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2014

Dedication

I dedicate this work to the soul of my brother shadi,

to my parents,

my wife Hala,

my daughters Retal and Jowan,

and finally to my brother, sister, and their families

Yazid Khalil alkhatib

Declaration

I hereby Certify that this thesis submitted for the Degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed: .....

Yazid Khalil sadeq Alkhatib

Date: …….

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Abstract

Cloud Computing is an advance technology revolution that offers flexible and effective cost efficiency. Once people start running programs over the Internet, they will not need to install or purchase such software on their own computers. However, according to my experience in Palestine at the present time, it's very difficult to find an IT lab that includes all types of devices that should be used for the purpose of teaching operating systems and computer networks.

This thesis takes into account two aspects: on one hand, it explores and analyzes several literature resources with similar ideas that provide cloud services for remotely located users. On the other hand, using the information acquired in the previous step, the thesis will be researched, designed, implemented and experimented on how cloud computer resources could be provided in the optimal manner.

Also, the thesis discusses implementing a cloud lab for providing cloud computer resources in the optimal manner to achieve an infrastructure lab service. It is undeniable that conventional labs must be supportive and not substitutive to on-campus labs. Therefore, a cloud infrastructure that has the ability to offer training sessions for different operating systems and networking techniques should be build. Thus, this will lead to build cloud IT infrastructure solutions.

We built an environment to publish a package of operating systems and network programs using a central database that depends on a compilation we made using VMware ESX server and GNS free source solution. This environment comes with user access limitation that depends on permissions controlled by an administrator on central database founded on a Linux system. As a result, users can connect to this central database to use different infrastructures with limited permissions controlled by an administrator. In this context, users can face real experiments as

they are in a real lab with lower risks, secured and customized access through offering software applications, data storage and processing power that are available as a service over the Internet.

This solution will be oriented, not only for IT students at universities, but also for employees in the IT branches located in far places. Not doing so leads to restrict the improvement for their skills in the world's new technologies and new software applications that found in the main IT building. Providing cloud computer resources as an infrastructure service called IT cloud lab will give the different trainee groups, the computer engineering ,the IT students and the employees responsible for IT affairs the opportunity to work and examine different IT infrastructures. These infrastructures are consisting of different operating systems such as Linux, Windows, Solaris and platforms to achieve hybrid solutions.

A comprehensive evaluation for exposing the merits and inferiorities of introducing computer resources as a cloud lab service in higher education and for measuring some pedagogic and usability criteria has been carried out. The respondents in this evaluation contain network engineers, IT employees and computer and electronic engineer students who interact with system via different client interfaces that are discussed and examined by two expert Engineers in both fields (Network and operating system). The respondents have to solve a simple network topology. Hence, the results obtained from the comprehensive evaluation reveal that the cloud infrastructure lab is capable to support the student's educational process. Therefore, the cloud lab helps delivering information in easy and smoothly manner jointly with the traditional labs in our companies and universities.

مختبر البنية الحوسبية السحابي

اعداد : يزيد خليل صادق الخطيب

اشراف : الدكتور صلاح الدين عودة

ملخص الرسالة

يعتقد الخبراء أن تكنولوجيا الحوسبة السحابية تشهد تطوراً خلال السنوات القليلة القادمة، وسيشهد السوق اعتمادا كبيرا عليها من قبل الشركات المتوسطة والكبيرة على حدٍ سواء، حيث تمكنك نظم الحوسبة السحابية من الوصول إلى البيانات الخاصة بمؤسستك من أي مكان وفي أي وقت عن طريق الارتباط بالإنترنت بدون الحاجة لاستخدام برامج مساندة او شراء برامج مكلفة.

من حكم تجربتي ومن وجهة نظري فإنه يصعب العثور على مختبر خاص بتكنولوجيا المعلومات لغرض التدريب على مختلف أنظمة التشغيل والشبكات الحاسوبية، بما في ذلك الأجهزة النادرة باهظة الثمن التي يجب أن تتوفر مع مختلف أجهزة الشبكات في نفس المكان.

هذه الرسالة تأخذ بعين الاعتبار جانبين مهمين: من ناحية تعرض وتستكشف وتحلل العديد من الموارد الأدبية المماثلة بالأفكار والتي تقدم الخدمات السحابية للمستخدمين عن بعد،ومن ناحية أخرى، باستخدام المعلومات المكتسبة من الخطوة السابقة تقوم ببحث ومناقشة وتصميم وتنفيذ و تجربة الحل الأمثل لتوفير الاجهزة الخاصة بالشبكات ومختلف النسخ الخاصة بأنظمة التشغيل كسحابة متاحة للإستخدام.

