

KEMI-TORNIO UNIVERSITY OF APPLIED SCIENCES

Software Development in Cloud Computing Environment

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PREFACE

This thesis is a reflection of my strong interest in cloud computing. I came up with this thesis topic after conversations I had with some friends concerning cloud computing.

I will like to express my sincere gratitude to Harri Järkkälä for introducing me to cloud computing back in 2010; Antti Niemelä for his technical guidance at all times during the writing of this thesis. I will like to say thanks to Teppo Aalto for being my supervisor for this thesis.

My sincere gratitude goes to the head of the information technology department Soili Mäkimurto-Koivumaa for accepting this topic as my final thesis topic. To Martta Ruottu, my tutor for her help at all times.

Last but not the least will like to thank my parent and my siblings for their support, especially my mother Mrs Rebecca Damalie for the emotional support and the encouragement during the very difficult times of writing this thesis.

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ABSTRACT

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The objective of this thesis is in three folds, a look into cloud computing and anything associated with it, I will take a look at software engineering and development and finally a link between cloud computing and systematic way of using the cloud computing environment for software development.

The first part of the thesis which is the theoretical part was a pure in-depth research work. A study of cloud computing. A look into some cloud computing platforms like Google and Eucalyptus. The merging of cloud computing and software development. Designing software using both cloud computing and software development methods, precisely agile method.

Results of this thesis are astonishing and it answers questions of how much can be done in cloud computing environment. The variety of work that can be done with and in cloud computing. The significant of this thesis is huge to the information technology field and also will affect the direction cloud computing is heading towards.

Keywords: cloud computing, software engineering, platforms, service.

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EXPLANATION OF CHARCTERS AND ABBREVIATIONS

API	Application Programming Interface
APPFabric	Application Fabric
AJAX	Asynchronous Javascript and XML
AWS	Amazon Web Services
CISE	Closed Information Service Exchange
CPU	Central Processing Unit
EC2	Elastic Compute Cloud
EIGRP	Enhanced Interior Gateway Routing Protocol
EMCUK	Egan Marino Corporation United Kingdom
FTP	File Transfer Protocol
Gmail	Google Mail
HTTP	HyperText Transfer Protocol
IaaS	Infrastructure as a Service
IBM	International Business Machines Corporation
IDC	International Data Corporation
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Organization for Standardization
IT	Information Technology
JRuby	Java Ruby
JVM	Java Virtual Machine
KVM	Kernel-based Virtual Machine
MB	Mega Byte
MS DOS	Microsoft Disk Operating System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NIST	National Institute of Standards and Technology
OSEL	Open Source Exchange Library
PaaS	Platform as a Service
PHP	Hypertext Preprocessor

REP	Reputation Network
S3	Simple Storage Service
SaaS	Software as a Service
SGE	Sun Grid Engine
SME	Small Medium Enterprise SQL Structured Query Language
SOAP	Simple Object Access Protocol
TCP	Transmission Control Protocol
UML	Unified Modeling Language
VCloud	VirtualCloud
VDP	Video Datagram Protocol
VM	Virtual Machine
VMware	Virtual Machine ware
VPN	Virtual Private Network
WAN	Wide Area Network
X86	32-bit generation of Intel microprocessor architecture
XEN	Virtual-Machine Monitor
VOIP	Voice over Internet Protocol

1. INTRODUCTION

In winter of 2010 I created a new email account with Gmail. It was just an email address created for receiving and sending mails. A friend showed me the other things you can do with a Gmail account. A Gmail is a Google mail account-he explained to me how these features of my mail account work. Along the line he mentioned cloud computing. I instantly became fascinated with the word cloud computing especially the cloud part of it. He explained to me what cloud computing was about and I developed a remarkable interest in cloud computing. Almost a year later I thought about software development in cloud computing environment, if it is possible or not.

By now we have all heard about cloud computing. Cloud Computing is one of the biggest technology advancement in recent times. It has taken computing in general to the next level. Cloud computing has generated a lot buzz in the IT world.

Cloud computing is one of the biggest thing in computing in recent time. Its popularity in the IT world is growing at an incredibly fast pace. It is a key issue in the design because the main goal of the design depends on cloud computing. Documentation, storage and other computing work are all being done in cloud computing now. With all this happening in cloud computing it goes to show how successful cloud computing has been so far.

Virtualizations is one of the fundamentals enablers of cloud computing. The designing I am hoping to achieve relies heavily on virtualization to work. There are virtual servers and virtual desktop involved with this design. A deep understanding of virtualization is very essential for the understanding of the design. How virtual servers work. The design will go on to deepen the understanding of the link between cloud computing and virtualization.

This thesis involves a good understanding and virtualization and how to host resources for software development. The success of this thesis will impact software development in a lot of ways. Cost effectiveness is going to be the biggest impact this thesis will have on software engineering projects. Also the utilization of open source tools for software

development will all be in the same place. This is to mention a few. A proper understanding of this design will enhance the productivity of software engineering engineers. For all the advantages it will bring to big companies, it is also beneficial to small and medium size software engineering companies.

1.1. Purpose of Study

The purpose of this thesis is to introduce cloud computing and understanding the benefits of cloud computing. Understanding what cloud computing is, it is essential for adaptation of cloud computing by companies, organizations. It developers and IT specialist. Extensive research work was done to fully understand cloud computing as a concept, as a computing solution and also as the future of computing in general.

The buzz about cloud computing is so intense that it will be to anybody's disadvantage to just ignore it. My research work on cloud was done to understand, cloud computing, its uses and how it could be exploited for development purposes. Additionally the thought of doing everything including software development in cloud computing was and is very compelling.

As information technology is evolving in so many ways to meet the increasing demand, many information technology companies and business organizations are seriously examining cloud computing as the solution to so many information technological needs.

Also considering the current economic downtown information technology information technology companies and businesses are searching for that big break in computing. That new computing solution that will solve and meet the increasing computing demands of consumers.

Cloud computing is very beneficial to business organizations, information technology companies and consumers to understand the benefits and the full ability of cloud

computing. It is here to stay. This is what this thesis is about. Cloud computing is going to revolutionized computing as it has already started doing.

The current pace of the popularity of cloud computing is so fast. I decided to look into the development of software in cloud computing environment. I mean everything about software development in cloud computing environment and with cloud computing. The benefits of being able to develop a software in cloud computing is good for information technology companies. This further elaborates the benefits and usefulness of open source products.

1.2. Structure of Study

This thesis is divided into five chapters. The first chapter discusses the purpose of the study and the structure of the study. The research topic, questions and methodology is discussed in chapter two. Chapter three is about cloud computing. It is a complete research on cloud computing. What cloud computing is and all the major aspects of cloud computing. From what it is to security issues of cloud computing. Chapter four is about software engineering. A general knowledge on software development, the processes and activities involve in developing software and a look at some process model. Software development in cloud computing is discussed in chapter five. The possibility of developing a complete software in cloud computing is the main idea here. This chapter links the software engineering and cloud computing. Chapter five also contains designs. Designing tools like UML is featured in this chapter. Chapter six closes this thesis with conclusion of all that has been done.

2. RESEARCH TOPIC, AND METHODOLOGY

This chapter features the research work and contributions. The research work is the foundation of this thesis. The chapter looks at the research questions. The chosen research method is discussed in this chapter.

2.1. Research Topic

Good research involves collection, selection, analysis and presentation of data. These activities are made possibly easier by many of our everyday skills, such as reading, listening and watching. The goal of research is to observe, describe, explain and to answer specific questions for better understanding, decision making, predictions and creation. /38/

In this particular case, the purpose of this research is to understand cloud computing, software engineering and the possibility of linking the two to create a software engineering suite. Integration of a software development suite into cloud computing. The processes for making this idea possible are:

In-depth research on cloud computing and cloud computing platforms:

1. An in-depth research on software engineering process models and activities.
2. Discussions about how to link the two main components to meet the main goal of this thesis.
3. Discussion about the best cloud computing platform to use and the best software engineering process model to use.
4. Identification of beneficiaries of this final design

2.2. Research Methodology

Research and development work are activities that increase the knowledge about a particular subject, topic or issue. It is about answering a question or searching for a solution to a problem. Research can be defined as a scientific and systemic search for pertinent information on a specific topic. /38/

The research method that will be used in this thesis is a combination of both descriptive method and exploratory method.

Descriptive research is used to obtain information concerning the current status of a phenomenon to describe “what exist with respect to the variables or conditions in a situation

The main goal of descriptive research is to have a better understanding of a topic. /38/

Exploratory research helps to determine the suitable research design. Exploratory is based on reviewing available data or qualitative approaches such as case studies or pilot studies. This research method is going to help me get a better understanding of cloud computing. It will also merge the two aspects of this project to meet the goal of this thesis.

Using these research methods, this thesis attempts to develop a very new and different approach to the normal software engineering. This could go a long way to influence the software engineering standardized culture. /38/

3. CLOUD COMPUTING

This chapter focuses mainly on cloud computing. This chapter takes a critical look at cloud computing as a concept, cloud computing as a service, as an emerging phenomena in both the information technology, the business and enterprise world .The chapter also touches on security of cloud computing . /16/

3.1. Introduction

The definition of cloud computing varies. There is no one specific definition for cloud computing. The definitions differ, but a pattern is found in all of the definitions such that certain words or terms are in almost every definition or explanation.

These terms are delivery, internet, computing as a service, shared resources, software and infrastructure.

The National Institute of Standards and Technology(NIST) defines cloud computing as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage applications and services)that can be rapidly provisioned and released with minimal effort or service provider interaction. /44/

Cloud computing defined by Jeff Kaplan who writes blogs examining cloud computing defines cloud computing as “ as a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a pay-as-you go basis that previously required tremendous hardware/software investments and professional skills to acquire. Cloud computing is the realization of the earlier ideas of utility computing without the technical complexities or complicated deployment worries.” /45/

Cloud computing is also defined as an information process model in which centrally administered computing capabilities are delivered as services ,on an as-needed basis, across the network to a variety of user-facing devices. /39/

IDC definition of cloud computing is an emerging IT development and delivery model ,enabling real-time delivery of products, services and solutions over the internet(i.e. enabling cloud services). /46/

Cloud computing infrastructures can allow enterprises to achieve more efficient use of their IT hardware and software investments. Cloud computing can and will play a very important role in variety of areas including virtual worlds, e-business, social networks and search. I will like to also state that there is a possibility that it can be used in software designing which this thesis will dive into in chapters to come. Figure 1 is an illustration of cloud computing. /27/



Figure 1. Cloud Computing. /47/

3.2. Factors that made cloud computing possible

The fast advancement of today's world has caused a lot of evolutions in different areas. Technology advancement is one of it .The existence of certain technological products solidifies that fact that there is a technological evolution going on.

As technology evolves, methods of delivery of some applications and services are also evolving. Cloud computing is one of the major outcomes of the evolving nature of application and service delivery.

3.2.1. Internet

One of the basic factors that made cloud computing possible is the internet .The existence of the internet and large internet bandwidth. You cannot talk about cloud computing without talking about the internet .If we talk about factors that influence or has made cloud computing possible we have to certainly mention the internet.

The evolution of the internet from the Arpanet days back in 1969 to the Arpanet network in 1970 to the development of emails in 1971.The year 1974 marked the beginning of TCP/IP. Then came about the email client in 1975.The PC modem came about in 1977.

In 1983 Arpanet computers switched over to TCP/IP. The domain name system was created in 1984 along with the first Domain Name Server (DNS). By the year 1987 there were almost 30,000 hosts on the internet, 1987 saw the proposal for the World Wide Web.

The first webpages were created in 1991. The internet was commercialized in 1995. The first web based mail service was in 1996. 1998 marked the birth of Google and also internet based files sharing got its root in the same year. The year 2004 saw the birth of web 2.0. John Batelle and Tim O'Reilly described the concept of the webs as a platform.

From Arpanet in 1969 to the internet today shows how much evolution occurred with the internet. In terms of cloud computing the internet performs a major role in the success of

cloud computing.

The internet acts as a connection between the consumers of cloud and the cloud. Most cloud computing services are all internet based. With the internet the consumer can have access to his or her cloud environment anywhere in the world.

