anywhere from any connected devices
- To improve of quality of services provided by ICT

1.6 Research Contributions

This research presents a conceptual architectural framework for Higher Educational Institutions in the Sultanate of Oman based on Cloud Computing to allow anytime, anywhere access to computing resources and makes learning tools accessible for a large number of students.

This research is going to help via good reasons and a proposed model for the Ministry of Higher Education to adopt Cloud Computing in the Higher Educational Institutions in Oman. The architectural framework might be used as the pattern and model for employing the Cloud Computing in HEIs.

1.7 Thesis Organization

This Thesis provides important details and reasons for adopting Cloud Computing in Higher Educational institutions. This Thesis is organized expediently into seven chapters which proceed as follows:

Chapter One is introductory in nature which discusses the background information about Cloud Computing, the statements of the problem, objectives, methodologies, hypothesis and contribution.

Chapter Two presents the conceptual discussion about Cloud Computing and a detailed literature review, together with the following questions: What are the trends in Cloud Computing? What are service and deployment types Cloud Computing? How is Cloud Computing used in Higher Education? How will the future of Higher Education be affected by Cloud Computing?

Chapter Three covers the Methodology which includes the analysis of the online questionnaire to ensure whether Higher Educational Institutions in Oman currently adopt Cloud Computing. It highlights the time of migration to the Cloud Computing in Higher Education.

Chapter Four presents a comparative study of the adoption of Cloud Computing in the higher educational sector in different countries: in Asia, Africa, UK and US.

Chapter Five contains information about the proposed framework for HEIs. It contains the proposed details for the Cloud Computing framework architecture of Higher Educational Institutions in Oman with details. Additionally, it introduces the significance and benefits of adopting the proposed framework in HEIs.

In Chapter Six Results and Discussion are provided. It includes the results obtained from the questionnaire analysis together with a discussion about the advantages and limitations of the proposed Cloud Computing framework.

Finally in Chapter Seven conclusions about the research and recommendations for future research direction are presented.

Chapter 2

Literature Review

2.1 Cloud Computing

2.1.1 Definition of Cloud Computing

Currently, there is no unique definition of Cloud Computing because the area of Cloud Computing is a comparatively recent area and is constantly growing up. Experts and companies from the Cloud Computing field provide their own definitions of Cloud Computing as follows:

> **NIST** : " Cloud Computing is a model for enabling ubiquitous, 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." [Mell & Grance, 2011, p.2]

> **Forrester** : "A pool of abstracted, highly scalable, and managed computing infrastructure capable of hosting end-customer applications and billed by consumption." [Staten, 2008, p.3]

> **Gartner** : "Cloud Computing is a style of computing where massively scalable IT-enabled capabilities are delivered as a service to external customers using Internet technologies." [Plummer, Bittman, Austin, Clearley & Smith, 2008, p.3]

Jeremy Geelan, Chairman and CEO of the 21st Century Internet Group, Inc, gathered definitions of Cloud Computing proposed by many experts giving a clear idea of the different concepts that ICT experts have about Clouds (illustrated in Figure 2.1.1) [Geelan, J., 2009].

Author/Reference	Year	Definition/Excerpt
M. Klems	2008	*you can scale your infrastructure on demand within minutes or even seconds, instead of days or weeks, thereby avoiding under-utilization (idle servers) and over-utilization (blue screen) of in-house resources...*
P. Gaw	2008	*using the internet to allow people to access technology-enabled services. Those services must be 'massively scalable...*
R. Buyya	2008	*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*
R. Cohen	2008	*Cloud computing is one of those catch all buzz words that tries to encompass a variety of aspects ranging from deployment, load balancing, provisioning, business model and architecture (like Web2.0). It's the next logical step in software (software 10.0). For me the simplest explanation for Cloud Computing is describing it as, "internet centric software...*
J. Kaplan	2008	*a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a 'pay-as-you-go' basis that previously required tremendous hardware/software investments and professional skills to acquire. Cloud computing is the realization of the earlier ideals of utility computing without the technical complexities or complicated deployment worries...*
D. Gourlay	2008	*...the next hype-term...building off of the software models that virtualization enabled*
D. Edwards	2008	*...what is possible when you leverage web-scale infrastructure (application and physical) in an on-demand way...*
B. de Haff	2008	*...There really are only three types of services that are Cloud based: SaaS, PaaS, and Cloud Computing Platforms. I am not sure being massively scalable is a requirement to fit into any one category.*
B. Kepes	2008	*...Put simply Cloud Computing is the infrastructural paradigm shift that enables the ascension of SaaS. ... It is a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a pay-as-you-go basis that previously required tremendous hardware/software investments and professional skills to acquire*
K. Sheynkman	2008	*Clouds focused on making the hardware layer consumable as on-demand compute and storage capacity. This is an important first step, but for companies to harness the power of the Cloud, complete application infrastructure needs to be easily configured, deployed, dynamically-scaled and managed in these virtualized hardware environments*
O. Sultan	2008	*...In a fully implemented Data Center 3.0 environment, you can decide if an app is run locally (cook at home), in someone elses data center (take-out) and you can change your mind on the fly in case you are short on data center resources (pantry is empty) or you having environmental/facilities issues (too hot to cook). In fact, with automation, a lot of this can can be done with policy and real-time triggers...*
K. Hartig	2008	*..really is accessing resources and services needed to perform functions with dynamically changing needs...is a virtualization of resources that maintains and manages itself.*
J. Pritzker	2008	*Clouds are vast resource pools with on-demand resource allocation...virtualized ...and priced like utilities*
T. Doerksen	2008	*Cloud computing is ... the user-friendly version of Grid computing*
T. von Eicken	2008	*outsourced, pay-as-you-go, on-demand, somewhere in the Internet, etc*
M. Sheedan	2008	*...'Cloud Pyramid' to help differentiate the various Cloud offerings out there...Top: SaaS; Middle: PaaS; Bottom: IaaS*
A. Ricadela	2008	*...Cloud Computing projects are more powerful and crash-proof than Grid systems developed even in recent years*
I. Wladawsky Berger	2008	*...the key thing we want to virtualize or hide from the user is complexity...all that software will be virtualized or hidden from us and taken care of by systems and/or professionals that are somewhere else - out there in The Cloud*
B. Martin	2008	*Cloud computing encompasses any subscription-based or pay-per-use service that, in real time over the Internet, extends IT's existing capabilities*
R. Bragg	2008	*The key concept behind the Cloud is Web application... a more developed and reliable Cloud. Many find it's now cheaper to migrate to the Web Cloud than invest in their own server farm ... it is a desktop for people without a computer*
G. Gruman and E. Knorr	2008	*Cloud is all about: SaaS...utility computing...Web Services... PaaS...Internet integration...commerce platforms....*
P. McFedries	2008	*Cloud Computing, in which not just our data but even our software resides within the Cloud, and we access everything not only through our PCs but also Cloud-friendly devices, such as smart phones, PDAs... the megacomputer enabled by virtualization and software as a service...This is utility computing powered by massive utility data centers.*

Figure 2.1.1: Cloud Computing Definitions, Source: [Geelan, J., 2009]

Simply, Cloud Computing can be considered to be a collection of hardware, software and other resources that can be accessed over the internet, and used to assemble a solution on demand (that is, at the time of the request) to provide a set of services back to the requester [Singh & Hemalatha, 2012].

The minimal definition of Cloud Computing should contain some features like: scalability, pay-per-use utility model and virtualization [Vaquero, Rodero-Merino, Caceres & Lindner, 2009]. When Cloud Computing definitions are analyzed, there is a consensus on a few key points provides Cloud Computing : (1) ensures on-demand access to a pool of computing resources, (2) dynamically scalable services, (3) is device and media independent, and (4) has easier maintenance of applications due to no need to be installed on users' computers. Cloud Computing should be elasticity and scalability [Singh & Hemalatha, 2012].

According to the US National Institute of Standards and Technology (NIST), the Cloud Computing model is composed of five essential characteristics, three service models and four deployment models [Mell & Grance, 2011, p.2]. They are described in the following subsections.

2.1.2 Characteristics of Cloud Computing

The US National Institute of Standards and Technology (NIST) provides five essential characteristics of Cloud Computing [Mell & Grance, 2011, p.2]:

1. **On-Demand Self-Service**: Customers can unilaterally provision computing capabilities and resources as needed automatically without requiring any human intervention.

2. **Broad Network Access**: Capabilities and access are available over the network through standard mechanisms such as cellular phones, tablets, laptops, PDAs, workstations, etc.
3. **Resource Pooling**: Resources include storage, processing, memory, network bandwidth, etc. are pooled together to serve multiple customers using a multi-tenant model with different virtual and physical resources dynamically assigned and reassigned based on need and customers' demands.
4. **Rapid Elasticity**: Capabilities and resources can be rapidly and automatically deployed and scaled outward and inward commensurate with demand at any quantity at any time.
5. **Measured Service:** Resource usage by the costumers are automatically monitored, controlled, and reported, providing and offering transparency for both the provider and consumer of the utilized service.

2.1.3 Service Models of Cloud Computing

The US National Institute of Standards and Technology (NIST) introduced three service models of Cloud Computing [Mell & Grance, 2011, p.2-3]:

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

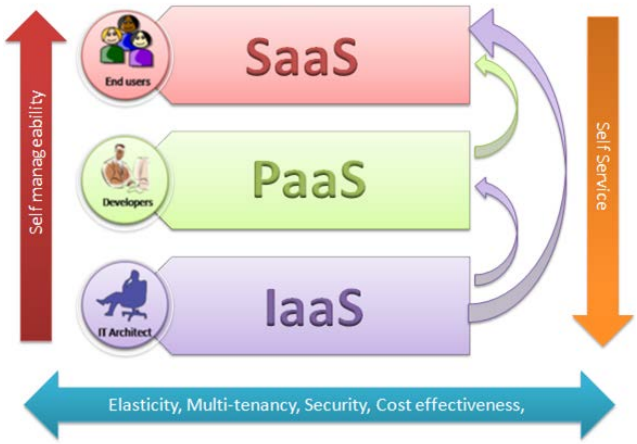

Figure 2.1.3: Cloud Computing Service Models
Source: http://tecires.ecs.soton.ac.uk/cloud_computing.php

Software as a Service (SaaS): The customers are able to entirely access the providers' applications in the Cloud through various devices such as cellular phones, tablets, laptops, PDAs, etc. through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The providers are responsible to provide, manage, control the underlying Cloud infrastructure including individual application, network, servers, operating systems, storage, etc. SaaS examples include MyErp.com, Salesforce.com and Workday.com, Google Docs, Twitter and Facebook [Massadeh & Mesleh, 2013].

Platform as a Service (PaaS): The consumers are able to deploy onto the Cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider. In other words, the customers have control over the deployed applications and possibly configuration settings for the application-hosting environment. Similar to SaaS, the Cloud providers are responsible to provide, manage, and control the underlying Cloud infrastructure except for applications. PaaS vendor examples include Wolf Frameworks, Dell-Boomi

Atmosphere, Heroku, Google App Engine and Microsoft's Azure [Massadeh & Mesleh, 2013, p.39].

Infrastructure as a Service (IaaS): The customers are able to deploy and run arbitrary software, which include operating systems, storage, deployed applications, processing; and possibly limited control of select networking components (e.g., host firewalls). The Cloud providers provide, manage and control the underlying Cloud infrastructure. IaaS vendor examples include Flexiant's Flexscale, Rackspace and Amazon's Elastic Cloud Compute (EC2) and their Simple Storage Service (S3) [Massadeh & Mesleh, 2013].

2.1.4 Deployment Model of Cloud Computing

Cloud Computing can be classified based upon the underlying infrastructure deployment model as Public, Private, Community, or Hybrid Clouds. According to the US National Institute of Standards and Technology [Mell & Grance, 2011, p.3] Cloud services can be deployed into four models:

- **Private Cloud**: The Cloud infrastructure is operated solely for an organization. It may be owned, operated and managed by the organization or a third party, and may exist on premise or off premise.

- **Community Cloud**: The Cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, and policy and compliance

considerations). It may be owned, operated and managed by the organizations or a third party, and may exist on premise or off premise.

- **Public Cloud**: The Cloud infrastructure is made available to the general public or to a large group. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the Cloud provider.
- **Hybrid Cloud**: The Cloud infrastructure is a composition of two or more Clouds (private, community or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., Cloud bursting for load balancing between Clouds).

To sum up, the five characteristics of Cloud Computing, service models and deployment models as described by NIST [Mell & Grance, 2011] don not work independently but are interrelated and connected to each other [Jain & Pandey, 2013] [Massadeh & Mesleh, 2013] [Usman & Noordin, 2013]. Jerry Bishop, the Chief Information Officer at Chippewa Valley Technical College in Wisconsin, visualized the three elements (illustrated in Figure 2.1.4) of the NIST Cloud definition (i.e. five characteristics, the service models, and the deployment models) to display the inter-relationships and connections of these elements [Bishop, 2011]. This visual demonstrates that a Cloud-based strategy can take on different configurations depending on institution's needs. Usually, institutions begin with one service model, such as SaaS and a Public Cloud deployment model as a pilot, and then slowly scale if the pilot proves

successful. Further, it is possible to use several deployment models to support one or more service models (as indicated by the various red, green, and grey arrows) depending again on the institutional needs and costs [Jain & Pandey, 2013] [Massadeh & Mesleh, 2013] [Usman & Noordin, 2013].

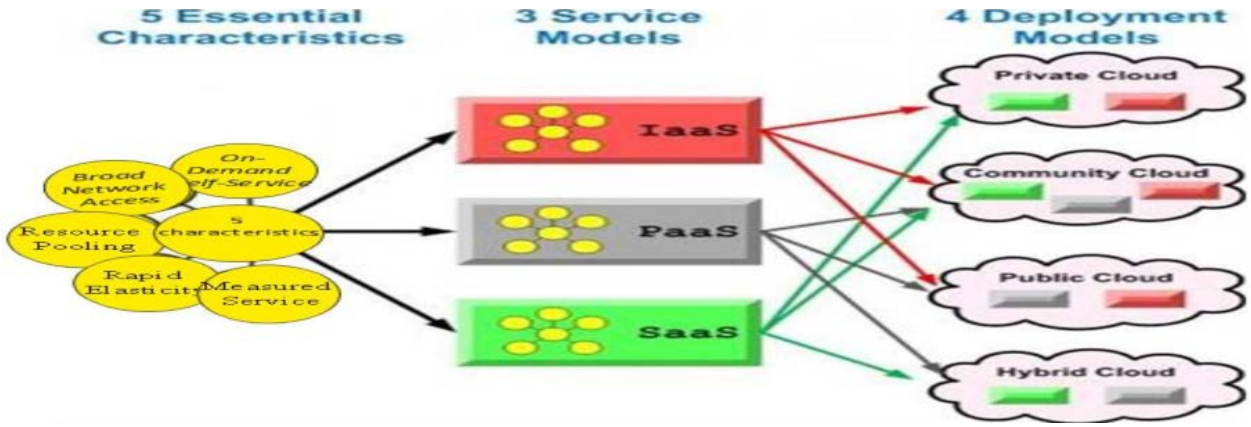

Figure 2.1.4: The interrelationships with the characteristics, Service and Deployment Models
Source: http://blog.thehigheredcio.com/2011/02/23/cloud-definition-model/

2.2 Cloud Computing in Higher Education

2.2.1 Adoption of Cloud Computing in Higher Education

"Education is not the filling of a bucket but the lighting of a fire." William Butler Yeats (1865–1939) Irish poet, dramatist.

Higher education is the most substantial pillar for the country's intellectual development. Through the partnerships between universities, government and industry, researchers and students have proven their contribution to the transformation of society and the entire world economy. In the field of education, Cloud Computing is very practical for a variety of reasons. Indeed, Cloud Computing will enable a certain

educational institution to actually make use of the global internet resources for data analysis and data storage [Jain & Pandey, 2013].

Nowadays, many Educational Institutions intend to adopt Cloud Computing in order to solve computing problems and storage. There are three main benefits for Cloud Computing [Singh & Hemalatha, 2012] [Saidhbi, 2012]:

1) 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
2) The exponentially growing data size in scientific instrumentation/simulation and Internet publishing and archiving
3) The widespread adoption of Services Computing and Web 2.0 applications

2.2.2 Benefits of Cloud Computing for Higher Education

Cloud Computing services provide Educational Institutions with the opportunity to continue to take advantage of new IT technologies as it has the following advantages:

- ***Cost Savings:*** The most vital incentive associated with Cloud Computing is the cost reduction. Educational Institutions can reduce IT capital expenditures and decrease ongoing operating expenses by paying only for the services they use without the need to purchase hardware, software licenses, or implementation services [Massadeh & Mesleh, 2013] [Cisco, 2010]. Westmont College declares that after deploying six cloud-centric service platforms, it has achieved numerous benefits, including a 65 percent cost reduction up front (over more traditional deployments), and a 55 percent cost saving over the useful lifetime of the solutions. Addition to the cost savings, the college reports a significant increase in

user satisfaction, as well as a significant decrease in the amount of IT management time required [Jain & Pandey, 2013] [He ,Cernusca & Abdous, 2011].

- ***Rapid Elasticity and Scalability:*** Cloud elasticity means the resource allocation can get bigger or smaller depending on demand. Elasticity enables scalability, which means that an application can scale when adding users and when application requirements change. In other words, the Cloud can scale upward for peak demand and downward for lighter demand [Massadeh & Mesleh, 2013].
- **Flexibility**: Cloud Computing offers more flexibility in matching IT resources to Academic institutions functions than past computing methods. It can also increase students, faculty and researchers mobility by enabling access to business information and applications from a wider range of locations and services [Cisco, 2010].
- **Cost of setup and maintenance:** Nowadays, many complex new technologies and applications are continually being invented which make it harder for IT staffs to install, configure, secure, and upgrade to the latest technologies during the workday. The adoption of Cloud Computing will move the burden of technology setup and maintenance to the Cloud service providers [Jain & Pandey, 2013] [He ,Cernusca & Abdous, 2011].
- **Self-service provisioning**: Cloud customers obtain Cloud services without going through a long process. The customer requests an amount of computing, storage, software, process, or more from the service provider. After these resources are used, they are automatically de-provisioned [Massadeh & Mesleh, 2013].