لا يمكن إنكار أن المختبرات التقليدية الموجودة في الجامعات والكليات التقنية من وجهة نظري بحاجة إلى دعم مادي متواصل، بحيث يجب أن تكون مواكبة لأحدث الاجهزة والتكنولوجيا المتاحة في السوق، لذلك تقدم هذه الرسالة حلاً عن طريق إنشاء بنية مختبر سحابي له القدرة على تقديم حلول تدريبية على مختلف أنظمة التشغيل وتقنيات الشبكات المتنوعة. في هذا السياق، يمكن للمستخدمين القيام بتجارب حقيقية كما الواقع في المختبر الحقيقي مع مخاطر أقل، وتأمين وصول ناجع من خلال تقديم تطبيقات برمجية بالإضافة لتخزين البيانات بالإعتماد على قدرة المعالجات المتوفر كخدمة عبر الإنترنت.

لقد قمنا ببناء بيئة سحابية تساهم وتساعد المختبرات التقليدية الموجودة في الجامعات بحيث لا تكون بديل عنها، حيث تم عمل مختبر سحابي باستخدام التكامل بين VMware ESXو GNS3 solution لإنتاج قاعدة بيانات حوسبية قادرة على استيعاب جميع الأنظمة التشغيلة المعروفة، بالإضافة الى القدرة على استيعاب جميع الأجهزة المختصة بالشبكات بحيث تكون مرتبطة بصلاحيات المستخدمين للوصول لقاعدة المعلومات المركزية حسب المرغوب من قبل المستخدم المسؤول عن ادارة واعطاء الصلاحيات، بهذا فإن المستخدم قادر على التعامل مع أجهزة حقيقية كما المختبر التقليدي مقدمة كخدمة سحابية بأمان وبأقل المخاطر.

تم إجراء تقييم شامل للمختبر السحابي ونجاعته في التعليم المختبري بمشاركة مجموعة من مهندسي الشبكات والطلاب وموظفي دوائر الحاسوب المختلفة لقياس مقدار تفاعلهم مع النظام عبر واجهات مختلفة تمت مناقشتها مع خبراء شبكات وأنظمة تشغيل. بعد الاطلاع على نتائج التقييم تبين أن المختبر السحابي يقدم دعم بالتعاون مع المختبر التقليدي في العملية التعليمية بصورة متكاملة من عدة نواحي تشمل (القدرة على الاستخدام والتفاعلية وسهولة التعلم ومقدار الرضى الموجود من المختبرات التقليدية بالمقارنة مع هذه المختبر والاضافة التي يقدمها عند استخدامه، فالمختبر السحابي قادر على ايصال المعلومة بطريقة تربوية سلسة وعملية.

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Chapter 1

1. The state-of-art - Introduction

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1.1. Introduction

With all information and communication available these days, it is possible to provide cloud computer resources that can be used in different activities and experiences. While providing a real infrastructure as a service, users can face real experiments as they are in a real lab with lower risks, secured and customized access through offering software applications, data storage and processing power that are available as a service over the Internet.

From the earliest days, laboratory-based courses had been the main essential part of scientific and engineering experiments. They play a critical role in the scientific and engineering education and they are realized in many forms depending on the different requirements in various fields of these disciplines.

Online education makes a very big step and growth in the past decade. According to a report released recently by U.S. Department of Education: "students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction; instruction combining online and face-to-face elements had a larger advantage relative to purely face-to face instruction" [1]. This shows that the demand on the remote hands-on labs has been rising rapidly while the budget for the new technologies to update labs has not been increasing proportionally [2].

Engineering education goals depend on preparing students in a practical manner for being able to deal with real-life problems and materials. Thus, the practical components and the instructional laboratories became the main corner part of undergraduate engineering curriculum and one of the most important factors in forming the engineering graduate qualities. Physical lab experiments allow the students to be sure that mathematical models reflect the nature and the

limitations of these models. Thus, applying these experiments and practical projects will support the knowledge base for students to cope with natural real-world problems and gain the hands-on experience [3], [4].

1.2. Research motivations and problem statements

Laboratory-based courses had been the main essential part of scientific and engineering experiments. The practical training and the instructional laboratories became the main corner part of undergraduate engineering courses and one of the most important factors in forming the engineering graduate qualities.

Through my previous experience, as an engineer, by HP and my current employment as an IT engineer for Awkaf Ministry, I faced many difficulties to make training sessions for employees in our branches in far places. This matter led to restrict the improvement for the employees' skills in the world's new technologies and new software applications that found in the main IT building. Such difficulties will be bypassed if we develop our labs according to this type of cloud computer service as we will give our employees an opportunity to work, to examine different operating systems and platforms like Linux and Windows servers and to get them ready to work on our new applications. From the previously discussed, we can emphasize that one of the most interesting sectors in the new research IT area is cloud computing. Therefore, the researcher takes forward step to be one of the researchers in this sector.