The bandwidth of internet in modern times is one of the major factors that allow the cloud application to be used efficiently and easily: smaller bandwidth will make cloud computing experience very bad. Imagine waiting for so many minutes and hours for an application to open or upload to be ready to be used after you open it due to the small size of the internet bandwidth.

Big and bigger bandwidth which is high speed internet is the link or the bridge between users or consumers and the data in clouds. Example is the Google cloud environment. Internet browsers are used to have access to the cloud data and applications. That goes a long way to tell you how important and a driving force the internet is when it comes to cloud computing. / 10/

3.2.2. Virtualisation

Virtualization is one of the fundamental enablers of cloud computing. Virtualization is the use of virtual version hardware platforms, operating systems, a storage device or network services.

Philip Dawson a Gartner Analyst defines virtualization as a packaging technology that can be used in data centers and on desktop to make software component more portable.

The reason for stating that virtualization is one of the fundamental enablers of cloud computing is because cloud computing utilizes virtualization. It works as the foundation for clouds. Virtualised appliances in cloud computing environment can be implemented as a standalone package vs. to do all of the things necessary to implement an application.

Virtualizing physical resources provides a flexible foundation to support the delivery of

Information technology as a service. By implementing virtualization at all layers of the architecture (servers, storage, networks, applications, and clients) ensues the flexibility of the intense demands cloud computing puts on information technology resources.

Flexibility is supported by virtualization that allows applications to spin up on demand and allow applications to move from one location to another location either within a single datacenter or between datacenters.

According to Gartner X86 server virtualization infrastructure provides the foundation for cloud computing. Virtualization is improving utilization, improving the speed of the delivery of these resources. Looking back at the advantages and characteristics of cloud computing you can clearly see how virtualization serves as a primary footing for cloud computing.

Virtualization is a better utilization of existing physical resources. Because of virtualization scaling is quicker.

Virtualization reduces the number of servers to be used when adopting cloud computing.

/17/ /39/

3.2.3. The Economy

With the current server down turn of the economy the adoption of cloud computing is one of the best moves a company or business can make. The adaptation of cloud computing reduces spending by companies. Cloud computing is going to reduce the costs of entry and production drastically.

The demand for computing services is very high. Computing solutions are needed in tough economic times like this. This makes cloud computing idea and concept a very favorable solution.

Is all about reducing cost and providing better service. This I believe is one of the major factors that assisted in bring about cloud computing. The methods companies are adopting now is to reduce cost but produce efficient outcomes. Computing is very expensive.

Considering infrastructures, personnel etc.

Now the pressure to develop solution is very high. EMCUKS says cloud computing adoption is to generate more than £763 billion in economic benefits by 2015. In the financial sector £183 billion of cumulative economic benefits would be realized through cloud computing adoption by 2015. These figures tell you why development of cloud computing is so important.

The economy's effect on the need to find solution to computing in this time and age is a major factor in the creation of cloud computing. Its effect on the economy is staggering. Cloud Computing helps to deliver agile services at lower cost.

World economy forum made a survey, they asked everywhere what is the most important benefits for potential cloud users? A staggering percentage (71%) answered reduce cost.

3.2.4. Abstraction layers

Abstraction layers are major factors that help make cloud computing possible. The different abstraction layers are the fundamental and important building blocks of cloud computing.

Abstraction layers is a way of hiding the implementation details of a particular set of functionality. Software models that use layers of abstraction include the ISO 7-layer model for computer network protocols, the openGr graphics drawing library and the style stream input/output model originated by Unix and adopted by MSDOS, Linux and most other operating system

It is also defined as a very important critical and basic foundation for cloud computing. It allows users to think of a service as a particular protocol, processing cycles with CPU or a storage capacity on a hard disk. Without thinking or knowledge about a particular piece of hardware that is providing that service.

To answer the question I asked about the different layers of abstraction we look at the

seven layers of abstraction.

The seven layers of abstraction is the standard forms of abstraction in the computing world. It has been standardized by the international organization for standardization. The seven layers of abstraction are collectively called the open system interconnection model (OSI model).

These seven layers define the various stages that data has to go through to travel from one device to another over a network: these seven layers are further categorized into two. Namely application set and transport set.

The Transport set comprises of

Layer 1: Physical

This is the hardware level of transport set. It is the physical characteristics of the network. This layer governs the layout cabled and devices.

Layer 2: Data

This layer provides a link for data to be sent over the physical layer. The devices in this layer are the bridges and switches. Packets are received in this layer from the network layer.

Layer 3: Network

Routing, addressing and protocols are handled in this layer. It is the domain of WAN, REP and EIGRP are some of the common protocols used by routers in this layer.

Layer 4: Transport

This particular layer is all about the flow control of data. Recovery of data and error

checking all happen here in this layer. TCP and UDP are the important protocols in this layer.

The Application set comprises of

Layer 5: Session

Session layer deals purposely with communication. This layer establishes, maintains and ends communication with receiving device. Some of the services or functions of this layer is management of flow of data communication, dialogue control, token management and synchronization

Layer 6: Presentation

Layer 6 which is presentation deals with the convention of data that is provided by the application layer into standard format for the layer to understand. This layer is also referred to as the syntax layer. Its main tasks are data compression, decompression, encryption and decryption.

Layer 7: Application

This layer allows users to communicate with the computer. The very common protocols here are HTTP, FTP, Telnet etc. The layer's main functions are file transfer, email, enabling remote access and network management activities.

Operation of the OSI Model

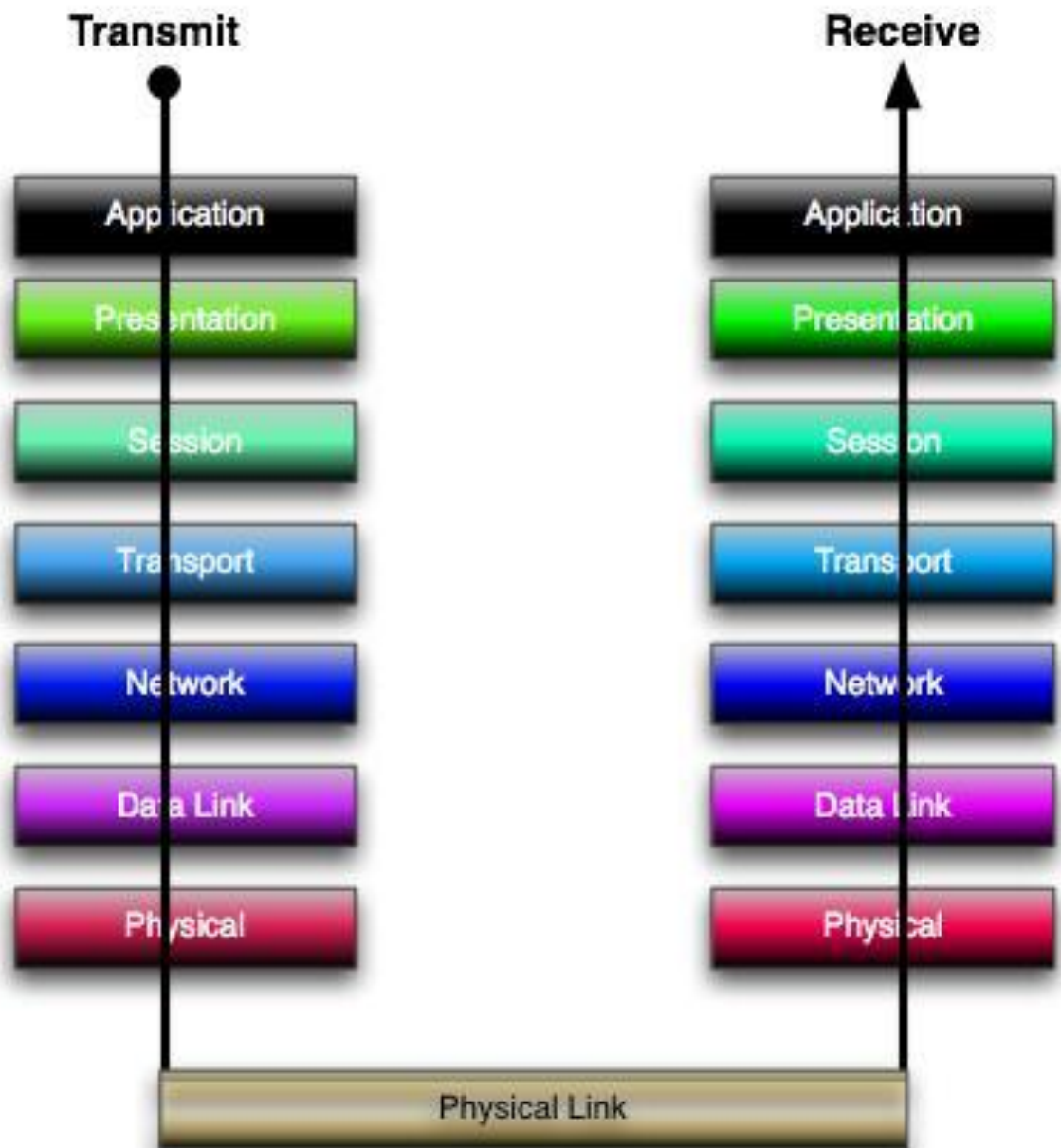


Figure 2. Abstraction Layer

Abstraction and abstraction layers are one of the essentials of cloud computing, without this I think cloud computing could or would not have been possible. Virtualisation which is

the next factor is also all about abstraction. Without abstraction virtualization is just not possible and ultimately cloud computing. Figure 2 shows the abstraction layers in correct order. /39/

3.3. Importance of cloud computing

The influence of cloud computing is very significant in all aspect of life. Technology and delivery of information technology services is going to be made easier and cheaper. Cloud computing has a major impact on business and enterprises.

When you talk about the importance of something, you are talking about the significance of that particular thing on society. These are just some importance of cloud computing.

1. Cloud computer allow users to access technology solutions faster and quicker reducing business risk. This enhances business. /4/ /9/
2. Cloud computing is very significant in SME.SME with limited budgets can afford computing services by using cloud computing. /4/ /9/
3. Big business and corporation continue to manage their new branches anywhere in the world with same technology (cloud computing) and maintains consistency in their organizational management without startup costs of installing new software. /4/ /9/
4. Cloud computing is easy on the environment. Energy is saved. It reduces the need of physically installing computers and reduces the usage of power. /4/ /9/
5. Companies business operating cost will be reduced by the effective use of cloud computing. /4/ /9/
6. System backups and updates which use to be problematic for a company is auto with cloud computing. /4/ /9/

7. Since clouds computing is a web based application it can be used by any person who is travelling without any server to connect back to the office through any kind of VPN. /4/ /9/
8. There is better tracking of activities of companies technological calamities like data loss, computer virus and system crushes with cloud computing. /4/ /9/

3.4. Advantages and Disadvantages of Cloud Computing

There is a buzz and huge amount of hype surrounding cloud computing .There is no technology that does not come without advantages and disadvantages. All other computing forms all have their advantages and disadvantages.

Despite how cloud computing has been propagated and hyped it still has some disadvantages and we will look into that here. The advantages are almost the same as the importance or benefits stated in early parts of this thesis. /32/

3.4.1.1. Advantages

1. Reduced Cost

Reduced cost for users and companies. An example of this reduced cost for users is in the basic use of Google and Yahoo. With Google cloud computing you have access to services like presentations, discounts etc. Instead of buying expensive softwares like Microsoft office which cost a lot more, Google cloud provides these services for free. /32/

For companies the cost of maintaining data centers up and running. The persnnel to manager server, utility bills and internal technical people to assess new hardware offering. All these can be avoided or are avoided when cloud computing is being used. Research firm IDC summed it up as “The cloud model offers a much cheaper way for business to acquire and use **IT.In** an economic downturn the appeal that cost advantage will be greatly magnified”.

