

A CLOUD COMPUTING FRAMEWORK FOR COMPUTER SCIENCE EDUCATION

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ABSTRACT

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With the rapid growth of Cloud Computing, the use of Clouds in educational settings can provide great opportunities for Computer Science students to improve their learning outcomes. In this thesis, we introduce Cloud-Based Education architecture (CBE) as well as Cloud-Based Education for Computer Science (CBE-CS) and propose an automated CBE-CS ecosystem for implementation.

This research employs the Cloud as a learning environment for teaching Computer Science courses by removing the locality constraints, while simultaneously improving students' understanding of the material provided through practical experience with the finer details and subjects' complexities. In addition, this study includes a comparison between Cloud-based virtual classrooms and the traditional e-learning system to highlight the advantages of using Clouds in such a setting.

We argue that by deploying Computer Science courses on the Cloud, the institution, administrators, faculty, and the students would gain significant advantages from the new educational setting. The infrastructure buildup, the software updating and licenses managements, the hardware configurations, the infrastructure space, maintenance, and power consumption, and many other issues will be either eliminated or minimized using the Cloud technology. On the other hand, the number of enrolled students is likely to increase since the Cloud will increase the availability of the needed resources for interactive education of larger number of students; it can deliver advanced technology for hands-on training, and can increase the readiness of the students

for job market. The CBE-CS approach is more likely to allow faculty to better demonstrate the subjects' complexities to the students by renting the needed facilities whenever it is desired.

The research also identified several potential Computer Science courses which could be launched and taught through Clouds. In addition, the selected courses have been classified based on three well-known levels of the Cloud services: Software as a Service (SaaS), Platform as a service (PaaS), and Infrastructure as a Service (IaaS). Subsequently, we propose to build a framework for CSE-CS considering the service layers and the selected courses.

The proposed CBE-CS framework is intended to be integrated in a Virtual Classroom Ecosystem for Computer Sciences based on Cloud Computing referred to as VCE-CS. This ecosystem is scalable, available, reliable, and cost effective. Examples from selected pilot courses (i.e., Database, Operating System, Network, and Parallel Programming) are discussed. This research describes VCE-CS and argues for the benefits of such systems.

To my family and all who supported me in my studies

To my parents, my husband, and my daughter

To every seeker of knowledge

I dedicate this research

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CHAPTER 1. INTRODUCTION

1.1. Background

The accelerated development in Information Technology and the necessity for enhanced learning environments by harnessing existing technologies and resources has created a need to teach Computer Science students more effectively. Cloud Computing appears to be one of the most beneficial technologies for this purpose due to its numerous characteristics such as: availability, scalability, agility, elasticity, and reliability for on demand services. These characteristics, among many others, can give the impression that Cloud Computing could significantly enhance the Computer Science learning environment.

Bowling Green State University (BGSU), like many other institutions, has been pushed to revise its IT infrastructure structure and follow the Cloud development. The traditional infrastructure may only meet the QoS of the advanced e-learning tools and systems; Accordingly, BGSU is moving to the Cloud within the next five to ten years. Consequently, we should know the Cloud-based framework in general and more specifically on behalf of the Computer Science Department. This preparation would largely reduce the amount of planning time of converting the current system infrastructure architecture to Cloud-based when the University moves to the Cloud-based infrastructure in the near future. Since Cloud Computing has emerged in the past few years, emphasis and significant effort has been involved in exploring and defining this new technology (Dong et al., 2009a; Marinos & Briscoe, 2009; Gong et al., 2010; Scale, 2010; Wang et al., 2010; Marston et al., 2011; Vaquero, 2011). Technology experts

said by 2020, most institutions and companies are going to move to the Cloud which will eliminate the dependency of desktops (Anderson & Rainie, 2010). “Cloud Computing” is a buzz term which could have various definitions, e.g. "large data centers permit resource sharing across hosted applications and lead to economies of scale at both the hardware and software level" (Terry, 2011); however, the universal scheme among all Clouds is the scalability of providing service capabilities through the Internet (Zhang, 2009). These services vary, starting from any needed hardware until it reaches an application as a software service. Numerous research efforts (Dong et al., 2009a, b; Rao et al., 2010; Vaquero, 2011) in the education field have focused on using public Clouds, such as Windows Azure (Microsoft, 2011c), Amazon Elastic Compute Cloud (EC2) (Amazon, 2011a), and Google AppEngine (Google, 2011a). These researchers seek the power of the Cloud’s infrastructure, platforms, and software known as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) respectively.

In this research, we propose to build a framework to utilize the Clouds’ features in the teaching process of Computer Science courses. The Clouds’ platforms, in our case, are considered educational tools for Computer Science. Since there are a variety of Cloud types and services, we identify the courses that could apply Cloud Computing to their teaching processes. We used Bowling Green State University (BGSU) Computer Science department’s curriculum with in respect to the ACM and IEEE Computer Society’s latest curriculum to categorize the courses; this classification was based on how we could maximize the advantages of the Clouds’ services. In the second step, we organize the selected courses according to the service layers (IaaS, PaaS, and SaaS) of the Cloud. Based on the preferred courses, the framework was built to include all the needed functionalities. The framework was designed with respect to the basic Service Oriented Architecture (SOA) classification to provide a flexible and independent

approach (Papazoglou & Heuvel, 2007; Vouk, 2008; Fang & Sing, 2009; Feuerlicht & Govardhan, 2009; Seo et al., 2010) which can be easily constructed into a robust infrastructure (Sedayao, 2008). After performing short experiments with Windows Azure and Amazon Clouds to explore the available services, this research considers the Computer Science courses with some examples of how these courses exploit Cloud Computing in students learning abilities. The goal is to provide more effective learning environments for both the faculty and students by focusing on development (Truong & Dustdar, 2011) without addressing unnecessary hardware configurations, software updating, or any maintenance issues in the non-theoretical courses. For instance, testing a security algorithm in a distributed environment requires network connectivity before testing the code which distracts the student and faculty from focusing on the original problem. As a result, testing the algorithm on the Cloud keeps the student focused and may give him/her the ability to go beyond that point of knowledge and produce better outcomes (Cappos et al., 2009; Ivica et al., 2009). Due to the financial crisis, corporation budgets were significantly decreased in 2009 (Gudaneseu, 2010) which made Cloud Computing one of the best solutions for their e-learning environments. As a result, companies can train their employees using the Cloud solutions, and the educational institutions can also educate their students by using Cloud tools and infrastructure.

1.2. Problem Statement

Current Computer Science educational settings are traditional and often unable to face the demand of rapid changes in technologies in an interactive learning environment. The same is true for e-learning which appears to have numerous limitations starting from use of local surroundings. In addition, the infrastructure limitations often force institutions to avoid using

multimedia contents in synchronized form due to the cost. Because of these limitations and many others, institutions often eliminate the use of sophisticated educational platforms.

This research is intended to create a framework for Computer Science education to remove some of the above limitations and challenges by harnessing the power of Cloud Computing. The framework removes the locality constraints, allowing students and faculty to collaborate in a distributed and interactive surrounding. In addition, Cloud Computing provides a set of tools to help educators explore subject complexities in a manageable manner without the risk of harming the system because of the virtualization technology within the Cloud Computing preventing the damage (Vouk, 2008). The new Cloud-based E-learning environment can be solid, hold more sophisticated packages, and support synchronized contents without much concern about the infrastructure limitations. The resources, when they are needed, can be rented from the Cloud.

1.3. Research Goal and Objectives

The research goal of this project is to build a Virtual Classroom Ecosystem for Computer Science Education based on Cloud Computing (VCE-CS) which will enhance the learning progression. We propose a new framework that deploys a hybrid Cloud model which allows better utilization of the IT infrastructure for educational purposes for a learning institution like BGSU.

The main objective of the research is to explore Cloud Computing potential for Computer Science education due to the intimate relationship between this domain and the Cloud which distinguishes CBE-CS from any other Cloud-Based education. While most CBE operates on the top level of the Cloud, CBE-CS can penetrate into all levels of the Cloud to explore, for example,

Distributed Operating System, Communication Networks, Parallel Programming, Database Managements, Web-based applications, and many others.

The research's second objective is to provide an enhanced learning environment by answering the following questions: How can we harness the Cloud as a learning environment to teach Computer Science courses?

Other objectives include providing a cost effective solution, scalable, and accessible environment that could be deployed in any learning institution which teaches Computer Science courses. More details are described in Chapter 5, specifically in Section 5.1.

1.4. Contributions

This research presents a Virtual Classroom Ecosystem for Computer Science (VCE-CS), a framework based on Cloud Computing to teach selected Computer Science courses, such as Fundamental Programming, Data Analytics, Net-Centric Computing, Computational Science, Distributed Systems and Simulation, Network Communications, Service Management, Virtualization, Human-Computer Interaction, Information Management, Computer Security, and Operating Systems. The framework aims to obtain the benefits of Clouds' services in the teaching processes by using those services to test and apply the Computer Science course concepts, especially the programming-based courses. The major Contributions are as follows:

- I. Describing a Cloud-based education in general and for Computer Science in particular.
- II. Providing framework architecture for Cloud-Based Education (CBE) and Cloud-Based Education for Computer Science (CBE-CS).

- III. Implementing a Virtual Classroom Ecosystem designed for Computer Sciences based on Cloud Computing (VCE-CS).
- IV. Piloting Computer Science courses on CBE-CS.
- V. Identifying and describing the benefits of CBE-CS for students, faculty, administrations, and universities.
- VI. Exploring the future direction of CBE-CS.

The VCE-CS is a framework that uses Clouds and the services provided by a Cloud Service Provider (CSP). It delivers a Platform as a Service for the selected Computer Science courses to be launched on the Cloud. VCE-CS utilizes the three layered architecture of the cloud services to clearly identify the courses' positions on the frameworks with respect to the service-oriented architecture (SOA). The VCE-CS framework uses OpenNebula, an open source package, to manage and automate the operation of the virtual infrastructures for both BGSU's Cloud (the private Cloud) and the integrated public Cloud. On top of OpenNebula is Aneka, which controls the software and the platform layer by providing a configurable, flexible, and multi-programming model that provides a hybrid cloud deployment model.

1.5. Organization of the Thesis

This research proceeds as follows. In Chapter 2, there is an overview of Cloud Computing followed by an outline of a Virtual Data Centers (VDC). Cloud-Based Education (CBE), which explores the virtual classroom (VCR) and their technologies along with the CBE benefits and limitations, is discussed in Chapter 3. In Chapter 4, the related work is presented with four subsections, starting from the existing platforms and applications, moving to some of the available simulation toolkits and available frameworks of Cloud implementations, and ending

with the knowledge gap of the proposed work with the presented related work; in other words, the significance of the proposed study. Chapter 5 describes the objectives and the methodology of the proposed work. Examples from the pilot courses are explained in Chapter 6, while Chapter 7 proposes the Cloud-Based Education for Computer Science (CBE-CS) ecosystem framework. A discussion of the presented work is offered in Chapter 8 followed by future work in Chapter 9. Finally, the research's conclusion is offered in the last chapter.

CHAPTER 2. CLOUD COMPUTING OVERVIEW

2.1. Definition of Cloud Computing

Currently, there is no standard definition for Cloud Computing. In this section, we try to clarify what Cloud Computing is. Cloud Computing is Internet-based technology (Chine, 2010; Cubillo et al., 2011) which provides computational resources via a computer network and provides flexible, scalable, and on-demand services to the end users by centralizing the storage and network bandwidth as well as processing memory. Cloud Computing is a computing platform that offers computing power for scientists when they are exceeding institutions' local computing capabilities (Armbrust et al., 2009). Cloud Computing has moved the user from being attached to a single machine to the Internet (Yixin, 2010); therefore, the user is freed from thinking about the file's physical location. For example, the user is no longer concerned about a specific desktop or flash drive, but instead focuses on the availability of Internet connection. CSPs assure their runtime performance of individual applications by Quality of Service (QoS) (Buyya et al., 2010; Doelitzscher et al., 2011). These services are classified into three basic layers—applications, platforms, and infrastructures—which serve different purposes and provide various services (Creeger, 2009).

In recent years, Clouds have spread dramatically (Pocatilu et al., 2010) because of features which make it the target of most Cloud Service Providers (CSPs). Currently, there is no comprehensible definition or standard for Cloud Computing that all CSPs agree upon since each provider utilizes terminology based on its own product's portfolio. Despite several standardization efforts, there is no clear standard for the Cloud Computing (Qian et al., 2009). Furthermore, Cloud Computing is considered a combination of Distributed Computing, Grid

Computing, and Utility Computing (Kim et al., 2011). A simple illustration of Cloud Computing development is shown in Figure 1:

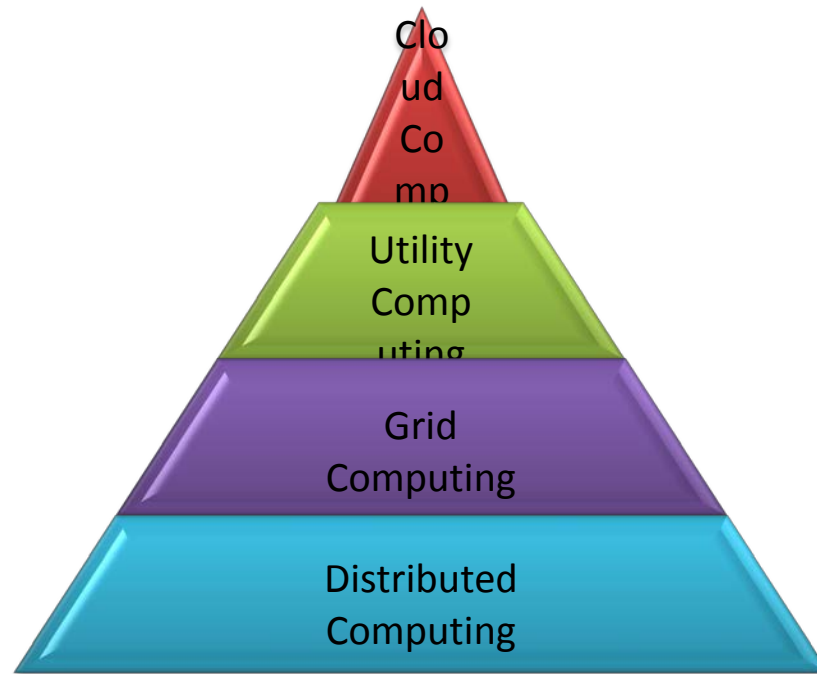


Figure 1: Evolution of Cloud Computing based on other Computing models

Vaquero et al. (2009) stated that it is an important issue to have a standard definition for Cloud Computing. They believe that the unified definition will help to expand the view of Cloud Computing rather than focus on industry benefits. Subsequently, they collected around 22 definitions and identified the similar features between them. Based on their analysis, they proposed a definition which included most of the existing feature of Cloud Computing. Because of overlap in the Grid Computing and Cloud Computing definitions, Vaquero et al. compared Grid Computing with Cloud Computing from 17 different angles, distinguishing between the two paradigms. Gong et al. (2010) have studied the differences between Grid Computing and Cloud Computing from eight angles, and they summarized their findings in Table 1. The first chosen characteristic is service oriented architectures (SOA) representation adapted by both Clouds and

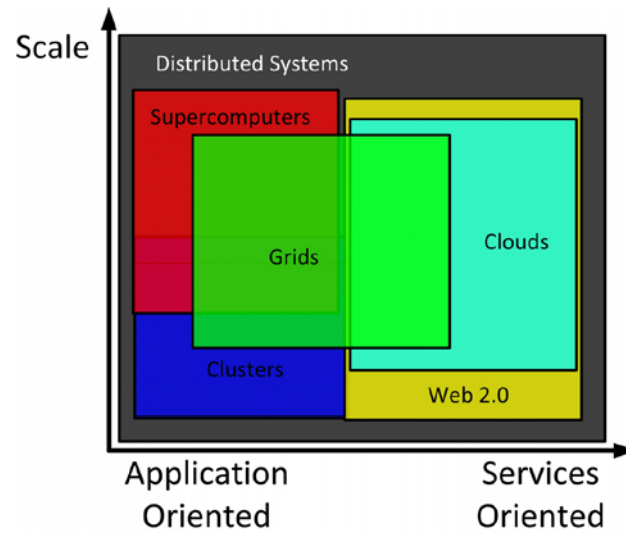
Grids. The other characteristics are the loose coupling, strong fault tolerant, ease of use, TCP/IP-based, and virtualization which all Clouds are based upon while the Grids do not have the whole characteristic which represented as a half, in Table 1.

Table 1: Characteristics of Cloud and Grid Computing (Gong et al., 2010)

Characteristic	Cloud computing	Grid computing
Service oriented	Yes	Yes
Loose coupling	Yes	Half
Strong fault tolerant	Yes	Half
Business model	Yes	No
Ease use	Yes	Half
TCP/IP based	Yes	Half
High security	Half	Half
Virtualization	Yes	Half

Foster et al. (2008) have illustrated the overlap between Grid Computing and Cloud Computing as shown in Figure 2. The figure showed that the Clouds have built on top of Web 2.0 while the Grids can be utilized in Web 2.0. Furthermore, The Clouds are more scalable and service oriented when comparing them to the Grids.

The most important consideration when choosing a CSP is the Service Level Agreement (SLA). The terms of use, privacy, security, usage of the services, and how these services will be delivered to the user must be clearly stated in the SLA. The user has to understand the SLA details to avoid any problems in the future.



(Foster et al., 2008)

Figure 2: Overview of Grids and Clouds overlapping

In essence, the basic definition of Cloud Computing is providing on-demand services based on a Service Level Agreement (SLA) which guarantees a specific level of performance and services uptime (Broberg et al., 2009) and the principle of payment per used amount.

2.2. Service Models

Cloud services can be categorized into three main service models. These services, with each one considered a layer in the Cloud, are illustrated below.

2.2.1. Infrastructure as a Service (IaaS)

The first layer is the Infrastructure as a Service (IaaS). In this layer, the whole IT infrastructure can be delivered as a service. The CSPs offer different services, for example, computing power represented in the Virtual Machines (VMs), storage, networking services such as switches, routing services with load balancers, and workload capabilities. The user can easily obtain the needed resources like servers, storage, and connections. The infrastructure services are

distributed to the users via the CSPs' data center. Amazon Elastic Compute Cloud (Amazon EC2), for example, provides compute capacity via Amazon's data centers.

IaaS offers a scalable infrastructure with the rapid provisioning feature (Pathan et al., 2009; Zeng et al., 2009). In addition, users will pay only for the used resources which eliminate the capital expenses; thus, the budget will be controlled, which is the most difficult task for small institutions and businesses. By integrating Clouds to offer additional infrastructure, institutions will no longer be worried about resource limitations.

2.2.2. Platform as a Service (PaaS)

The second layer is the Platform as a Service (PaaS), a virtual platform over the Internet gives users the ability to develop and deploy their applications. CSPs provide a set of tools to help the developer to build their applications easily by using any number of servers. In the PaaS layer, the user can select appropriate operating systems to develop the intended application. The user can use plug-ins or prebuilt sub-programs for any Web-based applications which are compatible with the CSP's applications to save time. PaaS provides services in different levels; the user can use an existing set of deployed applications via an interface which is considered a high level of service, or user can build a platform or applications using the provided operating systems and middleware.

The PaaS users and SaaS developers do not need to install any application or use specific hardware; all they need is a device connected to the Internet, and can browse web pages. Platform as a Service provides a set of preconfigured images for different VMs with different operating systems; thus, all the developers (users) need is to select the images then start developing their applications on the Cloud.

2.2.3. Software as a Service (SaaS)

The third layer is the Software as a Service (SaaS). SaaS is the simplest layer of this category; it simply means accessing an application through the Internet on demand. In the SaaS layer, the CSP provides a single instance on the Cloud for multiple users. Google Apps, one of the most powerful SaaS used by many institutes (Google, 2011b), provide a variety of Web-based applications for business, education, and government.

Figure 3 shows examples of CSPs in respect to the Cloud service layers illustrated above. In the bottom of Figure 3, the Infrastructure as a Service (IaaS) layer shows servers, storage, connectivity, load balancing, and firewall services. As the figure showed GoGrid which provides IaaS services. Moreover, Amazon EC2 provides compute capabilities while Amazon S3 offers a storage service. On top of IaaS, the Platform as a Service (PaaS) layer that acts as a container enables the users to modify the environment as well as develop and deploy their applications, such as Force.com, Windows Azure, and Google AppEngine. The most abstract layer of the Cloud service layers is Software as a Service (SaaS) which enables users to run hosted applications on the Cloud and use them remotely. For example, Yahoo mail and Gmail which provides email service over the Cloud. Additionally, as we see in the top of Figure 3 Salesforce which provides Customer Relation Management (CRM) applications.