We faced different education problems especially with the engineering labs that motivate us to go ahead and try to find a solution. Some of the problems are listed below➔

- The difficulty to find a lab for the purpose of teaching operating systems and computer networks, including all type of devices that must be available in the same place.

- The high cost of giving the company employees or students of IT infrastructure labs the opportunity to get the appropriate training on a hybrid IT infrastructure.

- The problem of requiring full trained IT person by the companies.

- The question of "How we can have Special training and Certifications without visiting the Far Countries?"

- How our students work on up to date Devices?

- Opening new laboratories for our students that depend on the new technology with Zero infrastructure.

1.3. Literature review

In the recent times, there are a huge amount of research material and contributions in the field of cloud computing published. Most of the cloud computing literatures are published in the beginning of 2009. The idea behind cloud computing is to provide both platform and applications on demand through internet and intranet. This will allow sharing, allocation and aggregation of software, computation and storage network resources with a very special key benefits that include hiding and abstraction of complexity, virtualized resources and, thus, efficient use of distributed resources [5][6]. It is noticeable that all world big companies, such as, VMware, Microsoft, Citrix Systems, Oracle VM, Red Hat, etc. start to investigate strongly in this field as they recognize that cloud computing will take a large space and size in IT technology in

the future. That is because of the advantages of this technology, which provides people a way to share large amount of distributed resources belonging to different organizations.

Companies with global operations require faster response time, and thus, saving time by distributing workload requests to multiple Clouds in various locations at the same time. This creates the need for establishing a computing atmosphere for dynamically interconnecting and provisioning Clouds from multiple domains within and across enterprises [7].

North Carolina University started to test virtual computing LAN in 2003, with main goal to use standard industrial components, along with a combination of open source and software including proprietary software developed in Perl and PHP language [8]. Accordingly, with this interface, students could use to request access to specific images of operating systems in blade servers. Thus far, the number of users increased every semester to serve more than 30000 students and faculty members with more than 400,000 sessions since the project began [8].

The first leader company in virtualization is Amazon Web services whose EC2 services present a true virtual computing environment. The services allow customers to use web service interfaces to launch instances with a variety of operating systems, load them with the customer's application environment, manage the belonging network's access permissions, and run a customer's image using as many or few systems as desired [9].

Google applications engine is one of the most comprehensive collaborative products available. The program includes applications for e-mail, calendar, hosting different domains e-mail service document storage editing and video sharing and supporting APIs for the data store. All the systems and platforms are on the cloud side in which many web operating systems exist on the terminal side which can integrate web and local applications easily. The more well-known

web operating systems are as follows: Google Chrome OS, DeviceVM Splash top, Windows Cloud, Joli cloud and Red Flag in Mini, etc. [10][11].

FOS is a new multi-core and cloud computing operating system, developed by Carbon Research Group which uses micro-kernel and support multi-core processor by providing a single OS image to shield the difference of multi-core and cloud environment [12].

Microsoft with windows azure and SQL azure enable cloud service help users to build, host and scale applications in Microsoft datacenters. They do not require up-front expenses or long term commitment; also they enable cloud service customers to pay only for the resources they use. Its work can be summarized in a sentence "Focus on your application; not the infrastructure" [13].

1.4. Contributions

The goal of this thesis is to overcome the listed problems in section (1.2 above) and try to solve it with the following contributions ➔

- Build an environment to publish computer resources that include a package of operating systems and network devices with user access limitation that depend on permissions controlled by an administrator on central database founded on a Linux system.

- Design an IT lab for the purpose of teaching operating systems and computer networks, including all types of devices that must be available in the same place.

- All services and powerful network devices should be centralized in one service lab with easy-to-use user-interfaces for both experiment designers and students.

- Big companies with many branches can offer many courses sessions for its employees without spending much money and time on arranging a session for them with all of its requirements like tickets, hotels and others.

1.5. Types of laboratories

There are essential differences between the main three types hand's on, simulated and remote labs. However, while in other cases there are many emerging technologies which have been used to develop the virtual and remote laboratory. Recently, advances in technologies have dramatically changed the nature and practice of the laboratory education landscape by two main new technology-intensive automations: simulated labs and remote labs, in which they can be considered as alternatives for the hands-on conventional labs [14].

It is of great significance to differentiate between the three main labs hands-on, simulated and remote labs in order to show strengthens and weaknesses of each lab type.