2. Remote Accessibility

Accessing cloud computing is possible anywhere in the world. It is not restricted to only one location like these other computing services are. Since is internet based it could be access anywhere in this world. This makes work easier for companies and individuals who are always on the move. Also for companies establishing branches all around the world. /32/

3. Shared Resources

An important aspect of cloud computing is that the company shares resources. In a company resources are shared through cloud. These resources are placed in the same location and this saves time and money. It is easy for workers to access. /32/

4. More Storage

One of the biggest advantages of cloud computing is its storage capacity. It has a virtual unlimited storage because is online. Its storage capacity surpasses that of a server and a harddrive. Storage space can be easily increased in cloud computing. Upgrading and maintaining softwares and bug fixing is done by cloud provider thus there is no need for a specialized IT stuff. Automatic updates are also used. /32/

5. Green computing

Cloud computing contributes to green computing. Green computing is defined as the efficient use of energy by computing resources. Microsoft claims that cloud computing can reduce carbon emission by 30%. /4/ /26/

3.4.1.2. Disadvantages

One of the biggest disadvantages being discussed concerning cloud computing is privacy and security. The whole idea of putting on trusting a whole business data to a second party

which is the provider is very worrying.

The other concern is the storing of data on the web. There is worry among business that people can always bypass the security. A survey conducted by IDC found that security was and is still the main worry of business concerning cloud computing.

Cloud users worry about privacy. Which is a big issue because clients want to make sure their private data is not accessed by unauthorized person or user. A detailed security model has not yet been developed for cloud computing.

1. Internet Dependency

We know that cloud is web based computing solution. The fact that it relies on the quality, availability and performance of the internet connection is a major concern for many organizations and businesses. So the question is what happens if there is no connectivity or limited connectivity? What about locations with no internet access or low internet bandwidth?

2. Cost

While some organization say cloud computing is less expensive than other computing methods, which is also stated above as an advantage. Some other schools of thought also think that cloud computing is actually expensive. There are hidden cost involve with cloud computing. Cloud computing is basically an outsourcing service that a company goes for or pays for. These services are often very expensive because it involves another company. Company cost in maintenance, researching since is a new thing can be high and normal services are expensive at the start .Early cloud computing users and adopters are likely to pay and spend more on cloud computing.

3. Dependency

There is complete lost of control by the company that adopts cloud computing. All activities concerning the cloud has to be done by the cloud service providers. This is not so good for the financial wealth of the company. The company hardly has influence on most

of the things concerning the cloud. Things like maintenance, deployment and expansion. These are some of the basic and common advantages and disadvantages of cloud computing.

3.5. Characteristics of Cloud Computing

These are the five essential characteristics of cloud computing. There are some other characteristics but I will concentrate on the essential ones.

1. On demand self service

Computer services can be set up by user without any human interaction with the service provider. This ability means it is easy to use. Good user interface that allows user to manage the services. This saves time and money. Some of the major cloud service providers providing on demand services are Amazon web services, Microsoft, Google and Cloud.com.

2. Broad network access

Cloud services are available over the network. They can be accessed through standard internet –enable devices such as laptops, mobile phones etc.

3. Rapid Elasticity

Cloud computing systems can rapidly change to suit demands of users. It is capable of scaling up to meet demand and scale downwards for lighter demand. Cloud computing can be decreased or increased within a matter of short time. Elasticity is all about demands. The cloud meeting the demand. Either more or less.

4. Resource Pooling.

Resources are pooled together to meet consumers demand. These resources include storage, processing, memory, network, bandwidth, virtual machines and email services. Resource pooling is for increasing advantages and reducing risk to users. These resources are used by any user on demand and as soon as one user releases the resources another user can use it. This enables better use of resources available.

5. Measured service

Cloud computing can be measured. The usage of its resources utilization is measured for billing. It works like airtime or electricity billing. Services are pay per use. The more resource you utilize the higher the bill. Consumers are billed only for the services they use. /14/

3.6. Types of Cloud Computing

Cloud computing is classified into four types. These are

3.6.1. Private Cloud

With private cloud the infrastructure belongs to one organization. Only members of that organization have access to the infrastructure. The infrastructure is put together purposely for the needs of the organization. It is also known as "internal cloud computing". Private cloud is divided into two types namely on-premise private clouds and externally hosted private cloud. On-premise private cloud is hosted within the organization and externally hosted private cloud is hosted by cloud infrastructure specialist. In private cloud your data stays in your data Centre, since it is private it cost more. /23/

3.6.2. Hybrid Cloud

Some organizations host some of their data and applications that are only for private purposes on a private cloud at the same time some applications that the organization want to make public is hosted on a public cloud. The two clouds together providing services is called a hybrid cloud. The hybrid cloud combines the advantages of both public cloud and private cloud. This is probably the best cloud type for some companies and organizations. /23/

With hybrid cloud the cost involve is less than that of the private because of the public part of the hybrid cloud. The challenge of the hybrid cloud is the integration of both

infrastructures into a single system. Middlewares are used to solve this problem. /23/

3.6.3. Public Cloud

Public cloud is the most popular and very common cloud computing type that people know of and use daily. The computing infrastructure is provided by a cloud provider at the providers premises. Users of this cloud do not have any access or control over the structure. This is the cheapest type of cloud. Examples of public clouds are Google and Yahoo. There is allocated resources on per user basis through web applications. All you need to have access is a very good internet bandwidth and a browser. /23/

3.6.4. Community Cloud

This is a cloud infrastructure owned by the community. A community made up of the same organizations. An example of such community is government agencies in a city and municipality. This cloud is managed by the organizations or a third part. It may be hosted on premise or off premise. /6/, /21/

3.7. Cloud Services

The three main services provided by cloud computing are

3.7.1. Software as a Service (SaaS)

Is the model in which applications and software are provided or made available as a service to customers who access it through the internet. The customer is not in charge of the maintenance or the support. This is taken care of by the service provider. A typical example of this is Google Docs.

This solves all problems with software installations on different types of operating systems such as compatibility issues and others. This saves money. As an individual user, you do not need to have to buy hardware to host or get to the software. With companies, employees to install, configure and maintain the software. All this is being handled by the

provider.

As a company your IT-staff can concentrate on other pressing IT issues. SaaS were developed to use web tools like the browser. Customers can access any software and application anywhere they are since the software or application is managed at a central location.

The biggest advantage and major advantage of SaaS is the cost involve. It cost less than buying software and application. Service providers offer more reliable applications at cheaper rates. Figure 3 is a diagram of SaaS. /35/

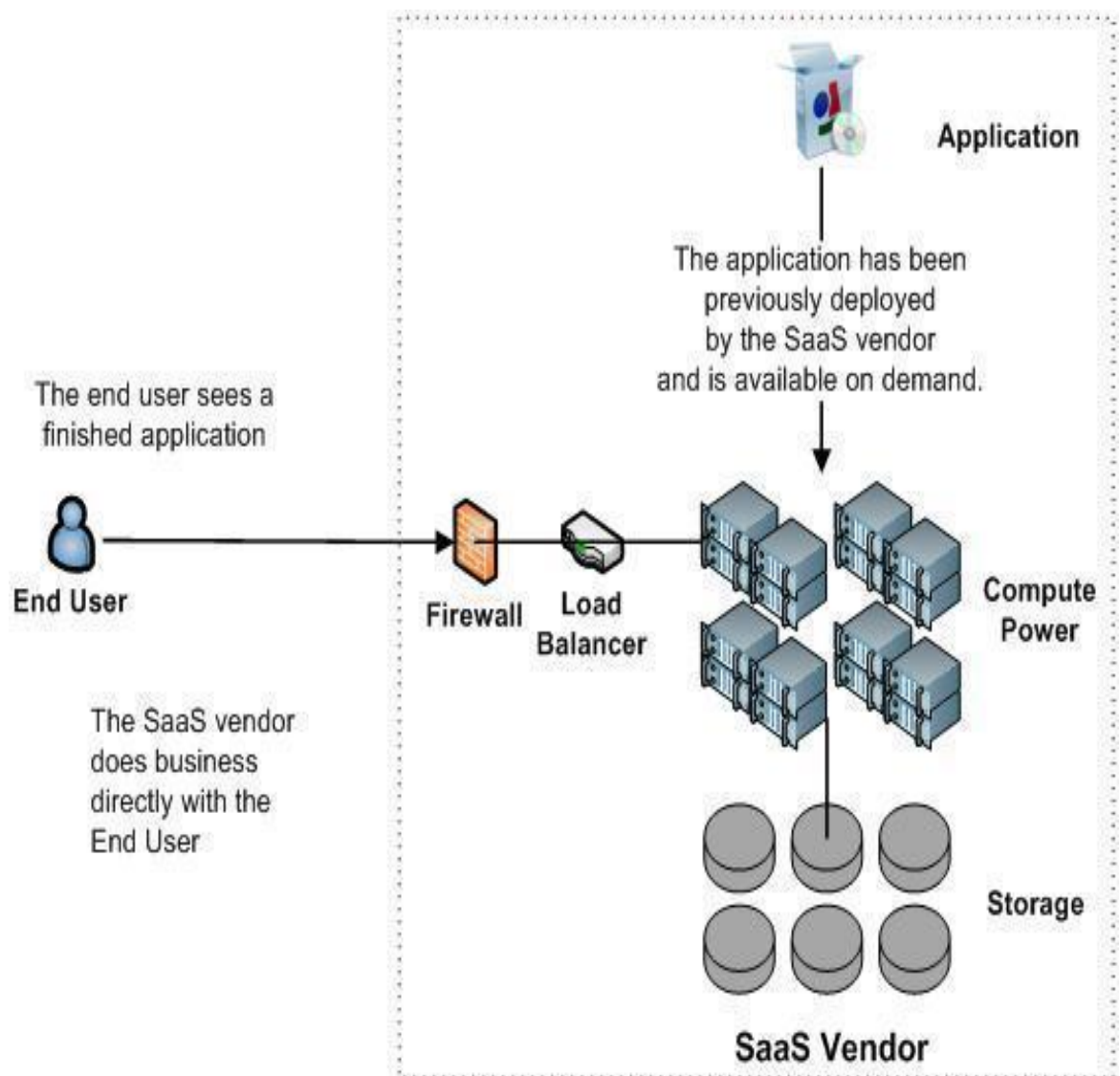


Figure 3. Software as a Service. /48/

3.7.2. Platform as a Service (PaaS)

PaaS is a development environment that provides the tools for building, developing testing, deploying and hosting web applications. PaaS resources are needed for application building and developments are all from the internet.

Services provided by PaaS are development, designing, testing, deployment hosting, team collaboration, web services integration, database integration, scalability, storage, security, versioning and state management.

Its applications are written in specific languages such as Python or Java. An example is the Google app engine. PaaS has its own flaws. When a developer develops on a specific PaaS, it's very difficult and expensive to move that same application on to another PaaS. This is called lack of interoperability and portability among different platforms. Figure 5 is PaaS diagram.