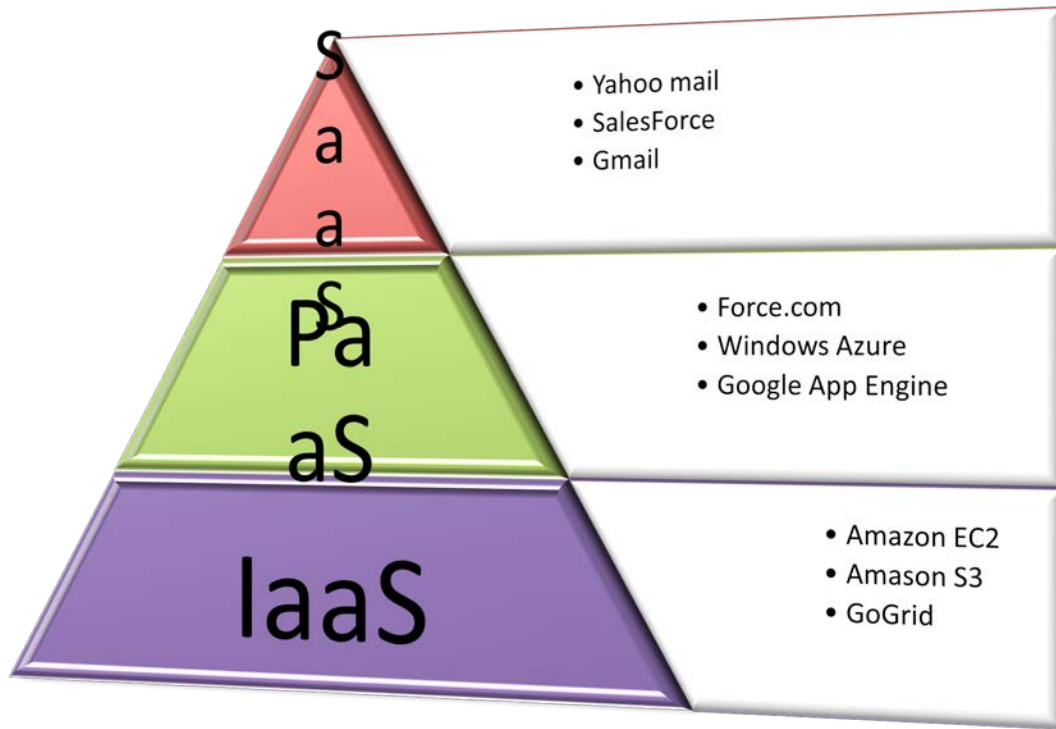


Figure 3: Basic Service Layers of Cloud Computing with some selected Cloud service providers for each layer

2.3. Importance of the Cloud

Important characteristics of Clouds include scalability, flexibility, elasticity, interoperability, and reliability of on-demand services (Jadhvani et al., 2011). The client (user) strives for such characteristics. Besides the payment based on usage which offers a cost effective solution, the CSPs offering Clouds services likewise benefit in return for paying for such services.

One of the most important characteristics is scalability (Kondo et al, 2009) also known as "the power of scale" (Delic & Walker, 2008) which is gained from the virtualization that the Cloud builds upon. Without having such virtualization, the Cloud could not exist in its current shape with unlimited scalability (Zhang & Zhang, 2009; Idziorek, 2010; Jadhvani et al., 2011)

by having the illusion of the unlimited resources availability (Goldstein, 2010), flexibility, and elasticity which save a lot of configuration, updating, and maintenance effort.

One of the primary benefits of Clouds is cost reduction (Sobel et al., 2008; Powell, 2009; Pocatilu, 2010; Cubillo et al., 2011). Cloud users employ the hosted applications on the Cloud on top of the SaaS layer which eliminates the expenses of updating, maintaining, and securing applications while still allowing the user to benefit from the massive ability of the Cloud's scalability in user number and file size. Cloud Computing storage and delivery services have significantly reduced the cost (Broberg et al., 2009), thus presenting a valuable solution during the current financial crisis to enable the institutions to maintain the quality of services (Mircea, 2010).

Cloud Computing with virtualization is decreasing the expense of capital (Kondo et al., 2009; Nandi et al., 2010) by increasing virtualization of the resources. This procedure removes operational expense by automating the requested service. It provides a user interface which contains all the services that can be delivered. Delivering the services via Cloud Computing increases the resource utilization and availability (Chahal et al., 2010).

In addition to cost reduction, the Cloud can save time (Ekanayaka & Fox, 2009; Ramani, 2011), energy consumption (Berl et al., 2009; Richards et al., 2010; Ferzli & Khalife, 2011), and effort in building infrastructure (Basak et al., 2010; Hofmann, 2009). Furthermore, doing the mobile computational process on the Cloud can save a mobile's battery (Gember & Akella, 2010; Miettinen & Nurminen, 2010; Zhu et al., 2011). We can easily get the needed solutions from Clouds. Further, the Cloud offers massive data processing and sophisticated applications which can solve the computational needs of a wide range of scientific disciplines, such as e-science (Mustafee, 2010; Fox, 2011; Truong & Dustdar, 2011) and climate research (Evangelinos &

Hill, 2008) due to the numerous virtual data centers that they provide as servers. In addition, the Cloud collaboration tools and application have attracted scientists who desire to share their information and imitate others' work (He et al., 2010; Richards et al., 2010). Kseneman et al. (2010) have stated that Cloud Computing offers a robust and fast computing environment. Moreover, using Cloud Computing Infrastructure with its remote management ability creates communication, collaboration, and resource sharing abilities with other institutions (Veni & Masillamani, 2010). For more detailed information about the benefits, see Section 3.5.

2.4. Virtual Data Centers Overview

2.4.1. Definition of Virtual Data Centers

Virtual Data Centers (VDCs) are a combination of data centers and virtualization. The data center is a collection of server farms and computers in a physical location known as a Cloud Computing base (Tsai et al., 2010). These data centers have to be managed by human involvement. In Figure 4, Tsai et al. have showed Cloud services that have been built on top of data centers. The virtualization is a software-based technology considered as core technology to enable Cloud Computing (Zhang & Zhou, 2009). Nick et al. (2010) have defined a virtual data center as "a pool of virtual resources that appear in terms of performance to be locally connected, and can be managed as a set." VDC gives the illusion of dealing with real hardware or software by using partitioning and time-sharing mechanisms, while it provides partial or complete images to optimize and integrate servers (Kotov, 2001; Kant, 2009). Each Cloud's user is the only one who knows how to use the server or application, for example. The incorporation of virtualization methodology into the data centers divides the resources among numerous execution environments which increases the flexibility and efficiency of Cloud's infrastructure which

affects all types of services since they are built on top of the infrastructure layer. Virtualization is a helpful technique to provide an isolation of the VMs images and underlying infrastructure which enable high portability (Vouk, 2008).

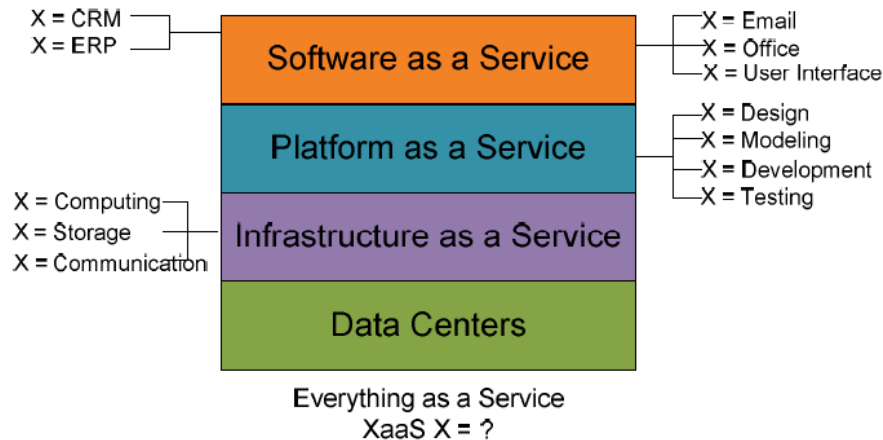


Figure 4: Hierarchical view of Cloud Computing based on the data centers
(Tsai et al., 2010)

2.4.2. Services

The main service gained from the VDCs is the infrastructure as Utility Computing services. These services provide high performance infrastructure, such as server, compute, storage, and network resources in Cloud Computing known as Infrastructure as a Service (IaaS).

VDC services keep the users away from outdated hardware, provide the ability to implement disaster recovery backup efficiently, and permit the users to deploy their applications and develop their projects on a highly scalable and flexible infrastructure with different operating systems regardless of the servers' operating systems.

2.4.3. Importance of the Virtualization

Virtualization plays an important role in using VMs by providing more secure Clouds (Basak et al., 2010; Liu et al., 2010b) and by using sandboxes to run their applications (Di Costanzo et al., 2009). VMs guarantee the isolation of non-trusted applications from the running VMs which imply an additional secure layer. Adding to the security feature, the VMs can handle any operating system regardless of the physical machine's operating system. Using VMs allows users to run different operating systems simultaneously which presents shared memory multiprocessors and opens the door to effective compatibility. Through the use of the virtualization, we can incorporate new features in the current operating systems, make backups, and recover from disasters easily. The use of VMs enables users to customize their environments on top of the physical infrastructure (Di Costanzo et al., 2009).

By using virtualized data center technology, we can reduce the costs (Gambi et al., 2009) of hardware, management, administration, and maintenance. The virtualization technology uses virtual machines and tools to show the underutilized machines with maximum resource utilization by running more than one virtual machine (VM) on a single physical machine. Before virtualization, several servers were needed. These VMs are used to consolidate servers, so the CSPs centralize the workload, thus allowing one virtual server to exist in different geographical areas.

Virtual machines can assure the quality of service by creating test scenarios since VMs are isolated from the physical machines. This isolation feature provides a valuable environment for researchers and academic experiments to encapsulate their applications and systems. These characteristics add to the ability to test the system behavior for fault command. In addition, VMs give the system mobility which simplifies software migration. Access control and security are

increased while the maintenance cost is reduced (Kotov, 2001). Moreover, VDC can be deployed on the Cloud in minutes compared to physical data centers deployment of days or weeks (Basak et al., 2010).

CHAPTER 3. CLOUD-BASED EDUCATION

Distance Learning (DL), also known as e-learning, has played an important role in support of the educational process, especially for people who have health, work, location or disability conditions that make it difficult for them to attend a traditional classroom. In addition to addressing these concerns, distance learning also provides flexibility in time, place, and scheduling (Blake, 2008). Distance learning involves teaching students who are not physically present in traditional classroom settings via the Internet (Zhang & Nunamaker, 2003). Students may also join online discussions and chats, watch videos, take online exams, meet online to complete term projects, and complete other homework assignments to meet the learning objectives of a class (Finke & Bicans, 2010). This use of electronically distributed knowledge is considered e-learning (Dong et al., 2009c). Even with such a flexible learning environment, there are limitations and challenges (Rajaei, 2004), such as scalability, quality, real-time interaction, and affordability due to the space restriction and the technology used. This technology is a typical Client/Server model of interaction with network bandwidth limitations. When many requests are sent to the server, it will result in congestion. Having online courses on such advanced e-learning environment requires an infrastructure with a system implementation of management and maintenance (Tang & McCalla, 2003). This environment secures the job for the working people and provides improved career opportunities due to flexibility, cost effectiveness, and school choices regardless of geographical boundaries while also maintaining individual learning pace (Zhang & Nunamaker, 2003). On the other hand, most of the available

environments lack social interaction caused by current technology restrictions and limits to assure quality of service (QoS). Moreover in 2006, International Data Corporation (IDC) has estimated that e-learning market would reach up to \$28 billion by 2008 (Brown, 2006), and by 2006 the synchronous e-learning alone will be worth over \$5 billion (Stephen & Gary, 2006) which has been as least doubled by 2011 based on the e-learning trend.

3.1. Virtual Classroom

3.1.1. Definition of Virtual Classroom

The virtual classroom is an interactive environment where the learners and instructor interact via computers (Chen & Liu, 2009). Such a network environment can be accessed via any mobile device that has Internet access. In a virtual classroom, the virtual learning environment can be created by using multimedia technologies (Liu et al., 2003) that enable interactive content containing audio and video. With the evolution of Web 2.0, social interactions (Sankey & Huijser, 2009; Redondo et al., 2010; Jaligama & Liarokapis, 2011) have played an important role in the virtual environment functionality beyond that of simple game-based learning. Unlike a traditional classroom, in the Virtual Classroom (VCR), the content of the course is reusable (Das et al., 2010). Furthermore, Wong (2007) has defined e-learning as the involvement of computer multimedia, and network technologies in the learning process.

Learning via the Internet involves learning content that is hosted on the Internet, thus making it accessible anytime or anywhere the learners need it (Zhang & Nunamaker, 2003). Since e-learning offers such flexibility, it has been adopted by many companies and universities to eliminate traveling expenses and time delay (Zhang & Nunamaker, 2003). Zhang (2002) has

claimed that many companies, such as Dell Learning, CISCO E-Learning, and HP Virtual Classroom are moving toward e-learning to train their staff.

3.1.2. Types of Virtual Classroom

VCR has two types of learning environments (Liu et al., 2003) which can promote interaction between the learner and educator.

3.1.2.1. Computer-Based Training (CBT)

In this type of interaction, the learning content can be accessed anytime or anywhere since it has been prepared in advance and placed on the Internet. This type of learning is considered as an asynchronous learning mode. In asynchronous mode, the learners cannot interact in real-time.

3.1.2.2. Real-time Distance Learning

Video conference systems allow real-time interaction because the educator and learners are in one physical place, though not the same shared physical space. This mode is called an “asynchronous learning mode,” and it provides a vivid virtual learning environment, such as streaming media (Liu et al., 2009b) which creates an interactive environment by enabling the learner to play a large audio or video file before the file is completely downloaded. This type of learning environment is available for users via the internet (Chen & Liu, 2009) in which human interaction, such as facial expressions bring into VCR (Callaghan et al., 2009a, b; Martin, 2010). Moreover, they usually are streaming video or audio resources into the virtual world, such as Second Life (Second Life, 2011).

There are several VCR software applications which provide asynchronous VCR, such as Adobe connect (Adobe, 2011), Microsoft Live Meeting (Microsoft, 2011a), and WebEx (Webx, 2011). Figure 5 shows a 3D virtual classroom which can be accessed via the Internet.



Figure 5: Avatar-based 3D virtual classroom
(Callaghan et al., 2009a)

Based on the VCR's applications, Martin (2010) has categorized VCR features into three groups:

1. Discussion and interaction facilities which focus on chat, videos, and so on, including the interaction applications, are shown in the next figure which shows some possible interaction options.



Figure 6: Interaction options in online discussion (Martin, 2010)

2. Instruction and reinforcement which contains any sharing tools, such as a blackboard and Moodle.
3. Classroom management tools which give the ability to upload, store, and archive documents, as well as usage details are shown in the following figure:




Guest Access Link:	http://67.202.210.15/launcher.cgi?room=uncwV4_s_430935283131			
Here is the list of the recorded archives for this room:				
Title	Type	Enter	Access	Delete
MIT 511 Fall 2008 Virtual Classroom - 10/13/2008 18:09	Archive			
MIT 511 Fall 2008 Virtual Classroom - 11/03/2008 18:04	Archive			

Figure 7: Guest access link to archives of e-learning system (Martin, 2010)

3.1.3. Benefits and features

Using VCR in learning environments enables collaboration between different institutions (Nyarko & Venture, 2010), which can enhance the learners' knowledge. Moreover, a Virtual Learning Environment (VLE) is the best fit for student-centered (Morón-García, 2002) learning, an approach that is more effective and more enjoyable from the learner's perspective. In addition, VCR allows for increased enrollment numbers and enables students to manage their time more effectively (Thomas, 2003).

There has been rapid growth in VCR and online education (Jaligama & Liarokapis, 2011) because it provides ease of access with online based knowledge. Using a virtual environment in higher education promotes potential experience benefits in the learning process (Liarokapis &

Anderson, 2010). VCR is usually presented with a user friendly interface and gives the illusion of being in a classroom.

Using VCR (Das et al., 2010) has increased enrollment numbers while also potentially enhancing the learners' performance. The educator is presented in the learning environment, but travel time and cost are reduced. Furthermore, the recorded sessions are reusable, and the solid based knowledge has been provided for the learners. In VCR, many activities such as recording sessions, participating in discussions, video conferencing, and asking real-time questions by raising a hand (albeit a virtual one) can be done.

3.1.4. Challenges and Limitations

There are many challenges and limitations regarding VCR. When a university or institution decides to deploy or build a VCR, they should consider the following points (Das et al., 2010):

1. The underlying Internet connection and cable should have sufficient capability since the VCR needs a wide bandwidth; otherwise, the Internet speed would be slow and result in audio or video delay (Zhixiao et al., 2008; Bahiraey, 2010; Jurgelionis et al., 2010).
2. The initial building and infrastructure should be constructed with a detailed plan because it will be the base of the VCR (Tucker & Gentry, 2009). In the current e-learning system, some of the legacy software, such as Blackboard which is currently being used by BGSU, WebCT, WebEx, and Shareable Content Object Reference Model (SCORM) lack portability, ubiquity, and scalability (Fiaidhi, 2010). To enhance such software, the need for refactoring the applications is raised. Refactoring software increases the software's

flexibility by adding a dynamic approach which allows the system to combine services and contexts (Redondo et al., 2010).

3. The number of e-learners increases each year, thus contributing to a data processing problem (Zhang & Nunamaker, 2003; Yuru et al., 2010) because many requests are sent to one site or server that cannot handle such situations. Cloud Computing can solve such problems and overcome data processing in capabilities by providing the needed networking functionalities and the underlying infrastructure. Another challenge that could be solved by Cloud Computing is the massive storage requirements for multimedia content, a problem identified by Zhang and Nunamaker (2003) even before the invention of Cloud Computing.
4. Building an e-learning environment is very costly (Lee et al., 2009; Wong, 2007). Establishing e-learning using mobile technology by Cloud Computing (Sattler et al., 2010) can cut the upfront cost.
5. Background noise in the transmitted audio or video can be problematic since the underlying infrastructure cannot deliver high quality sound (Zhixiao et al., 2008), but part of this noise, which causes learners to lose their focus, can be solved by using high quality microphones with a noise cancellation system.
6. The learners' level of knowledge and their motivation, i.e. "the exact pulse of the audience" (Das et al., 2010), are difficult to obtain. This problem has existed for a long time, and it is considered one of the opening questions in educational settings, even in face-to-face learning environments.

3.2. Virtual Classroom Technologies

The key to success in VCR is the initial building and constructing represented in the underlying infrastructure which impacts deployed services. Building sustainable architecture leads to outstanding communication and thus, a flourishing e-learning environment. It is important to note that scalability is critical to a VCR environment (Aldhalaan, 2010). VCR must be scaled to the number of the institutions' users, which in our case, is the number of university students. Consequently, VCR should support hundreds to thousands of real-time interactions. There are different technologies and network architectures which could be used to build VCRs, but the most commonly used are client/server, multi-server, and peer-to-peer (Gasparyan, 2007). A Grid is a popular form of technology for deploying VCR.

3.2.1. Client/Server

This is one of the most common network architectures. The processing and workload in client/server architecture are centric, and they are usually done using single or multiple servers to deliver the requested services. Client/server networks are represented with multiple workstations in one layer with the server as centralized storage and processing in other layers (Wittgenstein, 2000). Client/server network architecture contains a high performance system represented by the server and other lower performance systems of the clients. Clients use the server to get the needed services without sharing any resources (Schollmeier, 2002). The control and the security of the client/server application, such as VCR and file sharing systems, are guaranteed while the scalability, reliability, and bandwidth are limited (Gasparyan, 2007). Furthermore, there could be a single point of failure in the client/server model (Mavroudi et al., 2010).

3.2.2. Peer-to-Peer (P2P)

P2P is a commonly used form of scalable network architecture. It consists of a distributed collection of terminals which form network architecture ensuring that the networks will not lose the service if one terminal goes offline. Each terminal (participant) shares hardware resources with others (Schollmeier, 2002). The content of each terminal (node) can be shared directly since there are no clients or servers; all terminals are equal and can play either client or server roles (Jadhav et al., 2010).

P2P architecture minimizes the delay of real-time interaction since the server-based model requires centralization; thus, the clients cannot communicate directly. P2P network architecture is highly scalable because of the ability to add more terminal devices. P2P is considered a reliable form of technology because it avoids the single point of fails (Nyarko & Ventura, 2010), but security becomes an essential concern since there is no central control. The following figure illustrates P2P architecture.