- **Sustainability:** The poor energy efficiency of most data centers in Educational Institutions, due to substandard design or inefficient asset usage, is now understood to be environmentally and economically unsustainable. Cloud service providers, by using economies of scale and their capacity to manage computing assets more efficiently, can consume far less energy and other resources than traditional data center operators [Cisco, 2010].
- **Reallocation of resources:** As Cloud Computing moves the technology setup and maintenance burden to Cloud service providers, the IT staffs in Educational Institutions can focus on providing more support to faculty and students. There are several areas in which more intensive help from IT staff can be beneficial to the faculty. First, as instructors move toward more online and mobile instruction in their courses, IT staff can help them to optimize the use of the available LMS systems to increase both the effectiveness and the efficiency of the instructional process. Second, as online instruction strives to become more personal through the extensive use of online conferencing tools (e.g. Blackboard Collaborate, Webex), instructors can benefit from more intensive initial support with the technical aspects of integrating these tools into their teaching activities. Third, IT staffs can help faculty to improve their technical skills in using various Web 2.0 tools (such as blogs or wikis) and can therefore help them to effectively integrate these collaborative tools in their courses in order to improve their students' learning experiences and performance [Jain & Pandey, 2013] [He ,Cernusca & Abdous, 2011].

Additionally, the benefit realization depends on the architecture chosen for Cloud Computing deployment. In a Public Cloud, the infrastructure is made available to the general public or a large industry group and is owned by an organization selling Cloud services. In the Private Cloud approach, organizations develop or procure their own dedicated cloud-computing environments either alone or in group community Clouds. Further, there is a hybrid option where an organization might use a Public Cloud for some functions (for example, basic business applications such as email) and their Private Cloud for storage for personnel data that is very sensitive [Bansal, Singh, Kumar, 2012].

2.2.3 Challenges of Cloud Computing In Higher Education

Many challenges of Cloud Computing for Higher Education relate to the relative newness and the underdevelopment of the marketplace for Cloud services. For Higher Education, decisions to adopt Cloud Computing will be influenced by more than technical and cost considerations [Cisco, 2010] [Jain & Pandey, 2013]. Information is the lifeblood of higher education, and decisions on how to manage that information can have far-reaching political, social, and economic considerations on the students, faculty and the society. The adoption of Cloud Computing causes many risks and challenges such as deciding to use a more traditional outsourcing arrangement. The academic institutions need to weigh the costs and benefits but a major factor of these decisions will be their level of trust in both the Cloud deployment model under consideration and the entity providing it [Jain & Pandey, 2013] [He ,Cernusca & Abdous, 2011] .

Rosalyn Metz [Metz, 2010] offers the example below to explain why the traditional IT infrastructure is sometimes not good enough:

When an institution develops or deploys a new application, they first must jump through a number of hoops. For example, if an institution decides they would like to install the learning management system Moodle, they might have to order a server, wait for the vendor to ship it, install the server in the data center, provision an IP address for the server, set up the DNS for the new IP address, install the operating system, etc [Jain & Pandey, 2013] [Metz, 2010].

While Cloud Computing poses challenges and risks which require careful consideration during the planning process, Carnegie Mellon University has developed a useful overview of some of the challenges that higher education will face in adopting Cloud Computing (illustrated in figure 2.2.3) [Cisco, 2010].

Security	The key concern is data privacy: users do not have control or know where their data is being stored.
Interoperability	A universal set of standards and/or interfaces have not yet been defined, resulting in a significant risk of vendor lock-in.
Control	The amount of control that the user has over the cloud environment varies greatly.
Performance	All access to the cloud is done via the internet, introducing latency into every communication between the user and the environment.
Reliability	Many existing cloud infrastructures leverage commodity hardware that is known to fail unexpectedly.

Figure 2.2.3: Barriers to Adoption of Cloud Computing in Higher Educational Institutions
Source: http://www.sei.cmu.edu/sos/research/cloudcomputing/cloudbarriers.cfm

The Cloud Computing challenges have a great impact on migration decisions, so it is possible to effectively handle these challenges and concerns, including training, contract negotiation, and vendor management through careful planning. As a matter of fact, many Academic institutions and organizations are turning toward actual Cloud adoption and deployment and are “outsourcing” computing to the Cloud. For example, the University of Alabama at Birmingham has moved its Blackboard system from on-site

hosting to vendor hosting [He ,Cernusca & Abdous, 2011]. In fact, the Cloud Computing market is projected to grow from $40.7B in 2011 to $240B in 2020 [Cisco, 2010].

Consequently, it is important to note that the challenges of Cloud Computing can be greatly reduced or overcome through careful planning, through collaboration, and through sharing of best practices. In order to adopt Cloud Computing in Academic institutions successfully, the cooperation among administrators, practitioners, other campus personnel, Cloud users (instructors and students), and Cloud service providers is needed [He ,Cernusca & Abdous, 2011] [Jain & Pandey, 2013].

Chapter 3

Methodology

3.1 Introduction

There are four different types of research methods: Exploratory, Descriptive, Analytical and Predictive. Descriptive research can be used to identify and classify the elements or characteristics of the subject [Neville, 2007]. Creswell [1994] stated that the descriptive method of research is to gather information about the present existing condition. The emphasis is on describing rather than on judging or interpreting. The aim of descriptive research is to verify formulated hypotheses that refer to the present situation in order to elucidate it. Moreover, it aims to obtain an accurate profile of the people, event or situation. In order to use this type of research method the researcher should have a clear prospect or view about the phenomena being inspected before gathering the data. Hereafter, it will be easy for the researcher to collect the first hand data from respondents, analyze them by using analysis tools to formulate the conclusions and recommendations for the study [Jelica, 2010].

In this research, the descriptive method of research is selected to ensure whether Cloud Computing is adopted in Higher Educational Institutions in Oman or not during the time of research and to identify the importance of Cloud Computing services usage in the Higher Educational Institutions. Additionally to overview if the Cloud Computing is being the next stage of evolution in IT at Higher Educational Institutions. The respondents of the survey are the faculty in IT fields and employees who are working in ICT. The data collected for this research was gathered from the answers of respondents.

3.2 Online Questionnaire

3.2.1 Purpose and Requirements of Online Questionnaire

The main purpose of the online questionnaire is to ensure whether Higher Educational Institutions in Oman currently using Cloud Computing or not. The perceived concerns of adopting Cloud Computing that engaged the Higher Educational Institutions as well as the reliability of using Cloud services in the Higher Educational environment were also part of the objectives. Additionally, the online questionnaire aims to answer the following questions:

Are the Educational Institutions in Oman planning to move into Cloud?

Has the time of migrating the IT at Higher Educational Institutions in Oman arrived?

The major requirements assigned for the online questionnaire were:

- The survey is written in an academic and simple language to be sure that every participant would understand it easily
- The survey is comprised of different types of questions which make it interesting for the survey-person to fill in
- It is included with the researcher's Email address for any inquiries
- Filling the online questionnaire should not take more than 15 minutes

3.2.2 Designing the Online Questionnaire

The form of the online questionnaire was created and designed by using Google Docs, whereas the content was provided by this researcher. The survey was activated from June 22nd, 2014 to July 10th, 2014 and accessible under this address: https://docs.google.com/a/unizwa.edu.om/forms/d/1_DGco5PQPQl6x0Z-qAX8IZNHaFbUpahQc52XwfsZ_Sw/viewform

3.2.3 Questions of the Online Questionnaire

The online questionnaire contains a welcoming form at the beginning which demonstrates the purpose of the study with general objectives and specific objectives. The questions are divided into three parts: part one contains general information about participants. Part two specifies the participant knowledge about Cloud Computing. Part three checks the adoption of Cloud Computing at the institutions. Additionally, the email address of the researcher is provided to be contacted by the participants if they need any support during filling the survey.

3.2.4 Target of the Online Questionnaire

The online questionnaire targets are Faculty in IT fields and employees who are working in ICT. The online questionnaire will be distributed via Emails to Higher Educational Institutions in the Sultanate of Oman including a Government University, Colleges of Applied Science, Private Universities, Private Colleges and Colleges of Technology.

3.3 Results and Analysis of the Online Questionnaire

3.3.1 Responses of the Online Questionnaire

The online questionnaire was distributed via Emails to around 25 Higher Educational Institutions in the Sultanate of Oman: a Government University, five Colleges of Technology, five Colleges of Applied Science, four Private Universities and ten Private Colleges.

After a runtime of about three weeks, a total of 86 respondents had accomplished the online questionnaire: 75% of them are faculty who are working in IT fields and 25% are employees working in ICT management and data center. These participants represented 13% (Count: 11 of 86) a Government University, 20% (Count: 17 of 86) Colleges of Applied Science, 21% (Count: 18 of 86) Private Universities, 16 % (Count: 14 of 86) Private Colleges and 30% (Count: 26 of 86) Colleges of Technology. The pie chart below shows the percentage of each Educational Institutions participants' responses.

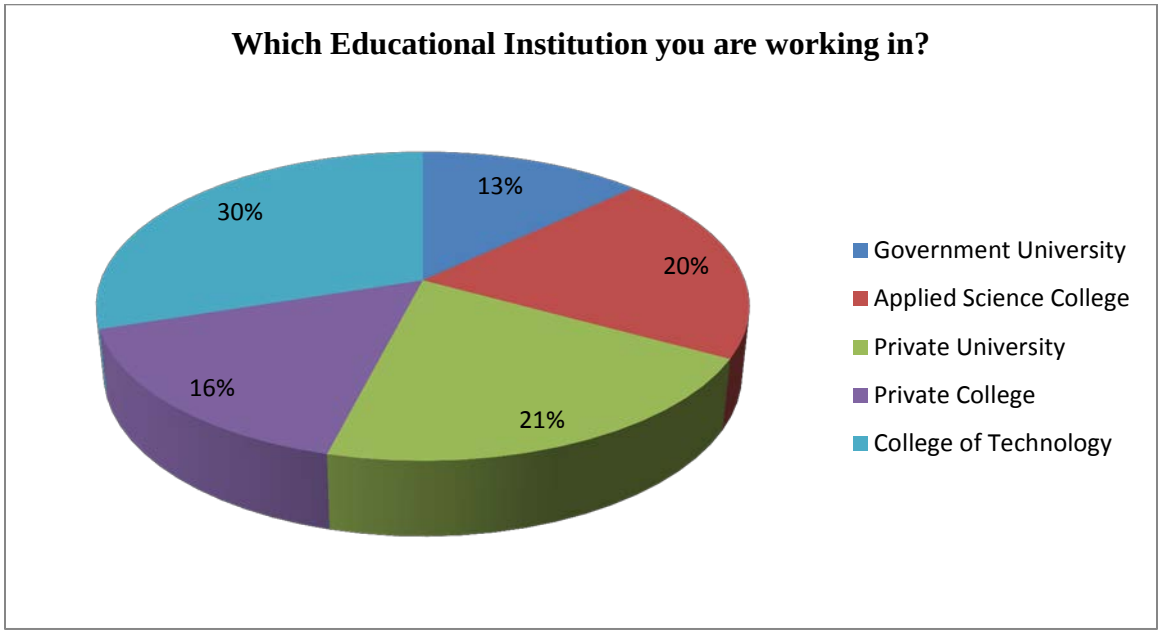

Figure 3.3.1: Responses of the Educational Institutions participants in the Online Questionnaire

3.3.2 Opinion about adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman

The majority of the participants indicated that Cloud Computing is part of their IT strategy. Thus, they affirmed that adopting Cloud Computing in the Educational Institutions will improve the quality of delivering services.

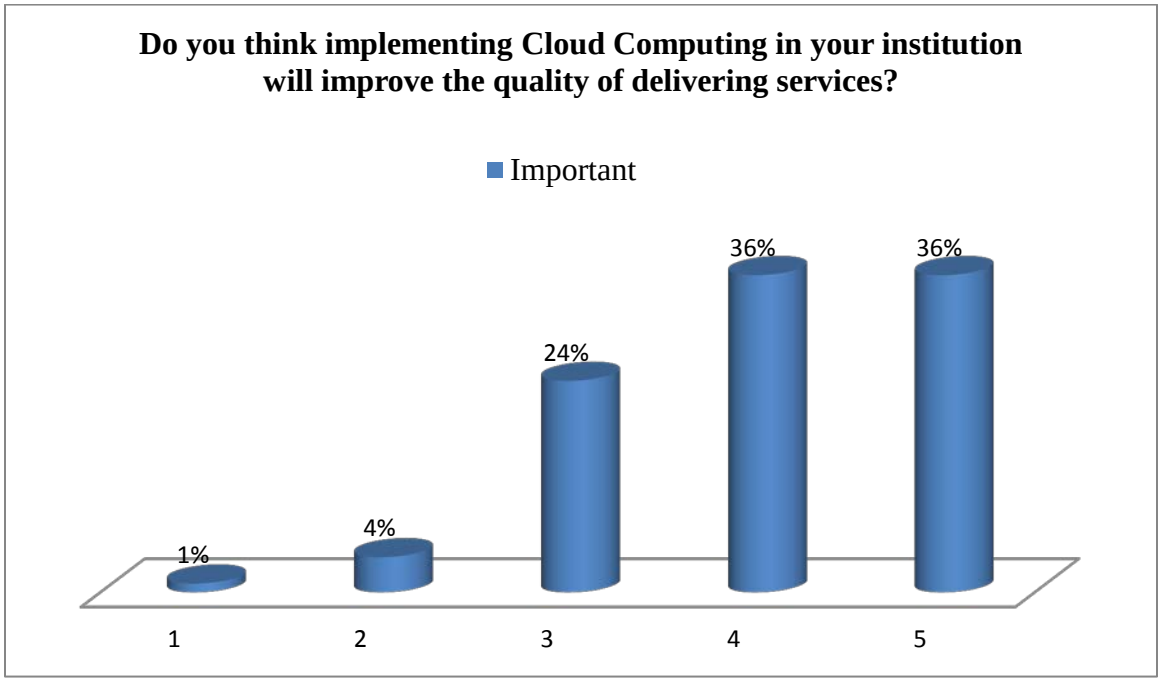

Figure 3.3.2: Improving service delivery via adoption of Cloud Computing

The respondents stated that the most suitable deployment model for Educational Institutions is Software as a Service 29%, than Platform as a Service 21% and in the last Infrastructure as a Service 5%. Accordingly, 35% of them indicate that individual software packages (SaaS) is the most likely used.

3.3.3 Usage of Cloud Computing in the Higher Educational Institutions in the Sultanate of Oman

The online questionnaire shows that 75% of Higher Educational Institutions, which participated in the questionnaire, are currently adopting Cloud Computing or willing to adopt Cloud Computing in the future. The pie chart below displays detailed description of this usage.

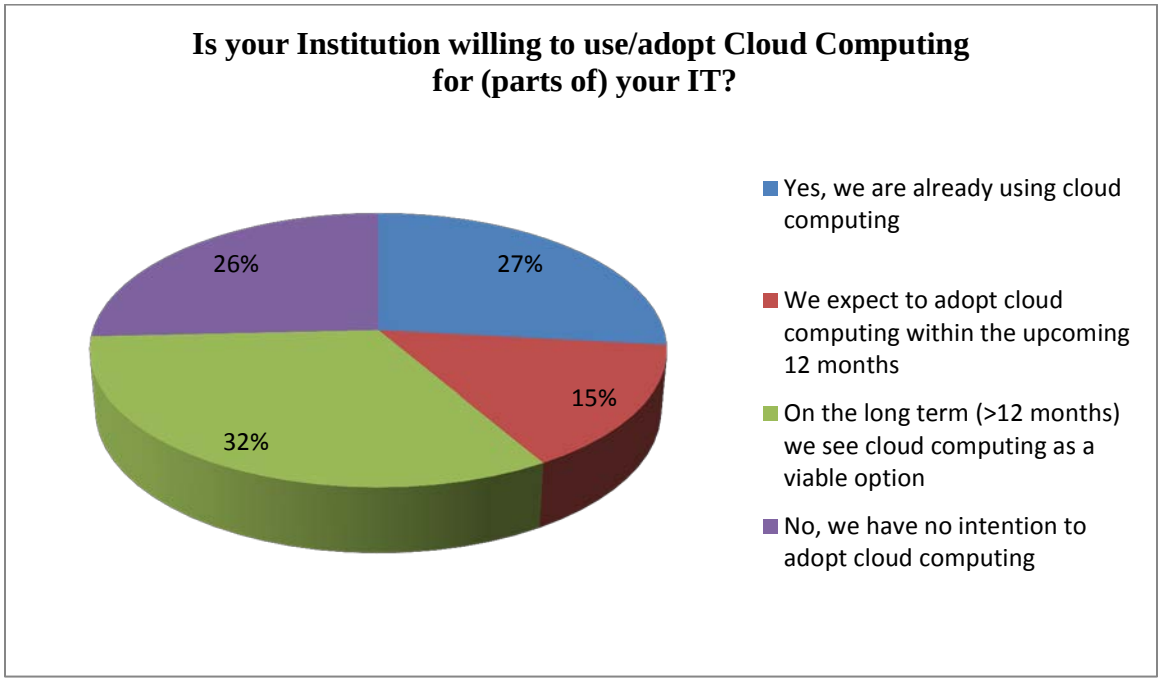

Figure 3.3.3a: Usage of Cloud Computing in HEIs in the Sultanate of Oman

The Educational Institutions that are currently adopting Cloud Computing or willing to adopt Cloud Computing in the future are divided as the follows: 12% of applied Science Colleges' participants declared that they are using Cloud Computing since 35% of them declared it will be adopted in the future. Additionally, more than half of Private Universities' participants affirmed that Cloud Computing is implemented while 33% of them indicated that it will be a future solution. Furthermore, 57% of

Private Colleges' respondents asserted that Cloud Computing has been adopted however 21% stated there is a future plan for Cloud Computing adoption. Moreover, just 12% Colleges of Technology indicated about Cloud Computing adoption whilst 73% of them declared there is an intention to adopt Cloud Computing in the future. Lastly, no one of the Government University's respondents declared any current usage of Cloud Computing nevertheless 64% of them predicted adopting Cloud Computing in the future. The chart below illustrates the percentages of Cloud Computing adoption currently or in the future.