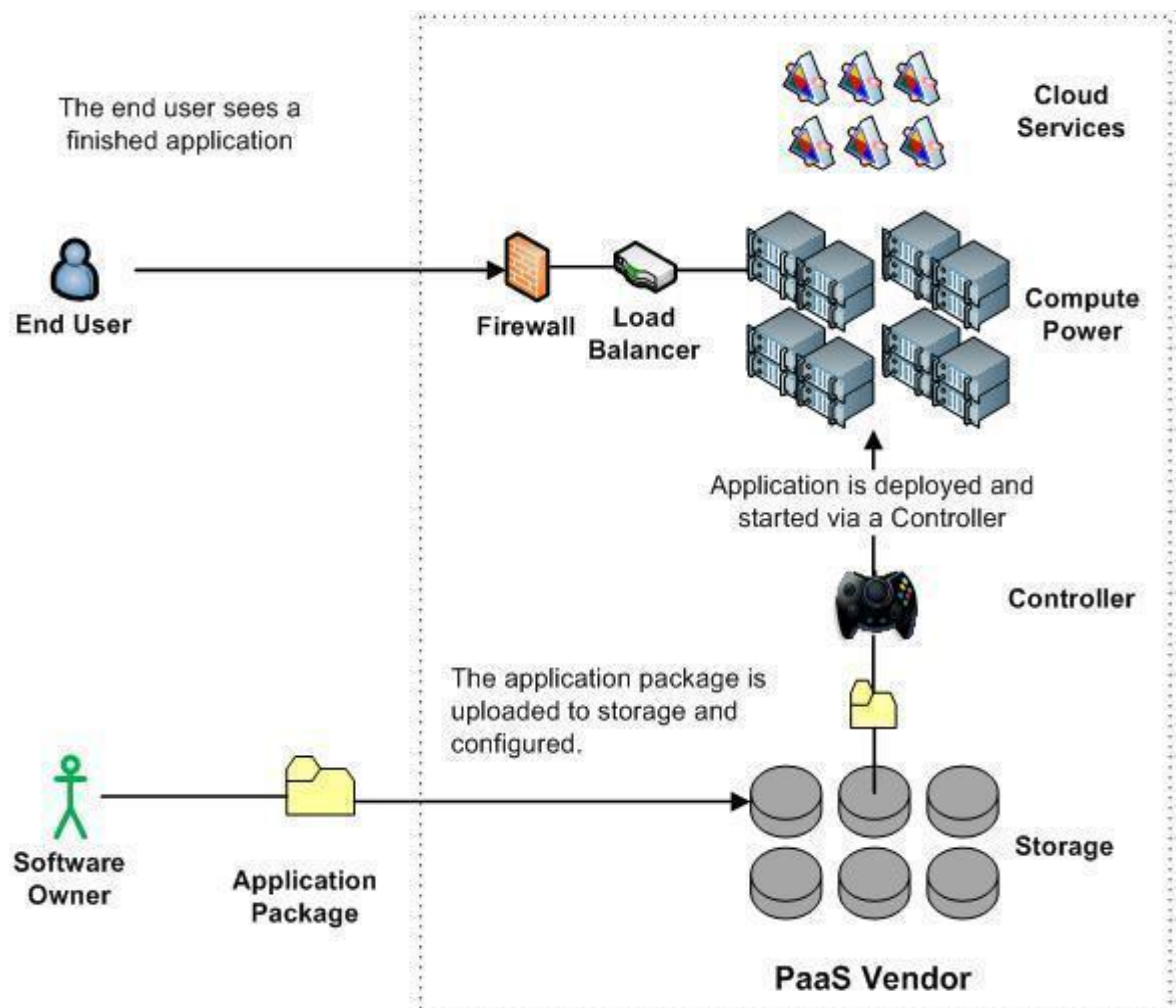


Figure 4. Platform as a Service. /5/

3.7.3. Infrastructure as a Service (IaaS)

While SaaS and PaaS deal with applications, IaaS deals with hardware. The provision of hardware to organizations so that they can put whatever they want on it. This service actually saves organizations from purchasing software, servers, racks or paying for datacentre.

These resources are rented out to other organisations at the same time. IaaS is very scalable. Billing is based on utility computing basis. Customers are charged according to how much resources they consume.

Several things come together to make IaaS. IaaS consist of Platform virtualization environment, utility computing billing, network, computer hardware, service level agreement etc.

IaaS is basically the delivery of computer infrastructure as a service. One of the most important advantage of IaaS is that of the use of the latest technology. /5/. Figure 5 is diagram of IaaS.

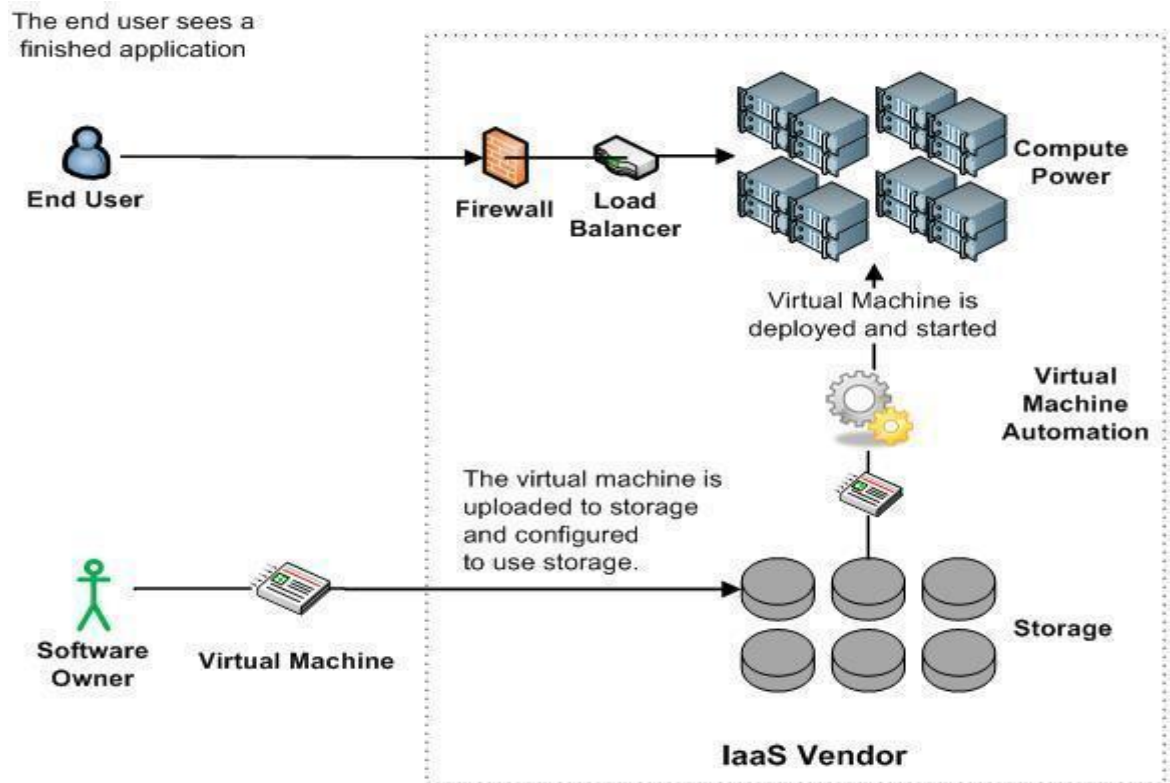


Figure 5. Infrastructure as a Service. /5/

3.8. Cloud computing Platforms

One of the most important part of cloud computing and cloud adaptation is the cloud platforms. This platform allows the medium for developers to write applications that run in cloud. It also allows developers or cloud users use services provided from the cloud. Simply cloud platforms provide cloud-services for creating applications.

The development of cloud applications depends on the availability of a cloud platform. So having or acquiring a cloud platform first before you can create or use a cloud application. Fortunately, some IT vendors are creating cloud platforms and there are some platforms technologies available today.

Cloud platforms are generally categorized into two. Namely open source cloud platforms and closed source platforms. Open source is a term for any program where the source code is available for editing, use or modification by users and developers to fit their own

demands and requirements. Closed source is a term for any program whose source code is not available for modification by users. Only the final product is available to the public or user.

The platforms that are going to be discussed here will be categorized into open source and closed source.

3.8.1. Google App Engine

Is a platform as a service cloud computing platform. It is for hosting and developing web applications in Google data centers. Google App Engine was designed to help users to stop depending on the operating system. /8/

It is easy to build apps in here, easy to manage and easy to scale. Its runtime languages are Python and JVM languages (JRuby, Scala, Jython, Groovy). The astonishing thing about Google App Engine is the amazing amount of free resources available to anyone. You are only billed when you start to exceed the limits. Google App Engine allows you to run web applications on Google's infrastructure. With this there is no maintenance of servers. /8/

All its applications can use up to 500MB of storage and enough CPU and bandwidth to support an efficient app serving around 5 million page views a month for free.

Some features of Google Engine App are:

- Google Docs
- Gmail
- Google Calendar
- Google Talk
- Page Creator
- Control Panel
- Google Gadgets

- Start Page
- Single Sign on and directory integration
- Internet domain integration

3.8.2. Cloud.com

Cloud.com is an open source cloud computing platform for building and managing private and public cloud infrastructure. Cloud.com simplifies and accelerates the deployment, management and configuration of multi-tier and multitenant private and public cloud services.

This platform provides an AJAX based interface. With this interface users can access machines, networks and storage which are computing infrastructure resources available in private and public cloud services.

Cloudstack is software designed by cloud.com which delivers virtual data centers as a service. These services are building, developing and managing.

Cloud.com features are:

- Multiple Hypervisor support from a single management pane.
- Support for cloud API's like Amazon Web Services API, VMware Vcloud API
- Elastic IPs and security Groups
- Virtual Machine Snapshots and Roll back
- Support for Linux and Windows Virtual Machine (VMs)
- Virtual resource Managements and Isolation
- On-demand Virtual Datacentre Hosting
- Event /Audit logs
- In-browser console access

Cloud.com believes cloud computing is a major shift in data center computing

3.8.3. Open Nebula

OpenNebula is the world's leading cloud management solution. It is an open source cloud computing toolkit. OpenNubula is for data center virtualization. Open Nebula gives complete management .It lets you manage your public, private and hybrid cloud by using the OpenNebula toolkit. The features of the tool kit are:

- Integration
- Management
- Scalability
- Accountability

It is used by different organizations including IT service providers, telecom operators and hosting providers. It is run on Linux based computers.

Is it an actual cloud computing platform or not?

3.8.4. Eucalyptus

Eucalyptus is an open source deployed cloud computing software platform for private infrastructure as a service cloud.

Eucalyptus first began as a university project at the University of California, Santa Barbara under the direction of Professor Rich Woleski.It works with Linus operating systems including Ubuntu, Dabian, Fedora and Red Hat Enterprise Linux.

It has the ability to use some virtualization technologies. Virtualization technologies including XEN, VMware and KVM hypervisors. / 19/

Eucalyptus has been designed to be API compatible with Amazon EC2 platform. Eucalyptus builds hybrid clouds between its on premise clouds and AWS and AWS-compatible clouds. /18/

Features of Eucalyptus

- Amazon AWS compatibility
- Supports for Linus and Windows (Virtual machines)
- Accounting reports
- Dynamic Resources management
- Self-service resource provisioning
- Security Group management
- Web user interface and command line
- Tools for cloud administration and configuration
- Hypervisor-agnostic architecture.

3.8.5. Nimbus

Nimbus is an open source cloud computing platform that was developed to for scientific work. It was designed to enable scientists to use IaaS. Nimbus allows for the creation of virtual machines.

It supports Xan hypervisor and virtual machine schedules PBS and SGE. It is written in python programming language. Runs on Linux Kernel. Creating virtual cloud is relatively easy with Nimbus.

Nimbus has been used in scientific researches like SFAR nuclear physics experiment Heavy-Ion collider. Nimbus platform allows users to combine Nimbus, Openstack,

Amazon and other clouds. /24/, /25/

Some features of Nimbus

- Open Source IaaS
- Storage Cloud Service
- Remote deployment and lifecycle management of VMs
- Compatibility with Amazon's Network Protocols
- Easy to Use cloud clients
- Fast propagation
- Multiple protocol support
- Flexible group management
- Per-client usage tracking
- Flexible request authentication and authorization
- Easy User management
- Configuration management
- Xen and KVM plugins
- VM Network configuration

3.8.6. OpenStack

OpenStack cloud computing platform was recently launched by openStack and Nasa. It is an open source platform. OpenStack is made up of three components namely Nova which is an infrastructure as a service suite, swift which is a scalable redundant storage system and open image service which is use for registering, discovering and retrieving virtual machine images.

There is an integrated code for NASA Nebula platform and Rackspace cloud files platform. All the parts of open stack is written in python program language.

The most beneficial part of this cloud is that is an open source cloud computing platform. All of the codes of OpenStack is free and available for use by anyone.

Some features of OpenStack. /19/,/30/

- Unlimited storage
- Storage and manage files programmatically through API
- Create public or private containers
- Image as a service
- Image status
- Image checksum
- Back-end store option
- Manage Virtualized commodity server services
- Manage Local area networks
- Float IP address

- Security Group
- Projects and Quotas

OpenStack's main competitor is Eucalyptus. Rackspace, Dream host, and AT&T are some of the companies using OpenStack. /12/

Some of the closed source cloud computing platforms are :

3.8.7. IBM Smart cloud

IBM Smart cloud is the cloud computing products and solutions developed by IBM. This cloud consists of software as a service, platform as a service and Infrastructure as a service. These cloud services are offered by the cloud public, private and hybrid delivery models.

The services of IBM smart cloud that are being offered are categorized into three groups namely IBM Smart cloud Foundation, IBM Smart cloud service and IBM Smart cloud solutions.