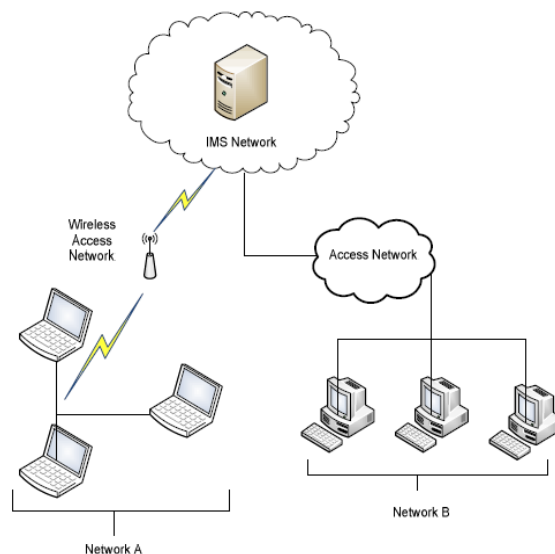


Figure 8: A P2P network architecture which has two sub networks in each subnet the peers directly send their requests to each other (Nyarko & Ventura, 2010)

3.2.3. Multi-server

Online gaming uses this network architecture to assure high resource availability to meet the daily growth in the number of players. There are multiple distributed servers available to meet real-time interaction quality. For example, the player will be assigned to the nearest server to his/her location. This allows for increased performance while reducing the delay in time (Chen & Lee, 2004). A general architecture of a multi-server network with a dispatcher is provided in the next figure.

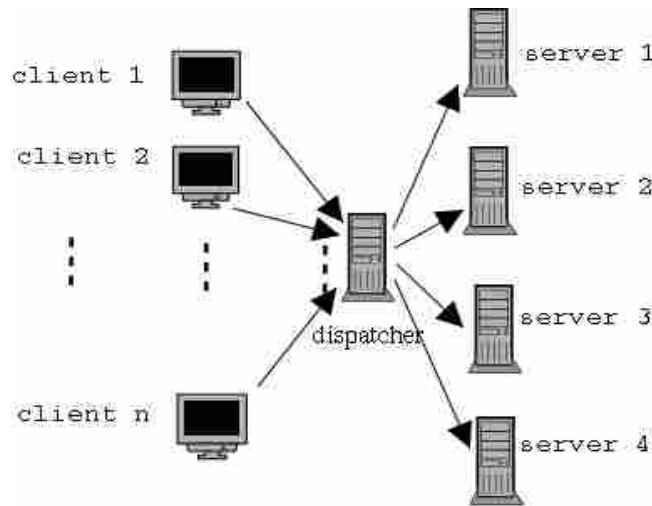


Figure 9: Multi-Server online game system with dispatcher (Chen & Lee, 2004)

The multi-server network is similar to client/server architecture in security and infrastructure control, but it is more scalable which lowers failure rates since there are many available servers.

3.2.4. Grid

A Grid is considered one of the large distributed computational infrastructures which delivers dependable, consistent, and accessible resources (Foster, 2002). A Grid enables coordinated distributed resources to solve computational problems typically resulting in building

virtual organizations. Grid networks are highly scalable because of their underlying infrastructure, but this kind of network demands a significant financial investment in both creation and maintenance. Despite these costs, the Grid is considered one of the most secure network architectures because of its centralized control.

3.3. Cloud-Based Education (CBE)

Cloud-based education, also known as a blended learning environment, serves as a complementary mechanism to a face-to-face learning environment as a means to enhance the students' outcomes and knowledge (Singh, 2003; Zuvic-Butorac et al., 2011). In CBE, students attend face-to-face traditional classrooms with e-learning environments which deliver learning materials and knowledge via multiple technologies (Yang et al., 2010) as the next figure explains. Unfortunately, many educators are unaware of the new technologies' capabilities which could enhance the learning environment and the learner's skills as well as their knowledge (Conole & Culver, 2010).

CBE builds the learning environment on top of Clouds, utilizing Cloud services IaaS, PaaS, and SaaS to maximize Cloud benefits. This environment has dynamic capabilities which lead to success in a complex environment (Iris & Vikas, 2011) that is both elastic and scalable. Additionally, using PaaS supports and customizes the institution's ecosystem learning environment by implementing specific functionalities and interfaces, while using SaaS eliminates software updating, licensing, and maintenance. Incorporating traditional face-to-face learning with other tools (Stephen & Gary, 2006) such as online applications, which in our case are hosted on the Cloud, improves the traditional learning environment (Gudanescu, 2010) as

shown in the next figure. This learning environment is called a blended-learning environment or hybrid e-learning as Smith and Kurthen (2007) stated in their research.

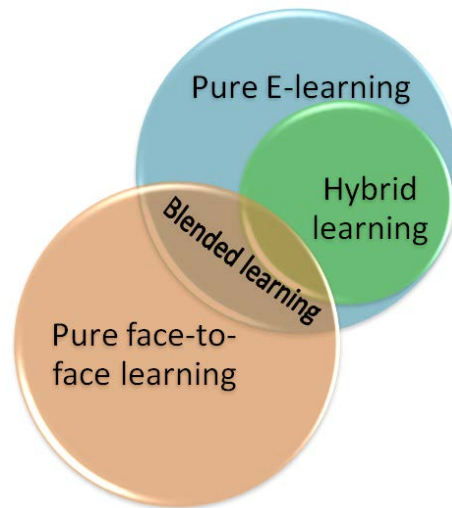


Figure 10: Educational learning environments

To overcome quality problems (Rao et al., 2010) and real-time interaction concerns, virtual classrooms have emerged. The idea behind this technique is to make the student co-exist and be more interactive in the learning environment, and therefore improve the quality of educational materials by providing incredible storage space for the learning objects (Shih et al., 2011). Despite the huge jump provided by the virtual classroom and the simulation of a student's educational environment through three-dimensional programs and avatars, the problems of quality and scalability still exist due to availability of resources (Zuvic-Butora et al., 2011).

Cloud Computing overcomes these problems with a promising infrastructure (Dong et al., 2009a, b; Cai, 2010; Liu et al., 2010a; Palmer & Dodson, 2011) that can be gained from IaaS. Using this technology will reduce administration and maintenance operations while increasing the resources' availability to all users, regardless of the hardware and software used to access the e-learning environment. Moreover, there are educational institutions that cannot provide such

hardware or software to build their e-learning (Jun & Zi, 2010; Pocatilu et al., 2010); therefore, Cloud Computing is a perfect solution for them.

Table 2 contains a comparison that emphasizes the differences between non-Cloud based DL and the Cloud-based e-learning. The comparison criteria are cost, infrastructure needs, management, maintenance, accessibility, scalability, compatibility, affordability, availability, and resource utilization. In the following lines, details and explanations are given for each criterion.

- Cost: This includes the total cost to setup the needed machines, hardware, and software for a course that will be taught via this environment.
- Infrastructure: This criterion shows if we need physical storage, compute, or servers to teach.
- Maintenance: We can measure the need of the system to be updated and reconfigured when installing new hardware or software.
- Accessibility: When there are no time or location constraints, the system is accessible.
- Scalability: This term refers to the number of enrolled students or attendees.
- Compatibility: If the e-learning environment does not need special hardware, we can classify the environment as compatible since it works on any operating system.
- Resource Utilization: This shows how the learning system utilizes the available resources, such as storage, network, and compute resources.

Table 2: Comparison between E-learning and Cloud-based virtual classrooms

Criteria	Advance E-Learning	Cloud-Based Virtual Classroom
Cost	High	Low
Need for Infrastructure	Yes	No
Need for Maintenance	Yes	No
Accessibility	Yes	Yes
Scalability	Limited	Unlimited
Compatibility	Yes	Yes
Resource Utilization	Not utilized well	High utilization

Due to the financial crisis, educational institutions are facing problems in providing the needed IT infrastructure for their research and activities (Mircea & Andreescu, 2010). This problem can be solved using Cloud Computing (McCrea, 2009) rather than building a complex infrastructure with maintenance and configuration issues that can be significantly reduced by Cloud Computing (Tout et al, 2009).

The learning content can be easily created and deployed in Cloud-based environments (Redendo et al., 2010). Moreover, Cloud-based virtual classrooms are advantageous because of their abilities to host educational material for system users. Building a Cloud-base education utilizes computer technology and improves the quality of the teaching process (Wen & Chen, 2011). Table 3 compares the courses hosted on Cloud-based and traditional client/server advances e-learning environments. This comparison is based on different criteria including cost, accessibility, course content maintenance, management of the system, content scalability, cross

platform integration, security control, single point of failure, privacy, data location, disaster recovery, monitoring, and resource utilization needed for the special infrastructure.

Table 3: Course benefit comparison between E-Learning and Cloud-based virtual classrooms

Criteria	Advanced E-Learning	Cloud-Based Virtual Classroom
Cost	Medium - high	Low
Need for Special Infrastructure	Yes	No
Course Content Maintenance	Needs time	Easy in a few steps
Ease of Access	Yes	Yes
Different Access Levels	Available with limitations	Highly available
Course Content Management	Needs some effort	Minimal
Security Control	Depends upon the institution	Depends upon the SLA
Single Point of Failure	If the server fails, the whole system will fail	No
Physical Content Location	Known	Unknown
Content Privacy	High	Low - Medium
Disaster Recovery	No	Yes
Monitoring	Needs time and effort	Available as a tool
Resource Utilization	Not well utilized	Highly utilized
Content Scalability	Limited	Unlimited
Cross Platform Integration	No	Yes

The client/server network model, which most e-learning systems rely on, is based on a centralized server. The entire network will fail if the centralized server is shut down (Gasparian, 2007), so there is a high dependency in the traditional e-learning systems based on the client/

server model. In contrast, in Cloud-based systems, there is no notable dependency since the information on the Cloud duplicate is in different geographical areas. In the following table, the system users and corresponding benefits of using Cloud-based virtual classrooms are presented.

Table 4: The users' benefits in Cloud-based virtual classrooms based on our selected criteria

Benefit	Student	Educator	Administrator
Low Cost	Yes	Yes	Yes
Ease of Access	Yes	Yes	Yes
Management	Easy	Medium	Medium
Interactivity Level	High	High	Medium
Ease of Use	Yes	Yes	Yes

The system users, including students, educators, and administrators will gain a magnitude of benefits from Cloud-based classrooms. The students will have high levels of interactivity with each other and with the educators since there are no hardware limitations; thus, the environment is scalable for video and audio streaming. Likewise, the cost reduction will be shared among all system users. The students no longer need to install specific applications or buy an access code for training tool kits, such as myITlab. Furthermore, the educator will no longer have to spend unpaid hours preparing for assignments. The administrator will also save time because updating, licensing, and configuration issues will be eliminated using the Cloud. All of these elements add to the cost reduction and ease of access (Wainhouse Research, 2010) and use (Gill, 2011) when dealing with the Cloud.

Using the Cloud as a base to build institution infrastructure for virtual classrooms will be highly beneficial to all users involved. Scalability and reliability are the top advantages of virtual classrooms and the whole e-learning system on the Cloud except the critical information. The next figure shows the benefit interconnection between system users.

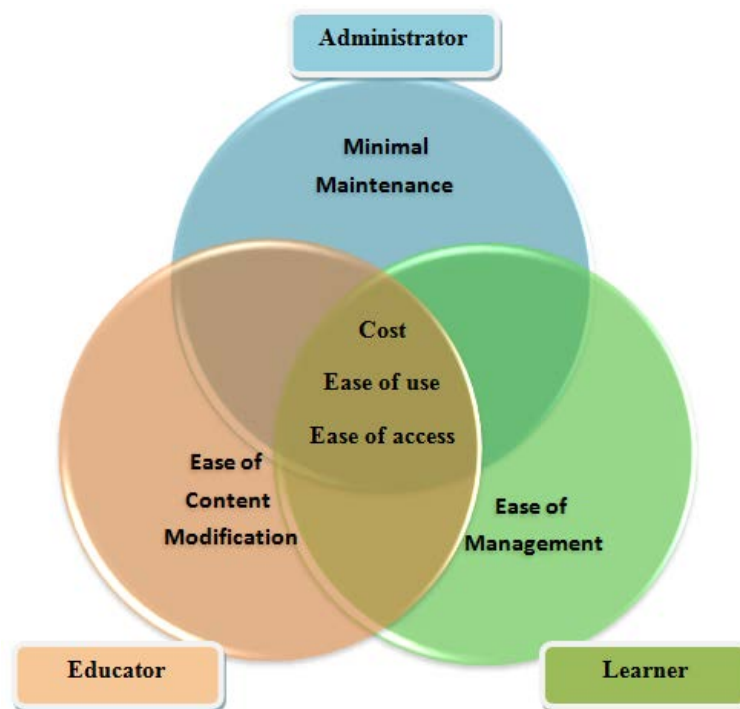


Figure 11: Users' benefit interconnection of using Cloud Computing services

3.4. Cloud-Based Education for Computer Science (CBE-CS)

The enrollment number of Computer Science students between 2004 and 2008 has dropped significantly (Beaubouef & Mason, 2005; Vegso, 2008) because the knowledge base and skills of graduates did not satisfy the industry needs. As a result, recent graduates were left with unsecure careers and professional lives (Chen & Zhang, 2008).

Most system users will gain benefits from using the IaaS and SaaS services on the Cloud. They may need additional hardware resources which can be requested via IaaS. Furthermore, the

users may use existing applications on the Cloud, such as e-mail, word processing, mathematical applications, and so on available in the SaaS layer. On the other hand, the Computing Science major can recognize the benefits beyond those of just IaaS or SaaS. Computer Science learners and educators using PaaS service can enjoy additional services which enable them to build, develop, and deploy their applications on such a layer. PaaS provides a middleware that can contain and run the deployed applications developed by the user. Taking parallel computing and database courses, for example, in such distributed environments, Cloud Computing will enhance the student's understanding and outcomes as well as improve their experiences. Furthermore, Cloud Computing appeals to parallel and distributed simulations research as it utilizes the available services (Malik et al., 2010) since Cloud Computing offers high resource availability, accessibility, and reconfigurable resources. As a result, it prevents users from dealing with hardware and software complexities when acquiring and managing the underlying infrastructure. The next section contains detailed information about the advantages of using Cloud Computing in a learning environment for different system users.

North Carolina State University has constructed a Virtual Computing Laboratory (VCL) using IBM Cloud solutions that give the students the ability to allocate and access VMs as a basic machine or as a specific application image, such as Matlab (Vouk et al., 2008).

Using Cloud-based education for Computer Science not only utilizes IaaS and SaaS services, rather it provides a high capability tool that allows students to practice, build, develop, and deploy programming based courses, assignments, and homework by utilizing PaaS layer services. In this regard, there are multiple Cloud Service Providers (CSPs) which support different platforms for a variety of programming languages and Interface Application Programs (IAPs). For example, Windows Azure from Microsoft produced .NET framework which

provides an excellent environment to develop database applications and Amazon Elastic Cloud Compute (EC2) offers different Compute power as an Amazon Machine Images (AMIs). These images are commonly used in high performance Computing (HPC) to add more computing power and solve the computational problems quickly on a demand basis (Migue et al., 2009). Furthermore, Amazon announced GPU support in their EC2 services used in image processing.

3.5. Advantages

3.5.1. Students

The main advantage for the students who have courses on the Cloud is the availability of the needed resources (Vecchiola et al., 2010; Vaquero, 2011). Besides the portability which enables students to work on their programs or applications from multiple computers (Lawton, 2008), students will be able to access the system without any time or location restrictions like those of distance learning. This approach will assist the students in focusing on their assignments without any distractions (Ivica et al., 2009; Vaquero, 2011) such as lack of resources, networking problems, hardware or software restrictions, or needed maintenance to accomplish their task or assignments. Also, it helps them to accomplish their tasks faster (Caeiro-Rodríguez et al., 2010; Vaquero, 2011). In addition, teaching Computer Science courses on the Cloud provides students with a strong foundation that better enables them to address the needs of a leading technology. Thus, using Cloud technology enhances the students' results (Vaquero, 2011) and gives them experience in dealing with such technology that will support them in their future work as employers in companies that seek people who are knowledgeable in such technology. The students using programming languages will no longer need to download the software, setup configurations, or use additional high quality equipment (Zhang et al., 2010a) since the software will already be on the Cloud, more specifically on SaaS layer of the ecosystem. The students

only need to write their code and then run it. The communication between the students and the instructor would be easier, using video conferencing applications available on the SaaS level, such as Sakai (Sakai Project, 2011). The research (Ivica et al., 2009; Vaquero, 2011) showed that the development of the application on the Cloud platforms PaaS resulted in quicker delivery than setting up a lot of host servers, networking configurations, and underlying infrastructure. Moreover, the students will have the ability to experiment on the actual system without creating errors in the whole system. These advantages may lead the students beyond the basic level of knowledge (Vaquero, 2011) which will make them more competitive job candidates.

3.5.2. Faculty

In the case of faculty, besides the availability of resources, access portability, and flexibility (Borangu et al., 2010), the Cloud gives agility to the hosted applications; therefore, the teacher can more easily construct multiple levels of difficulty for beginners, advanced, and more advanced assignments. In addition, it is unnecessary to create multiple applications to be compatible for each OS. Rather, there is only one application for any Web OS (Lawton, 2008). By using the Cloud, the faculty is now freed of thinking about maintenance issues which will impact the learning process (Ivica et al., 2009; Vaquero, 2011) because of non-related issues to the course material, such as networking and installation problems. In addition, the faculty will expose the students to real situations that cannot be faced in locally simulated environments, thus building a deep knowledge base for the students (Vaquero, 2011). Using such technology allows the teacher to easily show the complexities of the course to the students (Vaquero, 2011), as well as the best ways to deal with such complexities (Ivica et al., 2009). On the other hand, the lab preparation for Cloud assignments takes more time initially since the technology is new, but

when running the same assignments the second time, no preparation time is needed since the VMs images have previously been uploaded to the Simple Storage Service (S3) (Vaquero, 2011). In a word, Cloud Computing improves teaching efficiency without placing additional loads on the faculty (Bai, 2010).

3.5.3. Administrator

There is no software license to be taken into account (Jun & Zi, 2010); thus, the cost of software licensing will be eliminated (Pocatilu et al., 2009; Vaquero, 2011). In addition, the hardware constraints will disappear because of virtualization (Dong et al., 2009a, b; Borangiu et al., 2010) which gives the ability and allows resource sharing with multiple operating systems regardless of the hardware used. Likewise, the administrators can run large-scale applications without considering resource limitations. The number of enrolled students would not be an issue because Cloud provides unlimited space, resources, and accounts. Beside the previous benefits for administrators, maintenance would be minimized since all the resources on the Cloud will take care of maintenance issues (Ivica et al., 2009; Caeiro-Rodríguez et al., 2010; Scale, 2010). On the other hand, administrators should be concerned about the SLA of service availability which identifies QoS the backup and the disaster recovery process in case of CSP down services.

3.5.4. Institution

The institution is one of top beneficiary using Cloud-based education; the number of the enrollment (Bai, 2010) will be enlarged due to the increase of job opportunities, depth of knowledge, resource availability, accessibility (Wu et al., 2010), and advanced technology for hands-on training. Adding to the increase of the enrolled students, there is a huge cost reduction

(Dong et al., 2009a, b; Ivica et al., 2009; Sriram, 2009; Vaquero, 2011) since the maintenance, software updating and licensing, hardware configuration, power, and diminishing infrastructure space would help the institutions in the current economic crisis without affecting the quality of services (Kajita, 2010).

3.6. Limitations

3.6.1. Security and privacy

Cloud Computing suffers from security concerns (Grossman, 2009; Rimal et al., 2009; Huang & Yang, 2010) when using Cloud technology. Since CSPs provide their services via data centers located in geographically diverse environments, the critical private information may be available to governments according to national policies. Thus, it is important that CSPs choose the countries which do not compromise an individual's privacy. Additionally, the users should trust the CSP (Hofmann & Woods, 2010) since they will have control of the users' data (Hayes, 2008). Moreover, the user will never know the physical place of the data (Buyya et al., 2010) besides the unknown data policies (Grossman, 2009; Rimal et al., 2009).

Until now, there has been no security standard for the Cloud to be employed (Grobauer et al., 2011) which could help in security improvement. Shen and Tong (2010) have stated that Cloud Computing security is complicated since there are different systems from multiple environments involved in the built system.

3.6.2. Latency and Network Limits

Since the information and data are being transferred via an Internet connection, it is important to choose appropriate cables to avoid data latency (Hofmann & Woods, 2010). In

addition, when the user transfers a large amount of data, such as Tbytes, data bottleneck will increase.

3.6.3. Interoperability and Lock-In

Each Cloud provider has its own unique architecture and implementation (Raines, 2009) which make interoperability and migration the challenging issues. They have made each Cloud provider speak different languages (Hofmann & Woods, 2010). For example, Google uses BigTable for data storage, while Amazon uses Dynamo, and Facebook uses Cassandra. Different frameworks and storage architectures have made the migration process impossible without changing the developed applications (Tsai et al., 2010). The data lock-in problem can be solved by using hybrid Cloud Computing model (Armbrust et al., 2010) which mixes and matches different services from multiple Cloud service providers.