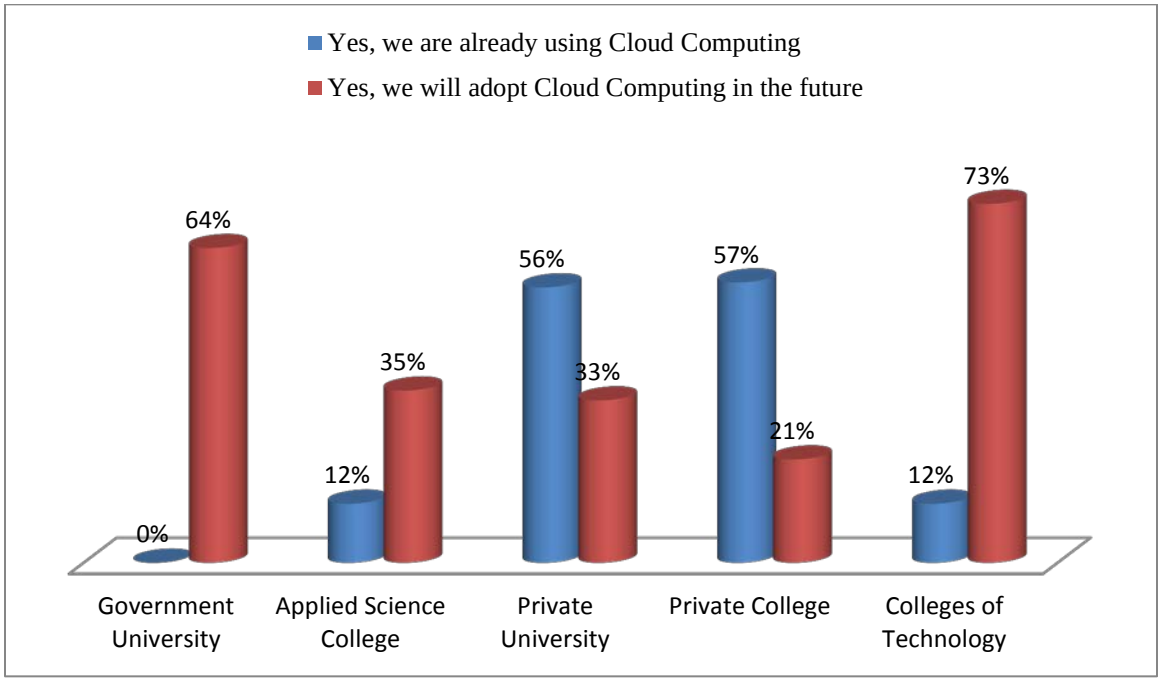

Figure 3.3.3b: Percentages of adopting Cloud Computing in HEIs vs. Future adoption

The participants from the Educational Institutions that are already using Cloud Computing indicated that the most commonly used type of Cloud Computing is Private Cloud (60%, Count 45 of 86).

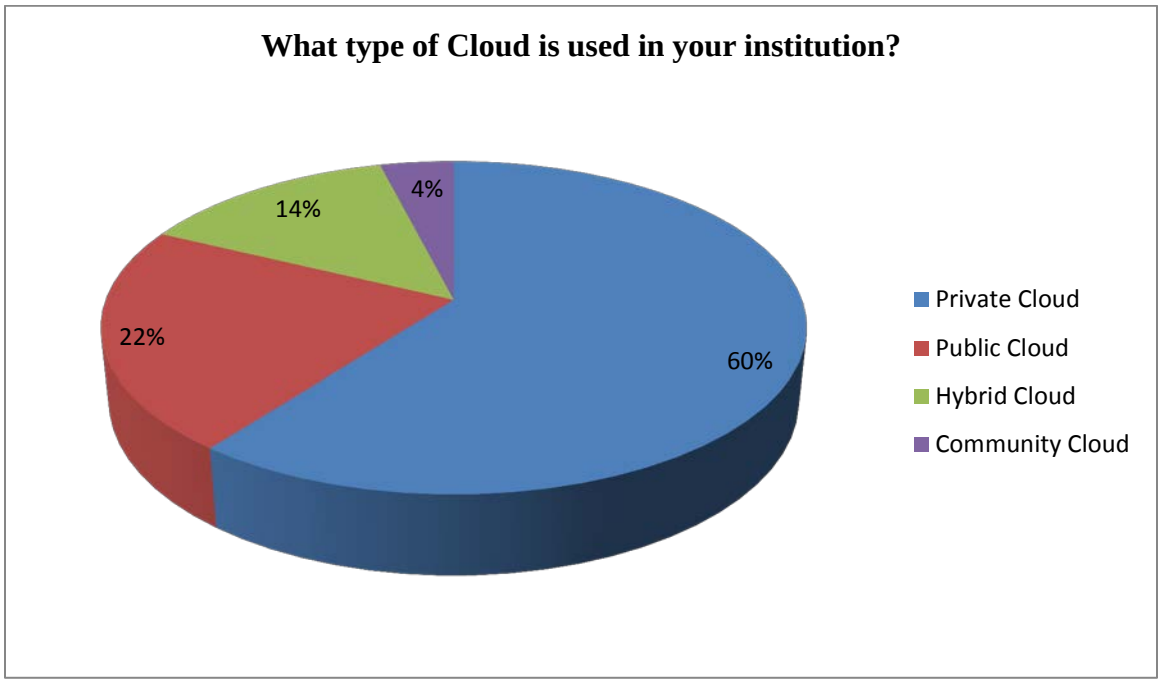

Figure 3.3.3c: Types of Cloud Computing used in Higher Educational Institutions

Furthermore, about 33% of the participants indicated that higher flexibility of resource allocation and de-allocation has encouraged them to adopt Cloud Computing. Moreover, about 49% of the respondents declared that they are using Software as a Service (e.g. Google Docs). Consequently, 34% of the respondents (Count 55 of 86) use Email and messaging.

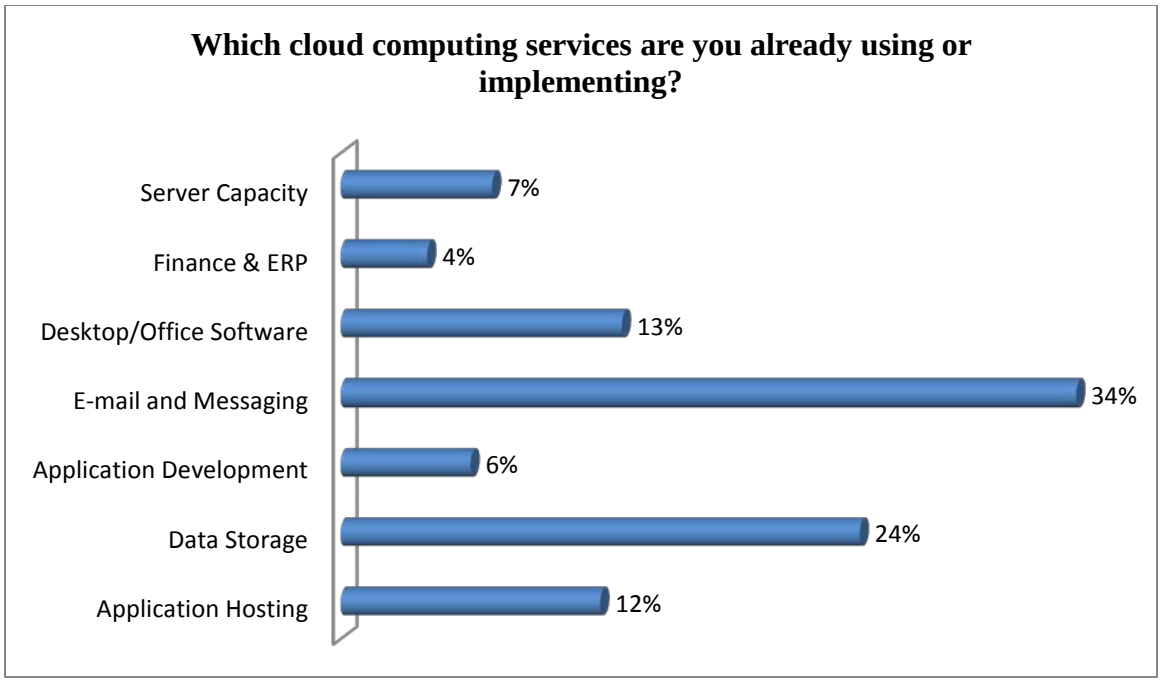

Figure 3.3.3d: Cloud Computing Services usage in Higher Educational Institutions

In addition, the top perceived concerns that engaged the Higher Educational Institutions respondents were:

- The need for a stable and fast Internet connection 49%
- Security 47%
- Availability of services and/or data 39%
- Integrity of services and/or data 35%
- Privacy and Confidentiality of corporate data 34%
- Loss of control of services and/or data 23%
- Lack of liability of providers in case of security incidents 21%
- Difficulty of migration to the Cloud (legacy software etc...) 19%
- Limited functionalities and options 15%

3.3.4 Migration of the IT at Higher Educational Institutions in the Sultanate of Oman to Cloud Computing.

The online questionnaire indicates about 64% of Higher Educational Institutions respondents see the Cloud Computing as the future successful model of IT in Educational Institutions. Consequently, more than half of respondents indicate that the time to migrate the IT at the Higher Educational Institutions has arrived.

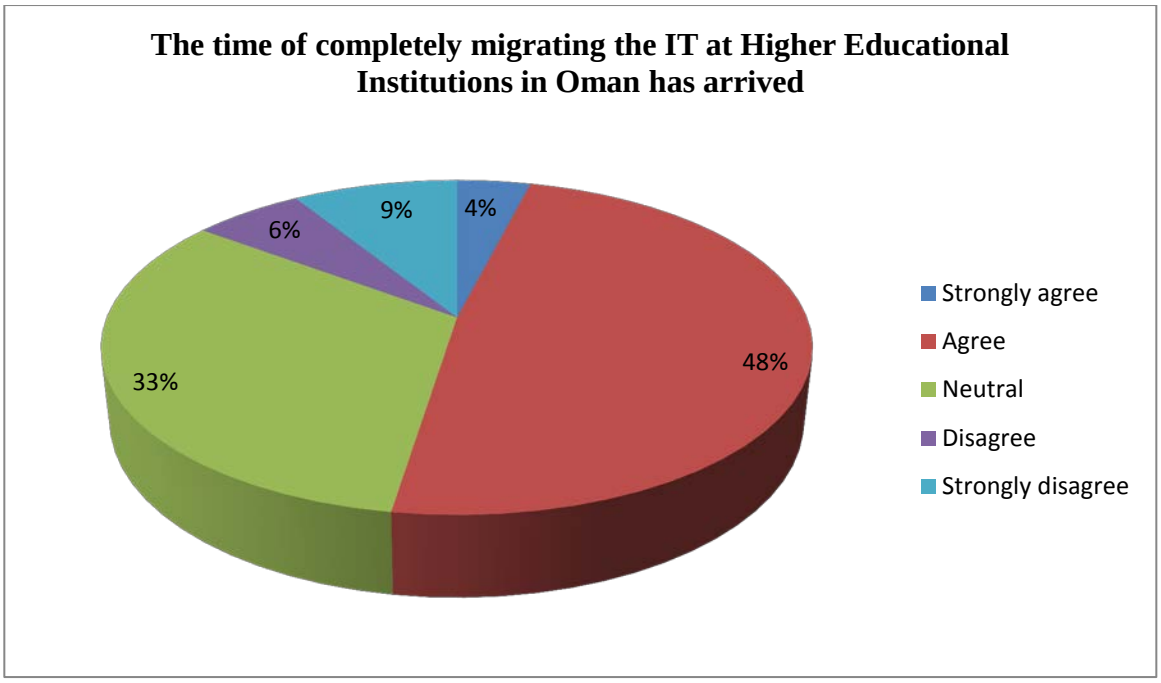

Figure 3.3.4: Migration of the IT at Higher Educational Institutions in the Sultanate of Oman to Cloud Computing

Furthermore, the majority of respondents predict the migration to Cloud Computing will succeed in relation to adopting Cloud Computing in small or medium Educational Institutions and then spread to the large Educational Institutions.

Chapter 4

Comparative Study of Adoption Cloud Computing in Different Countries

4.1 Introduction

The potential of adopting Cloud Computing to increase the efficiency in Higher Education has been recognized in many universities around the world. Cloud Computing offers to universities the possibility of concentrating more on teaching and research activities rather than on complex IT configuration and software systems [Mircea & Andreescu, 2011]. Adoption Cloud Computing in Higher Educational Institutions increases computing power and storage capacity [Erkoç & Kert]. Cloud Computing shifts the users from being on-premises to being in the Cloud [Ercan, 2010].

Worldwide, many Educational Institutions have decided to move partially or completely to the Cloud. For these reasons, many countries started building their own Cloud Computing Architecture in the Higher Education in order to facilitate the process of adopting Cloud Computing in their Higher Educational Institutions. The following are examples of Cloud Computing adoption in different Countries.

4.2 Adoption of Cloud Computing in Higher Education in Asia

4.2.1 The Proposed Architectural Framework of Cloud Computing for Bangladesh Education System

The proposed architecture can be used to provide the most efficient way to balance the resources with the current economic condition in Bangladesh by utilization of unused resources and elimination of third party involvements [Al Noor, Mustafa, Chowdhury, Hossain & Jaigirdar, 2010].

The proposed architectural framework consists of cloud partners, local servers and cloud central system. It is illustrated in figure 4.2.1:

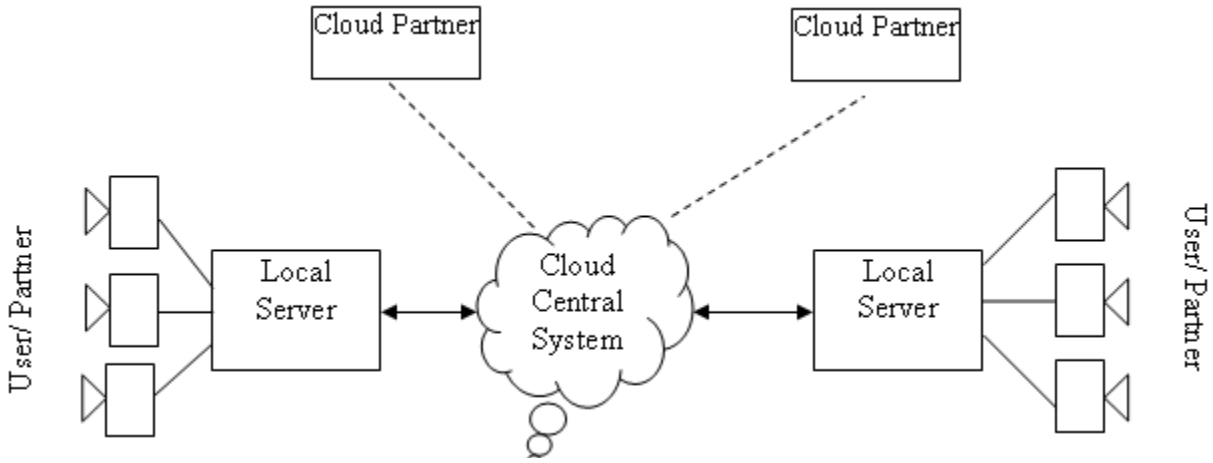

Figure 4.2.1: Cloud Computing Architecture for Bangladesh Education System
Source: [Al Noor, Mustafa, Chowdhury, Hossain & Jaigirdar, 2010]

Each cloud partner represents the individual PC which is owned by the educational institute whereas the institute owned those PCs from the budget sanctioned by the government for that particular institute. The local server acts as a linkage between the cloud partner and the cloud central system which is responsible to verify, collect and

forward the request sent from clients in its domain within specific time period to the cloud central system. Additionally, there are some providers who have agreement with cloud system and offers different services to the user.

The cloud partner communicates the local server in order to get the services from the cloud central system. The steps of communication procedures are summarized below:

1) The request is sent by the user to the local server with identification information.
2) After the local server authenticates the user, it sends a graphical user interface form to the user.

3) Once the user provides the service specifications through the user interface, the local server verifies the current available resources to the Cloud like pricing policy, encryption system and other data security etc.

4) Local server is responsible to inform the cloud partner to use the alternative ways of payment if the user does not have an agreement to receive the requested services.

5) An acknowledgement reply message will be sent to the local server when the cloud partner agrees with the current policy.

6) Once the local server receives the requested resources from the cloud system, it sends them to the cloud partners

The proposed architecture illustrated above can be used by any developing country because it is very beneficial which helps to use the limited resources in a most efficient way.

4.2.2 A Conceptual System Architecture for Cloud-Based E-learning Systems for Higher Education in India

The architecture contains three layers: user interface layer, cloud layer and hardware layer.