Smart cloud Foundation is made up of cloud infrastructure, cloud provision, cloud management, cloud integration, cloud security and application development and deployment. Virtual machine monitoring is included in the Smart cloud Foundation. Basically it offers different levels of control over cloud service delivery and management. Creation and delivery of both infrastructures as a service and platform as a service environment is done with smart cloud Foundation Services.

Smart cloud services: they are basically services that are provided by the smart cloud. Services such as Platform as a service, IBM Smart cloud Application services, Infrastructure as a service (IBM smart cloud enterprise and enterprise +) and cloud backup services (IBM Smart cloud managed back up services).

Smart cloud solutions are made up of a number of collaboration, analytics and marketing Service as service applications.

Some features of IBM Smart cloud.

- Self –Service web portal enterprise account management.
- Pay-as-you go pricing
- Security rich environment designed to protect systems and data.
- Pay-as-you go pricing
- Rapid access.
- Access to rich catalog of software images for improved flexibility and rapid provisioning.
- Tools and standardized configurations for improved teaming and quality.
- Tivoli management software

The services of IBM Smart cloud are priced. /11/

3.8.8. Windows Azure

Windows Azure is a cloud computing platform developed by Microsoft. It is classified as Platform as a service. It is a constituent of Microsoft's cloud computing Strategy.

It is flexible and allows users concentrate on solving business problems and also attends to customer needs.

Windows Azure provides specific set of services to application developers. It is a closed

source cloud computing platform. The platform's on-demand services are hosted in Microsoft data centres.

Windows Azure's main components are windows Azure, SQL Azure and Windows Azure AppFabric.

Windows Azure provides a scalable environment with compute, storage, hosting and management features.

SQL Azure is Relational Database for the cloud is a full relational database in cloud. You can access your data at any place and at any time.

Windows Azure AppFabric is a middleware in cloud. It is pretty much the glue that holds everything together. AppFabric provides network services for the cloud. These services are

- Access Control Service
- Service Bus
- AppFabric Applications
- Caching
- Integration

3.8.9. Amazon Web Services

Amazon Web Services is a cloud computing platform made up of a collection of remote computing services. Amazon web Services is offered by Amazon. It was launched in 2002. Amazon web services delivers a highly reliable, scalable and low cost infrastructure platform.

It is a closed source service. You pay for only what you use. Every service has its pricing. Amazon web services is a pace setter in cloud computing. Some of these web services are Amazon S3, Amazon EC2, Amazon Elastic Map Reduce, Amazon Fulfillment Web services.

It is narrowed down to the most central and well known services amongst all the Amazon Web Services. These are Amazon S3 and Amazon EC3

Amazon S3 is an extremely simplified web-based storage service. It provides its simple

storage service through web service interfaces (REST, SOAP and Bit-Torrent). S3 is capable of storing computer files up to five terabyte in size and two kilobyte of metadata. It also has static website hosting options. Dropbox Ubuntu one and Mine craft use S3 storage and servers.

Amazon EC2 is the core part of Amazon Web Services. It is a web based service. Application programs are run on this computing environment. Virtual computing is a major functionality of Amazon EC2. Users can create a virtual machine with amazon machine image. These virtual machines contain any software you want. Virtualization being used by Amazon EC2 is Xen. EC2 communicates with S3 .S3 is accessible to EC2 instance. Billing is based on the capacity that the customer uses. It is very elastic, calling up and down depending on the needs. Amazon EC2 works with the other Amazon web services. It is very secured. Configuration of firewall settings that control network access. Firewalls is just one of the numerous ways for securing computing resources in Amazon EC2. /1/

Features of Amazon EC2

- Amazon Cloud Watch
- Elastic IP Address
- Multiple Locations
- Auto Scaling
- Elastic Load Balancing
- VM import
- Amazon Elastic Bookstore

Billing is based services used. Different services are billed differently. /2/

3.9. Security Issues of Cloud Computing

Cloud computing is known as a cost effective method of computing and a very easy computing method. Unfortunately cloud computing has some security issues that need to be identified and addressed when adopting cloud computing. Listed here are some of the most basic and very important cloud computing security issues.

3.9.1. Data Location

Data location is one of the most basic security issues because the customer of the cloud services does not know the whereabouts of the data. The cloud provider reveals the location of all the data. The data might probably not be in the same city as the customer. It can be located anywhere.

3.9.2. User Access control

User access control is very important security issue since cloud computing services is provider by another company. More like Outsourcing and because of that the customer has no control over the staff of the cloud provider. The level of risk is very high. Attacks from personnels of the cloud provider company are very possible. So a customer needs to know more about the people managing their sensitive data. How much access control are applied to personnel of the cloud provider?

3.9.3. Trust

In cloud computing a company entrusts its privacy and security into a cloud provider. This type of computing is solely based on trust. Companies understand the risk in trusting a cloud service provider. No matter the security measures put in place, a cloud provider being trust worthy comes first. This is considered a real security issue. Once a company

adopts or decides to move to cloud computing the company is exposed to all kinds of security risk. Trust issues. Trust that cloud service provider will secure the company's assets in the cloud. But the truth is no service provider is to be trusted.

3.9.4. Data Segregation

Cloud providers provide their services to more than one customer. Data from customers are stored in the same cloud environment. Precisely a shared environment. This is where data encryption comes in. It is very important to know how a cloud service provider segregates data at rest. Gartner advises "Find out what is done to segregate data at rest". Without data segregation how sure are you that customers of the same cloud services cannot have access to your information.

4. SOFTWARE ENGINEERING

This chapter focuses mainly on software engineering. Software engineering is an essential part of this thesis. Understanding the fundamentals of software engineering, processes, process models, requirements analysis, designing and testing is the only way the main goal of this thesis to be achieved.

First of all we have to understand what software is. Software is a collection of computer programs and related documents that are to provide desired features, functionalities and better performance.

Software products maybe developed for a single customer, based strictly on the specifications of the customer. Software is developed for the general market also.

The term software engineering was coined at the meeting of a group formed by NATO Science committee over 30 years ago. Software engineering is defined by Fritz Bauer as “the establishment and use of sound engineering principles in order to obtained economically software that is reliable and works efficiently on machines”. /41/

IEEE defines software engineering as the application of a systematic, disciplined, quantifiable approach to the development, operation and maintenance of software that is, the application of engineering to software”. /51/

Software engineering is also defined as a branch of engineering whose focus is the cost effective development of high quality software systems.

Stephen Schach defined software engineering as “A discipline whose aim is the production of quality software, software that is delivered on time, within budget and that satisfies its requirement”.

Software engineering is also defined by others as the discipline whose aim is the production of fault-free software that satisfies the user's needs and that is delivered on time and within budget.

There is no limit to what software can do and can be. Software can be very simple or very complex. Software engineering has contributed so much to our everyday lives, in all aspects, from health to space exploration.

4.1. Software Engineering Process

Software engineering process is a number of activities that are carried out during a software projects no matter how big, small, simple or complex the software project is. Ivar Jacobson, Grady Booch and James Rumbaugh state that "A process defines who is doing what, when and how to reach a certain goal". /41/

Software engineering process is important for any software development. Following the process, software of any kind is developed on time. The processes define what needs to be done, when it has to be done, how it is suppose to be done. It also forms the basis for software projects management control. There are different process models. Organizations create software according to how they define and execute their processes. The Capability Maturity Model is one of the leading process models with other popular ones being ISO 15504, Six Sigma and ISO 9000. /41/

Software engineering processes is composed of activities. The common activities and most important ones that are found in all the process models are the following /41/

4.1.1. Planning

Planning is the first activity that is carried out in almost all software engineering process models. Planning is a very important activity for software development. Planning includes the following: /41/

- What activities that need to be done

- In what order
- By whom
- When
- What tools will be used
- Design methods that will be used
- Test methods
- Problem solving approach
- Scheduling
- Risk Management
- Quality management

4.1.2. Requirement Analysis and Specification

Requirements analysis determines what the software is supposed to be developed for. Software engineers get these requirements from the customer or stakeholder. They must obtain the requirements to find out what is wanted and really needed. This is more than just question and answer session between the engineers and the stakeholders. This involves developing and asking the right and necessary questions. During this phase stakeholders and developers must have a common understanding.

Requirement specification is the complete definition of the behavior of the system to be developed. It describes the new system and the capabilities. Specifications can be written documents, graphical models, collection of usage scenarios, a prototype or a combination of these. There are two types of specifications. They are system requirements and functional specification. The outcome of the requirement analysis is a functional specification containing detailed requirements. Functional specification is the formalized description of the system. It includes relationship diagrams, data flows, use case diagrams and logic flows. System requirement is the documented requirement in common everyday language. It describes what the final software should do for the users. This documentation involves both the stakeholder and the engineer. /41/

4.1.3. Designing

Designing is the technical core of software engineering and is present in all software engineering process models. The design phase provides details about software data structures, architecture, interfaces and components that are necessary to implement the system. Design sets up the platform for implementation and testing.

There are four design models in the design phase. Namely data class design, architectural design, Interface design and component level design. The quality of the software is achieved during the design phase. As C.A.R. Houre stated "There are two ways of constructing a software design. One way is to make it so simple that there are obviously no deficiencies and the other way is to make it so complicated that there are obviously no deficiencies. The first method is far more difficult". Without design to follow building unstable software is very likely. /41/

4.1.4. Implementation

Implementation is the execution part of the process. This is the stage where the design is put into action during the implementation phase there is programming. Programming demands the knowledge of programming languages, programming skills, operating system and hardware. Examples of programming languages are Java, C++, C and FoxPro.

Design of the software must be well defined before implementation starts. Programmers do the coding and documentation. This documentation is to describe the code and what the program is supposed to do. /41/

4.1.5. Testing, Validation and Verification

Software must be tested during the development and tested when it is completed. Testing is done from the coding stage throughout the rest of the project. /41/

Testing can be done by the same programmers doing the coding or others trained purposely for testing. Test cases are used for testing. A successful test is the one that finds errors. This ensures that errors are recognized and fixed as soon as possible. If testing is properly done during the software development, the last testing is the full correct functionality of the software and fulfilling the requirements of the stakeholder.

Validation and verification are the two specific types of software evaluation. Validation is the performance of the software that determines if the right specific software has been built. The question that needs to be answered during validation is, does the software meet the requirements that were analyzed at the initial stages of the software development.

Verification is performed to determine whether the software has been built to meet the actual design that was constructed during the design phase. Software can be verified but not validated that making the project unsuccessful. /41/

The software is supposed to be both validated and verified.

4.1.6. Maintenance

Stakeholders and users are trained and taught about the final software after the development. At this stage users discover new things they will like to add or change. Maintenance is a very essential after development. About 70% or more of most of the money spent on software is spent on maintenance. Problems not discovered during development are noticed and fixed during maintenance. Maintenance also consists of the addition of some new functionality or software modifications.

Software maintenance is a project and consists of some the activities mentioned earlier for software development. /41/

4.2. Software Engineering Process Models

Software engineering process models are sequence of activities, objects, transformations, tasks, milestones, actions and events that are required to produce high quality software.

Software engineers use the process model that will work perfectly for their needs. Software engineering process models improve productivity, stability, quality, control and organization. Selection of the type of process model to be used for a project actually depends on what type of software engineering project it is. Regardless of the model that is selected. All models encompass the following framework activities: Planning, requirement analysis and specifications, design, implementation, testing validation and verification and maintenance.

Let us examine some of the very popular and most used process models. /41/

4.2.1. The Waterfall Model

This is the oldest and well known process model. It is sometimes called the classic life cycle. It is a sequence of transition from one stage to the next stage in order. It is a very systematic and sequential approach to software development. The stages are communication (project requirement gathering), planning (scheduling tracking), modeling (analysis design), construction (codes, test), deployment (deploy and maintenance). Figure 6 is a diagram of Waterfall model. /41/

The waterfall model is the oldest standard for software engineering. This model has its shortcomings:

- It is very difficult for the customer to state all requirements beyond any doubt.
- A working version of the software is and will not be ready until late into the project.
- Real projects do not follow the sequential flow of the model.