1.5.1. Conventional Lab (Hands-on)

Benjamin Franklin said: 'Tell me, and I forget. Teach me, and I may remember. Involve me, and I learn' [15]. This proverb implies the fact that an active participation in a direct and practical way to be involved in a physically real investigation process is the main goal for hands-on labs. When mankind penetrates deeper and deeper in the mysteries of nature, the number of needed physical experiments should be increased, and, at the same time, not declined from the principle that we must try it before we use it [4].

Hands-on labs involve physically real investigation processes that have two characteristics distinguishing it from the other labs:

(1) All equipment needs to be prepared and installed in the lab physically.

(2) The students when performing the experiments must physically present in the lab.

Hands-on labs provide students with real data and prepare them for the worst case as it exists in the real world. Doing so, the students are not deal only with the theoretical aspects of natural phenomena, but also, they can deal with the practical side achieved by experiments that provide more experience and logical thinking [14].

One of the most important corners in preparing the graduate engineering student is the practical sessions and experiments that he/she faces when he/she works in the engineering laboratory with opportunities to work collaboratively, interact with equipment, learn by trial and error, test conceptual basic knowledge and perform analysis on experimental data. Hands-on education allows students to experience the backbone of engineering by conducting experiments, observing dynamic phenomena, testing hypotheses, learning from their mistakes and reaching their own conclusions[16].

Basic conventional laboratory course consists of several modules that are divided into three sections: pre-laboratory, laboratory and post laboratory. In the pre-laboratory, students prepare for the laboratory theoretically and access many resources depending on web links, books or papers. An evaluation test ends this section. The second section, the laboratory, is the most interesting one of the three sections[17].

From my previous experience in engineering college laboratories the Students spend more than four hours and collaborate with other students as a team in the laboratory. Just well-prepared students can work through the laboratory sessions with a help from the instructor in the places that needed to be more experienced in it. At the end of the lab, they need to solve tasks and pre-prepared questions or install and configure some devices such as servers or routers for network labs [17].

We may ask the question: how much does an average student benefit from working in a conventional lab under pressure of ending the required section in a specific sessions without enough knowledge to troubleshoot the equipment and then to have the opportunity to repeat these sessions calculation?.

On the one hand, the conventional labs require a real financial investment from the university in developing the labs infrastructure periodically, including all new devices and software platforms. On the other hand, a significant scheduling effort from students and academic staff is required for meeting the labs time programs lately to be far from being archaic and only depends on conventional labs with all of its requirements.

If we consider that many companies need to send its employee's yearly outside to have more experience and improve their skills in special courses and that those companies compete with each other to get new technologies and new product to the market faster as possible as it can, then we must think mainly about how much they must pay from the yearly budget for taking such special sessions including tickets, hotels, transporting and courses cost, leading that a continues decline faces the conventional laboratory that has been noted [14], [16].

In Palestine, operating systems and networks labs of many computer engineering and IT departments at universities, referring to my experience, suffer the absence of the high-quality learning IT infrastructure, such as, servers and high-speed networks. Those labs are of a great significance for teaching their students the state-of-the-art IT technologies. The graduated student will face a different world outside his/her university, and thus, a very big gap will take place between the learning process at the university and the required experience to be acceptable employee for big companies. From my opinion and my experience, the most of IT companies prefer to employ qualified trained students with experience in configuring and installing contemporary IT equipment. That is because companies always try to overcome investing huge magnitudes amounts of money in order to update the knowledge and skills for fresh employees.

A fresh graduated student needs to invest money and time to get more experience in IT field, and to be ready for IT works. Therefore, the university IT laboratories play a central role in promoting the students' IT experience that represents one of the key selection criteria for IT position applicants.

Conventional network lab course session is usually supervised by one or two instructors. The instructor directs the lab session in which he explains for the students the necessary instructions for installing and configuring a computer system. After that, the students do exercises on these installation and configuration steps that are also specified in the lab manual. The devices are selected with respect to what is needed in the experiments in a particular session. At the end, the students read the network manual and evaluate the result; if they are acceptable, the students record them in the laboratory report. However, if this is not the case, troubleshooting with the experiment instructor will be helpful.

1.5.1.1. Conventional IT infrastructure lab for IT students

The key to the computer revolution of the 1980s was the invention of the microprocessor in the 1970s. Microprocessor invention gave the opportunity for the cheap computers to be everywhere in homes, schools and offices. Thus, due to this revolution, a new related technology and networks are developed to connect these computers in one place that termed as "computer lab". Hence, the existence of this technology still enriches our society in countless different ways.