1) User Interface Layer: The user interface layer hosted different learning objects such as online tests and assessments, online assignments, video tutorials, lecture notes, education portals and others which can be used by different stakeholders includes teacher, student, administrative staff and others.
2) Cloud Layer: The cloud layer contains three servers: single sign-on authentication server, web server and application server. The single sign-on authentication server is responsible to verify whether the user is authorized or not. The web server is responsible to deliver the learning elements on the user machine that can be accessed through the internet. The application server is responsible to provide the environment where stakeholder can execute their applications in an efficient manner.
3) Hardware Layer: The hardware layer is responsible to connect all the work stations to the Cloud.

When the user send a request to the cloud-based e-learning system, the authentication server in cloud layer which works as a master load-balancer will verify whether the user is valid or not or whether the user name and password provided by the user is correct or not. Once the user is authenticated as a legitimate user, the user needs to fill the registration form before starting using the resources. Then the user can use the applications hosted in Interface layer. Additionally, the user can execute the applications

in efficient manner in cloud layer. Moreover, once the hardware layer used two types of Clouds: Public Cloud and Private Cloud, the user can access or open the application only its own machine with the help of the Private Cloud and with the help of Public Cloud he/she can share that application to everyone [Khetan & Gupta, 2013]. The model architecture of a cloud-based e-learning system in India is showed in figure 4.2.2:

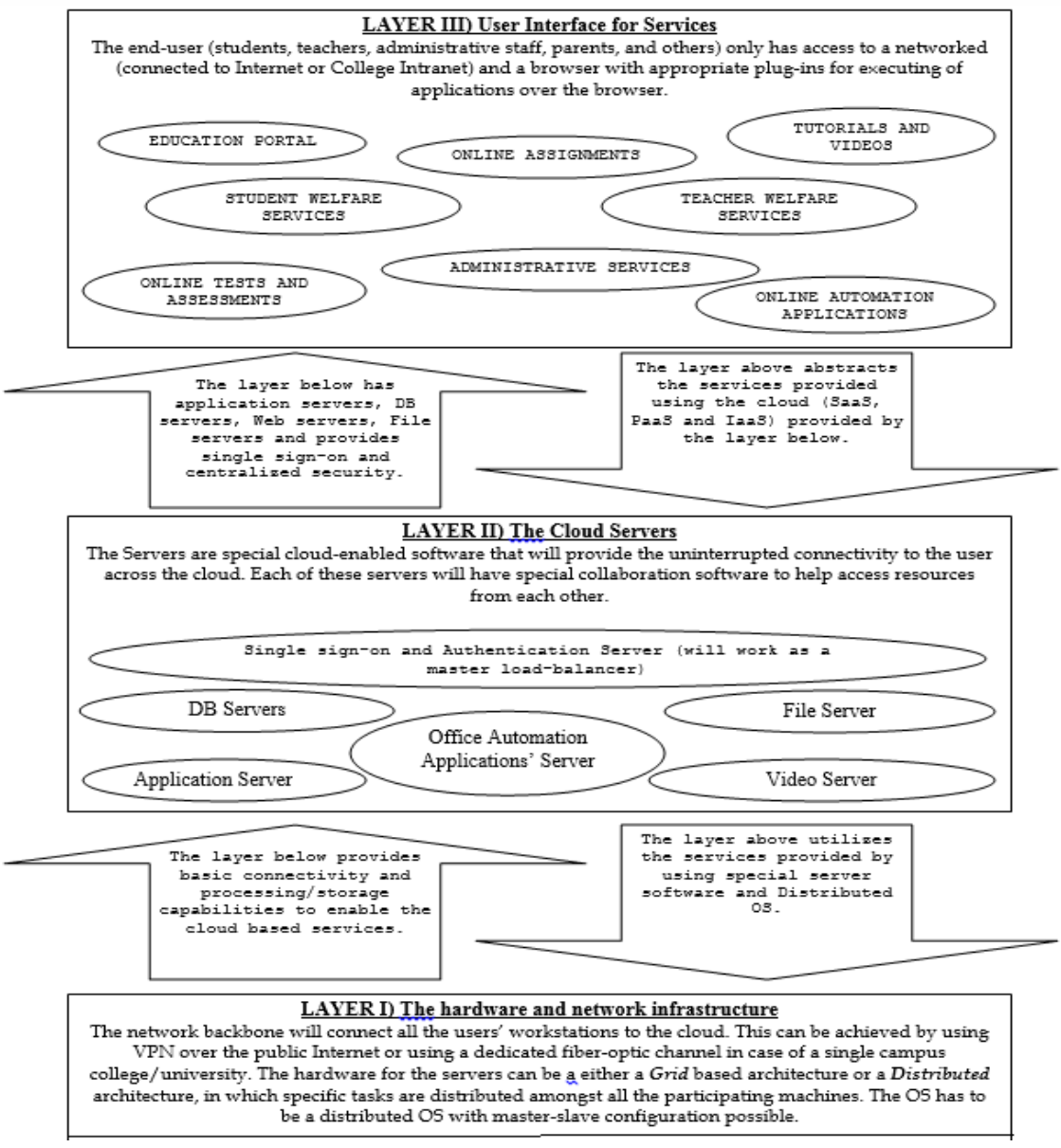

Figure 4.2.2: A model Architecture of A Cloud-Based E-learning System
Source: [Khetan & Gupta, 2013]

4.2.3 Suggested Cloud Infrastructure Prototype for Distributed University Campus in Turkey.

The Architecture aims to introduce a framework used by universities that have distributed campus. The most suitable type of Cloud Computing proposed to use is Community Cloud containing computing and storage infrastructure, development platform, and software delivering.

As a matter of fact, the large majority of university budgets are devoted to IT cost. A good illustration of this is in universities lots of computer used and many of them are not in use which lead to malfunction of computers and the maintenance is highly complicated due to lack of staff. Additionally, because of technology development, all software and hardware of universities must be renewed. Further, every year, the new versions of applications are used for courses with respect to the needs of industry. As a natural result of this progress, new software causes new hardware costs. In additions to what is mentioned above, students and researchers don't use the potential of collaboration-based research due to the diversified location of university campuses. However, installation, configuration, and transportation of new software tools would cause to loss of the researchers' workforce, and researchers don't focus on their basic tasks [Erkoç & Kert] [Singh & Hemalatha, 2012].

Using Cloud Computing will be of great help for universities that have a distributed campus and collaboration among the staff and student will increase. Students will have access to all software anytime, anywhere by any technological devices connected to the internet. Moreover, students will have access to a development platform, and develop their applications, and store such on the university infrastructure. Further, by

giving a virtual machine to everyone and a secure password, student and staff will work on their own virtual machine and if anything happens it will only crash the virtual machine not the entire system. By this way, lecturers will focus their basic tasks and not lose their workforce. With this Cloud Computing environment students can work from their lab as well from home where there data and application will be available always [Erkoç & Kert] [Singh & Hemalatha, 2012]. The proposed architecture is shown in figure 4.2.3:

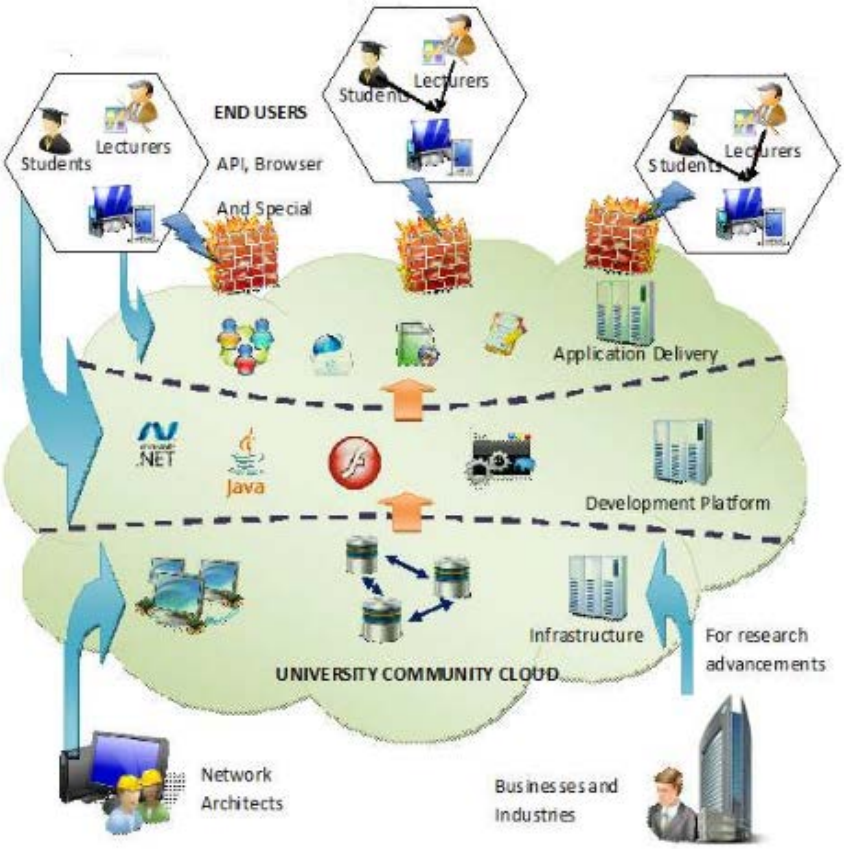

Figure 4.2.3: A prototype model for Distributed University Campus
Source: [Erkoç & Kert]

4.2.4 Hybrid Cloud for Higher Educational Institutions of Pakistan

The Hybrid Cloud architecture is used to serve the current IT infrastructure for educational institutions services. It consists of three tires which enable users to logon at a single machine.

1. Tier one provides user with access operations (i.e. Authentication, proxy, Data storage). It uses Eucalyptus open source Cloud provides architecture to manage such services.
2. Tier two acts as an intermediate model which facilitates developers to use scripting and programming languages, Web 2.0/3.0 and interconnecting Public Cloud APIs Google AppEngine and Sun's Cloud API and Microsoft's Azure Services. It uses Aneka cloud platform which enables the developers to run their own programming applications and deployed on the Cloud.
3. Tier three is responsible to support Virtualization and VM management and development platform. It uses OpenNebula open source for supporting on demand VMs provisioning and managing heterogeneous data center to build Public, Private and Hybrid Cloud resources.

The hybrid campus Cloud can provide services for all type campus of users that can be faculty members, students, researchers, software developer, and home users. It is operated for more than one university even if they are without infrastructure and hardware maintenance overhead [Butt, 2013]. The proposed architecture is showed in Figure 4.2.4:

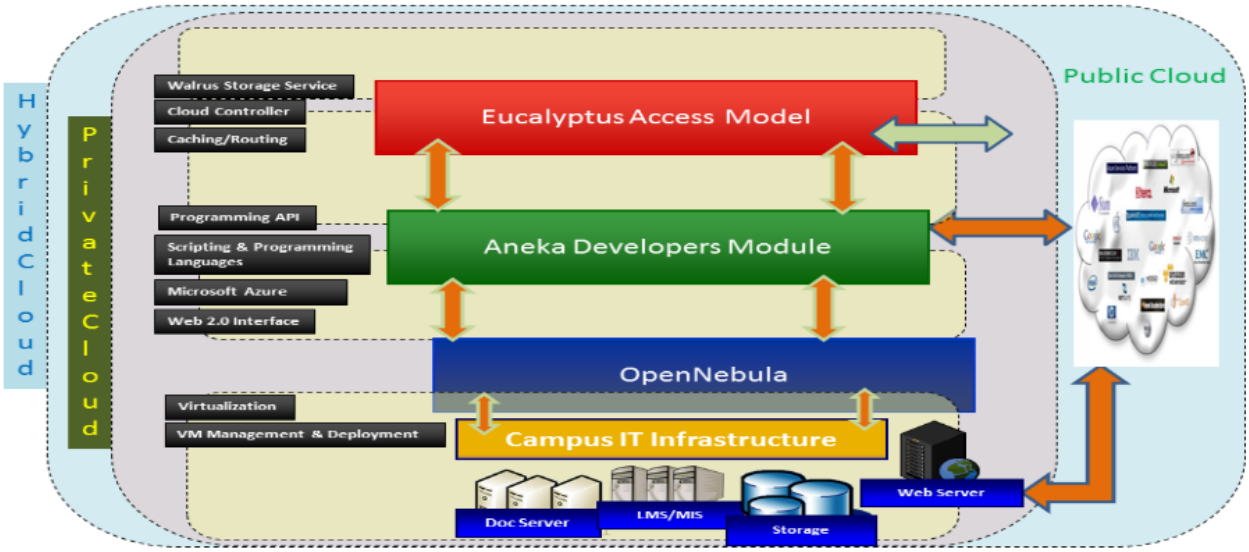

Figure 4.2.4: Hybrid Cloud Framework for Higher Educational Institutes in Pakistan.
Source: [Butt, 2013]

4.3 Adoption of Cloud Computing in Higher Education in Africa

A number of African educational establishments have adopted Cloud Computing due to their inadequate IT infrastructures and their inability to cope with the endless cycle of hardware and software upgrades. Cloud Computing helps the African education, not just by reducing IT costs but also by making education more efficient than before. A good illustration of this, Google which is the giant Cloud provider has partnered with a number of East African educational establishments (e.g., the National University of Rwanda, the Kigali Institute for Education, the Kigali Institute for Science and Technology, the University of Nairobi, the United States International University, the Kenyan Methodist University and the University of Mauritius) in order to provide Google Cloud services (e.g., Gmail, Google Calendar, Google Talk and Google Docs and Spreadsheets) to their students [Sultan, 2010].

4.4 Adoption of Cloud Computing in Higher Education in US and UK

Cloud Computing is a significant alternative today's educational perspective. Students, teaching staff, administrative staff, research staff and software developers have the opportunity to access various resources through the web page on demand which reduces the organizational expenses cost and offers more powerful functional capabilities [Ercan, 2010].

A number of US educational establishments recognize the benefits of adopting Cloud Computing in educational sectors in order to improve the efficiency and reduce cost. The University of California (UC) at Berkeley started using Cloud Computing in one of their courses which was focused exclusively on developing and deploying SaaS applications. UC was able to move its course from locally owned infrastructure to the Cloud by using Amazon Web Services (AWS). Hence, it able to acquire huge amount of servers (needed for the course) in a matter of few minutes [Mircea & Andreescu, 2011] [Sultan, 2010].

Another example is Medical College of Wisconsin Biotechnology and Bioengineering Center in Milwaukee, the researches rent processing time on Google's powerful cloud-based servers in order to get huge computing power for protein research and also to be more accessible to scientists worldwide [Sultan, 2010].

A good example of adopting Cloud Computing in Higher Education is Washington State University's School of Electrical Engineering and Computer Science (EECS). The university faced problems in budget cuts relating to financial crisis, as well as to do more with less. Therefore, the EECS selected a Cloud platform namely vSphere4 from VMware to support a move to Cloud Computing. The vSphere 4 platform manages

IT resources as a seamless, flexible and dynamic service that offers nearly limitless scalability with greater reliability and better performance than a traditional IT environment. Accordingly, the EECS could face the challenging economic climate, and be able to expand the services it offers to faculty and students rather than cut them back [Sultan, 2010].

Additionally to what is mentioned above, Cloud Computing is also finding its way in British academia. A number of UK Higher Education Institutions, e.g., Leeds Metropolitan University, the University of Glamorgan, the University of Aberdeen, the University of Westminster, the London University's School of Oriental and African Studies (SOAS) and the Royal College of Art (RCA) move to Cloud Computing [Sultan, 2010].

A good illustration of adopting Cloud Computing in Higher Education in UK is the University of Westminster (UOW). The university started embracing Cloud Computing to look for alternative options in order to solve the problems of University's student email service which began to look out-dated and the storage problem. It adopted Google apps which provide a whole campus with free email, messaging and shared calendars. In Addition, it provides a suit of productivity applications (e.g., word processing, spreadsheet, presentation) with functionality that supports collaboration (i.e., users can share documents remotely) which can be potentially useful for students working on group-based assignments). Furthermore, the new Google system provided each student with up to 7.3 GB of email storage capacity, which meant the likely end of using USB memory sticks as students would now have plenty of storage space online to store their large graphics and multi-media files [Sultan, 2010].

4.5 Conclusion

Adopting Cloud Computing in Higher Education is a vital to improve the efficiency of education and reduce cost. According to Said Akar, regional director of EMC for the South Gulf region, Oman is heading in the right direction of adopting Cloud Computing. On the service-provider side, there is service providers in Oman now prepared for the launch of public-cloud services. From the end-user side, the idea of adopting and moving on to cloud services is also at an advanced level. Additionally, according to Samer Abu Latif of Microsoft Gulf regional manager, the infrastructure in Oman is adequate to launch cloud services [Nair, 2012].

The best development model to be implemented in Higher Education in Oman is using a Hybrid Cloud since a Public Cloud is owned and managed by the service provider and the Higher Educational Institution has no control on it, and its access is only limited by subscription, on the other hand the Private Cloud is owned and managed by the Higher Educational Institution and its accessed is limited only to students, faculty and staff of the HEIs.

Chapter 5

Design and Implementation

5.1 Introduction

Cloud Computing has recently emerged as a new computing paradigm based on the concept of virtualization which aims to create a shared and highly scalable computing infrastructure from aggregated physical resources to deliver on-demand provisioning of software, hardware, and data as services [Ammar, Hamouda, Gamal, Abdelmoez & Moussa, 2012]. In other words, it is a solution within which resources such as hardware, software, network and storage requirements are provided to the user per demand [Patel & Soni, 2014].