3.6.4. Clarity of Service Level Agreements

There is a lack of clarity or non existing information (Katz et al., 2009) on such issues as guaranteed uptime (Hofmann & Woods, 2010) and data storage if the user decides to move to another Cloud. Other concerns include the consequences when CSPs fail to deliver intercept service at the agreed QoS. Some of CSPs offer a discount percentage for the month that they did not achieve the minimum uptime, but does this discount compensate for the business lost when the service was unavailable?

3.6.5. Storage Scalability

Many problems cannot be solved by simply adding a more compute power Rational Database Management System (RDBMS) because the Clouds do not support storage scalability.

CHAPTER 4. LITERATURE REVIEW AND RELATED WORK

This research starts with exploring the Cloud Computing concept and its state in the education fields. Studying the current related applications and platforms that used Cloud Computing in the education field, specifically in Computer Science courses, leads us to focus more on the overall results. Our literature review shows that other researchers try to focus on some of the Computer Science courses. They put their efforts in teaching those selected courses using the Cloud; unlike them, our focus is on which courses could be taught via Cloud Computing. Unlike other Cloud based education models which utilize SaaS and IaaS layers, Cloud based education for Computer Scientists—including the learners and the educators—has an intimate relationship with Cloud Computing since the Computer Science courses have a unique characteristics in which they can penetrate into all layers of the Cloud. In addition, we put some effort into exploring the existing simulators which simulate the Cloud Computing environments and services.

4.1. Frameworks and Applications

One of the platforms (Tian et al., 2010) serving high education fields and research institutes were developed by a group of researchers to manage a virtual Cloud lab's resources allocation, users, and access with the ability to deploy it on a public or private Cloud. They implemented the framework using the VMware workstation 5.5 which creates virtual platforms, Apache web server, MySQL database server, and security remote access tools. The end-user

sends the requests to computational platforms and how long they would need the requested services. In addition, the users have two choices: either immediate reservation or for the future. Their framework enhances resource utilization and sharing. The researchers design and implement the framework to manage PaaS in virtual Computing labs (VCL).

Seattle (Cappos et al., 2009) is a platform built for educational and research purposes. Seattle is based on donated resources exclusively for Seattle platform. They introduced Seattle as a flexible and non-dependent system which can adapt to any operating system or architecture without any dedicated infrastructure. Using an instance of Seattle programming language which is based on the Cloud Computing concept, the user can represent Cloud Computing, Grid Computing, P2P networks, distributed system, and general networking issues. They write two samples of Seattle complete program code to prove the concept of education, portability, and ease of use.

Ivica et al. (2009) have developed a system called StartHPC to teach parallel programming at MIT. This system is based on a virtual image of Amazon EC2 machine which is used to build the class cluster. Cloud Computing eliminates the need of dedicated compute clusters which directly impact the cost besides the ease of use, the ease of access, and scalability, especially in the peak hours. By using Cloud Computing, both the faculty and the students were allowed to focus on the concepts of parallel programming in OpenMPI and OpenMP without being distracted by non-related details such as networking and installation problems. The software package contains OpenMPI 1.2.4, Fortran, Eclipse Parallel Tool Platform 1.1, OpenMP, and Sun Studio IDE in the VMs. StarHPC can be used to teach simulations and numerical modeling courses. In addition, using remote clusters exposes students to distributed parallel programming challenges and complexities that do not appear in a local cluster. The total

estimated cost for the one course is 150\$ which is very low compared to building dedicated infrastructure.

Wei & Wang, (2010) introduced Google Sites and how a learning environment can benefit from such a Cloud service. They divided the Cloud Computing application into five forms: SaaS, PaaS, Utility Computing, Network services, and Internet integration. Their focus was on the Network Learning Environment (NLE). The authors analyzed the Cloud Computing in NLE by exploring the model of a learning environment, Cloud Computing application forms, and elements of building Cloud Computing in the NLE by adopting Hanna Fen's view which states that the NLE consists of four basic components (contexts, tools, resources, and scaffolds). The researchers go deeply into Google Sites' features, steps, and how Cloud Computing applications can be used in the NLE.

One of the reasons for moving forward to e-learning systems as a web oriented service is providing a dynamic e-learning environment. Xu et al. (2003) designed a framework to supply e-learning based on SOA. The authors stated that the SOA approach improves the reusability, interpretability, and the flexibility of collaborative e-learning environment. Their scope focused on services and business designing processes. The researchers had two research questions. One focused on designing a collaborative e-learning environment using SOA to allow flexible interaction between the different components in Learning Management Systems (LMSs) as he illustrated in Figure 12. The other question is how can we manage learning processes by utilizing Business Process Management (BPM)? Their framework for dynamic e-learning environments have integrated existing web services, such as Hypertext Transfer Protocol (HTTP), Simple Mail Transfer Protocol (SMTP), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL), Extensible Markup Language (XML), and Universal Description, Discovery

and Integration (UDDI) along with metadata. The interoperability is done by sending the needed information to a platform, and the learning objects are rounded together in SOAP message sent to the UDDI registry to let the two learning ends interact with each other. The researchers discussed two scenarios where their framework e-learning systems could improve the interactions between two learning management systems. The first one illustrated the single sign-on process in which a student could add two courses from two different systems with just one sign-on. The other case showed how learning content aggregated between different systems or instructors by reusing the available objects. From their literature study, Xu et al. (2003) found out that there are not many implementations for e-learning environment which works under SOA. The authors' method began from service requirements. They identified the Business Process (BP) with all possible workflows then they recognized the reusable services used later. The detailed implementation for their framework has been addressed using the web service, BPM, and e-learning.

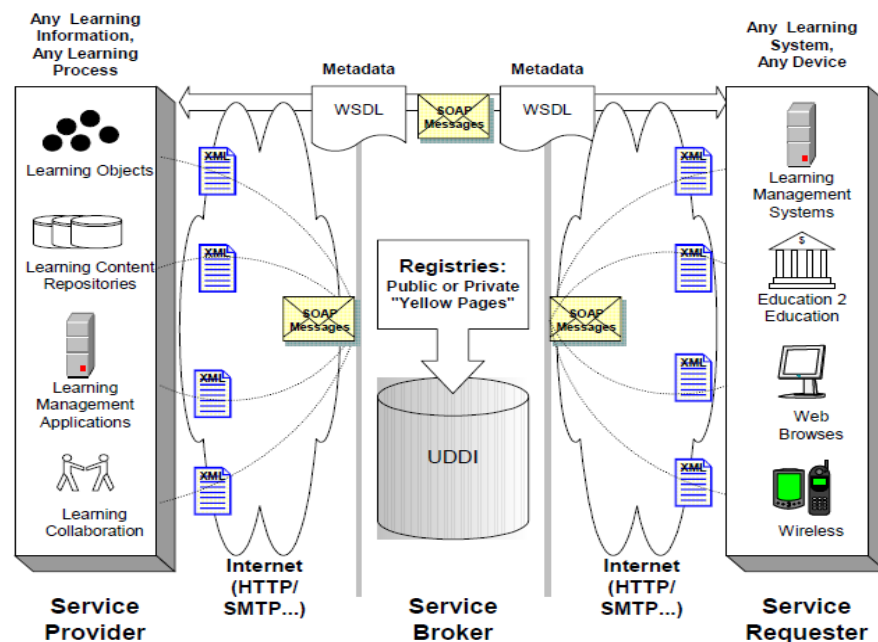


Figure 12: Web service oriented framework with multiple tiers for dynamic e-learning system (Xu et al., 2003)

One of the new directions in e-learning ecosystems is integrating Cloud technology into e-learning systems. Dong et al. (2009a, b) presented this approach which overcomes the lack of underlying infrastructure by allocating the needed resources dynamically. Since the Cloud infrastructure is promising, the Cloud based e-learning ecosystem will be sustainable and thriving. In addition, the resources can be allocated, configured, and utilized in real time with self-recovery from the software and hardware faults. The researchers presented architecture for e-learning ecosystem using promising infrastructure which Cloud Computing provided as shown in the next figure. Their architecture consists of three layers (Infrastructure, Content, and Application) and four modules (Monitoring, Policy, Arbitration, and Provision). Besides the architecture, the present four mechanisms were used to insure the e-learning ecosystem services (Pre-scheduling, Early Warning, Self-recovery, and Evolutionary). The developed architecture is reliable, flexible, self-recovered with QoS, and cost reductive; these features are the Cloud infrastructure features which the ecosystem inherits.

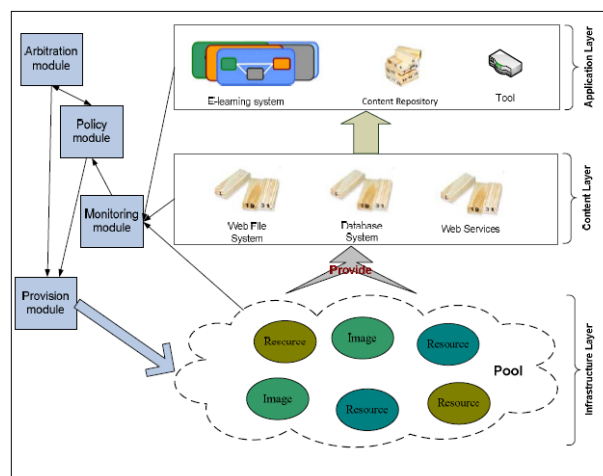


Figure 13: Architecture of an e-learning ecosystem based on Cloud Computing infrastructure (Dong et al., 2009a)

In higher education, the efficiency and the effectiveness of the learning environment is very important. South Dakota State University developed an active learning program on the Cloud for their blended/hybrid environment. A mechanical engineering course was selected as a case study. Since the Internet has been proven to increase learning flexibility, blended learning can gain benefits from such a method. Blended learning mainly focuses on incorporating different learning techniques, methods, and resources to have highly interactive learning environments; thus, it is a mixture of face-to-face and online learning environments while in the hybrid environment, most of the learning activity occurs online. The university aimed to utilize the existing infrastructure using Cloud Computing technology and resources. The Active learning (AL) Cloud goals were to be student-centered, empower faculty, secure and utilize financial resources effectively, and demonstrate accountability with plans for outcomes evaluation (Hu & Zhang, 2010).

Tillmann et al. (2011) presented Pex4Fun as a Computer Science learning environment to teach programming via social gaming. Pex4Fun provides a unique environment which connects the teachers with the students on the Web using the Cloud to execute and analyze. Pex4Fun from Microsoft Research has different interactive games to teach programming including solving puzzles and coding duels, exploring course materials, creating and teaching a course, and publishing created coding duels. The current learning environment includes C# and .NET.

Ma et al. (2010) discussed the suitable Cloud application used to construct a collaborative learning environment. They illustrated benefits of using Cloud Computing, such as solving the network storage when dealing with massive resources. Additionally, they have focused on reasonable construction of the learning environment to utilize all the needed educational tools accessible via Cloud Computing. To achieve such construction, they proposed four basic

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

Research by Vaquero (2011) focused on the effectiveness of using IaaS and PaaS in educational fields, specifically in teaching advanced Computer Science courses. He selected eighty four students and four professors to perform advanced network courses on probing with routing algorithms assignments and then evaluated which way of teaching was easier—the traditional system setup, IaaS, or PaaS—through a survey. The author claimed that there was no comprehensive evaluation of the Cloud's usage advantages. In addition, Vaquero mentioned the lack of identifying the appropriate service level of the Cloud abstraction which is the most effective and useful in educational fields. In this research, he presented how the Cloud utilization enhanced students' outcomes, and he also identified the most appropriate service in education. As a conclusion, Vaquero highlighted that using Cloud Computing helps students to focus on the giving tasks with saving their time from dealing with non-related issues. PaaS is easy to learn, and it is prevalent choice for the high level courses which the students do not need to deal with the hardware level; otherwise, IaaS is appropriate for the medium level courses, such as Operating System, Software configuration in which we need to touch on the details of VM level.

Kseneman et al. (2010) implemented a despeckle Synthetic Aperture Radar (SAR) using multi-core Graphic Processing Units (GPUs) connected to Clouds to enhance and extract information from the taken image. Synthetic Aperture Radar is a system for weather imaging in which the images are taken from satellite. These images usually have a speckle noise which means the image has bright or dark pixels as shown in the taken SAR image:



Figure 14: SAR image containing speckle noise (Kseneman et al., 2010)

The researchers were trying to perform faster image denoising using Cloud Computing GPUs to be compared to the conventional CPU. They have proposed a Cloud Computing base to distribute the SAR images illustrated in the next figures:

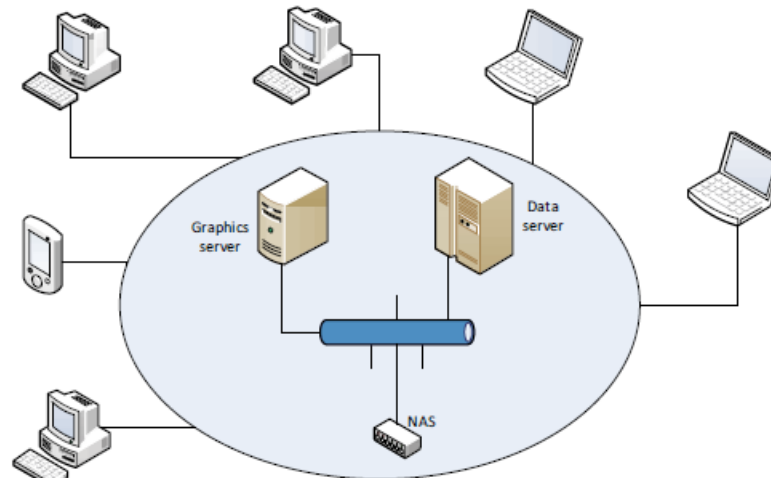


Figure 15: Proposed Cloud Computing conceptual design for SAR images distribution (Kseneman et al., 2010)

This distribution process needed "legitimate users over the web-based application" and to look natural, like Google Earth's satellite images. The experimental results showed that using GPUs which connected to the Cloud speedup the execution time 95 times compared to multi-core CPU performance.

Palmer & Dodson (2011) used a web-based Sakai Learning Management System (LMS) for twenty three students who were under the Oregon Rural Scholars Project (ORSP) for medical distance learning. Their main concern was the system scalability which could be solved by such a technology. They attempted to lower the cost of courses, create ease of the access system, provide a highly interactive experience, make a robust system to meet the student and faculty expectations and educational needs, and decrease the students' sense of isolation, highly reducing the need for the technical support. They focused on having an accessible system, which was cost effective, highly portable, and simple along with the user's choice of device. They built their ideas using Koole's FRAME model of mobile learning. The researchers used a survey allowing the students to evaluate their experiences with the system. They used Oregon Health and Science University's Sakai web-based LMS to host the course content which included the

recorded lectures, notes, assignments, and so on. Palmer and Dodson also included synchronous components which are the Student Clinical Round (SCR) in three different configurations. They used Adobe Connect on top of Sakai to build their virtual classroom. The first configuration enabled the distance learner to join on-campus students' live SCR sessions. The second configuration was an online video conferencing representation in which each user, including the faculty, enabled their webcam and participated. The third configuration allowed one presenter to use the webcam while the others were watching and chatting. They included the "raise hand" feature to enable voice streaming. Using the third configuration, they were able to add more students without affecting the quality of the session. Overall in the students' surveys, they expressed that their experiences with the new system were very positive in the ease of use, ability to connect to other colleagues, and they preferred to continue using this technology.

Another solution based on Cloud Computing for e-learning was presented by Al-Zoube (2009). The developed system is a virtual and personal learning environment, highly interactive by combining different tools and technologies, as shown in Figure 16. The Virtual Learning Environment (VLE) content was built by teachers. The management part of the system was done by the users—students or staff—by a set of special tools. The researcher used a Personal Learning Environment (PLE) because he saw the available VLEs were content-centric while he wanted the environment to be learner-centric, so he used PLEs, which depend on learner pace.

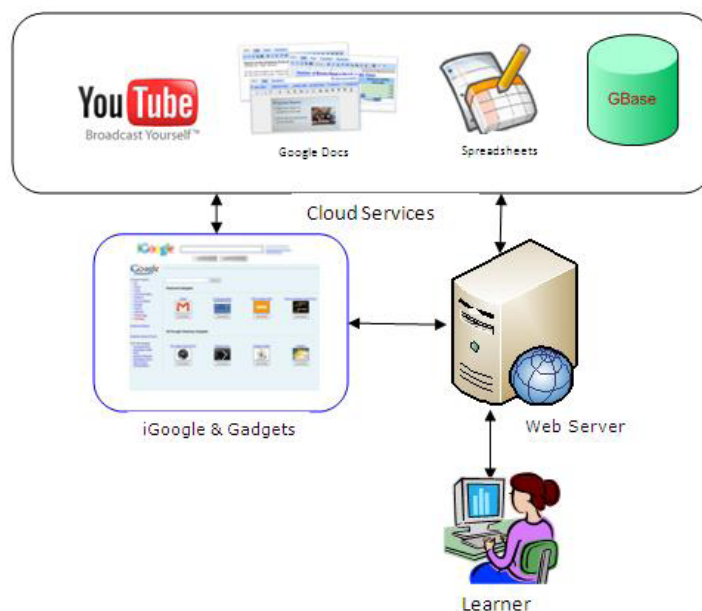


Figure16: The main components of Al-Zoube's system (Al-Zoube, 2009)

The developed system gives the learner the ability to choose the services and applications that s/he wants to build their environment upon or create a new one for his/her own site. This process is called a “mashup.” Al-Zoube built a Cloud base called the personal e-learning system. It consists of three main functionalities:

- 1- Course Management System (CMS): a web based system which allows the learner to access course materials for registered learners. A teacher uses XML to add a new entry if s/he wishes to create a new subject.
- 2- Personal Learning Environment (PLE): a variety of Cloud tools and applications which can be accessed via Internet connection. The researcher used gadgets and iGoogle as the application portal.
- 3- Smart agents: two agents responsible for specific tasks. The first agent provides an interactive environment with the learner to meet individual needs and progress in their learning paths using stored information, as metadata, which allows the learner to choose

the difficulty type and level for a specific topic. The second agent is responsible for generating a test as a multiple choices, using Google spreadsheets as a database where the information about questions is stored.

In the benefits and challenges of adapting Cloud Computing for the universities, Abdul Razak (2009) discussed the possible offerings that Cloud Computing could deliver, especially in Malaysian Universities. The 21st century students are not satisfied with the traditional learning process; thus, the researcher used Cloud Computing to enhance the learning environment by using Cloud Computing benefits in cooperation with the multimedia contents, and made the learning process highly interactive to meet student expectations. Abdul Razak (2009) discussed more than ten Cloud Computing offerings, pointing out that the Cloud Computing users gain the illusion of resource availability as an infinite on-demand resource, which enables storage and huge amounts of information on the Cloud. In addition, the researcher stated that introducing the students to Cloud technology will prepare them to work in the industry since they gained the skill of dealing with new technology. Cloud Computing offers cost-effective solutions for Universities, staff, and students since all of the needed hardware and software are available via the Cloud, which makes their files highly portable, easy to share while computing power is easy to manage. Additionally, Abdul Razak (2009) claimed using Cloud Computing would improve collaboration and communication in the learning environments. On the other hand, he clearly stated that the Cloud Computing has some drawbacks: need for Internet connection and trust in the CSP service availability, privacy of the data, and security.

Yang and Zhu (2010) built Open-source software (OSS) for e-learning based on Cloud Computing in China. They proposed the EduCloud platform to launch their e-learning environment on a public Cloud, using IaaS and SaaS to overcome resource limitation and lack of

e-learning scalability. They constructed their solution using Hadoop with two interfaces which were mapper and reducer. EduCloud consists of a set of tools and technologies to build a virtual and personal learning environment; thus, it focuses on migration of the current application to a Cloud based one via the SaaS level, especially interactive and collaborative applications, such as Sakai and Moodle which are Course Management Systems (CMS). The next figure illustrates EduCloud, which consists of one central module which manages the whole platform and the three layers. Each layer represents the corresponding service layer of the Cloud Computing layers: the Application layer, the Platform layer, and the Infrastructure layer. In the Application layer, there is just one instance for all of the users of the e-learning applications and tools. The last layer contains system resources used by the platform and application layers.

The researchers constructed EduCloud in two steps. In the first step, they built the runtime for the Cloud application environment starting from preparing the environment by setting up a unique IP and hostname for each server, then setting up the communications, the master node, the slave nodes, and lastly, verifying the Hadoop Cluster. In the next step, they converted the e-learning applications to the SaaS layer on the Cloud, taking into account that the traditional learning system is a single-tenant while moving to Cloud requires multi-tenant implementation.