As a result of computer revolution improving the quality of education become the main concern for most developing countries. Governments face the challenge of identifying efficient ways to use their scarce resources and raise the quality of education, as well as increasing student achievement in at least two ways. Firstly, the availability of information and communication technology (ICT) in the classroom shifts the level of educational inputs which can affect students' learning outcomes. Secondly, the exposure to ICT may increase the cognitive abilities of students, allowing them to learn faster [18].

Nowadays computer labs become an integral part of education system, which become the hub of activities in education in which it considered the most educational tool since the invention of books. Therefore, these computer labs need a lot of components to be structured and considered on starting up the lab also, these components will facilitate the work of lab stakeholders and the educational process [19][20].

1.5.1.2. Establishing a general-purpose computer lab

There are different requirements that should be considered in designing a computer lab, in order to be accessible from students and to give an equal benefit for them:

- **Lab location and accessibility:** The location of computer lab should be taken on consideration in the initial design of the lab to make sure that it is accessible. Also, it should follow the ethics of universal design that include beside designing the facilities and offering services for the average users, taking into consideration that these facilities should be designed for people with different ranges of abilities, disabilities, ages, reading levels, learning styles, native languages, cultures and other characteristics. Moreover, users or students should feel welcome, reach resources easily and work within it. Also, it should enable them to communicate effectively with support staff and offer them an easy access to the printed materials and electronic resources [21][22].

- **Lab space and facilities:** The space on the lab is an important aspect that it should be taken into consideration in designing computer lab, see Figure 1. A computer resources lab (Source by: gumskaya.com 2013), controls the system of furnishing and the layout of computers. Each computer should be placed roughly a full shoulder's length apart from one another to ensure that students using the lab do not end up crowding each other's space. Also space and design could affect the educational process and the interaction between the student and the instructor, in addition, it is important to take into consideration other facilities in designing the lab such as proper lightening, climate control and wiring the electrical system correctly [20][22].

Figure 1. A computer resources lab (Source by: gumskaya.com 2013)

- **Lab equipment's:** In order to have a good computer lab, the following equipment should be available ➔

- **Student's station:** computer lab can be generally classified by size and power. It's important to differentiate between the types of computers that are available and what is the best computer to be used in computer labs. Personal computers (PCs) are the most popular type of computers in use today in which they are small-sized and relatively reasonable priced computer that are designed for personal usage [24].

- **Student's management station:** a network management station is one that executes network management applications that monitor and control network elements, such as, hosts, gateways and terminal servers. These network elements use a management agent to perform the network management functions requested by the network management stations. The management station has direct access to the server. Besides, the management system of the switch must be able to monitor the client stations and have a better access to external resource, such as, Internet or communication software. The

management station, also, has better security because it makes a more interesting target for students wanting to hacker and because of its access to external resources; therefore, it provides a means for security, access control, system upgrades and policy enforcement. The many interconnections between computers often create opportunities for someone to break in and harm equipment or data. Firewall systems can constantly look for signs of an attack, while software often helps identify and eliminate viruses and other forms of intrusion [26].

- **Server:** A server is a software program or a computer, in which that program runs, that provides a specific kind of service to client software that run on the same computer or other computers on a network. The server performs some tasks on behalf of clients. The clients typically connect to the server through the network, but may run on the same computer. In the context of Internet Protocol networking a server is a program that operates as a socket listener. It often provides essential services across a network, either to private users inside a large organization, or to public users via the Internet. Typical computing servers are database server, file server, mail server, print server, web server, gaming server, application server, or some other kind of servers [27].

- **Switch:** Most business networks today use switches to connect computers, printers and servers within a building or campus. A switch serves as a controller, enabling networked devices to talk to each other efficiently. Through information sharing and resource allocation, switches save businesses money and increase employee productivity.

- **Router:** A router is an internetworking device that forwards packets between networks by processing the routing information included in the packet or datagram (Internet protocol

information from layer 3), in order for users to share the connection. A router uses its routing table to determine where to forward packets.

- **Network firewall:** A firewall is a part of a computer system or network that is designed to block unauthorized access while permitting outward communication. It is also a device or set of devices configured to permit, deny, encrypt, decrypt, or proxy all computer traffic between different security domains based on a set of rules and other criteria.

- **Wireless technologies:** wireless network can easily be attached to the local connections using different wireless technologies such as microwave, satellites, Radio and Free-space optical communication.

1.5.2. Virtual simulated labs

Many universities are going forward for investing in computing infrastructure. Consequently, less finance support has been left for modernizing general-purpose engineering laboratories. Even this step has many benefits; it leaves the students with less practical skills without trying and making errors when using real equipment. A video tape or CD with a recorded experiments are one of the most common alternatives, however, unfortunately this approach is not useful because of the fact that video does not provide the hands-on experience and lacks interactivity. Thus, this leads us to the second common alternative, namely virtual simulated labs, with new possibilities and new challenges for designing and deploying distance learning systems[28].