Due to the higher accessibility, availability and efficiency of cloud services many academic institutions are trying to use and get benefits from cloud services. Nowadays, Cloud Computing providers are offering Higher Education, the opportunity to substitute their data and information in the Cloud for universities with existing data centers, servers and application replacing these traditional campus machines [Mathew, 2012].

Introducing a conceptual architectural framework of Cloud Computing in Higher Education can provide an effective way of utilizing unused resources, reduce expenditure of IT infrastructure, manage the technological needs effectively and improve the quality of education by allowing access to the computing resources anytime and anywhere.

5.2 Designing the Conceptual Framework

Cloud Computing allows users from different academic institutions such as students, teaching staff, administrative staff, research staff and software developers using different types of services provided by the Cloud. Students, administrative staff and lecturers can use the services of providers of SaaS and IaaS Clouds. Any software launched by these groups of people resides on the servers of the SaaS cloud provider and is accessed online. Any requirement for disk space or additional hardware (e.g., a virtual PC or a virtual Server) is executed immediately online by the IaaS cloud provider. Additionally, developers can now use all the software they need for their development online and all the hardware for hosting their applications through a PaaS cloud provider. Furthermore, researchers whose projects require a great deal of processing power and/or additional server capacity can do so at the click of a button through an IaaS cloud provider [Sultan, 2010].

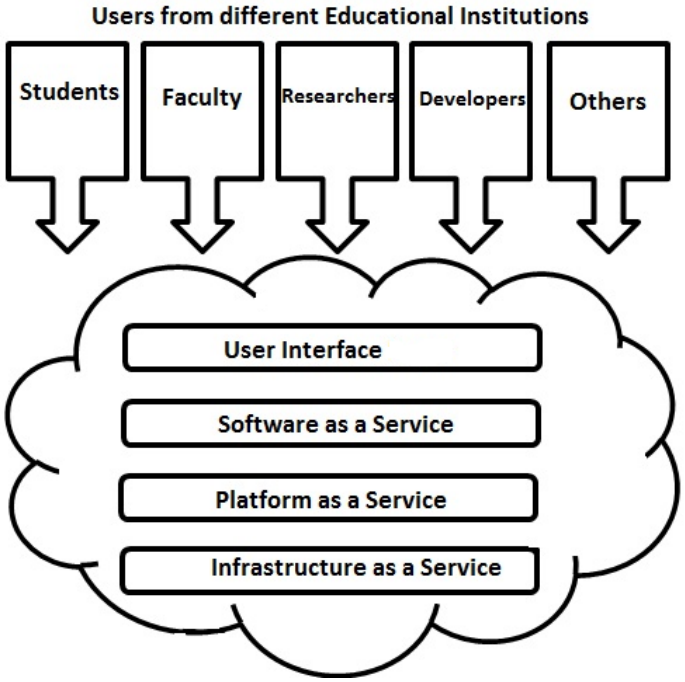

Figure 5.2a: Cloud based layout for Higher Education system Architecture

Figure 5.2a shows a general layout of Higher Education Architecture in Sultanate of Oman based on Cloud Computing with an interface layer which controls the user's access from different Educational Institutions to different cloud services. Applying the Cloud based architecture in the Higher 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 [Saidhbi, 2012]. Moreover, deploying Cloud based architecture in the Higher Education system will result in providing the necessary computational facility on demand for users from different academic institutions without any expenses. The architecture will create a common platform for sharing various resources from various institutions.

In order to provide higher accessibility, availability of cloud services in the Higher Education system, the researcher has proposed an Architectural Framework of Cloud Computing for Higher Education Institutions in the Sultanate of Oman. The following figure shows the Framework of Cloud Computing for Higher Education Institutions.

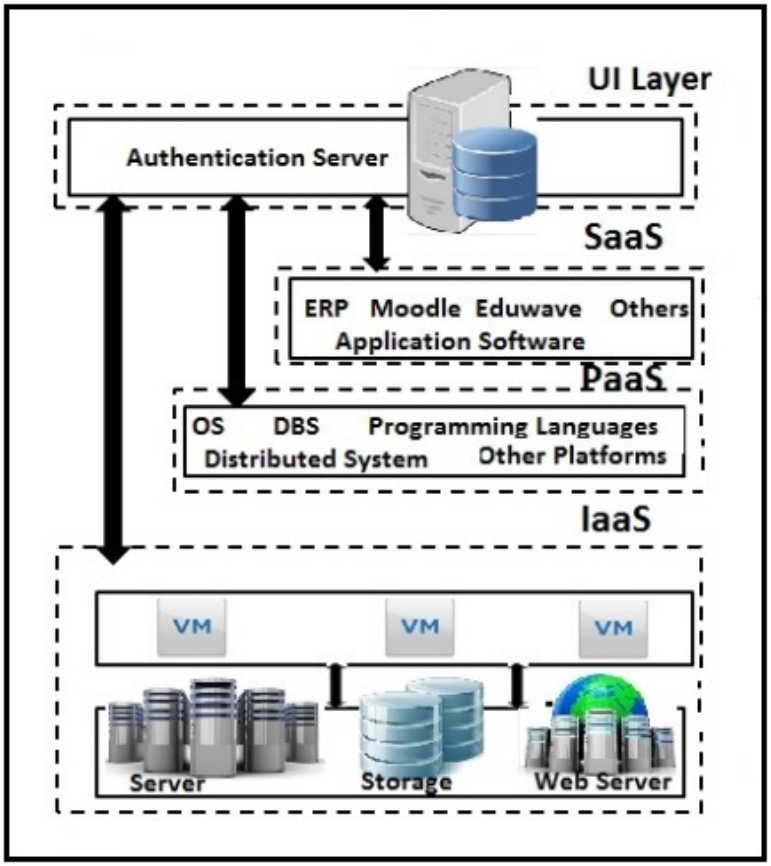

Figure 5.2b: Framework of Higher Education system services based on Cloud Computing

The proposed architectural framework namely Higher Education Hybrid Cloud (HEHC) consists of four layers: User Interface layer, Software as a Service layer (SaaS), Platform as a Service layer (PaaS) and Infrastructure as a Service layer (IaaS).

5.2.1 User Interface layer:

The user interface layer acts as an interface between the users and cloud contents. It connects users from different Higher Educational Institutions to the cloud contents. It contains an authentication server that works as a master load-balancer that verifies whether the user is valid or not or whether the user name and password provided by the user is correct or not.

5.2.1.1 Authentication server:

The authentication server associated with users from different Educational Institutions to submit their requests to the Cloud via the authentication server. It is responsible to collect the requests from users and forward them after verification to the cloud contents.

Each user terminal communicates the authentication server for receiving services from cloud side. The procedure is depicted in figure 5.2.1.1.

The steps of procedures are summarized below:

1. First of all, user request is sent to the authentication server with necessary user identification information like username and password.
2. The authentication server contains information about users such as access modes, user account name, and password and user type which is responsible to verify whether the user is valid or not.
3. After verifying the user as a legitimate user, the authentication server sends the request to the cloud system.

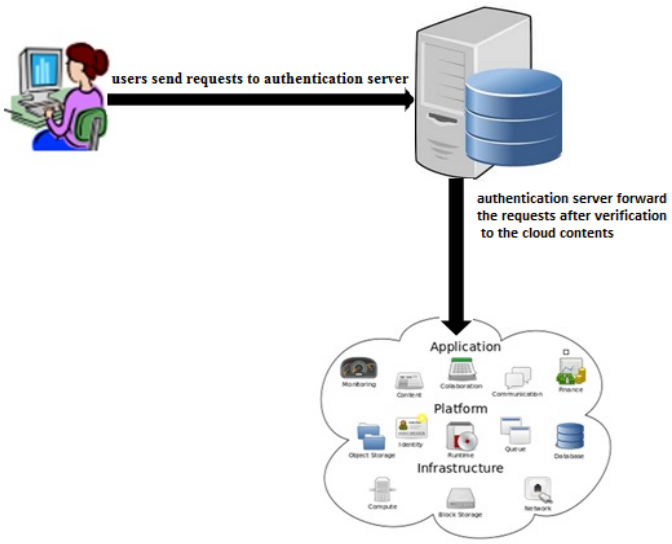

Figure 5.2.1.1: Steps of Communication between End User and Authentication Server

5.2.2 Software as a Service layer (SaaS):

This layer is a software delivery model which provides the access by using thin client, normally using web browser over the internet to the hosted programs and applications on the Cloud. The hosted programs and applications are licensed to the users for use as a service on demand which are disabled after use or after on-demand contract expire. Examples are ERP, Moodle, Eduwave and other application software.

5.2.3 Platform as a Service layer (PaaS):

This layer provides the access to different platforms programming language, distributed systems, net-centric systems and similar platforms. It provides a flexible and configurable platform that supports multiple programming languages and gives the ability to develop and deploy the applications either on Private or Public Clouds. It facilitates the deployment of applications without the cost and complexity of buying and managing the underlying hardware and software. It provides all of the facilities required to support the complete life cycle of building and delivering web applications and services entirely available from the Internet. It offers many facilities for application design, application development, testing, deployment and hosting as well as application services such as team collaboration, web service integration, database integration, security, scalability, storage, persistence, state management, application versioning, application instrumentation and developer community facilitation [Ammar, Hamouda, Gamal, Abdelmoez & Moussa, 2012].

5.2.4 Infrastructure as a Service layer (IaaS):

This layer is the lowest layer which is the responsible for building the servers and set up their configurations. It delivers computer infrastructure typically a platform

virtualization environment as a service along with storage and networking. It provides the flexible way of dealing with the hardware layer (servers, storage systems, switches, routers, and other systems) through virtualization. Rather than purchasing servers, software, data-center space or network equipment, clients instead buy those resources as a fully outsourced service.

5.3 Implementation of Conceptual Architectural Framework

The proposed architectural framework called HEHC stands for Higher Education Hybrid Cloud. This framework deploys a Hybrid Cloud which combines a local infrastructure as Private Cloud with selected Public Cloud. The Hybrid Cloud deployment model allows mixing and matching services from different CSPs (Cloud Service Providers) and provides more security for the applications and data hosted in the Private Cloud since part of the infrastructure is controlled by the institution [Saidhbi, 2012].

In other words, Hybrid Cloud is a judicious mix of Public and Private Clouds in order to gain the maximum advantage from the good aspects of each of these Clouds. Hybrid Cloud works out the most preferred infrastructure since it comprises of Public Cloud which used for less sensitive tasks and Private Cloud that used for most vital processing tasks [Viswanathan, 2014].

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 [Saidhbi, 2012].

Hybrid Cloud the Cloud infrastructure is a composition of two or more Clouds (Private, Community or Public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., Cloud bursting for load balancing between Clouds) [Mell & Grance, 2011].

In order to develop a framework for IaaS cloud services, the researcher proposed to use open source cloud middleware called OpenNebula (ON) which is an open source cloud middleware that provides a virtualized execution environment manager of the virtualized resources [Saidhbi, 2012]. OpenNebula (ON) is responsible to support the Hybrid Cloud environments consisting of Private and Public Clouds. It implements the functionality supported by the Amazon's EC2 API, mainly those related to virtual machine management. It can be used also to serve the PaaS and SaaS layers of the Cloud Computing architecture. It has the ability to manage the complexities and heterogeneity of distributed data centers [Ammar, Hamouda, Gamal, Abdelmoez & Moussa, 2012]. The following figure shows the architecture of OpenNabula.

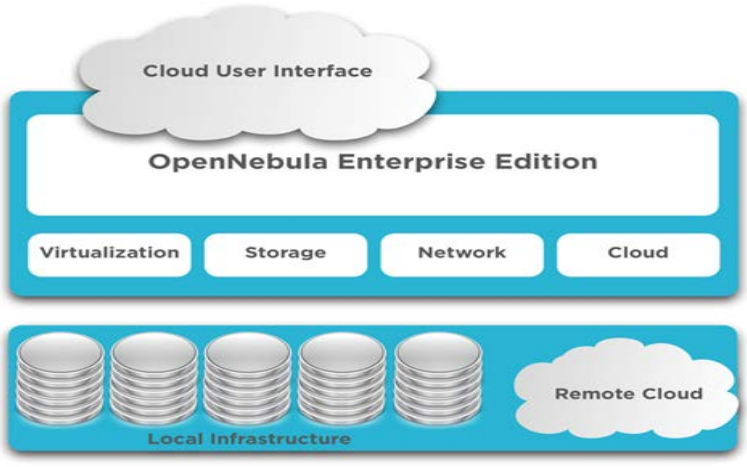

Figure 5.3.1: OpenNabula Architecture
Source: http://cloudcomputing.info/en/news/2010/12/release-c12g-labs-opennebula-2-0.html

As it is known, 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, so the need for a flexible, extensible, and accessible solution for developing and deploying the proposed framework is raised. The researcher proposed AppScale as a PaaS framework in order to satisfy the system requirements of the developers and researchers. AppScale is an open-source framework for running Google App Engine applications. It is an implementation of a Cloud Computing PaaS platform, supporting Xen, KVM, Amazon EC2 and Eucalyptus. AppScale allows users to upload multiple App Engine applications to a Cloud. It 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 [Ammar, Hamouda, Gamal, Abdelmoez & Moussa, 2012].

The next figure shows the proposed Hybrid Cloud Computing implementation architucture for Higher Educational Institutions in the Sultanate of Oman namely Higher Education Hybrid Cloud (HEHC).

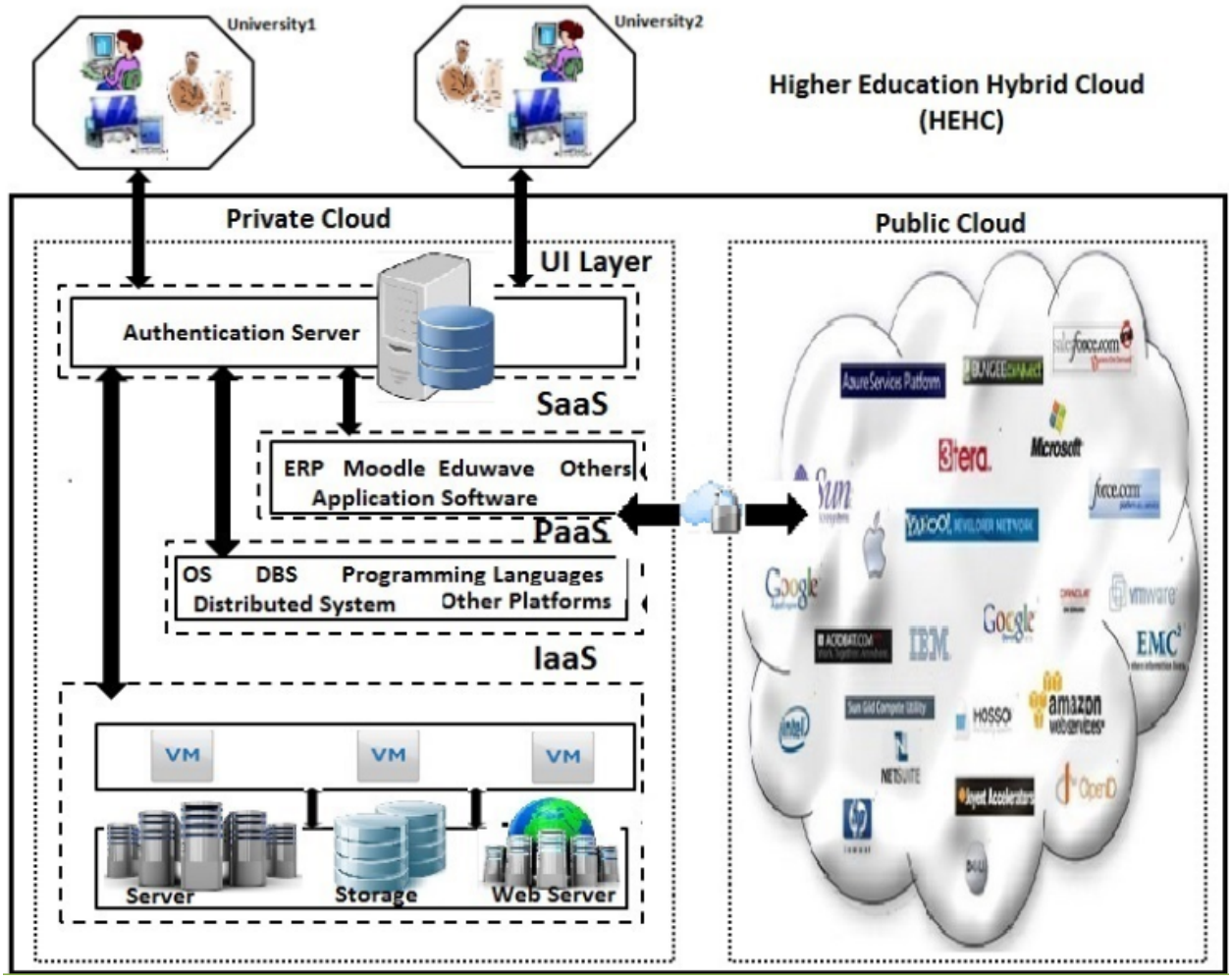

Figure 5.3.2: Proposed Hybrid Cloud Computing implementation architecture for Higher Educational Institutions in the Sultanate of Oman

Users from different academic institutions such as students, teaching staff, administrative staff, research staff and software developers can use different types of services provided by the Cloud.

The user can use the resources available in the Cloud by sending a request to the Higher Education Hybrid Cloud (HEHC) interface layer. The authentication server in the interface layer which used to store the information about users such as access modes, user account name and password, and user types will verify whether the user is valid or not or whether the user name and password provided by the user is correct or not. Additionally,

the user interface layer identifies the access model for the user that could be students, faculty, researchers, developers, or administrative staffs.

Once the user is verified as authorized user, the request will be forwarded to the appropriate layer.