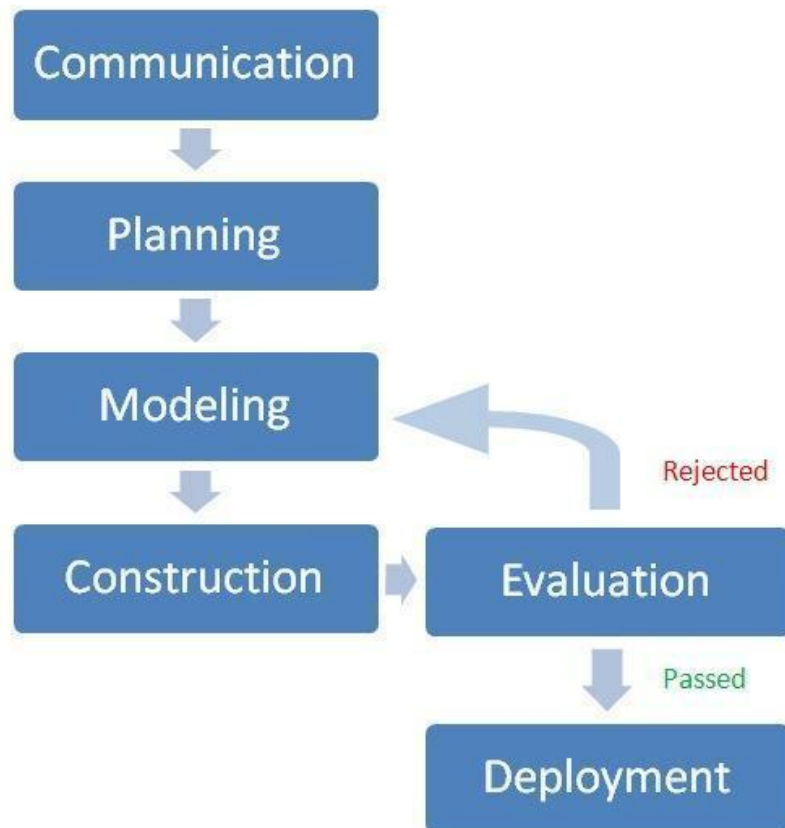


Figure 6. The Waterfall Model. /49/

4.2.2. Incremental process model

Incremental Process model puts together elements of waterfall models in an iterative manner. Incremental model is based on linear sequences. These sequences progress. Every single linear sequence produces an increase in deliverables of the software. Figure 7 is the diagram of an incremental process model.

The first increment is most times a base product. It deals with the basic requirements. The produce of the first increments under goes evaluation and based on this evaluation a plan is developed for the next increment. This plan consists of a modification of the product of the first increment to meet customers need. Additional features and functionality are added to the plan. This incremental process is repeated until the complete software is produced.

Incremental process model concentrates on working product with each increment. The product is evaluated with each increment by the user. Some advantages of using increment process model are:

- With incremental Process model, management of technical risks can be planned.
- Early increments can be implemented with fewer people. /43/ /41/

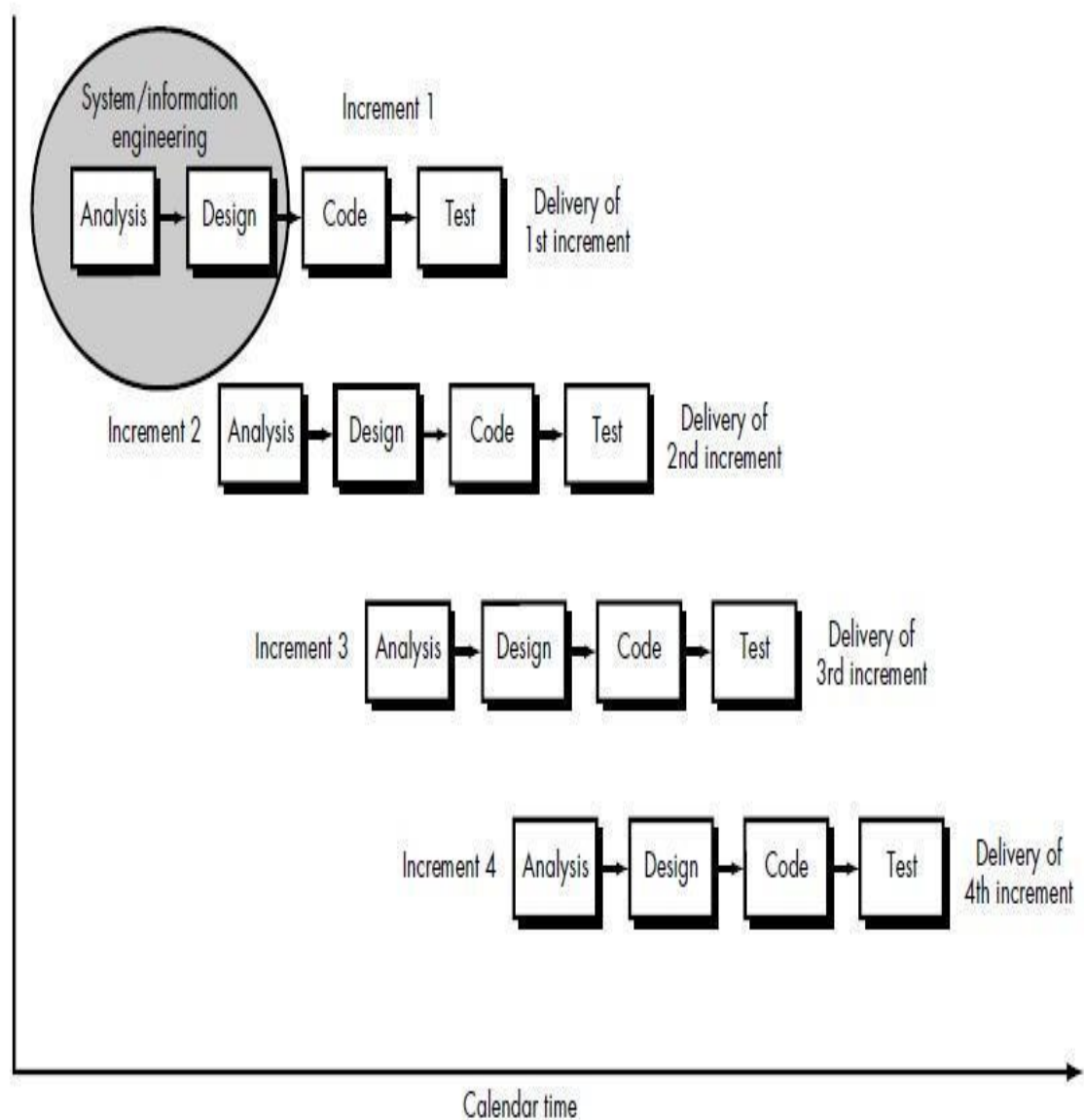


Figure 7. Incremental process model. /50/

4.2.3. Agile Modelling

Scott Ambler defined agile modelling as a practice-based methodology for effective modelling and documentation of software-based system. In Agile modelling enough modelling is done to document and explore your system effectively. This is not done so much that it becomes a burden that gradually slows down the project.

Agile modelling is an agile approach to software development. Agile modelling has some values and these are communication, simplicity, feedback, courage and humility. The basic principles of Agile modelling are assuming simplicity during modelling and welcoming changes as you are working because requirement change overtime. With agile modelling there is the recognition of incremental change in system and this enables agility.

The basic Agile modelling practices include creating several models in parallel, application of the right artefact to maintain without interruption at a steady pace. Modelling in small increments is also a fundamental practice of agile modelling. For a better understanding, each model should present a different facet of the system. Out of the multiple models only the model is of value to the intended users to be used. Models are not documents so most of them are discarded once they have fulfilled their purpose. /41/

5. DESIGN

In this chapter, there will be analysis and description of the final design that this whole thesis is about. A look at the system and the individual components in the system.

5.1. Software Development Suite

We know about the development of softwares. That is the processes and tools involve in developing software. From chapter 3, the benefits of cloud computing was decided. The effects and the rapid growth of cloud computing in the IT industry. We know that with cloud computing there is reduced cost, remote accessibility and shared resources. These strengths of cloud computing is what this thesis wants to utilize by designing a software development suite in cloud computing.

The system makes use of virtualization and it is based on all the category of cloud computing services namely Platform as a Service, Infrastructure as a service and Software as a Service. The system is made up of 7 layers namely:

1. Hardware Layer
2. Server Layer
3. Common tool layer (Application layer and User selector layer)
4. Virtual Desktop Layer
5. Authentication Layer
6. Internet Layer
7. User Layer

The system is for software development. The user layer is made up of designers, developers, tester, project manager etc. These users log into the system through the internet by login through the internet browser. The system is an integrated solution over the web. After user authentication has been done. The User uses any of the virtual desktop to work on .The virtual desktop provides the platform for work to be done on. For example if the

User at that particular time is a designer. The designer wants to use the UML application for his or her intended work. The designer has access to the UML application through the Virtual desktop. The designer has the ability to choose any application needed for designing from the application layer. All applications are connected to the virtual desktop. With the Virtual desktop any user can have access to all applications in the system.

All the applications are connected to a central database. The central database is where everything is stored. The system also has communication tools that connected to the server. Communication tools such as VOIP, instant messenger, and email enable communication between the various groups of users of the system. There are libraries for exchange of files between users. There is the open source exchange library and the Closed Information Service Exchange. All users of the system can use the OSEL and the CISE is not available to all users.

The virtual desktop layer and common tool layer are all connected to the server application. The hardware layer is giving CPU time to the server application. The functioning of the entire system starts from the hardware layer. Figure 8 is the high level diagram of the software development suite.

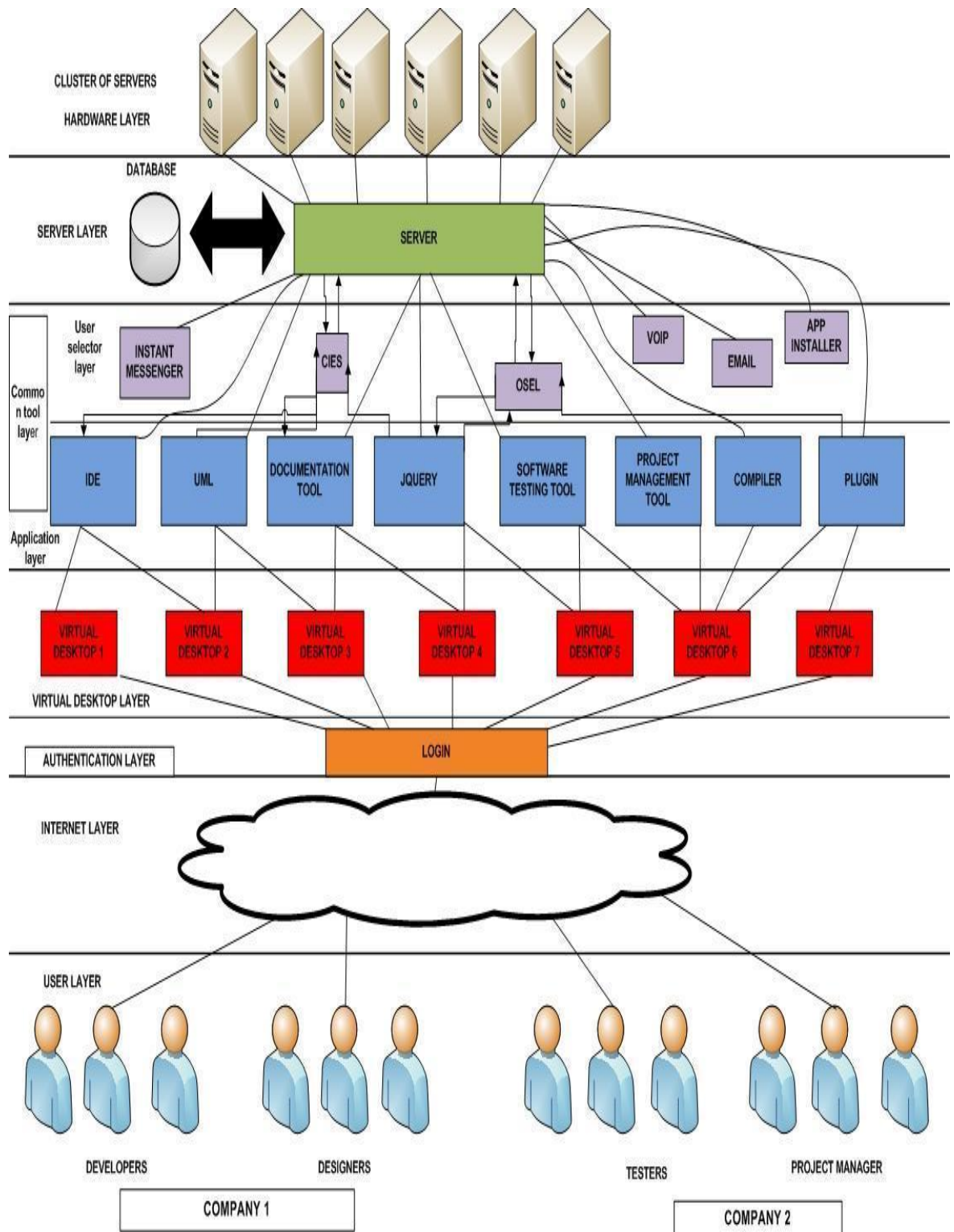


Figure 8. Software Development Suite in Cloud

5.2. Break down of the system layer by layer

5.2.1. Hardware Layer

The hardware layer is made up of servers from all over the world. More precisely a cluster of servers. These servers run simultaneously and work together as a single system providing CPU time to the server application. Cluster of servers provide availability of servers for users. Cluster of servers provide constant access to server based resources. Figure 9 is a further explanation of the software development suite.