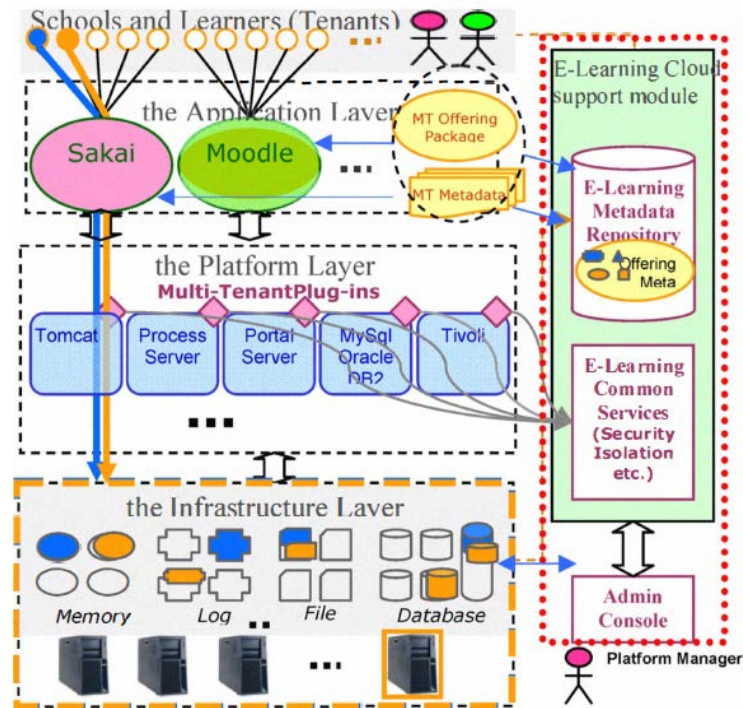


Figure 17: The logic structure of the EduCloud (Yang & Zhu, 2010)

They used the iterative model for their software development as illustrated in Figure 18. Finally, they conclude the impact of the new system on the e-learning ecosystem in terms of the learning content, available services, and existing applications.

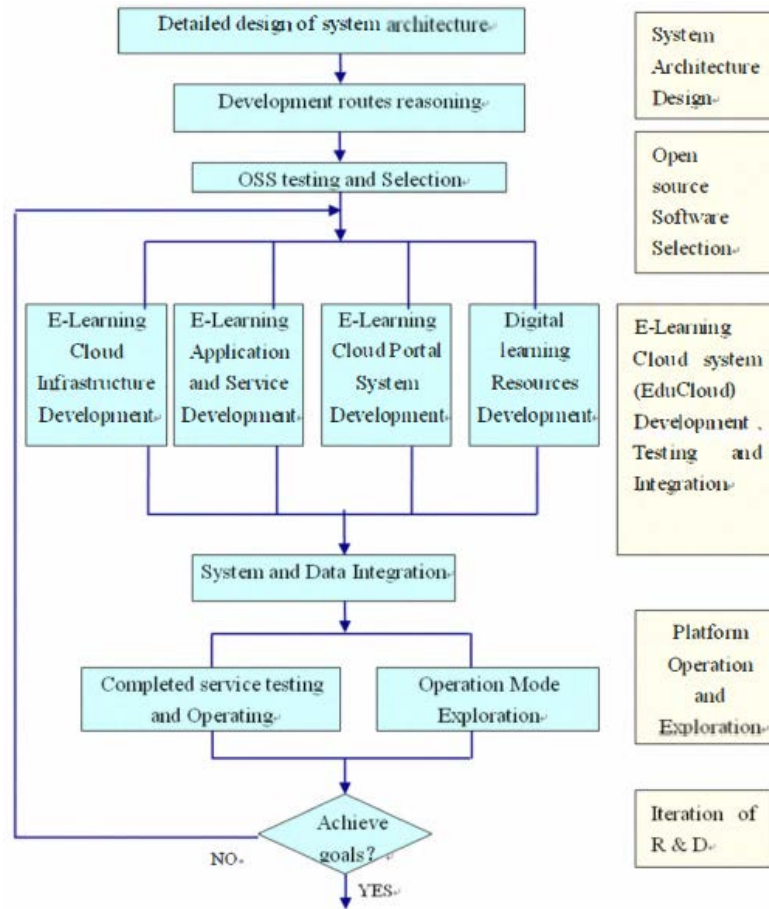


Figure 18: The iterative development route of the EduCloud (Yang & Zhu, 2010)

Yang (2011) proposed a map toward building a standard for Cloud. This standard is an Open-source solution for e-learning, e-research, and e2-government since there is no widely accepted standard. He also proposed "The open framework for e-Education Cloud" to make the migration between CSP to other CSP interoperable using four layers which are delivery platforms, core service, collaboration service, and user experience as demonstrated in Figure 19.

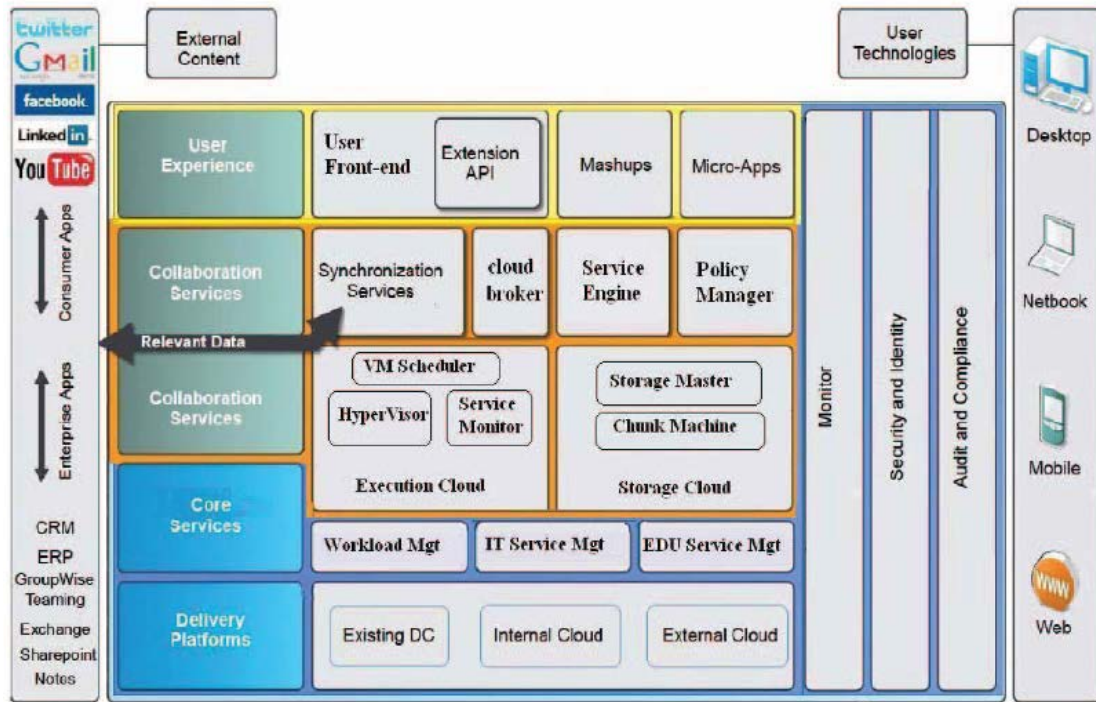


Figure 19: The open framework for e-Education Cloud (Yang, 2011)

In addition, Yang (2011) constructed an open map for his e-Education Cloud as shown in the figure above which considers the following four layers: application layer, platform layer, control layer, and virtual layer. These layers can be mapped to any open-source compatible with the layer functionalities. Unlike our framework which considers Computer Science courses, Yang proposed a general framework to utilize the Cloud services. As a final point, Yang concluded that this is a solution building Cloud for e-Education which needs to be studied more by industries and academia.

Yuru et al. (2010) discussed and summarized the current situation of Cloud Computing in a Web-based learning environment. They highlighted several benefits of Cloud Computing in the education fields for e-learning environments, which are the management and the maintenance for the normal operation which moved to CSPs. The data security for storage is high when using the Cloud because the user does not worry about losing their data or the incursion of a virus. The

hardware requirement is very low, and the easiness of data sharing on the Cloud is high. Then they presented different CSPs, with some information about each one of them and how we can get benefits from them. The discussed Clouds are Amazon, Google, Microsoft, IBM's Blue Cloud, Salesforce, Force.com, and SUN. Lastly, they proposed a simple model of application of Cloud Computing to improve the learning efficiency as shown in the next figure:

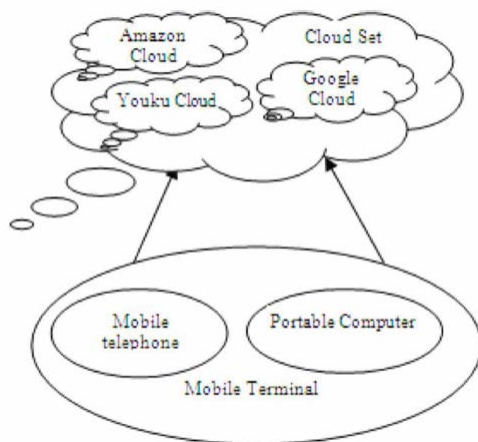


Figure 20: The model of application of Cloud Computing (Yuru, 2010)

Fiaidhi (2010) adapted Calm technologies, which adapt the learner centered concept, in a learning environment to provide a learner centered, personalized, and flexible learning environment. In his research, he claimed that the current traditional learning uses some legacy software for e-learning systems, such as Blackboard, WebCT, and WebEx which lack portability, scalability, and quality of collaboration materials. To overcome the previously mentioned limitations, Fiaidhi used a Web 2.0 mashup, an application that enables integration of a different content from different sources as one piece, using Cloud Computing technology. The researcher proposed a framework to develop a Calm personal learning environment using Cloud infrastructure to deploy the framework on it as illustrated in Figure 21.

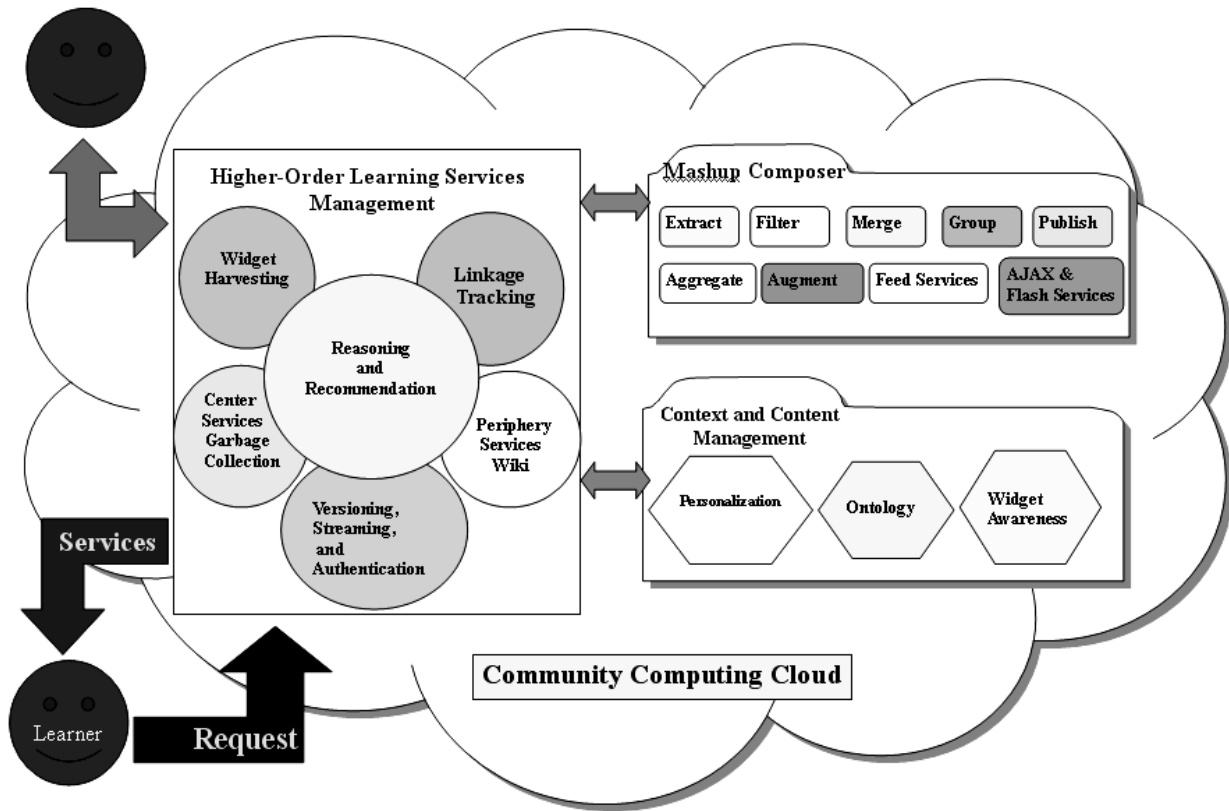


Figure 21: Framework for developing innovative personal learning environments (Fiaidhi, 2010)

Cloud Computing is not only for computer scientists, Cloud can be used to teach other sciences such as Math and Statistics. Chine (2010) discussed the Cloud affect on the Math and Statistics learning and teaching processes by using an Elastic-R platform with R and Scilab. Elastic-R is software which assists R, and Scilab usage scenarios with the Cloud usage scenarios gain benefits for the Cloud. Cloud Computing provides user-friendly and flexible access to the Cloud infrastructure layer, easy collaboration and resource sharing, on-demand elasticity, flexible deployment of applications, and recording capabilities which allow users to save snapshots of their virtual machine images.

Using the Cloud with R and Scilab overcome their limitations; thus, it provides the following capabilities:

1. The processing capability: with the Cloud, the user can connect to a remote R or Scilab engine at any location or platform.
2. The mathematical and numerical capability: when R or Scilab imports to the Cloud learning environment, the environment inherits the mathematical and numerical capability from the packages.
3. The orchestration capability: Elastic-R provides different programming interfaces with different scripting language interpreters beside the S language to program the data.
4. The interaction capability: using the Elastic-R workbench enables different built-in views and plug-in extensions.
5. The persistence capability: by using Amazon Elastic block Stores (EBS) as virtual disk on the Cloud, for example, the data will never be lost.

The next figure shows the environment of the general architecture which used Amazon EC2 to obtain an Elastic-R Amazon Machine Image (AMI).

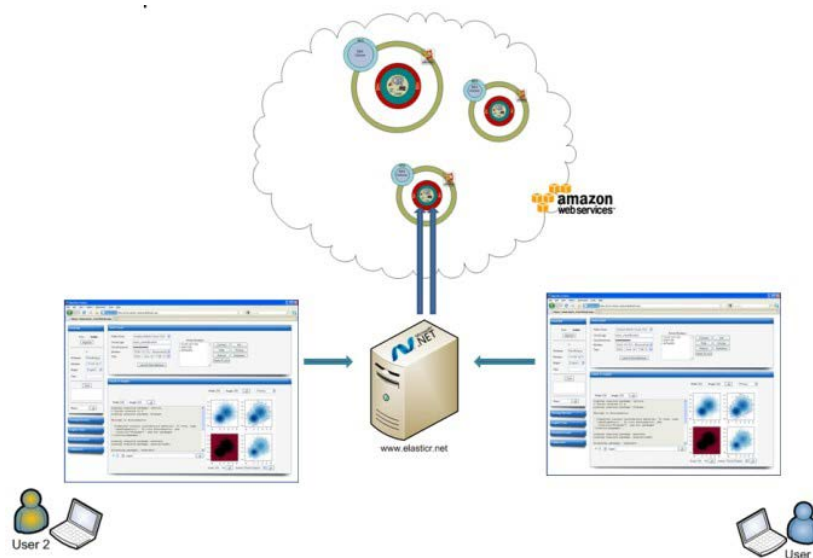


Figure 22: Elastic-R: Virtual e-Research/e-Learning environment (Chine, 2010)

4.2. Toolkits/Frameworks for Simulate Cloud Computing

4.2.1. CloudSim

It is a toolkit for a novel framework to simulate the infrastructures and the Cloud Computing management services. CloudSim is an open source and extendible simulation, allowing users and developers to do experimental studies on Cloud Computing infrastructure for different data center models, scheduling, and allocations policies (Calheiros et al., 2009). In addition, it allows use of either the time sharing or space sharing allocation. This toolkit is built on top of the GridSim toolkit (Buyya & Murshed, 2002) as shown in the following figure which simulates Grid Computing and distributed resources allocation. CloudSim simulates the creation and deploys the VMs on a simulated node of any virtual data center which can be used to ensure the Service Level Agreement (SLA) and the Quality of Service (QoS) for user requirements (Buyya et al., 2009). Furthermore, it allows the migration of VMs to guarantee reliability in keeping the automatic scaling feature and the bottleneck discovery.

There are four layers made up the CloudSim architecture as shown in Figure 23. The base layer is SimJava which handles the discrete event simulation engine. On top of the base SimJava engine is GridSim toolkit. GridSim manipulates high level of software components which control the infrastructure, such as networks, traffic control, resources, data sets, workload ... etc. The CloudSim as a third layer which is implemented on top of GridSim. CloudSim supports virtual data centers simulation functionalities which include VMs management, memory, storage, and bandwidth based on user Quality of Service (QoS) specifications. The top layer represents the user interface in which th users can deploy their Java codes to gather the needed information.

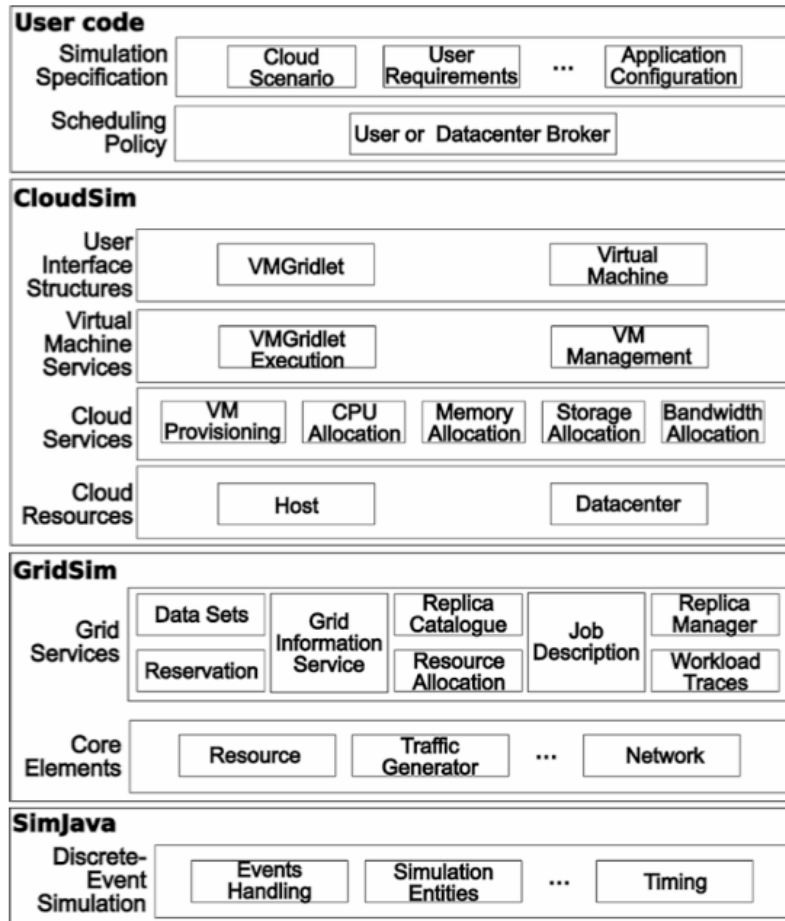


Figure 23: Layered CloudSim architecture (Calheiros et al., 2009)

4.2.2. GreenCloud

GreenCloud is a simulator built to reduce the power consumption in Cloud Computing data centers which the Cloud's infrastructure designer can use to direct them. It is a tool to reduce the power consumption (Bahsoon, 2010) by applying different typologies until it finds a suitable one with an acceptable level of energy consumption with accepted QoS. GreenCloud intends to indicate the consumed energy by the data center components, such as servers and switches. It allows utilizing the power by voltage and frequency scaling, and dynamic shutdown on all data centers' components, especially the computing and networking components which

consume the power primarily (Kliazovich et al., 2010a, b). The energy consumption analysis is visualized (Liu et al., 2009a) in Graphical User Interface (GUI).

4.3. The Proposed Work Differences

The majority of Cloud Computing researchers often ignore one of the beneficiaries of the Cloud Computing services. Computer Scientists make up one of the effective components in the education and development cycle in Clouds. In fact, this notable absence in the research area led to a slowdown in the movement of the Cloud Computing in the education field, comparing the involvement of these competencies in learning and the development of these environments; therefore, both will get the advantage. In addition, Computer Science learners are not getting the appropriate training in such new technology for their future careers while it is available for the public. How can we harness the Cloud as a learning environment for the Cloud Computing concept? This question is the initial problem that we begin to solve. However, when we begin look at the Cloud services and how we can get the benefit of using it to teach the Cloud Computing, we have found the intimate connection between Cloud Computing services and the Computer Science courses. We find out that the Computer Science Courses can be taught through Cloud Computing besides the Grid and Cloud Computing. Using the Cloud to build a Virtual Classroom Ecosystem for Computer Science has many advantages and benefits for all participants in this learning process, which will be clearly stated in the following section, including the institution, system's administrators, faculty, and students. This thesis's main focus is on building a Virtual Classroom Ecosystem for Computer Sciences based on Cloud Computing technology.