The following steps illustrate how the user can use resources from the Cloud.

1) The user sends a request to HEHC Interface layer
2) The authentication server in the Interface layer contains information about users such as access modes, user account name, and password and user type. It is responsible to verify whether the user is valid or not
3) Once the user is authenticated as a legitimate user, the request will be forwarded to the appropriate layer. Otherwise, the request will be rejected
4) In SaaS layer, the request is directed to the applications hosted in this layer
5) In PaaS layer, the user is enabled to develop and deploy the applications and programs with the ability to access Public Clouds resources and platforms
6) In IaaS layer, the physical infrastructures will be virtualized, so the request will be directed to the appropriate location for either Public or Private Clouds

5.4 The Technical Implementation and Importance of Higher Education Hybrid Cloud (HEHC)

Higher Education Hybrid Cloud framework is designed to be implemented and managed by the Ministry of Higher Education. The Ministry of Higher Education is responsible to provide the cloud services to all Higher Educational Institutions in Oman.

The researcher indicated that the proposed architecture (HEHC) consists of a User Interface layer which contains the authentication server; therefore the Ministry of Higher Education will provide sufficient computing facilities in order to authenticate the valid users from different Higher Educational Institutions.

In terms of advantages for Oman education, the Ministry of Higher Education can purchase software and host the programs and applications on the Cloud. Also, it can provide different platforms such programming languages, distributed systems, net-centric systems and similar platforms. Hence, the hosted programs, applications and platforms can be licensed to the different Educational Institutions for use as a service on demand which are disabled after use or after the on-demand contract expires.

In addition to what is mentioned above, the Ministry of Higher Education can act as a linkage between the Cloud Service Providers (CSP) and Higher Educational Institutions in Oman in order to provide more and more services like Google Docs. Consequently the HEIs can rent different services through the Ministry of Higher Education.

Therefore when the Higher Education Hybrid Cloud (HEHC) is implemented by the Ministry of Higher Education, all Higher Educational Institutions in Oman will receive benefits from using Cloud Computing not only for education and gaining necessary skills, but also for academic institutions in terms of resource saving. The HEHC provides flexible means for accessing the file, storages, e-mails, databases, educational resources, research applications and tools anywhere and anytime for faculty, researchers, developers, administrative staff, students and other users in university, on

demand. It allows an effective management of the technological needs of academic institutions such as software delivery, development platform provision, data storage, and computing as a centralized resource from the Ministry of Higher Education.

The proposed HEHC framework facilitates innovative teaching pedagogies, enables more effective knowledge transfer and encourages lifelong learning. It facilitates e-learning, knowledge transfer from academics and affords more teaching learning methodologies like improvements in course content with provision for lecture notes, presentations and assignments in digital form via the Web.

Since the presented HEHC framework is used to serve different users from different academic institutions, it is therefore clear that the users can receive benefits from HEHC. For example, students, administrative staff and faculty can access the services provided by cloud providers online. Further, the developers can use all the software needed for their development online and all the hardware for hosting their applications through a PaaS cloud provider. Additionally, the researchers whose projects and researches require a great deal of processing power and/or additional server capacity can carry out their projects and researches through an IaaS cloud provider.

Chapter 6

Results and Discussion

6.1 Introduction

Adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman is a vital in order to improve quality of education and use the resources anytime and anywhere. Cloud Computing meets the growing demand on different IT services and the budget cuts. Cloud Computing offers good business models for academic institutions in Oman since these academic institutions often do not have enough resources and knowledge to manage the necessary information technology (IT) to support research and development activities .

6.2 Results and Analysis

In this research, the current status of adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman was studied to ensure whether HEIs in Oman currently adopting Cloud Computing or not and to highlight the perceived concerns of adopting Cloud Computing that engaged the Higher Educational Institutions as well as to determine how we could improve the quality and accessibility to education via Cloud. After studying the current status of Cloud Computing adoption in HEIs, the research showed that Cloud Computing is a part of Higher Educational Institutions' IT strategy. Consequently, a high percentage of HEIs are currently adopting Cloud Computing or willing to adopt Cloud Computing in the future.

The main focal point of this research is presenting a Cloud Computing framework that can be used by Higher Educational Institutions in the Sultanate of Oman in order to enable service delivery much more efficient and effective than the current system.

A Hybrid Cloud Computing Model is chosen because this Cloud deployment type enables HEIs to combines the local infrastructure as a private Cloud with selected public Clouds in order to serve students and other users from different universities to enhance the teaching-learning and service delivery. Wherefore, the proposed Hybrid Cloud Computing and its components have been discussed. Additionally, open source Cloud Computing tools, OpenNebula and AppScale have been proposed for the implementation and testing of the proposed framework.

The presented framework is designed to be implemented and managed by the Ministry of Higher Education. It is provided to all HEIs in Oman to get benefits from using Cloud Computing such as reduce the hardware cost, solve the computing problems and storage and improve the quality and accessibility to education anytime and anywhere.

The Online questionnaire was distributed to around twenty five selective Higher Educational Institutions. Pilot study was done for the main questionnaire in order to get more suggestions for improvement. A high percentage of the questionnaire respondents indicated that Cloud Computing is the future successful model of IT at Higher Educational Institutions in Oman.

The main goal of the presented Cloud-based Framework is effective management of technological needs of universities such as delivery of software, providing of development platform, storage of data, and computing.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

Cloud Computing is here to stay. Cloud Computing is an emerging computing paradigm which produces a solution for old problems and provides opportunities for delivering a variety of computing services in a way that has not been experienced before. A few HEIs have already started using Cloud Computing technology for educational purposes. The main goal of suggesting the conceptual architecture is for effective management of technological needs of universities such as delivery of software, providing of development platform, storage of data, and computing.

This research demonstrated how academic institutions are already taking advantage of the benefits of using Cloud Computing in teaching-learning environments to overcome the current learning and service delivery system limitations. It presented the advantages of Cloud Computing usage in academic institutions for faculty, administrative staff, students and others. The research showed that deploying hybrid Cloud Computing is a better choice for the academic institutions since it gives the combined benefit of Private and Public Clouds. The proposed framework is just the pathway map for the implementation of a whole virtual cloud based teaching-learning and service delivery ecosystem.

To sum up, Cloud Computing offers a plethora of tools and choices that should be carefully evaluated to ensure that all educational institutions users obtain the maximum benefits from such technology.

7.2 Future Work

The proposed conceptual framework is just a road map for the implementation of a whole virtual system. Below is a list of future work to be done:

- ✓ The proposed architectural framework can be implemented at all HEIs and maybe modified based on users' requirements.
- ✓ Measure the architectural framework effectiveness by implementing this framework for some colleges at the selected HEIs. For Example, teaching courses in one college by using cloud resources and the other courses in another college without using cloud-based applications.

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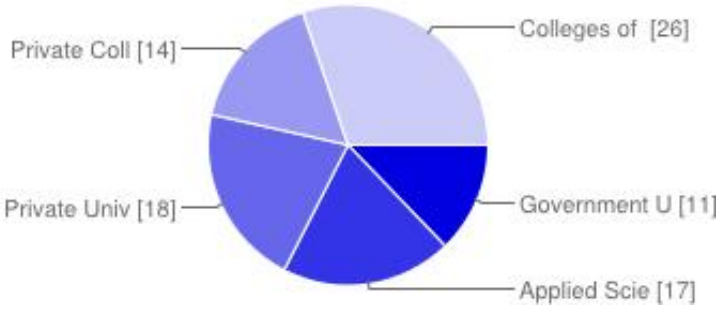
86 responses

View all responses Publish analytics

Summary

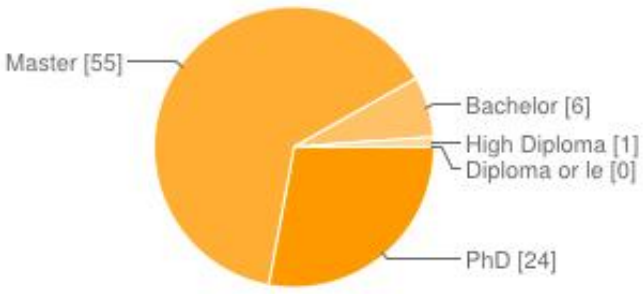
Section one: General Information

Which educational institution you are working in?



Government University	**11**	13%
Applied Science College	**17**	20%
Private University	**18**	21%
Private College	**14**	16%
Colleges of Technology	**26**	30%

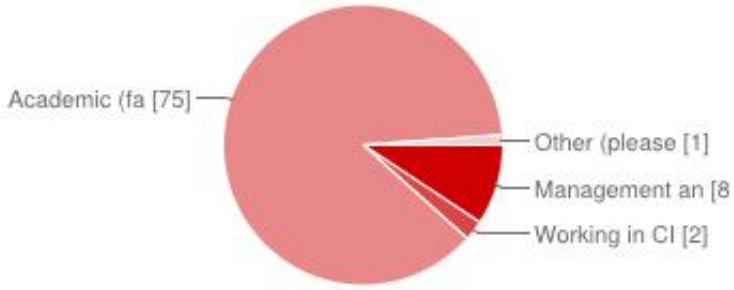
What is the highest level of education you have completed?



PhD	**24**	28%
Master	**55**	64%

Bachelor	**6**	7%
High Diploma	**1**	1%
Diploma or less	**0**	0%

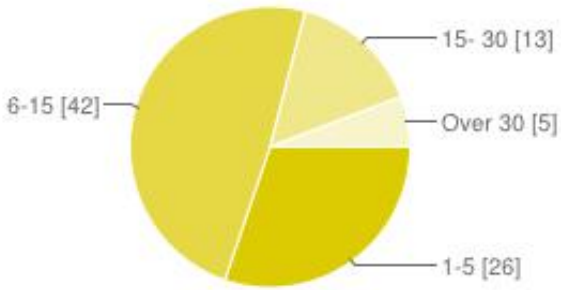
What is your work nature?



Management and Administration of the CIS or data center	**8**	9%
Working in CIS or data center	**2**	2%
Academic (faculty member)	**75**	87%
Other (please specify)	**1**	1%

IT Technical

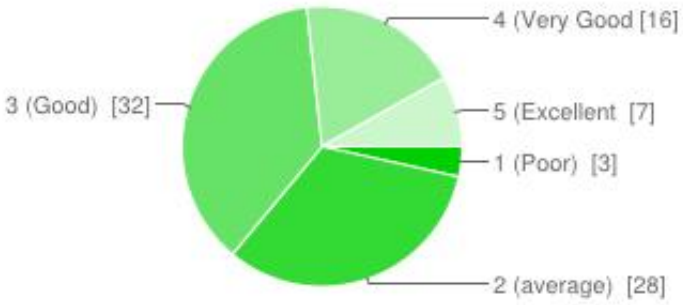
How many years of work experience do you have in your current position?



1-5	**26**	30%
6-15	**42**	49%
15- 30	**13**	15%
Over 30	**5**	6%

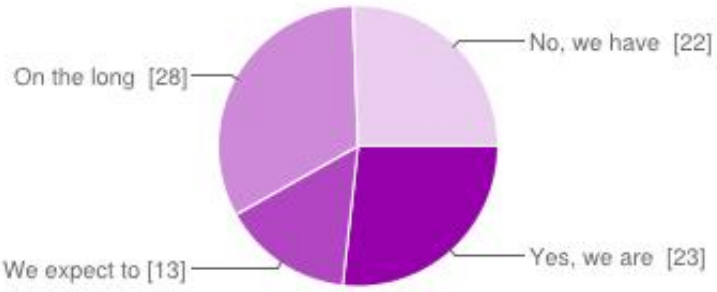
Section two: General Information about Cloud Computing

Describe your knowledge on Cloud Computing



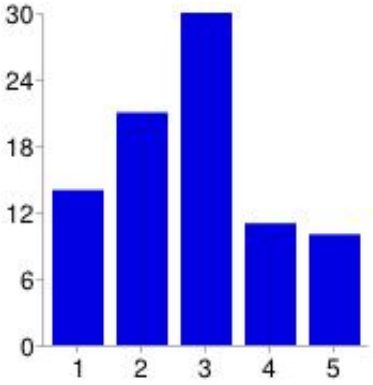
1 (Poor)	**3**	3%
2 (average)	**28**	33%
3 (Good)	**32**	37%
4 (Very Good)	**16**	19%
5 (Excellent)	**7**	8%

Is your Institution willing to use/adopt cloud computing for (parts of) your IT?



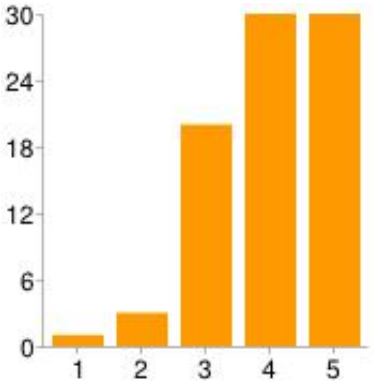
Yes, we are already using cloud computing	**23**	27%
We expect to adopt cloud computing within the upcoming 12 months	**13**	15%
On the long term (>12 months) we see cloud computing as a viable option	**28**	33%
No, we have no intention to adopt cloud computing	**22**	26%

Does your role influence your educational institution’s decision whether to adopt or not adopt cloud computing solution?



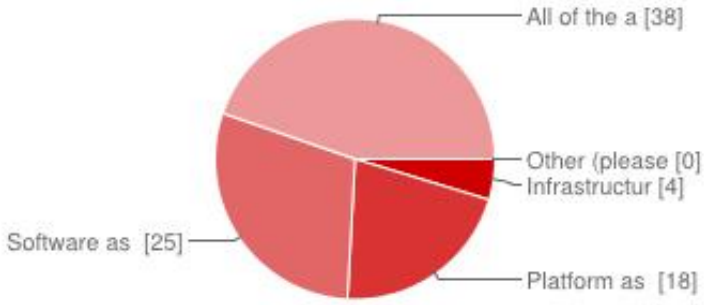
1	**14**	16%
2	**21**	24%
3	**30**	35%
4	**11**	13%
5	**10**	12%

Do you think implementing Cloud Computing in your institution will improve the quality of delivering services?



1	**1**	1%
2	**3**	4%
3	**20**	24%
4	**30**	36%
5	**30**	36%

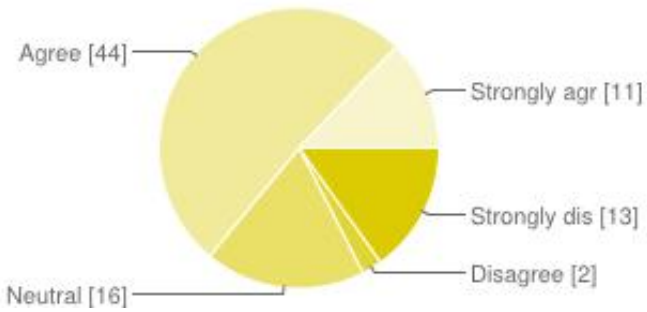
In your opinion, what kind of cloud deployment model is the most suitable for your institution?



Infrastructure as a Service (e.g. Amazon EC2, S3,)	**4**	5%
Platform as a Service (e.g. Google Apps, Salesforce, Microsoft Azure)	**18**	21%
Software as a Service (e.g. Google Docs)	**25**	29%
All of the above	**38**	45%
Other (please specify)	**0**	0%

we use both SAAS and PAAS

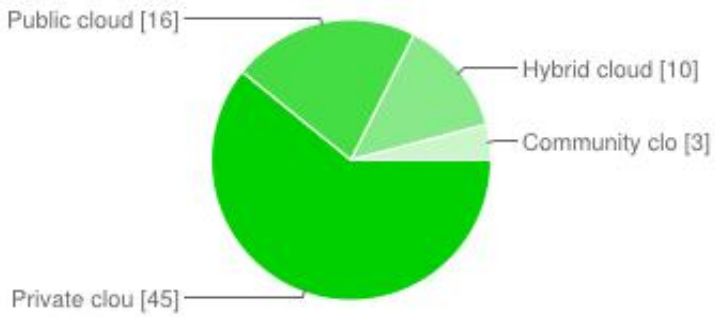
Do you agree with this statement "Cloud computing is the future successful model of IT in Educational Institutions"



Strongly disagree	**13**	15%
Disagree	**2**	2%
Neutral	**16**	19%
Agree	**44**	51%
Strongly agree	**11**	13%

Section three: Adopting Cloud Computing in Higher Educational Institutions

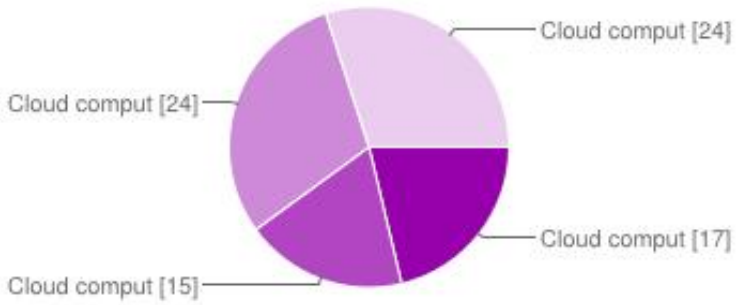
What type of Cloud is used in your institution?