5.2.2. Server Layer

This layer contains the server application. The server application is providing the user group virtual workstation which is located in the virtual desktop layer in the figure above. The server can be a java based server, a PHP server also running JavaScript. The server layer also has a massive database running .In addition to the database there is also the actual physical storage. The database gives information about what you have in each of these virtual workstation and who has access to them and also keeps track of all the user group. The database controls basically everything below the server layer. The database governs the whole system. This can be seen in the figure above.

5.2.3. Common Tool layer (User selector layer and Application layer)

The common tool layer is the next layer after the server layer. It is divided into two layers. Namely the user selector layer and the application layer. All the tools in this layer are common to all. The user selector layer is the layer where the user selects any of the tools there to use at a particular time. The user selector tool is made up of communication tools like VOIP, instant messenger and email. It also contains the two exchange libraries (OSEL and CISE). There is also the app installer in there for application installation of any type of software development application or tool that is in the server.

Application layer is the next layer in the common tool layer. It contains all the applications for software development. An example of an application in this layer is UML. All the

applications are all in the server. The user has access to these applications through the virtual desktops. The application layer can contain any number of application.

5.2.4. Virtual Desktop Layer

This layer is where all the development takes place. The server is providing the user group this virtual work station. Each of this virtual desktops contain the applications (IDE, compiler). The virtual desktops can be more than the number in the design figure above. After the user logs in at the webpage authentication level, this where the user gets to. On the desktop you have system icons there. After logging in the user can start a new project or take out a previous project that has been stored on the server. This is not accessible to all users. The virtual Desktop has a collection of links in the form of icons. When you click them it opens any of the application you want to use.

5.2.5. Authentication Layer

Authentication layer is the security layer of the system. You need username and password to go pass this layer to have access to the entire system and existing projects in the system. Authentication is done through an internet browser. Its style of operation is similar to that of the Google account.

5.2.6. Internet Layer

The internet layer is a vital layer of the system. Without the internet layer no work can be done. You need the internet layer to have access to the virtual desktop layer to be able to have access to the application layer. As the whole system is in a cloud, good internet and bandwidth speed are essential for the efficient use of the software development suite.

5.2.7. User Layer

This layer shows the types of users that have access to the software development suite. All users have username and passwords to have access to the software development suite. Each user has access to any of the virtual desktop. Examples of users of this system are software development designers, programmers, project manager and testers for testing during the

software development. User (project manager) logs in at the authentication layer to have access to the software development suite. After authentication the user has access to the virtual desktop to use the applications in the application layer of the system. The project manager can select project management tool for the application layer. Availability of applications for software development is made accessible to all users of the system.

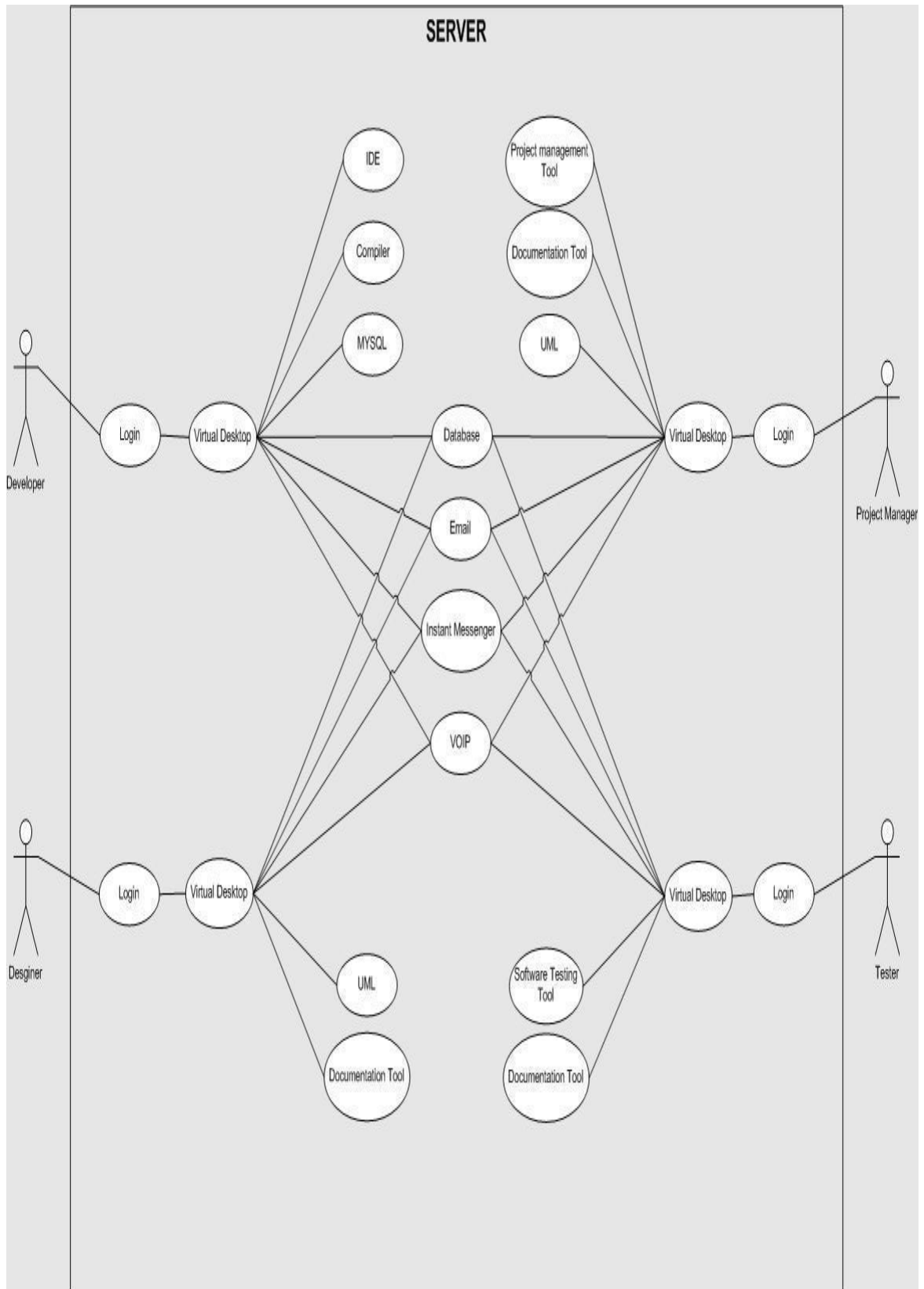


Figure 9. Further illustration of Software Development Suite.

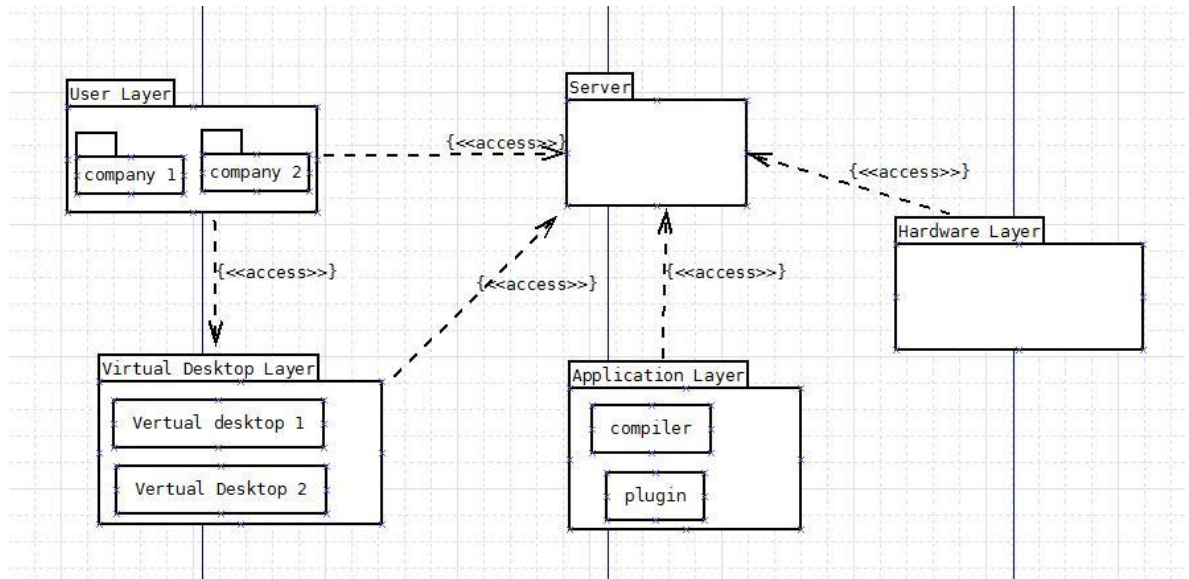
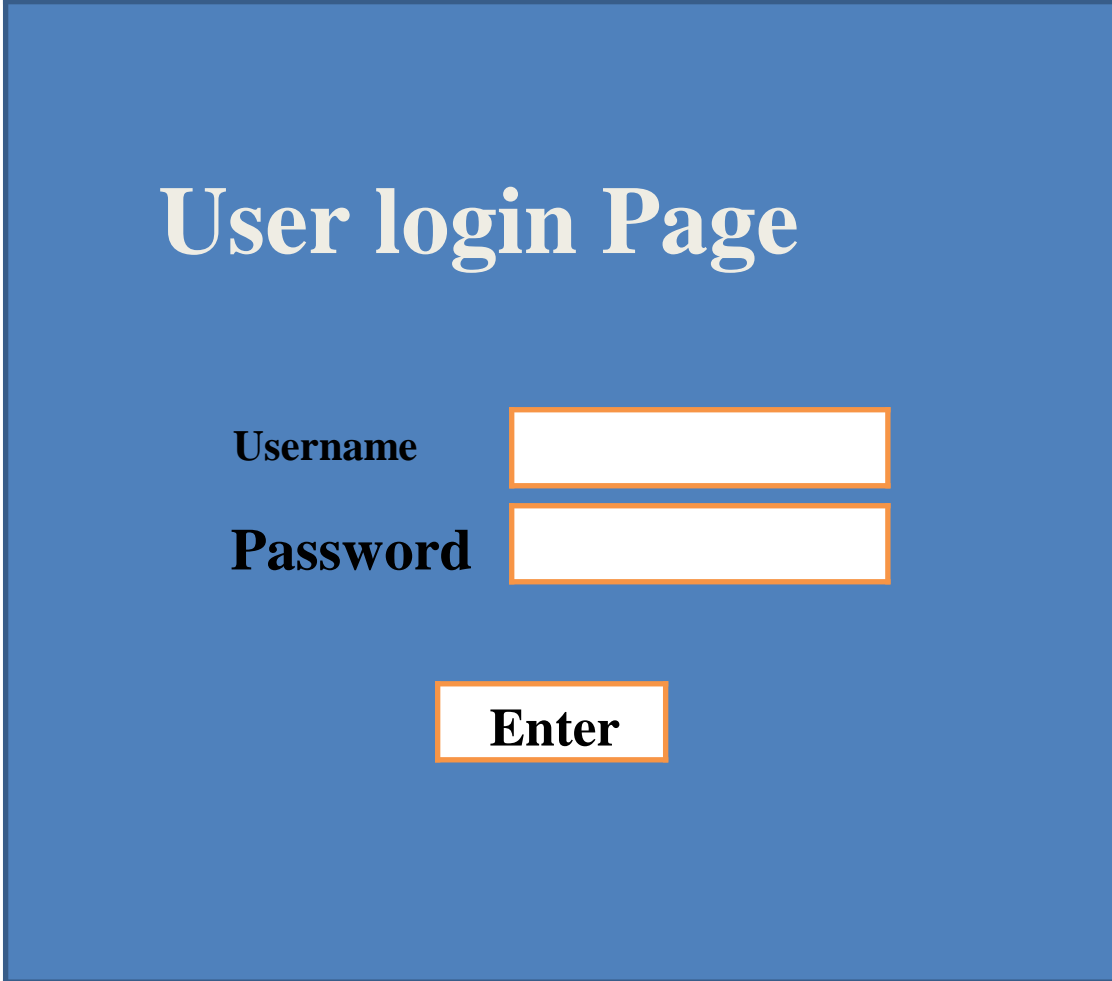


Figure 10. – Package Diagram to identify the levels.