Simulated labs are the mimicry of real experiments in which all equipment in the experiment environments are simulated by using software packages on computers. It is normally used with

experiments that require too expensive equipment, or unsafe environments such as nuclear plants or unavailable systems.

One of the most advantages of using virtual lab and one of the nine objectives for the engineering education laboratory defined by ABET [29], is to let students learn from failures without causing any real damages. It is also allow them to repeat an experiment many times and give them the opportunity to observe the different when change some configuration and how it affect the outcome, such as using some protocols on routers and notice its effect on the network [29].

The virtual simulated labs are the imitations of real experiments in which all devices and instruments are represented via mathematical models in order to be simulated in a computer. At the beginning, simulated labs are seen as a solution for the increasing expense of conventional laboratories. Simulations reduce the period of time necessary for a student to learn as it is the case in hands-on labs. During a simulator session, the students have the ability to step outside the experiment, for instance, to look up the experiment manual and instructions for the purpose of reviewing and understanding it better [14].

The virtual labs which provide simulated environments by many software packages proved themselves to be beneficial for giving effective illustration of theoretical engineering education concepts. This is achieved by conducting experiments, step by step, with easy interfaces and tools that developed with much less costs in some areas than the real lab infrastructures, such as, Packet tracer software, See Figure 2. In essence, one of the most important benefits achieved with well-designed virtual lab well be through the fact that a student can try many times to do the experiments with no limitation on time and physical restrictions [16].

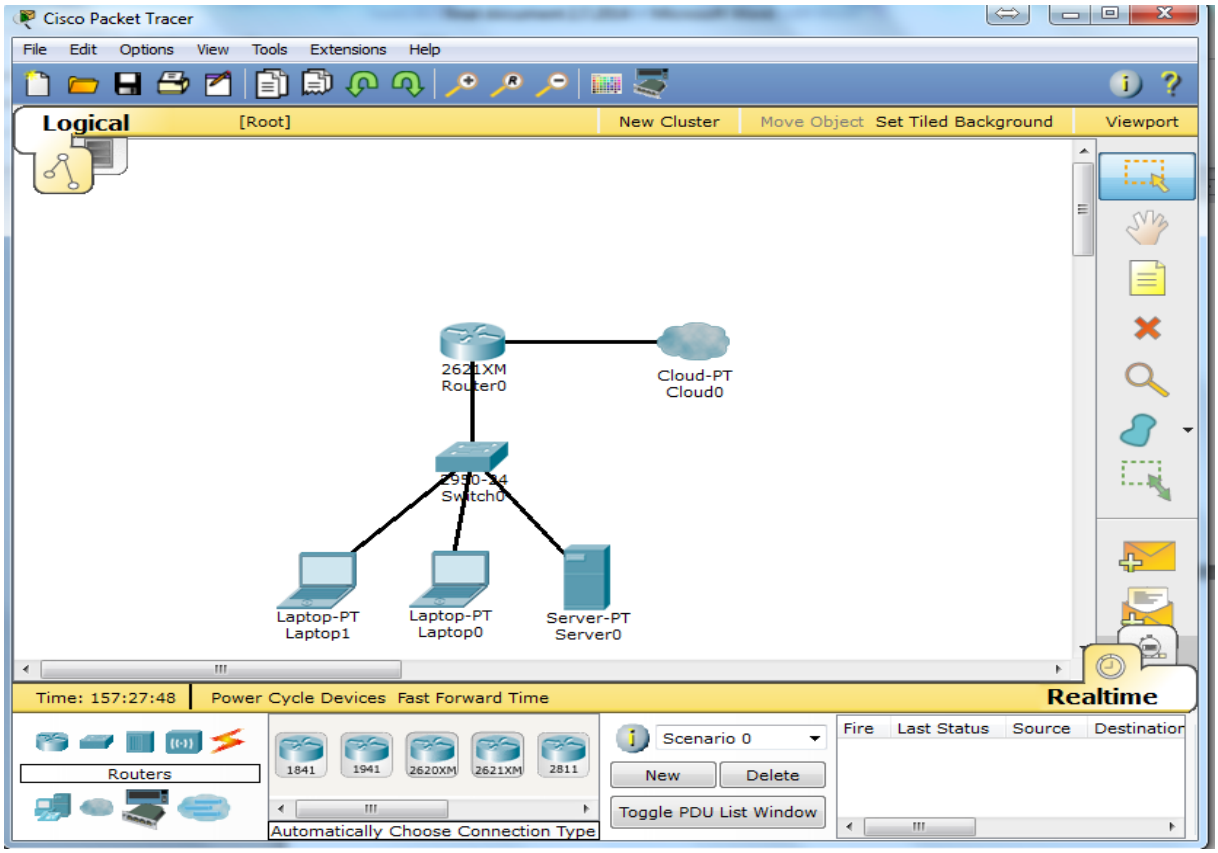

Figure 2 A simple experiment build on Packet tracer. Software developed by Cisco Company)