CHAPTER 5. OBJECTIVES AND METHODOLOGY

5.1. Objectives of the Study

We are striving to deliver an improved learning environment for the computer science educational settings. We focus on making the framework portable and generalized to offer a wider range of flexibility in its usage. In addition, we use a scalable environment to get the most benefits from the underlying technologies. Furthermore, we would like to improve utilization of the IT infrastructure at an institution like BGSU.

We can think of the Cloud as a car: you can build it, buy it, or just rent it. The Cloud gives the ability to use the needed hardware without buying it. Instead, you just pay for what you use. This feature is an illustration of the cost reduction that the Cloud will add to the teaching process. Instead of having a huge infrastructure that would not be utilized all the time, we can use the Cloud. To be more specific, we look at three of the system users (students, faculty, and administrators) besides the institution's benefits in Section 3.5.

To overcome the knowledge gaps, we will carry out the following tasks:

1. Identify the Computer Science courses that benefit from Cloud Computing in their teaching process.
2. Select three of the public Clouds that offer a wide range of services on the Cloud to be adapted to more courses.
3. Build the framework which underlines the way of teaching these courses and how to utilize the selected public Cloud in these courses.
4. Select examples for the pilot courses, such as Database, Operating System, Parallel Programming, and Data Communications and Networks.

5.2. Methodology

5.2.1. Identifying the Computer Science Courses

To determine the potential Computer Science courses, we start with analyzing BGSU's Computer Science department's curriculum in respect to the CS2008 Review Taskforce, which has been done by the ACM and IEEE Computer Society with fifteen members from different companies and associations by using their classifications of the Computer Science courses. The analyzing process was based on the assignment types, components of the syllabus, and the course specifications in the CS2008 Review Taskforce with respect to the basic Cloud Computing service layers, as shown in Figure 24.

When we looked deeply in to CSP services used in teaching the concepts of Computer Science courses in a much more interactive platform, comparing to simulation scenarios with a local cluster, we decided to spotlight the non-theory courses since most of the Cloud's PaaS services depend on a programming model which is our main focal point that identifies and highlights the intimate relationship between Cloud Computing and Computer Science. This does not mean that theory courses cannot benefit from the Cloud, rather that our main attention in this thesis was on PaaS services. All courses can benefit from SaaS and IaaS layers, such as Cloud based virtual classroom applications and tools. In addition, we identified multi levels of difficulty to the courses which can fit in more than one layer of Cloud basic layers of services in the SOA. Moving from the SaaS layer to the PaaS means the course depth and difficulty increases, and students have to understand course concepts more deeply. In the same way, when we moved from the PaaS layer to the IaaS, we had more sophisticated courses with higher levels of difficulty which reached the details of VMs configuration and fine details of networking and operating systems. For Intro to Information Management, Fundamental Programming, Intro to

Computer Security, Data Analytics, and Database courses located on SaaS layer, we used hosted applications and systems on the Cloud and obtain the benefit of eliminated licensing issues, maintenance, and updating.

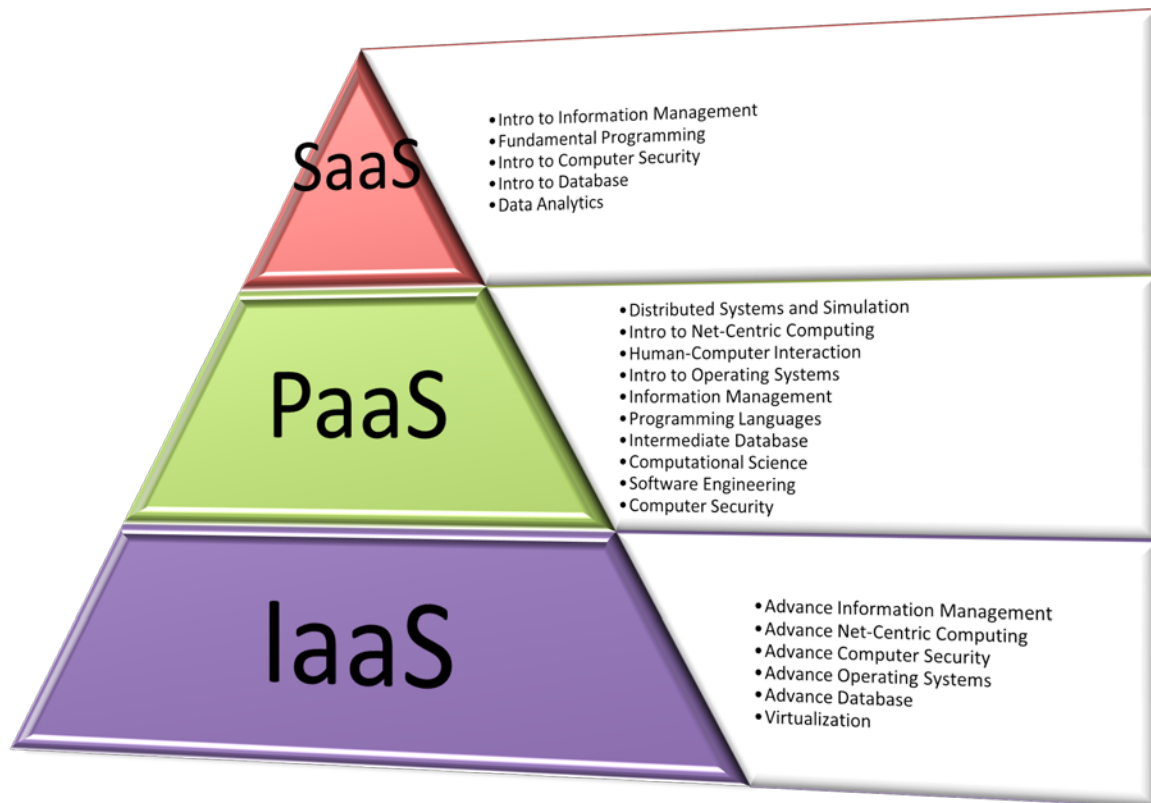


Figure 24: Cloud Computing and potential Computer Science courses

In Intro to Information Management and Database (DB) courses, we performed exercises on Microsoft Access to build simple DB and managed its information. For Fundamental Programming courses, we can use any programming language hosted on the Cloud. Managing a simple technique to deal with user access and group organization can be done on SaaS level for Intro to Computer Security course with other basic functions to control the safety of the information. Finally, in SaaS level courses, there was the Data Analytics course which uses any existing program or application for analysis purpose, such as Microsoft Excel and Customer Relationship Management (CRM) applications.

5.2.2. Selecting Clouds

We started with identification of Clouds that provide a platform as a service since it is the most appropriate layer to deploy the framework on. Since the courses would utilize the PaaS to develop and deploy their application besides the course interface which would be built using IaaS and PaaS, especially for virtual classroom tools that can be found in the PaaS layer. Afterward, we eliminate those Clouds to include the Clouds that afford a great amount of services to apply more courses. In the last stage, we select depending on ease of the use and the existence of ongoing technical support services. Our Cloud candidates are Amazon, IBM Clouds, and Windows Azure. In the following three sections, there are some details about each CSP's candidates.

5.2.2.1. Amazon

Amazon is one of the leading companies in the field of Cloud Computing. Amazon announced Amazon's Elastic Compute Cloud (EC2) in 2006 (Evangelinos & Hill, 2008; Ouf et al., 2011). It delivers services through Amazon Web Services (AWS) considered mainly as an IaaS layer. AWS provides flexibility, cost-effectiveness, scalability, elasticity, and security (Amazon, 2010; Amazon, 2011b) services which allow the user to manipulate the VMs sitting and configuration with a highly scalable platform. It also supports queuing, scheduling, and caching details to deal with operating systems and networking issues. Amazon Cloud provides a PaaS layer, where the user can develop and deploy their Linux-based applications with high availability to assure the customer's trust (Jadhav et al., 2010). Moreover, AWS provides a platform to deal with the database, SimpleDB. This service provides tools of relational database functionalities (Zhang et al., 2010b).

AWS provides scalable, elastic, and reliable resources (Varia, 2010), and it offers infrastructure as a service which include:

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

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

Simple Storage Service (S3), Amazon SimpleDB, and Amazon Elastic Block Storage (EBS) automatically in multiple physical locations repeatedly.

5.2.2.2. IBM

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

IBM SmartCloud provides the following solutions:

- **SPSS Decision Management for Education:** It is a Cloud based solution to analyze student information with different tools to identify students who will be enrolled in their institution by helping them maintain and succeed in their educational life and giving them appropriate information toward the right findings.
- **Virtual Computing Lab (VCL):** It provides a different services and tools via the Cloud for students and staff research. VCL (Averitt et al., 2007; Vouk, 2008; Mason Virtual Computing Lab, 2011) is simple to implement and maintain compared to other available solutions, flexibility, cost effective solution, and wide resources. VCL offers all of the three Cloud services: IaaS, PaaS, and SaaS. On the top is the infrastructure service which prevents students and staff from setting up any software or hardware on their computer

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

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

IBM assists the institutions and companies in their process of moving to the Cloud by helping to build strategies, developing architecture, selecting the right workloads, determining a suitable deployment model—whether private, public, or hybrid Cloud—and managing their Cloud (Boss et al., 2007).

5.2.2.3. Windows Azure

Windows Azure platform (Microsoft, 2011c) provides friendly interfaces to deal with the heart of PaaS in developing and deploying differently .NET applications start from very simple Hello World applications to distributed relational databases. One of Windows Azure's services is SQL Azure, which presents DB services from building the DB to deploy it and scale it through Microsoft data centers. SQL Azure includes relational database services, such as reporting, querying, and data synchronizing. Windows Azure offers several features including computing

resources, storage, database, Virtual Machines (VMs), access control, Content Delivery Network (CDN), caching, virtual network, service bus, business intelligence, and market place.

Windows Azure was built to help developers succeed in their application, especially for the developers who build remote data center applications by providing different tools. Windows Azure provides a platform service which includes operating systems, a set of developer tools, and different levels on network controls to develop, host, scale, and manage developed applications on web and non-web environments (Jadhav et al., 2010). Thus, students will focus on developing the assignment without any pre-configurations for specific software or hardware.

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

CHAPTER 6. PILOT CBE-CS COURSES

6.1. Database

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

IBM Clouds offers a database solution by providing DB2 images in their available instances which represents the OS. Students need to create their databases by adding DB2 images (Krook, 2011) as shown in the next figure:

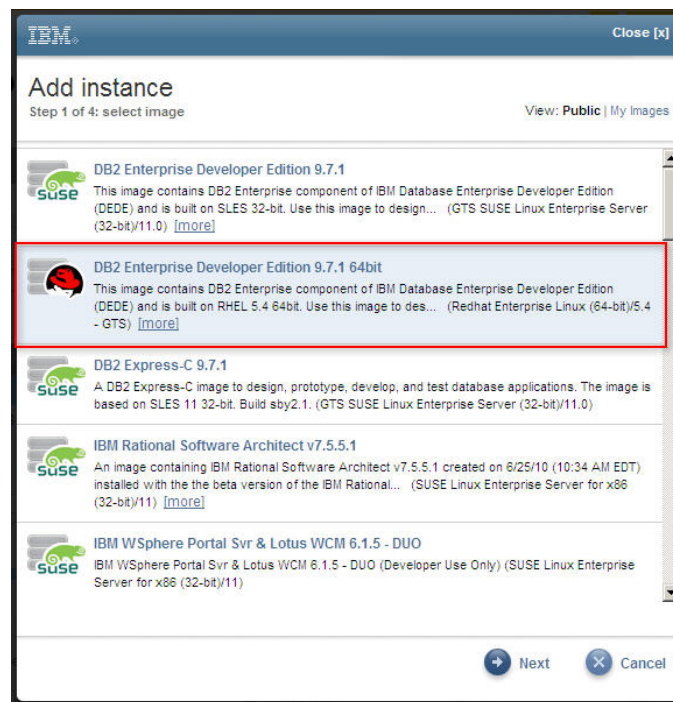


Figure 25: Select a DB2 image from IBM's Clouds to setup the operating system (Krook, 2011)

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

IBM

Close [x]

Add instance

Step 2 of 4: configure image

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

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

Request Name: dW DB2 data server

Quantity: 1

Server Size: Bronze 64 bit

Expires on: 10/9/10

Key: dW key (default) [+ Add Key](#)

Select IP: system generated [How do I add an IP?](#)

Mount Storage: Choose one [How do I add Storage?](#)

Image ID: 10010275

[Previous](#) [Next](#) [Cancel](#)

Figure 26: Configure the DB2 image from IBM's Clouds to deploy SQL and PHP example (Krook, 2011)

The access permissions must be identified. DB2 images give the ability to set three different access levels: the owner, administrator, and user. The password should be entered for each access level. Then, students can start to write the PHP and SQL codes using their user name and password on the Cloud interface. In addition, they can use PuTTY on their local machine by downloading the public and private keys. Furthermore, the database can be connected to a Zend Server to browse the database information using the available extension.

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

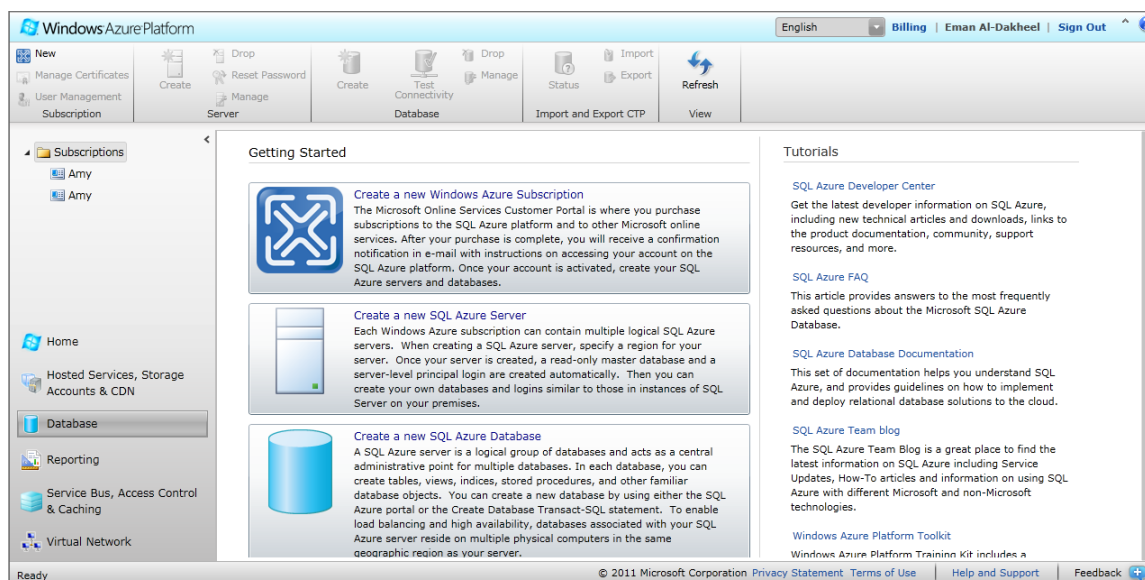


Figure 27: Windows Azure database solution interface snapshot

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

6.2. Operating Systems

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

Without the Cloud, students simulate the behaviors of different scheduling algorithms using any programming language, virtual memory, or device management, and so on, but using

Cloud Computing, students will experience building and testing a real algorithms which perform on any local or distributed systems.

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

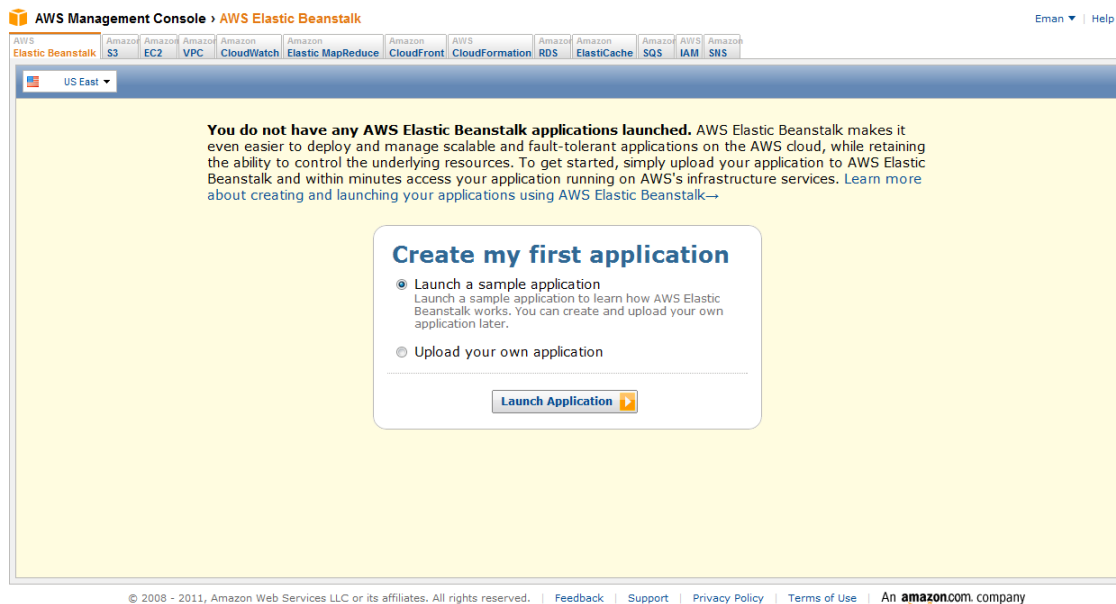


Figure 28: AWS interface with the selection of Elastic Beanstalk tap

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

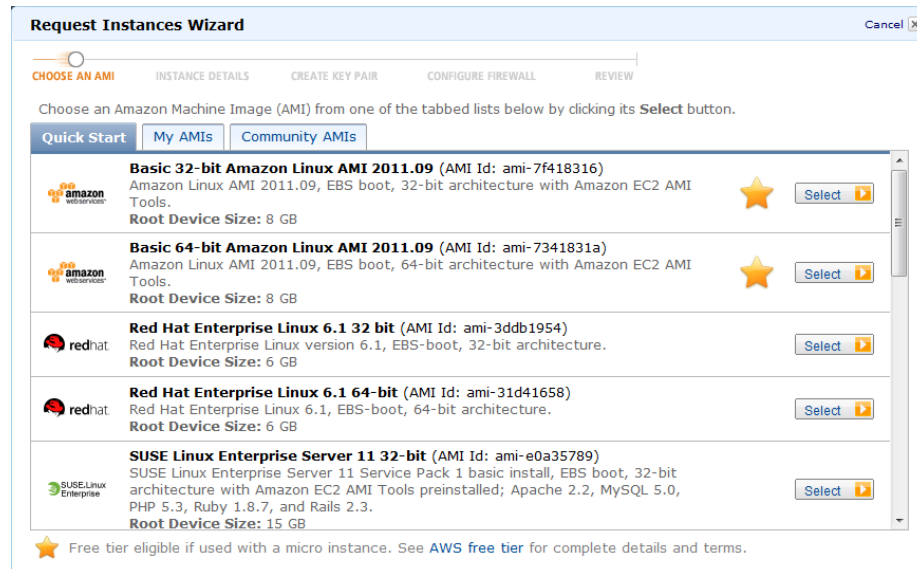


Figure 29: Select instance from the available virtual machine image to allow start implementation and dealing with the operating system

6.3. Parallel Programming

Teaching students programming based courses requires hands on training to teach effectively. Sometimes, the parallel computing is taught as a theoretical course without any lab exercises. However, the students were able to understand the concept. Applying the same rule when the students took the parallel computing and writing programs on local servers, the students understood the complexities of the parallel programming with some hidden and overlooked issues, but using an actual distributed servers improved student understanding for hidden issues related to the distributed environment and routing mechanisms, thus improving the learning outcomes.

Moreover, Cloud Computing overcomes the availability at a multi-core problem to solve parallel programming problems by enhancing the user experience which helps in the wide adoption of the Cloud technology (Dwivedi & Mustafee, 2010).

There are many models on parallel systems which can be taught in a parallel programming course. These models are multi-threading (shared-memory), message-passing, distributed systems, and SIMD-style mostly used in GPUs (Wolffe and Trefftz, 2009).

The student using Cloud Computing can implement a Message Passing Interface (MPI) and C/C++ languages to run their parallel program with the ability to balance the work load. Furthermore, they can debug their programs and try different scenarios and issues related to the performance in the parallel fields.

Using Amazon's EC2 as shown in the following figure, for example, students can implement use of a MPI which communicates using clusters, and supercomputer standard protocol (Fujimoto et al., 2010). Building MPI or OpenMP using OpenSSH (OpenSSH, 2011) allows students to test, run, debug, and deploy their application on a distributed environment. This process exposes students to hidden bugs in the non-distributed environment; thus, students will realize the parallel programming complexities.