From the Figure 10, we have 5 different packages namely user layer, application layer, virtual layer, hardware layer and server. The user layer has two sub packages to represent company 1 and company 2 as shown in figure 8 above. From the user layer you can easily interact with the server and the access in diagram indicates the connecting which is the internet. After logging in, user interacts with the virtual desktop layer. There are many desktop layers but for explanation purposes two virtual desktops were used. The user decides on what to do using icon which represents the application in the virtual desktop. Whatever the user decides there is still interaction between the virtual desktop layer and the server.

In the application layer you have compiler, plugins and many other tools but for explanation seek only two was used for illustration. The application layer also interacts with the server to have access to the application database which is stored in the hardware layer. The hardware layer consists of several computers which is called a cluster of servers. Entity diagram is used to represent the virtual desktops in the virtual desktop layer and series of application tools such as compiler, plugin.

In the user layer, sub packages are used to denote the two companies and these sub packages contains series of entities. The entities are used to denote developer, designers, testers or project manager.

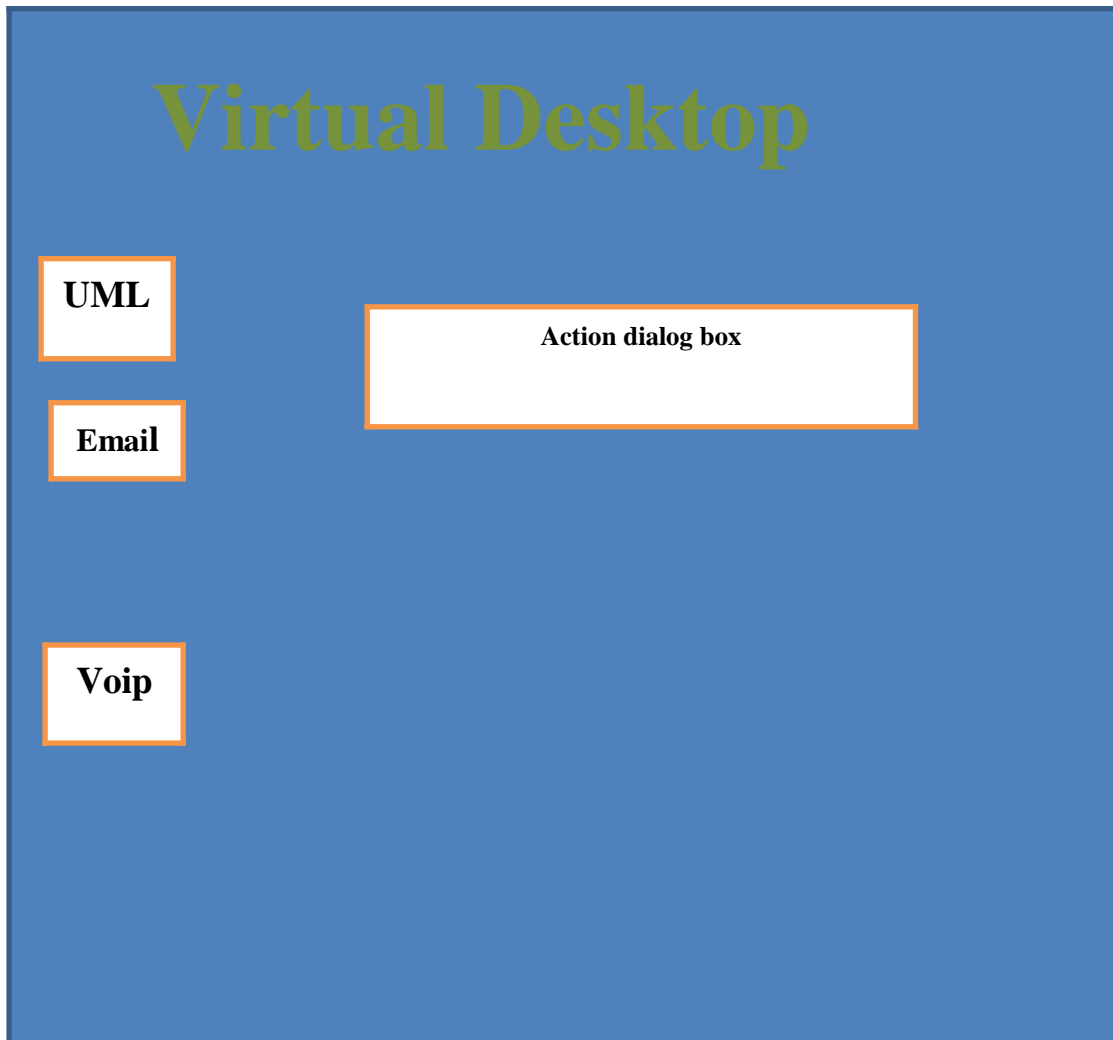


The image shows a user login page with a blue background. At the top, the text "User login Page" is displayed in a large, white, serif font. Below this, there are two input fields: one for "Username" and one for "Password", both with orange borders. Below the password field is a button labeled "Enter" with an orange border.

Figure 11. – Login Page.

5.2.8. Login Page

The user logs in with a username and password on the login page as shown in figure 11. After logging in the user has access to the virtual desktop shown in figure 12.



5.2.9. Virtual Desktop Page

The virtual desktop has a list of icons. These icons are the applications in the server. When the icon is clicked, it opens the application that is stored in the server. The server responds to the click and opens the application that the user wants to use on the virtual desktop. The action is performed after the server responds the clicked icon as shown in figure 12. The desktop has many icons and for illustration purpose three was used. The action is from the virtual desktop to the server and back to the virtual desktop.

CISE and OSEL and the file exchange medium that is used in the system. CISE is restricted and OSEL is open to all users. These can be seen in the common tool layer in figure 8.

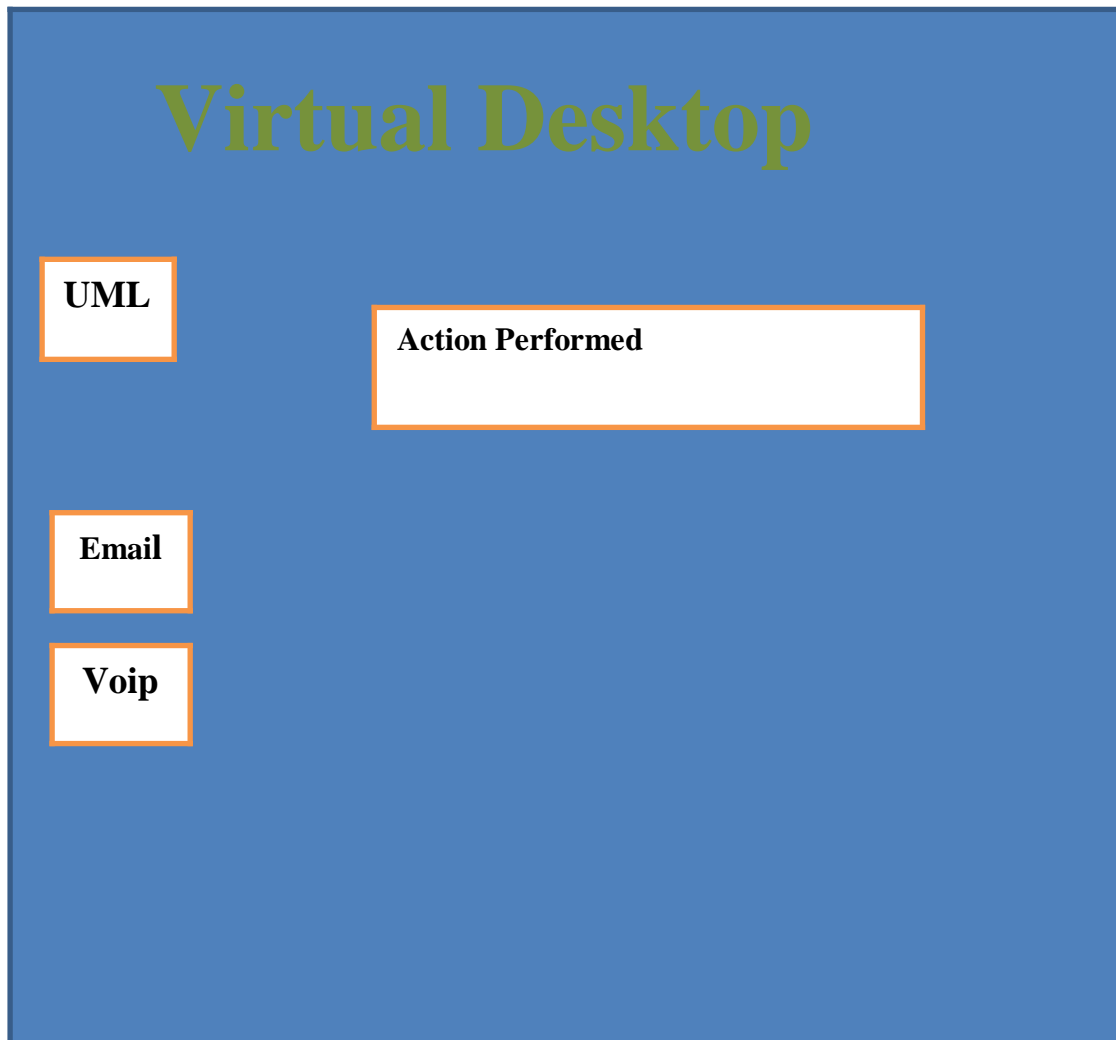


Figure 12. – Virtual Desktop 2

6. CONCLUSION

When I decided to write on this topic I expected difficulties in my research work and design. I managed to find enough materials for the research part of this thesis. The design is all based on facts. The product and the design of this software development suite is all based on knowledge of cloud computing and its advantages. The design of the system is very complicated but made easy to understand. It is very important to understand the benefits of this software development suite if it is implemented. Software engineering will move up another notch.

Cloud computing has come to stay. Embracing it and developing new computing solutions with it is a sign of advancement in technology in general. Abstraction layers, virtualisation, internet and the economy are major reasons for cloud computing and this particular software development suite.

This research has broaden my understanding of cloud computing and its importance. The research work has also deepened my understanding of virtualisation and abstraction of layers. During this research I discovered more cloud computing platforms that are not as popular as Google or Amazon Web Services.

Software development is a major part of IT. I think trying to develop other methods of development is good for the software industry. Methods that reduce cost but produces high quality softwares.

I hope that any reader of this thesis will understand what it is about and the aim of the software development suite. I hope the reader of this thesis after reading it will share my vision for software development.

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