On the contrary, an increase in using simulations for training will produce a big experience gap between real and virtual worlds for the trainees using such simulations. In general it refers to the weakness of simulation that depends on software models and math, thus, the results appear as ideal results with no effects from the environment. Therefore, virtualized training environments are considered to be as poor replacement for the practical work in a real laboratory. Moreover, the output data of a simulated lab does not reflect real experiment data and it is the reason for losing the spirit of collaborative work in a team. Trying and error experience, as well as, facing new problems that needed to be solved will be missing in simulations [14].

The budget needed for establishing a simulation lab is not necessarily lower than the budget needed to build its equivalent real one. That is because the software for the virtual labs demand

long implementation time and require much efforts for their development. Nevertheless, they still not capable to equal the model reality (e.g. Aircraft training) [14].

There are software packages used to develop simulated lab environments such as LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench), Matlab, Java Applet, Flash, etc. [30].

1.5.3. Virtualized labs: A new approach to realize IT labs

Server virtualization improves the efficiency and availability of IT resources and applications since IT administrators can clone the configuration of different virtual servers to produce new servers that are ready to be part of the network. Doing so not only makes life easy for the administrators, but also, it leads to significant cost savings from reduced hardware requirements and improve server efficiency as well. Nowadays, multiple virtualization platforms are available from which is VMware representing one of the most famous companies. It is a global leader in providing virtual infrastructure software with a complete package that improves the IT resources availability, performance and utilization.

VMware depends on the hardware resources of a single computer to build different virtual machines that each of them isolated from each other with no conflicts. Scalability, high performance and different operating system platforms can help IT experts to test different environments before using it and investing much money that makes virtualization to a very practical testing environment. VMware technology helps us support our business growth that make companies and IT departments 'think outside of the box' [33].

The most advantages for VMware virtualization are summarized as follows:

- The Most Trusted Virtualization Platform: VMware and VSphere form the main platform in which all solutions are built on. Customers trust in VMware in which keeps platforms secure and reliable hypervisor [31].
- Best Platform for Business Operational Applications: Business applications require maximum availability and save the highest service level agreements. VSphere provides a fully scalable, secure and supports to achieve high performance for the business applications environments [31].
- Lowest Total Cost of Ownership: IT departments are supposed to do more with less fundamentals and budget. VSphere with many advanced operational management can reduce both capital expenditures and operational expenses by providing high hardware utilization, resources management and efficient administration [33].

If we want to talk about network devices such as programmable routers or switches, we can choose RouterSim's CCNA network visualizer as a Cisco router and network simulator, offering a powerful tool for designing, building and configuring your own virtual network.

RouterSim's CCNA network visualizer supports more than 500 commands and about 180 labs that build test and preview a large number of CCNA courses. Many features supported labs, starting with simple network environments, Cisco IOS, IP routing, NAT, switch security, VLSM and other individual Labs [35].

1.5.4. Remote Labs

By definition, a remote lab is an experiment which is conducted and controlled remotely through the Internet characterized by mediated reality [29]. It is similar to its equivalent real one in such a way that space and devices are necessary for realizing it, but with the major difference that it can be distantly accessed by the student or trainer on one side, and the experiment in the remote lab on the other side [31].

Research laboratories are very expensive places because, on the one hand, the instruments and equipment needed to build them cost a lot of money. On the other hand, they require high budgets for both purchasing and maintenance. It's very difficult to build such research laboratories in everywhere [20]. In Palestine a different solutions have been explored [32]:

- Different institutes including schools universities and others keep purchase individually and employ a qualified staff to work on.
- Different institutes that need research labs keep make transportation for the equipment; also, qualified technician must follow the instrument.
- Students' displacement is the most used solution, but the transfer is not easy.
- The most promising way may be the distant monitoring of the instrument which we call the remote lab such as the cisco lab in Al-Quds University.

Remote and simulated laboratories may provide a way to share specialized skills and resources that lead to reducing overall costs. Educators might then satisfy economic constraints, as well as, produce better learning; in contrast to this view a dystopian expects that educators fool themselves in believing these technologies that are used to improve our life. To produce a real scientist, you need to make them work by their hands in a conventional lab and have the hand's-on experience that make them familiar with real equipment and deal with it face to face. It's very clear that the main objective of remote laboratory is to share high technology equipment's between universities and companies for different purposes like learning, demonstration before sales or even collaboration on projects [31].