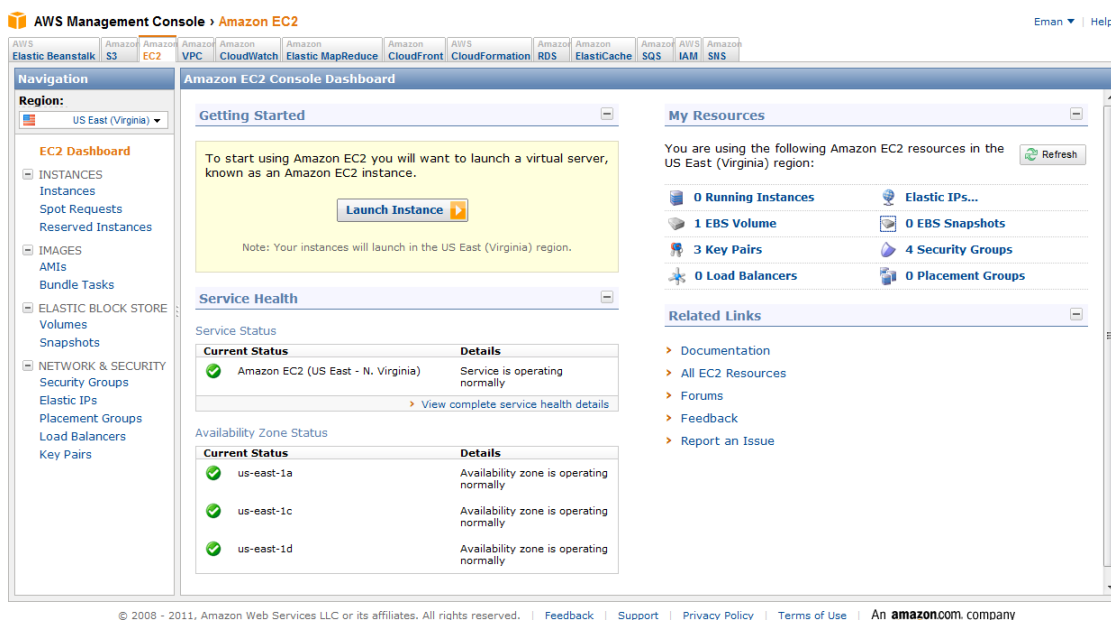


Figure 30: Amazon EC2 interface and services snapshot

6.4. Data Communication and Network

Amazon (Amazon, 2011c) is a rich environment to train students on practical applications for building networks since they are providing the service of building virtual networks, allowing students to apply many of the practical examples:

1. Routing
2. Scheduling
3. Network Topology
4. Security and network protection
5. Arrangement and distribution of IPs

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

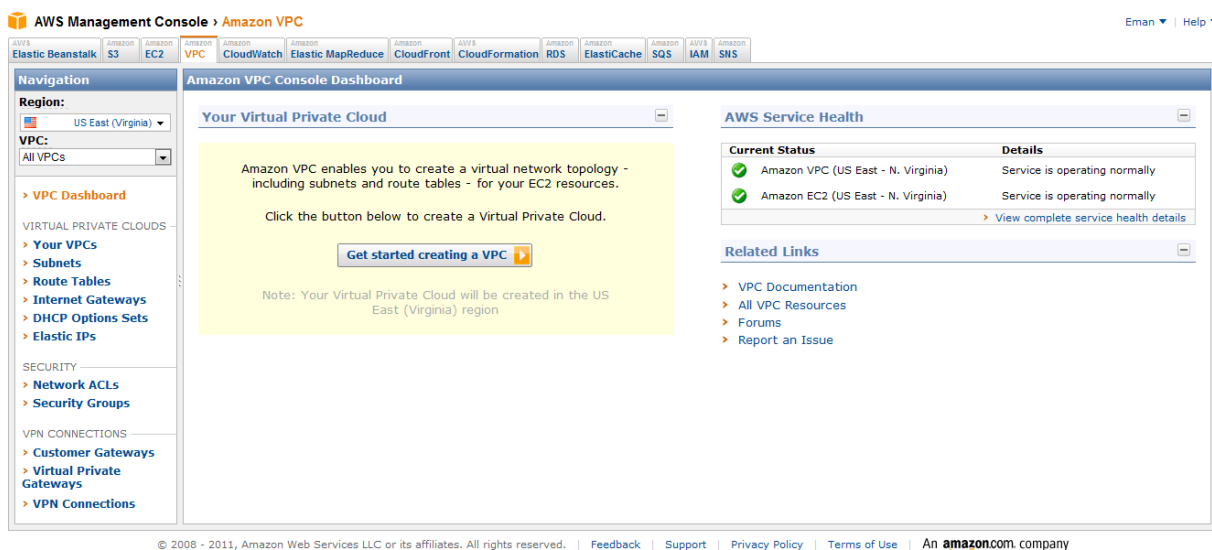


Figure 31: Amazon Virtual Private Cloud (VPC) service interface snapshot

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

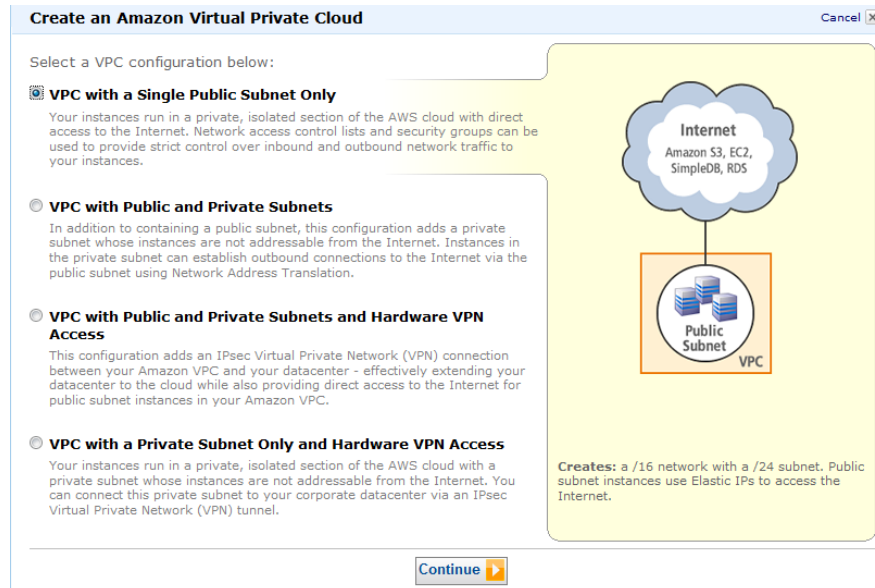


Figure 32: Select deployment methodology of the virtual private Cloud snapshot

CHAPTER 7. CLOUD-BASED EDUCATION FOR COMPUTER SCIENCE (CBE-CS) ECOSYSTEM

7.1. Building the Framework

We know that distance learning (DL) in its current shape is very primitive, as discussed in Section 3.2. Harnessing the Cloud into the e-learning environment gives more flexibilities and dynamic resource allocation which solves the scalability issue. Then the virtual classroom on the top of Cloud Computing layer helps to conquer some DL limitations. Figure 33 shows a general layout of the new e-learning system based on the Cloud Computing with an interface layer to control the users' access to different services.

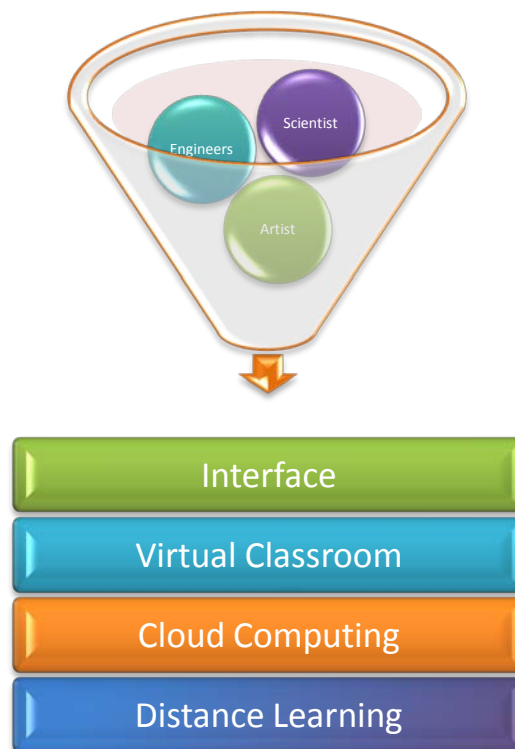


Figure 33: Cloud based virtual classroom architecture

Applying the Cloud based architecture to Computer Science courses will result in adding the course content in the appropriate layer through the interface by adding the content as shown in Figure 34. Using this architecture will enhance the QoS for adding more students and more multimedia content. In addition, the live video streaming is a problematic in the previous systems, but when utilizing the Cloud infrastructure, this problem will be eliminated when we have a good bandwidth for the private networking (Palmer & Dodson, 2011). Using CBE-CS for the Computer Science not only demonstrates the benefit of the underlying infrastructure (Dong et al., 2009a, b; Vaquero, 2011; Tian et al., 2010; Ivica et al., 2009), but also gains more a more solid base in programming and management skills by utilizing Cloud services.

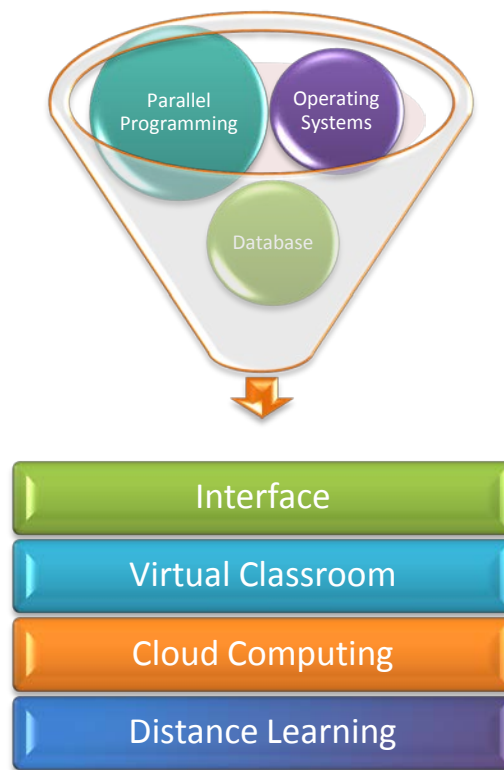


Figure 34: Cloud based virtual classroom for Computer Scientists architecture

Based on the identified courses and selected Clouds, we built a Virtual Classroom Ecosystem for Computer Sciences based on Cloud Computing (VCE-CS) framework. We

focused on how we can integrate the course to use the Cloud in its teaching process. The e-learning components, infrastructure, and their Learning Management System (LMS) are called the “e-learning ecosystem” (Mehta et al., 2010). By highlighting the how part, we can proceed to the details of the framework layers and architecture. The following figure shows the VCE-CS framework.

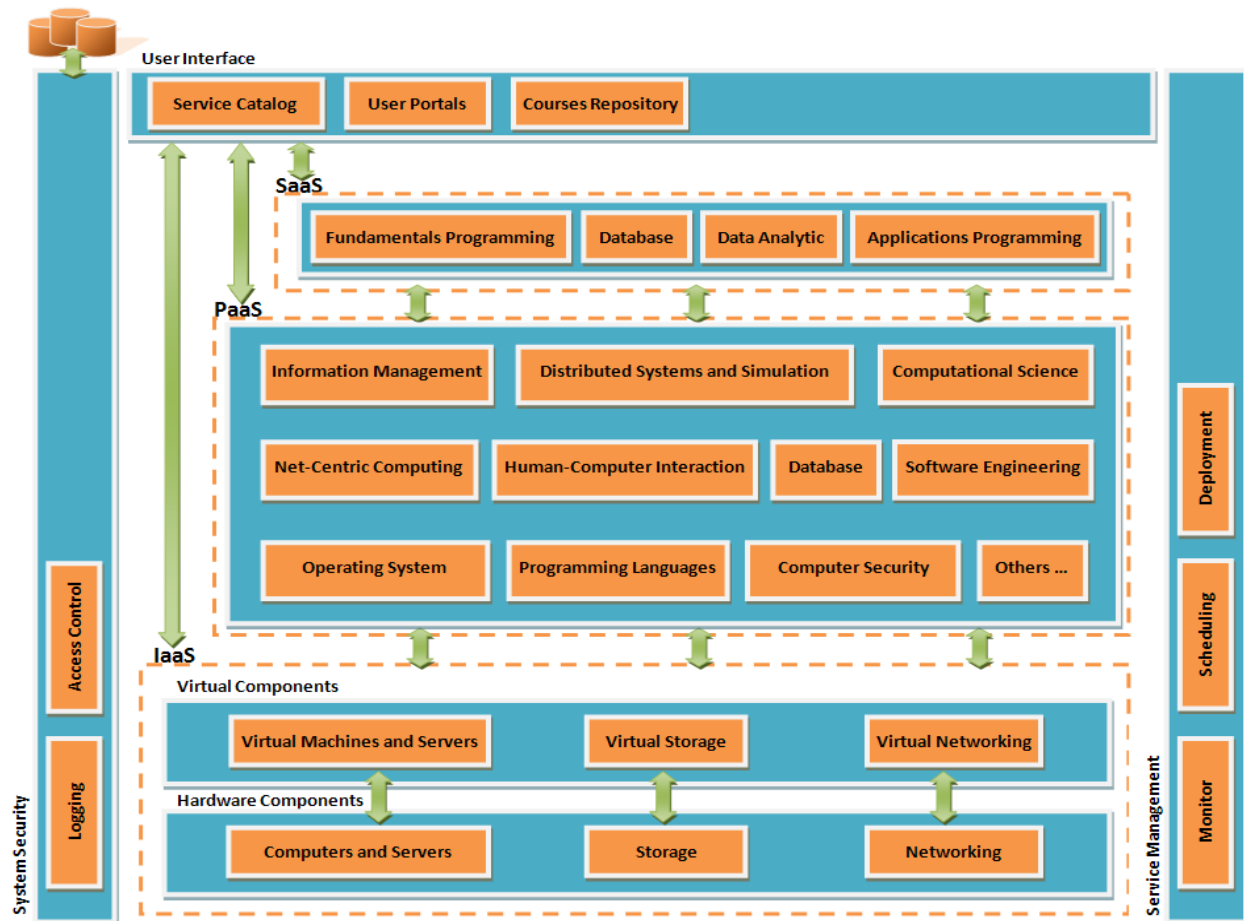


Figure 35: Virtual Classroom Ecosystem for Computer Science based on Cloud Computing

The presented frame work namely VCE-CS contains four layers (User Interface, SaaS, PaaS, and IaaS) and three modules (User log database, system security, and service management):

7.1.1. User Interface Layer:

A user Interface represents LMS since it acts as an interface between the user and the e-learning content. The User Interface layer contains three important components:

User Portals: provide an access path to specific web applications or services since everything is located on the web and can be accessed using an Internet connection.

Service Catalog: contains different types of services with detailed information about the additional access information, such as what layer the service is located and who can access this specific service.

Courses Repository: composed of the courses content categorized and arranged depend on the course name and access level which may be in one of the three other layers (SaaS, PaaS, or IaaS).

7.1.2. SaaS Layer:

This layer provides access to hosted programs—applications or tools on the Cloud—used most of the time by beginner levels, such as 1000 CS courses level. Using Microsoft Word or Microsoft Access, for example, as a hosted application on the Cloud by SkyDrive (Microsoft, 2011b) or Google Apps (Google, 2011b) is considered as a component for this layer.

7.1.3. PaaS Layer:

In the PaaS level courses, they need more than just an existing application to reach their goal. Building a distributed system or simulation needs control of the number and the IPs for the VMs with a platform to host the developed application. Similarly for the Human-Computer

interaction course, we need a platform to host and deploy the developed application or system to measure and test the usability of the deployed system. For the Information Management and DB courses, they are able to build more sophisticated systems and distributed DBs using different tools to manage these systems and DBs. They can use different programming languages to build an application or system on the provided platform for the PaaS level. In the PaaS level, the user can access the VM level with some limitations, and with this access, they are able to control part of the networking issues, such as IPs and routing mechanism which help in teaching Net-Centric Computing courses for the beginner. For the Computational Science course, they can build a temporary multiprocessing system using multiple VMs to solve an existing problem quickly and efficiently. The Software Engineering course needs a platform to develop the software which can be found on the PaaS level. We can choose multiple Operating Systems (OS), build specific scheduling algorithm, and compare the Central Processing Unit (CPU) utilization and speed when using different OS. Lastly in the Computer Security course, in the PaaS level the user is enabled to build inception keys and data encoding mechanisms.

7.1.4. IaaS Layer:

The IaaS level gives more flexibility when dealing with the Hardware layer but through the virtualization. Now, we have reached the point where we have to build the servers and set up their configurations as represented in the Advance Information Management and Database courses. For the Advance Computer Security course, the user can personalize their firewalls, ports, and IPs access. In this level, we can manipulate the OS and the network more deeply above the virtualization layer; thus, the OS and Net-Centric Computing fit perfectly in this level.

Additionally, the user can deal with the fine details of the virtualization with some limitation which makes the virtualization course set in this level.

7.2. Selection of Pilot Courses

This research intended to provide proof of the concept by simulation. Nevertheless, using the available simulator, such as CloudSim, we were unable to provide such proof since the proposed framework was based on PaaS layer and the CloudSim operates on the IaaS layer.

We gave examples on how the framework works in specific course context, for instance, high performance computing and operating system courses.

In this research, four pilot courses were selected; each course represented a separate case study as proof of the concept that we built our framework accordingly. An example from each course is chosen to show how it worked on the Cloud. The case studies are Database, Operating Systems, Parallel Programming, and Data Communication and network.

7.3. Implementation Proposal

The proposed framework utilized the existing IT infrastructure for institutions which would adapt the framework namely, Virtual Classroom Ecosystem for Computer Science (VCE-CS) as illustrated above. In such a situation, the framework needs to deploy a hybrid Cloud model which combines the local infrastructure as a private Cloud with selected public Clouds (Yara et al., 2009). This mashup process combines multiple services (Dong et al., 2009c) from different CSPs to serve Computer Science and enhance the e-learning ecosystem sustainability.

Hybrid Cloud is one of the Cloud Computing deployment models. It provides the ability to access, manage, and use third-party (vendors) resources from multiple CSPs and combines

them within in-house infrastructure (private Cloud). Using such a model allowed us to avoid lock-in and was blocked with one CSP by allowing mix and match services from different CSPs. In addition, it gave us the ability to secure the institution's critical application and data by hosting them on the private Cloud without having to expose them to a third-party. With a hybrid Cloud model, the institution has more control of their system since part of the infrastructure is under their control. For this model, the research needs software which manages the complexities and the heterogeneity of this distributed data centers. The framework's candidate is an open-source project called OpenNebula which can support on-demand VMs provisioning, pre-configured, and manage groups of interconnected VMs; thus, OpenNebula enhances the integration of external providers (CSPs) to enable the selected model of deployment. A historical time line for OpenNebula is illustrated in Figure 36. OpenNebula initially was a research project, and after its release in March 2008, it became one of the open source projects. OpenNebula is growing very fast to meet the industry and developer requirements (OpenNebula, 2011).

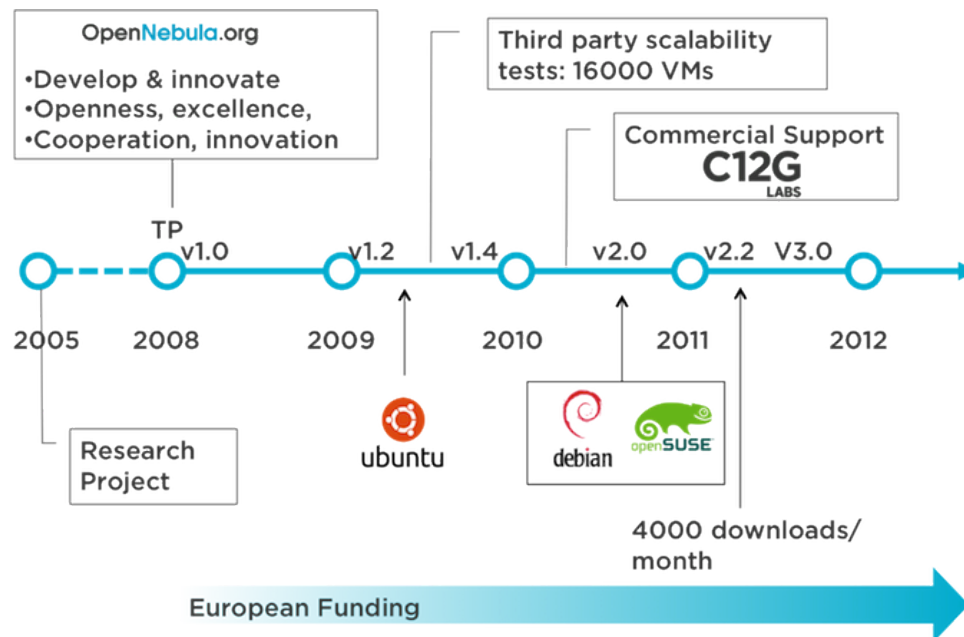


Figure 36: OpenNebula historical time line (OpenNebula, 2011)

Managing Cloud's infrastructure is one of the top concerns in IaaS; consequently, the need for a virtual infrastructure manager was raised. Using OpenNebula gives the ability to manage the local infrastructure and establish the first step toward hybrid Cloud solution by interfacing with a remote Cloud site.