Private cloud	**45**	61%
Public cloud	**16**	22%
Hybrid cloud	**10**	14%
Community cloud	**3**	4%

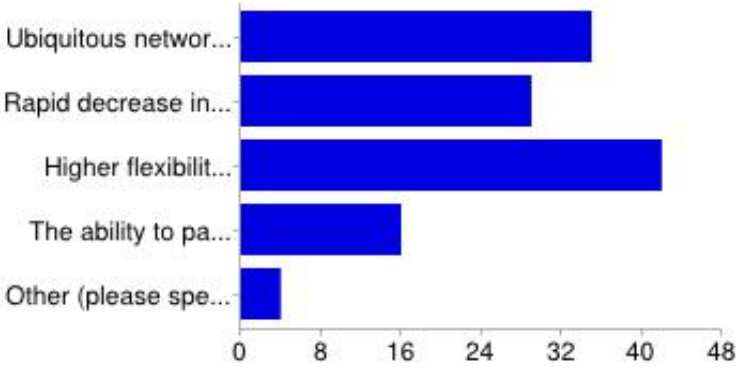
Has cloud computing been formally incorporated into your institution's

strategy?



Cloud computing has been discussed formally and it is part of our (IT) strategy	**17**	21%
Cloud computing has been discussed informally and it is part of our (IT) strategy	**15**	19%
Cloud computing has only been discussed informally	**24**	30%
Cloud computing has not been discussed as a topic within our organization	**24**	30%

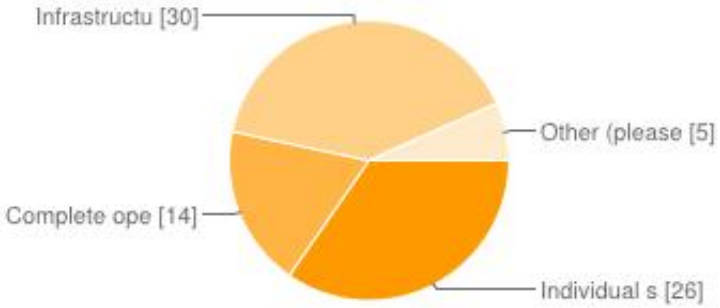
What has encouraged your institution to adopt the cloud computing? (Check one or more of the boxes)



Ubiquitous network access (i.e. access from anywhere and at any time)	**35**	28%
Rapid decrease in hardware cost and increase in computing power and storage	**29**	23%
Higher flexibility of resource allocation and de-allocation	**42**	33%
The ability to pay for the use of computing resources on a short-term basis	**16**	13%
Other (please specify)	**4**	3%

Who said anything about encouragement?! We did not adopt cloud computing it is not adopted yet

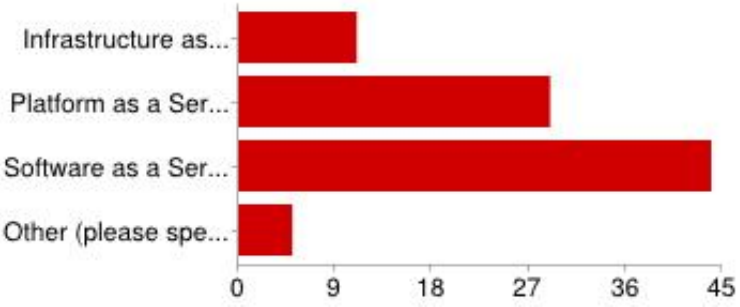
Which “layer” is the most likely used in your institution?



Individual software packages (SaaS)	**26**	35%
Complete operating system and software package available via cloud services (PaaS)	**14**	19%
Infrastructure services such as storage, network capacity etc (IaaS)	**30**	40%
Other (please specify)	**5**	7%

no Yet to use, but we are using Moodle nothing yet

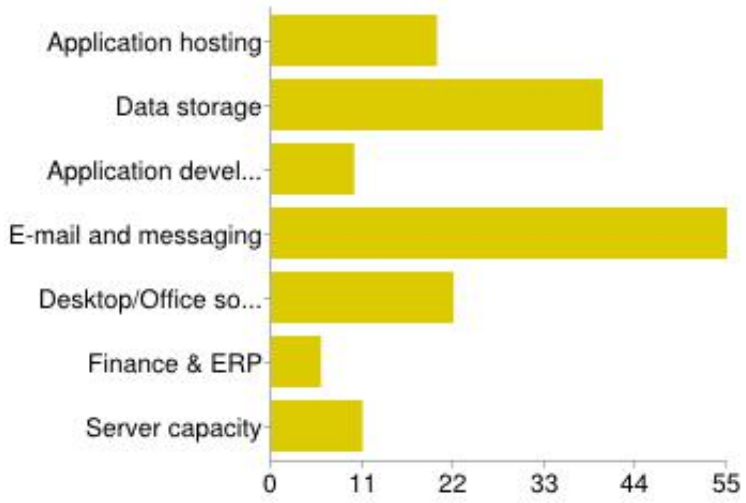
Please specify the type(s) of services that you are using in your institution (check one or more of the boxes)



Infrastructure as a Service (e.g. Amazon EC2, S3, Rackspace, GoGrid)	**11**	12%
Platform as a Service (e.g. Google Apps, Salesforce, Microsoft Azure)	**29**	33%
Software as a Service (e.g. Google Docs)	**44**	49%
Other (please specify)	**5**	6%

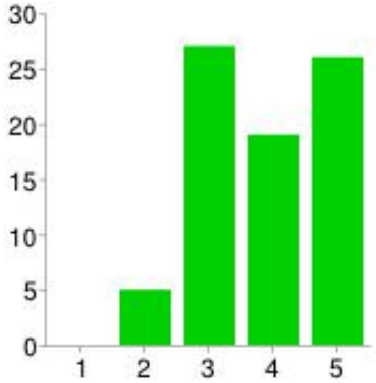
gmail none as i know

Which cloud computing services are you already using or implementing?



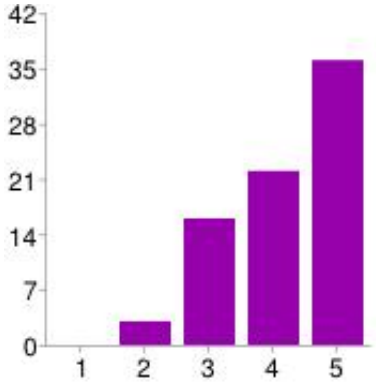
Application hosting	**20**	12%
Data storage	**40**	24%
Application development	**10**	6%
E-mail and messaging	**55**	34%
Desktop/Office software	**22**	13%
Finance & ERP	**6**	4%
Server capacity	**11**	7%

Privacy and Confidentiality of corporate data



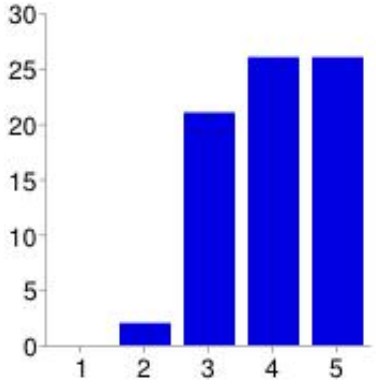
1	**0**	0%
2	**5**	6%
3	**27**	35%
4	**19**	25%
5	**26**	34%

Security



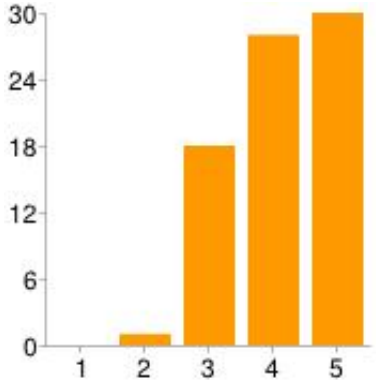
1	**0**	0%
2	**3**	4%
3	**16**	21%
4	**22**	29%
5	**36**	47%

Integrity of services and/or data



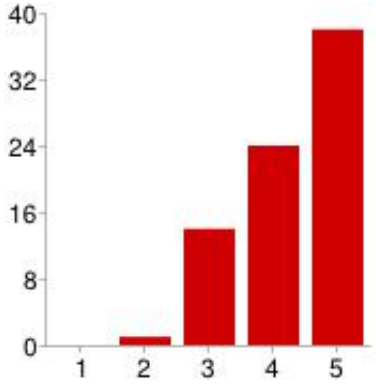
1	**0**	0%
2	**2**	3%
3	**21**	28%
4	**26**	35%
5	**26**	35%

Availability of services and/or data



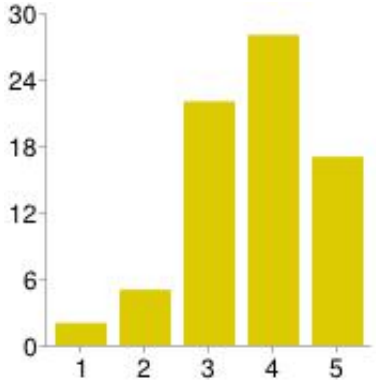
1	**0**	0%
2	**1**	1%
3	**18**	23%
4	**28**	36%
5	**30**	39%

The need for a stable and fast Internet connection



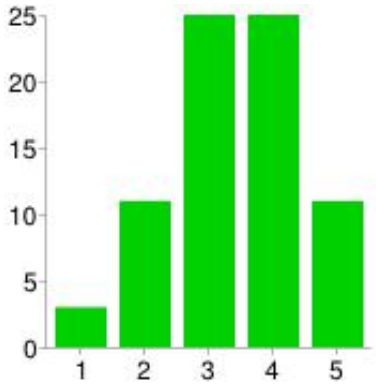
1	**0**	0%
2	**1**	1%
3	**14**	18%
4	**24**	31%
5	**38**	49%

Loss of control of services and/or data



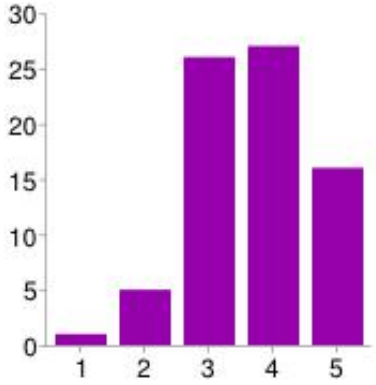
1	**2**	3%
2	**5**	7%
3	**22**	30%
4	**28**	38%
5	**17**	23%

Limited functionalities and options



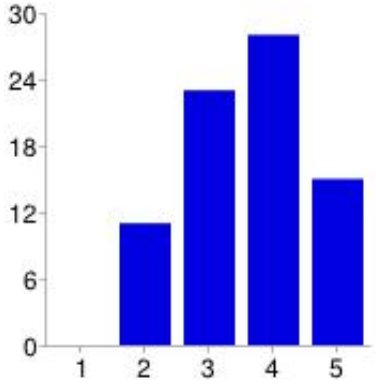
1	**3**	4%
2	**11**	15%
3	**25**	33%
4	**25**	33%
5	**11**	15%

Lack of liability of providers in case of security incidents



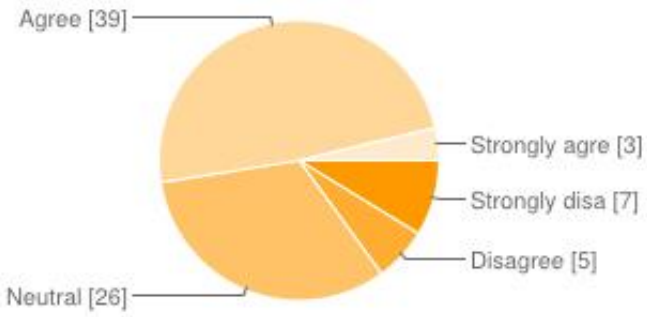
1	**1**	1%
2	**5**	7%
3	**26**	35%
4	**27**	36%
5	**16**	21%

Difficulty of migration to the cloud (legacy software etc...)



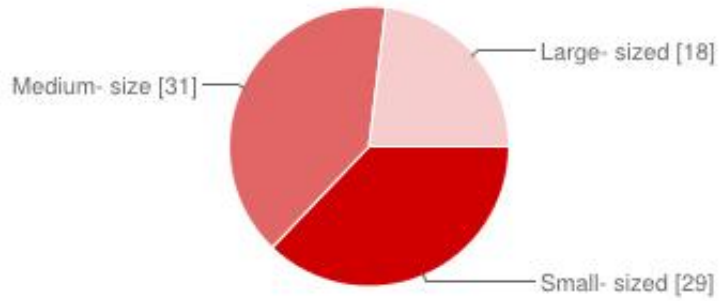
1	**0**	0%
2	**11**	14%
3	**23**	30%
4	**28**	36%
5	**15**	19%

The time of completely migrating the IT at higher educational institutions in Oman has arrived



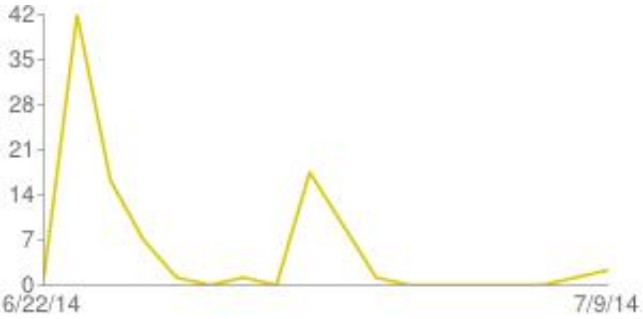
Strongly disagree	**7**	9%
Disagree	**5**	6%
Neutral	**26**	33%
Agree	**39**	49%
Strongly agree	**3**	4%

In your Opinion, the migration to the cloud computing start by:



Small- sized institution	**29**	37%
Medium- sized institution	**31**	40%
Large- sized institution	**18**	23%

Number of daily responses



A conceptual Architectural Framework of Cloud Computing for Higher Educational Institutions in the Sultanate of Oman

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Abstract: Higher Educational Institutions worldwide have become highly dependent on information Systems for their IT provision and service delivery. Thus, the crucial necessity for educational resources like hardware, software, study materials, teaching tools, teaching documentations etc. constantly arises. The objective of this research is to find alternatives and replace the computing machines and other peripherals that are not optimally used, by adopting Cloud Computing. This research studies the current status of adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman. It investigates the current state by distributing online questionnaires to Faculty in IT fields and employees who are working in ICT. Additionally, this research proposed a Higher Education Hybrid Cloud framework as a model for delivery to all Higher Educational Institutions in Oman to provide flexible means for accessing educational resources anywhere and anytime on demand. The model facilitates the innovative teaching pedagogies, enables more effective knowledge transfer and encourages lifelong learning. The research finding shows that adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman will be a better solution for learning progression and service delivery requirements. Accordingly, when the Proposed Higher Education Hybrid Cloud framework is implemented, different users from different academic institutions can access the services provided by cloud providers online which moves the user from being attached to a single machine to the Internet.

1.1 Introduction

In recent days, Higher Educational Institutions are struggling to adopt and adapt Cloud Computing for solving problems of computing and storage.

Cloud Computing introduces many benefits for Educational Institutions like rapid decrease in hardware cost and increase in computing power and storage capacity. The Cloud Computing trend of replacing software traditionally installed on computers with applications delivered via the internet. Cloud Computing provides a set of tools to help students, faculty, researchers and developers to use applications without installing them on their computers and allows access to saved files from any computer with an Internet connection which makes learning tools accessible for a large number of students

Higher Educational institutions, however, have a clear unique mission and a strategic purpose. Many educational institutions worldwide decided to move partially or completely their infrastructure to the Cloud. This trend didn't seem to be followed in Higher Educational Institutions in the Sultanate of Oman. Hereafter, this research paper intends to get answers for the following research questions: Are Omani Higher Educational Institutions (OHEIs) following this trend to move to the Cloud? Is Cloud Computing currently ready to meet the needs and requirements of Omani Higher Educational Institutions? Is it really the right time to switch the IT infrastructure of these institutions to the Cloud?

2.1 Review of Cloud Computing in Higher Education

2.1.1 Adoption of Cloud Computing in Higher Education

Higher education is the most substantial pillar for the country's intellectual development. Through the partnerships between universities, government and industry, researchers and students have proven their contribution to the transformation of society and the entire world economy. In the field of education, Cloud Computing is very practical for a variety of reasons. Indeed, Cloud Computing will enable a certain educational institution to actually make use of the global

internet resources for data analysis and data storage [Jain & Pandey, 2013].

Nowadays, many Educational Institutions intend to adopt Cloud Computing in order to solve computing problems and storage. There are three main benefits for Cloud Computing [Singh & Hemalatha, 2012] [Saidhbi, 2012]:

1) 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

2) The exponentially growing data size in scientific instrumentation/simulation and Internet publishing and archiving

3) The widespread adoption of Services Computing and Web 2.0 applications.

2.1.2 Challenges of Cloud Computing In Higher Education

Many challenges of Cloud Computing for Higher Education relate to the relative newness and the underdevelopment of the marketplace for Cloud services. For Higher Education, decisions to adopt Cloud Computing will be influenced by more than technical and cost considerations [Cisco, 2010] [Jain & Pandey, 2013]. Information is the lifeblood of higher education, and decisions on how to manage that information can have far-reaching political, social, and economic considerations on the students, faculty and the society. The adoption of Cloud Computing causes many risks and challenges such as deciding to use a more traditional outsourcing arrangement. The academic institutions need to weigh the costs and benefits but a major factor of these decisions will be their level of trust in both the cloud deployment model under consideration and the entity providing it [Jain & Pandey, 2013] [He ,Cernusca & Abdous, 2011].

Rosalyn Metz [Metz, 2010] offers the example below to explain why the traditional IT infrastructure is sometimes not good enough: when an institution develops or deploys a new application, they first must jump through a number of hoops. For example, if an institution decides they would like to install the learning management system Moodle, they might have to order a server, wait for the vendor to ship it, install the server in the data center, provision an IP address for the server, set up the DNS for the new IP address, install the operating system, etc. [Jain & Pandey, 2013] [Metz, 2010].

The Cloud Computing challenges have a great impact on migration decisions, so it is possible to effectively handle these challenges and concerns, including training, contract negotiation, and vendor management through careful planning. As a matter of fact, many Academic institutions and organizations are turning toward actual Cloud adoption and deployment and are “outsourcing” computing to the Cloud. For example, the University of Alabama at Birmingham has moved its Blackboard system from on-site hosting to vendor hosting [He ,Cernusca & Abdous, 2011]. In fact, the Cloud Computing market is projected to grow from $40.7B in 2011 to $240B in 2020 [Cisco, 2010]. Consequently, it is important to note that the challenges of Cloud Computing can be greatly reduced or overcome through careful planning, through collaboration, and through sharing of best practices. In order to adopt Cloud Computing in academic institutions successfully, the cooperation among administrators, practitioners, other campus personnel, cloud users (instructors and students), and cloud service providers is needed [He ,Cernusca & Abdous, 2011] [Jain & Pandey, 2013].

3.1 Methodology

An online questionnaire was developed and distributed via Emails to around 25 Higher Educational Institutions in the Sultanate of Oman: a Government University, five Colleges of Technology, five Colleges of Applied Science, four Private Universities and ten Private Colleges. After a runtime of about three weeks, a total of 86 respondents had accomplished the online questionnaire: 75% of them are faculty who are working in IT related fields and 25% are employees working in ICT management and data center.

The online questionnaire shows that 75% of Higher Educational Institutions, which participated in the questionnaire, are currently adopting Cloud Computing or willing to adopt Cloud Computing in the future. The pie chart below displays detailed description of this usage.

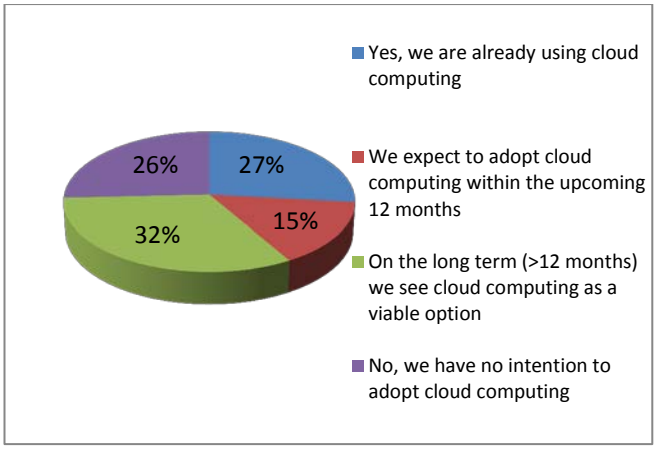

Figure 3.1a: Usage of Cloud Computing in HEIs in the Sultanate of Oman

Furthermore, the participants from the Educational Institutions that are already using Cloud Computing indicated that the most commonly used type of Cloud Computing is Private Cloud (60%, Count 45 of 86).

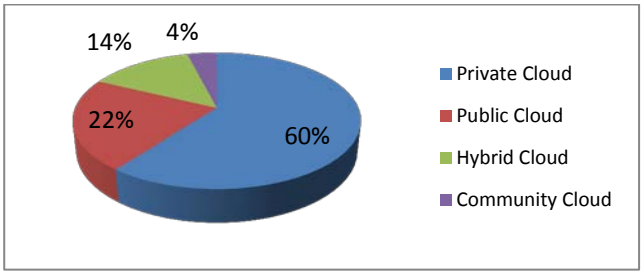

Figure 3.1b: Types of Cloud Computing used in Higher Educational Institutions

The online questionnaire indicates about 64% of Higher Educational Institutions respondents see the Cloud Computing as the future successful model of IT in Educational Institutions. Consequently, more than half of respondents indicate that the time to migrate the IT at the Higher Educational Institutions has arrived.

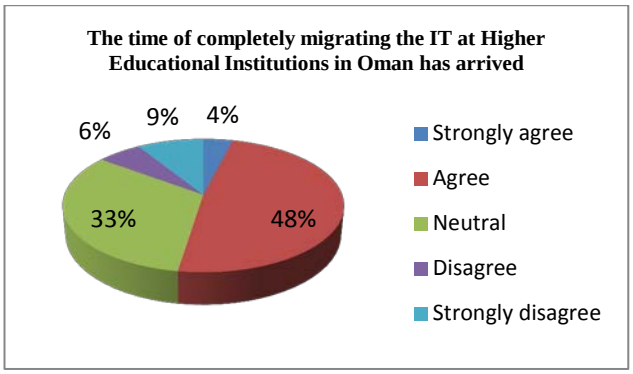

Figure 3.1c: Migration of the IT at Higher Educational Institutions in the Sultanate of Oman to Cloud Computing

4.1 Design and Implementation

The proposed architectural framework namely Higher Education Hybrid Cloud (HEHC) consists of four layers: User Interface layer, Software as a Service layer (SaaS), Platform as a Service layer (PaaS) and Infrastructure as a Service layer (IaaS).

4.1.1 User Interface layer:

The user interface layer acts as an interface between the users and cloud contents. It connects users from different Higher Educational Institutions to the cloud contents. It contains an authentication server that works as a master load-balancer that verifies whether the user is valid or not or whether the user name and password provided by the user is correct or not.

4.1.1.1 Authentication server:

The authentication server associated with users from different Educational Institutions to submit their requests to the Cloud via the authentication server. It is responsible to collect the requests from users and forward them after verification to the cloud contents.

Each user terminal communicates the authentication server for receiving services from cloud side. The procedure is depicted in figure 4.1.

The steps of procedures are summarized below:

1. First of all, user request is sent to the authentication server with necessary user identification information like username and password.
2. The authentication server contains information about users such as access modes, user account name, and password and user type which is responsible to verify whether the user is valid or not.
3. After verifying the user as a legitimate user, the authentication server sends the request to the cloud system.

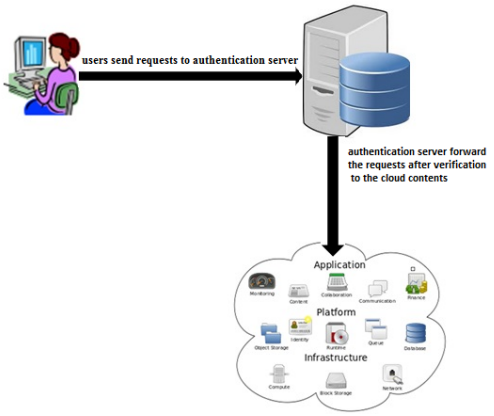

Figure 4.1: Steps of Communication between End User and Authentication Server

4.1.2 Software as a Service layer (SaaS):

This layer is a software delivery model which provides the access by using thin client, normally using web browser over the internet to the hosted programs and applications on the cloud. The hosted programs and applications are licensed to the users for use as a service on demand which are disabled after use or after on-demand contract expire. Examples are ERP, Moodle, Eduwave and other application software.

4.1.3 Platform as a Service layer (PaaS):

This layer provides the access to different platforms programming language, distributed systems, net-centric systems and similar platforms. It provides a flexible and configurable platform that supports multiple programming languages and gives the ability to develop and deploy the applications either on private or public Clouds. It facilitates the deployment of applications without the cost and complexity of buying and managing the underlying hardware and software. It provides all of the facilities required to support the complete life cycle of building and delivering web applications and services entirely available from the Internet. It offers many facilities for application design, application development, testing, deployment and hosting as well as application services such as team collaboration, web service integration, database integration, security, scalability, storage, persistence, state management, application versioning, application instrumentation and developer community facilitation [Ammar, Hamouda, Gamal, Abdelmoez & Moussa, 2012].

4.1.4 Infrastructure as a Service layer (IaaS):

This layer is the lowest layer which is the responsible for building the servers and set up their configurations. It delivers computer infrastructure typically a platform virtualization environment as a service along with storage and networking. It provides the flexible way of dealing with the hardware layer (servers, storage systems, switches, routers, and other systems) through virtualization. Rather than purchasing servers, software, data-center space or network equipment, clients instead buy those resources as a fully outsourced service.

4.2 Implementation of Conceptual Architectural Framework

The proposed architectural framework called HEHC stands for Higher Education Hybrid Cloud. This framework deploys a hybrid cloud which combines a local infrastructure as private cloud with selected public cloud. The hybrid cloud deployment model allows mixing and matching services from different CSPs (Cloud Service Providers) and provides more security for the applications and data hosted in the private cloud since part of the infrastructure is controlled by the institution [Saidhbi, 2012]. In other words, hybrid cloud is a judicious mix of public and private clouds in order to gain the maximum advantage from the good aspects of each of these clouds. Hybrid cloud works out the most preferred infrastructure since it comprises of public cloud which used for less sensitive tasks and private cloud that used for most vital processing tasks [Viswanathan, 2014].

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 [Saidhbi, 2012].

Hybrid Cloud the cloud infrastructure is a composition of two or more clouds (private, Community or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds) [Mell & Grance, 2011]. The next figure shows the proposed Hybrid Cloud Computing implementation architucture for Higher Educational Institutions in the Sultanate of Oman namely Higher Education Hybrid Cloud (HEHC).

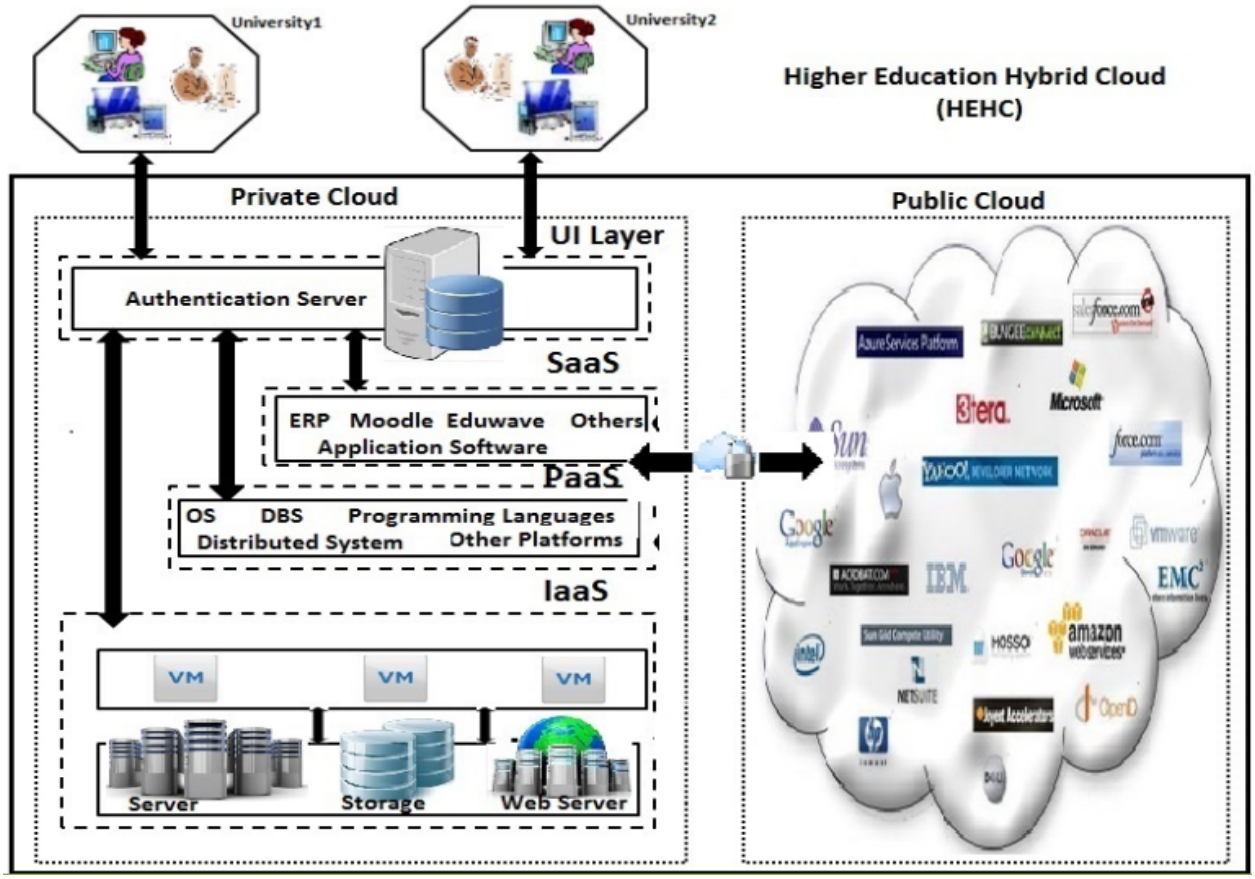

Figure 4.2: Proposed Hybrid Cloud Computing implementation architecture for Higher Educational Institutions in the Sultanate of Oman

Users from different academic institutions such as students, teaching staff, administrative staff, research staff and software developers can use different types of services provided by the cloud.

The user can use the resources available in the cloud by sending a request to the Higher Education Hybrid Cloud (HEHC) interface layer. The authentication server in the interface layer which used to store the information about users such as access modes, user account name and password, and user types will verify whether the user is valid or not or whether the user name and password provided by the user is correct or not. Additionally, the user interface layer identifies the access model for the user that could be students, faculty, researchers, developers, or administrative staffs.

Once the user is verified as authorized user, the request will be forwarded to the appropriate layer.

The following steps illustrate how the user can use resources from the cloud.

1) The user sends a request to HEHC Interface layer
2) The authentication server in the Interface layer contains information about users such as access modes, user account name, and password and user type. It is responsible to verify whether the user is valid or not
3) Once the user is authenticated as a legitimate user, the request will be forwarded to the appropriate layer. Otherwise, the request will be rejected
4) In SaaS layer, the request is directed to the applications hosted in this layer
5) In PaaS layer, the user is enabled to develop and deploy the applications and programs with the ability to access public clouds resources and platforms
6) In IaaS layer, the physical infrastructures will be virtualized, so the request will be directed to the appropriate location for either public or private clouds.

4.3 Importance of Higher Education Hybrid Cloud (HEHC)

Higher Education Hybrid Cloud framework is designed to be implemented and managed by the Ministry of Higher Education. It is provided to all Higher Educational Institutions in Oman to get benefits from using Cloud Computing not only for education and gaining necessary skills, but it is beneficial for academic institutions and can save a lot of resources as well. It provides flexible means for accessing the file, storages, e-mails, databases, educational resources, research applications and tools anywhere and anytime for faculty, researchers, developers, administrative staff, students and other users in university, on demand. It allows an effective management of the technological needs of academic institutions such as software delivery, development platform provision, data storage, and computing.

The proposed HEHC framework facilitates innovative teaching pedagogies, enable more effective knowledge transfer and encourage lifelong learning. It facilitates e-learning, knowledge transfer from academics and affords more teaching learning methodologies like improvement in course contents and providing lecture notes, presentations and assignments in digital form via the Web.

Since the presented HEHC framework is used to serve different users from different academic institutions, the users can get benefit from HEHC. For example, students, administrative staff and faculty can access the services provided by cloud providers online. Further, the developers can use all the software needed for their development online and all the hardware for hosting their applications through a PaaS cloud provider. Additionally, the researchers whose projects and researches require a great deal of processing power and/or additional server capacity can carry out their projects and researches through an IaaS cloud provider.

5.1 Results and Analysis

In this research, the current status of adopting Cloud Computing in Higher Educational Institutions in the Sultanate of Oman was studied to ensure whether HEIs in Oman currently adopting Cloud Computing or not and to highlight the perceived concerns of adopting Cloud Computing that engaged the Higher Educational Institutions as well as to determine how we could improve the quality and accessibility to education via cloud. After studying the current status of Cloud Computing adoption in HEIs, the research showed that Cloud Computing is a part of Higher Educational Institutions' IT strategy. Consequently, a high percentage of HEIs are currently adopting Cloud Computing or willing to adopt Cloud Computing in the future.

The main focal point of this research is presenting a Cloud Computing framework that can be used by Higher Educational Institutions in the Sultanate of Oman in order to enable service delivery much more efficient and effective than the current system.

A Hybrid Cloud Computing Model is chosen because this cloud deployment type enables HEIs to combines the local infrastructure as a private Cloud with selected public Clouds in order to serve students and other users from different universities to enhance the teaching-learning and service delivery. Wherefore, the proposed Hybrid Cloud Computing and its components have been discussed.

The presented framework is designed to be implemented and managed by the Ministry of Higher Education. It is provided to all HEIs in Oman to get benefits from using Cloud Computing such as reduce the hardware cost, solve the computing problems and storage and improve the quality and accessibility to education anytime and anywhere.

The Online questionnaire was distributed to around twenty five selective Higher Educational Institutions. Pilot study was done for the main questionnaire in order to get more suggestions for improvement. A high percentage of the questionnaire respondents indicated that Cloud Computing is the future successful model of IT at Higher Educational Institutions in Oman.

The main goal of the presented Cloud-based Framework is effective management of technological needs of universities such as delivery of software,

providing of development platform, storage of data, and computing.

6.1 Conclusion

Cloud Computing is here to stay. Cloud Computing is an emerging computing paradigm which produces a solution for old problems and provides opportunities for delivering a variety of computing services in a way that has not been experienced before.

A few HEIs have already started using Cloud Computing technology for educational purposes. The main goal of suggesting the conceptual architecture is for effective management of technological needs of universities such as delivery of software, providing of development platform, storage of data, and computing.

This research demonstrated how academic institutions are already taking advantage of the benefits of using Cloud Computing in teaching-learning environments to overcome the current learning and service delivery system limitations. This paper presented the advantages of Cloud Computing usage in academic institutions for faculty, administrative staff, students and others. The research showed that deploying hybrid Cloud Computing is a better choice for the academic institutions since it gives the combined benefit of private and public clouds. The proposed framework is just the pathway map for the implementation of a whole virtual cloud based teaching-learning and service delivery ecosystem.

To sum up, Cloud Computing offers a plethora of tools and choices that should be carefully evaluated to ensure that all educational institutions users obtain the maximum benefits from such technology.

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