OpenNebula's main role is to manage the VMs (Sotomayor et al., 2009). This management creates a life cycle for each VM (Llorente et al., 2011). The life cycle starts from the resource selection stage which results in a feasible placement on the selected VM by the scheduler. The VM is placed on the target physical resource which is considered as resource preparation in the second stage. After the VM placement, the VM creation stage boots the VM by the resource hypervisor. In the middle of the process, for example, the VM could be migrated to more suitable resources in the VM migration to optimize power consumption. The Final stage is VM termination which shuts down the VM image. The following figure shows the architecture of OpenNebula:

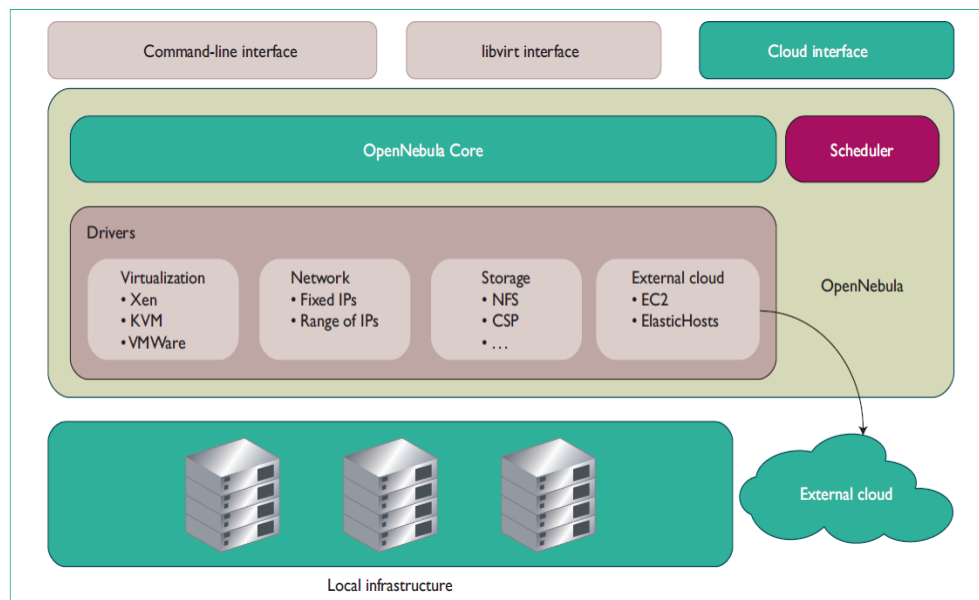


Figure 37: OpenNebula virtual infrastructure engine components (Peng et al., 2009)

The framework places as its base the hybrid Cloud. On top of OpenNebula, Aneka (Vecchiola et al., 2011) which is a platform for managing and programming applications that are built and deployed on the Cloud PaaS implementation solution, as the implementation model for the PaaS layer. Aneka provides software infrastructure for scaling applications using broad collection of APIs for the developers to design and implement applications. Aneka gives developers the ability to run their application on a local or remote distributed infrastructure which supports the hybrid Cloud deployment model.

Transferring the current system or platform to be managed and accessible within Cloud technology is a very hard task. Therefore, it needs lots of planning, preparing, testing, and changing of the current layers and architecture of the platform to be compatible with the Cloud-based educational environment; furthermore, the need for a flexible, extensible, and accessible solution for developing and deploying the proposed framework is raised. The Aneka platform met the listed requirements mentioned above which made it one of the best solutions in our case. The Aneka platform (Vecchiola et al., 2011) provides a flexible and configurable platform which supports multiple programming languages and gives the ability to develop and deploy the applications either on private or public Clouds as the following figure shows:

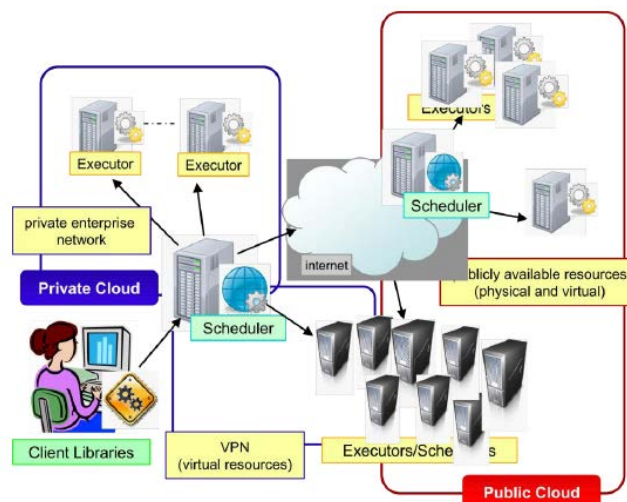


Figure 38: Typical Aneka Cloud deployment (Vecchiola et al., 2009)

Since BGSU's IT infrastructure is heterogeneous including their workstations and servers, Aneka (Vecchiola et al., 2011) is suitable to deal with such heterogeneity to maximize resource utilization in powerful manner as the following figure shows. Aneka was built on the service-oriented architecture which gave Aneka its extensibility to integrate different types of Clouds.

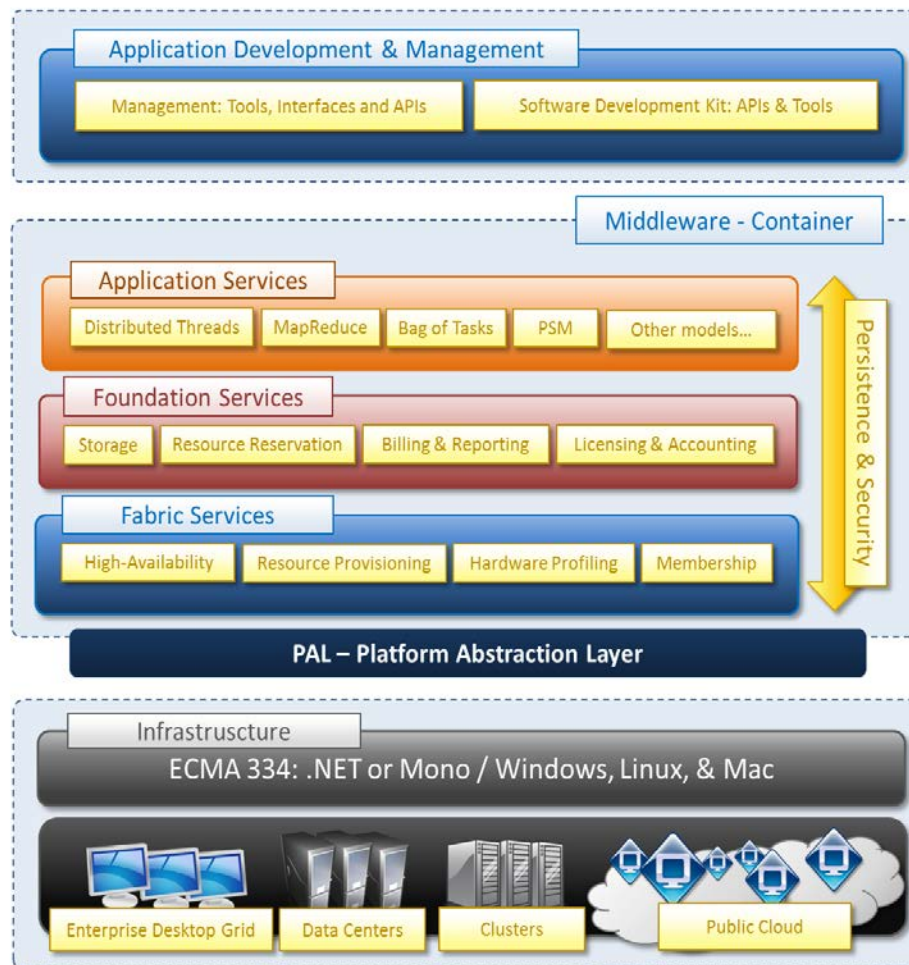


Figure 39: Aneka framework architecture (Sukumar et al., 2011)

As shown in the above figure, the Aneka framework architecture contains three different layers corresponding to the basic service layers of the Cloud Computing easily integrated with the external Cloud. Aneka enables the execution of the application on its runtime environment by using the underlying Cloud infrastructure for either private or public Clouds. It provides

management tools; administrators can easily start, stop, and deploy any application. The Aneka platform contains three classes of services which characterize its middleware layer:

1. Execution Services: Their primary responsibility is scheduling and executing deployed applications.
2. Foundation Services: They represent the collection set of management services, such as metering applications and resource allocation and updating the service registry whenever needed.
3. Fabric Services: They present the lowest level of middleware services classes. They provide access to Cloud resource management to enable resource provisioning which will scale the allocated resources to the applications to achieve the required QoS.

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

To build a powerful hybrid Cloud solution (Liu et al., 2011) which utilizes the current Bowling Green State University (BGSU) IT infrastructure (private Cloud), the research used Aneka middleware on top of OpenNebula. The combination of these two open-sources provided a manageable hybrid Cloud for BGSU. This approach utilized BGSU's IT infrastructure more efficiently, and it provided additional resources when the BGSU's IT infrastructure was at the peak time and could not provide all the requested resources, such as storage and computing power. The additional resources will be brought from the available public Clouds.

BGSU's hybrid Cloud contains several components to deliver the requested service. There are three layers made up for the private BGSU Cloud with two modules to manage the user's access and the content delivery. BGSU's private Cloud has the ability to be connected to public Cloud at the peak time. In addition, the user can request any needed service from the

public Cloud at any time, which results in BGSU hybrid Cloud. The following list describes BGSU hybrid Cloud's components:

1- Infrastructure layer:

The BGSU IT Infrastructure was placed at the bottom of this layer since BGSU's private Cloud would be built on top of the available infrastructure. Furthermore, these physical infrastructures were virtualized using OpenNebula which plays a critical role in the infrastructure layer.

2- Platform layer:

This layer contains the Aneka platform which worked and managed the platform to enable development and deployment of applications and programs with the ability to access public Clouds resources and platforms. Moreover, it is connected to the Course Repository module to integrate the Aneka platform service with the course content of assignments.

3- Use Interface layer:

This layer controls and is managed by the BGSU hybrid Cloud, identifying the access model which could be students, faculty, administrator, or others which can be created by the system's administrator. The authorization and identification process is done using the Users Logs module to verify the entered information. Then it forwards the users' request to the appropriate component in the same layer. Furthermore, this layer has three other components: IaaS, PaaS, and SaaS. IaaS provides a resource from the Infrastructure layer. A middleware container is used to develop applications and give Computer Science learners and educators the access to PaaS services provided by the PaaS component in the user Interface layer which provides an access to the Platform layer that contains the Aneka platform. Lastly is the SaaS component which provides access to either the Platform layer so as to use one of the deployed applications or to

public Clouds which may host an application used by system users, such as e-mail. There is a certain level of QoS which is granted by the provided SLA which includes detailed information about the services and available levels of resources to be accessed. This multi-layer in the BGSU hybrid Cloud architecture offers additional levels of security for the presented system.

4- Courses Repository module:

This consists mainly of e-learning systems content, such as database systems, Web file system, and so on. This module contains specific details about the homework and assignments. Computer Science learners accessed their programming assignments using this module.

5- Users Logs module:

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

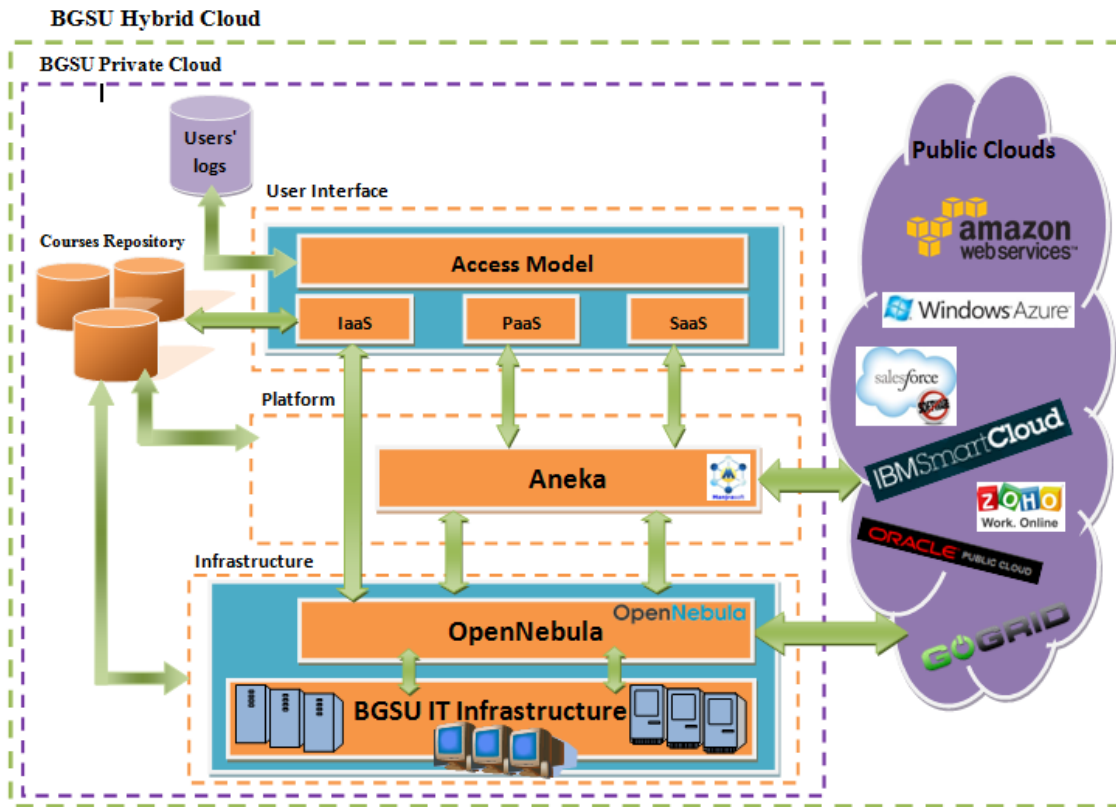


Figure 41: BGSU's hybrid Cloud architecture

CHAPTER 8. DISCUSSION

In this research, the current status of e-learning system was studied to highlight the limitations (Zhang & Nunamaker, 2003; Wong, 2007; Zhixiao et al., 2008; Lee et al., 2009; Das et al., 2010; Fiaidhi, 2010; Redondo et al., 2010; Yuru et al., 2010) and determine how we could improve the e-learning environment for Computer Science education. After identifying the challenges and limitations, the research showed that Cloud Computing can overcome most of these limitations (Pocatilu et al., 2009; Ekanayaka et al., 2010; Goldstein, 2010; Pocatilu et al., 2010) to improve the Virtual Learning Environment (VLE); thus, the idea of harnessing the Cloud Computing service at BGSU by utilizing Infrastructure as a Service (IaaS) to overcome the resource limitations (Abdul Razak, 2009; Dong et al., 2009a, b) and SaaS to enhance the learning environment by adding more interactive and valuable tools (Sclater, 2010; Yuru et al., 2010) seems feasible. The primary focus of this research is to utilize PaaS which would enable the student to develop and deploy applications and programming assignments in a real distributed environment, thereby enhancing the students' learning outcomes and knowledge base (Ivica et al., 2009; Vaquero, 2011).

A Cloud-based framework has been presented which combines the existing public Clouds and BGSU's private Cloud to host courses. The main objective was to enhance the Computer Science learning environment by utilizing PaaS and make it available for Computer Science learners and educators. PaaS enabled students to experience hands-on training in real environments which improved their learning and knowledge base as well as enhanced their learning outcomes. Three Cloud Service Providers (CSPs) were chosen for teaching a wide range of sophisticated Computer Science courses that will enjoy the benefits of the Cloud.

Examples of four pilot Computer Science courses have been given. The selected courses are Database, Operating System, Parallel Programming, and Data Communication and Network. Because CloudSim is the only existing open source simulation toolkit that simulates the IaaS, we could not use it to simulate PaaS, the main layer in our framework.

The generalized framework, along with the pilot Cloud-Based Education for Computer Science (CBE-CS) courses and their corresponding examples, was discussed. This framework eliminates unrelated issues in the progress of teaching courses for both the teacher and the students. Such issues include network connection details and implementing parallel distributed programs using MPI. In addition, using the Cloud allowed the student to work in real environments and get hands-on training. For example, it exposed the student to problems that could not exist with local clusters. By using the Cloud Computing which overcomes most challenges of the current e-learning systems, we provided a much better learning environment for Computer Science students and improved job opportunities because of the hands-on training, background, and knowledge of the Cloud Computing. Making the framework suitable for teaching Computer Science courses by utilizing public Clouds' resources would bring significant benefits for the Computer Science field if Computer Science programs utilized the framework in their teaching since the framework increases the allowable number of enrolled students and decreases cost.

CHAPTER 9. FUTURE WORK

The proposed framework is just a road map for the implementation of a whole virtual classroom ecosystem. After the system is ready to use, an independent study comparing the learning process using the proposed framework with the original learning environment should be conducted.

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

- 1- Implement the ecosystem using the agile approach with iterative feedback and reflection to produce high quality and accepted learning environments. Using such a model may change the initial vision of the sites to be developed to build more creative and effective learning environments.
- 2- Examine the impact of learners' programming background characteristics on the framework's effectiveness. Do the learners' backgrounds in programming affect their performance in the course? If so, what are the suitable solutions? How can inexperienced or unknowledgeable programmers improve their performance?
- 3- Explore how to provide more powerful environments to allow learners to gain new knowledge and skills. As an example, Cloud Computing provides different tools and solutions for virtual classroom environments. Thus, system administrators must always look for more powerful tools and applications to be deployed.

- 4- Study how the framework efficiency enhances learners' performance and knowledge base. Examine diverse scenarios that explore the strengths and the weaknesses of the proposed framework.
- 5- Investigate the effectiveness of the course content and placement in the framework as well as the ability to move and add courses. In other words, refine the framework after examining actual scenarios. Depending on the survey results, the framework can be modified by moving or adding courses or components.
- 6- Reevaluate work effectiveness to use the Cloud effectively as a new technology. Any proposed work should be refined and reevaluated to assure the resource level of its quality, thus promoting a robust learning environment.
- 7- Measure the framework effectiveness by having two classes study the same course material. One of these courses should study course material without Cloud-based applications, but the other section should utilize course material via Cloud. Moreover, these sections should complete their homework and programming assignments using the Cloud.
- 8- Conduct a comparison study on the usability of any two Clouds by running the proposed framework and measuring performance. The comparison study may consider the cost, ease of learning, network latency, ease of use, and any other important measurements.
- 9- Compare the implementation of the framework on the public Cloud, private Cloud, and hybrid Cloud by highlighting the strengths and weaknesses of each Cloud architecture while considering the performance and security issues.

In addition, all the opening questions can be considered as opportunities for future work. More questions would be regarding whether the Cloud augments the learning process, whether

the Cloud is superior to traditional server farms, how good Cloud-based e-learning would be, and whether Cloud-based education is superior to traditional classroom education.

CHAPTER 10. CONCLUSIONS

This research investigated the potential benefits of using Cloud Computing in e-learning environments to overcome the current e-learning system limitations. The research focused primarily on Computer Science learners and improving their learning via Cloud Computing.

The research identified the potential courses to be taught through the Cloud with the ability to add more courses. Since all of the previous work focused on the courses that can be used based on their platforms, we introduce Virtual Classroom Ecosystem for Computer Sciences based on Cloud Computing (VCE-CS), a new framework to adapt to the appropriate courses, making the platform easy to use in several courses.

Moreover, this study highlighted the benefits of using the Cloud for institutions, administrators, faculty, and the most important player, the student. Four courses (Database, Operating System, Parallel Computing, and Data Communication and Network) on different public Clouds were discussed as proof of the effectiveness of a VCE-CS framework. The benefits show that e-learning development cannot ignore Cloud Computing and its benefits (Pocatilu, 2010) in the educational field.

As debates regarding the use of social networking in teaching rage (Hoffman, 2009), so do the debates surrounding Cloud Computing as a ground-breaking form of new technology. This research identified the potential advantages of using Cloud Computing in educational settings as well as limitations that should be considered. In short, without any doubt, Cloud Computing offers a plethora of tools and choices, which should be carefully evaluated to ensure that all the educational stake-holders gain the maximum benefits from such technology.

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