The remote laboratory developments focused from the beginning on the distance education sections. Even though the experimentation in real laboratory is irreplaceable, there are certainly

aspects that make this option difficult to implement, and in some cases, like distance education for far students impossible to support. A well-designed remote laboratory can offer students A tele-presence in the laboratory, performing experiments on real lab, collaborating with other partners ,supporting the learn by trial and error and analyzing real data in the lab with a flexibility in choosing place and time to perform the experiments [16].

There are many different remote laboratories around the world which are used in a variety of disciplines. A large number of students always make very big problems to universities in laboratory courses; the requirements for space, lab instrumentation and human support supposed to be difficult to be handled. Using remote lab technology with its ability to handle a large number of student's universities can solve these problems in addition to support the limitation in the available experiments (e.g. Nanotechnology laboratories) [29].

Different techniques including Lab VIEW, Matlab, Ajax, Java applet flash and others that are used in remote lab developments reported in a large amount of research and publications. Different projects established by big companies and universities around the world depend on remote lab technology. However, the wide range of user interfaces is a big problem for students and teachers to deal with. Some efforts made to handle the situation. The i-Labs project at Massachusetts Institute of technology in USA has developed a suite of software tools that facilitates online remote complex laboratory experiments and gives users the ability to manage the laboratory infrastructure [34].

From my opinion and experience, almost all universities in Palestine for undergraduate education, have the same instruments in network or scientific labs, in which most instruments already support remote control. Students and teachers are already familiar with these

laboratories. Would it be possible to open such a laboratory for remote operations and control? If so, teachers in different countries could use existing teaching materials in their own language, instrument manual and materials could be downloaded from the manufacturer's website [4].

Remote laboratories have appeared as a third option between conventional and simulation lab. Remote labs are similar to simulation techniques in that they help in minimal space, few staff and time cases because it can be easy configured and run over the internet. Yet, with a good option for remote labs that provide real data.

The remote laboratory Net Lab has been developed at the University of South Australia. It is used by academic staff for teaching and demonstrations during lectures, and by student for connecting and work on their experiments remotely on real laboratory equipment [36]. Net Lab created to provide access to a real laboratory remotely through the internet with 24/7 availability. Net Lab developed to create a laboratory experience that allows students to perform these common experiments on any PC and provide a feel as close as possible to use a real laboratory [36][37].

1.6. Overview on the cloud infrastructure lab

In previous time, we collected information and references about a technology, called cloud computing. This was for the purpose of defining how this new technology can help us suggesting a cloud lab for providing cloud computer resources service, taking into accounts the different problems we found in the previous mentioned types of labs.

Providing cloud computer resources will take these labs step forward regardless of how to work on up to date devices or supercomputers. Therefore, the researcher has started to determine the software cloud tools that will help in hosting all different operating systems that will be used for supporting computer labs with its all needs. Also, it will help in hosting the network tools that will be used to represent switches, routers and different network devices. See unit 4.

A well-designed user-interface will simply use the configuration activities needed by the experiment designer to build their IT infrastructure experiment from the cloud computer resources. This experiment includes various operating systems with full network supported by network devices, like Cisco or others. Analyzing and collecting data about this method will lead to a practical result for using cloud systems as a computer resources lab.

We researched, designed, implemented and experimented how we can provide cloud computer resources in optimal manner to achieve an infrastructure lab service that has the ability to offer different operating systems and networking techniques. In addition, we evaluated the cloud infrastructure lab and did some statistics. See unit 5.

Chapter 2

2. Educational Technology

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2.1. Introduction

In the new digital society, education with its traditional ways of instruction and learning is facing great challenges to use more innovative ways. Educational transformation and reform have become an urgent issue across the globe to meet the demands of new educational objectives in the knowledge-based economy. Nowadays, information and communication technologies play the most important roles in educational systems and technology of education which are defined as an array of tools that proved to be helpful in students learning development. New techniques with methods of organization and some modern tools are included. However, they are not limited to overhead projectors, computers, IPAD, Laptops are beginning to draw intensive attention for their potential [40].

According to the Association for Educational Communications and Technology (AECT) [41], educational technology is defined as: "The study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources". Therefore, how can we use the available technologies to support education systems in our schools?. Technology should not merely be used for the sake of just wanting to use it. Otherwise, it can hinder educational opportunities. The first concern is to justify its use in order to support the teachers plan to incorporate the available technologies into their curriculums [42].

First, they must justify its use. Technology should not be used just for the sake of using it. In fact, if technology is misused, it can hinder educational opportunities. In order to help teachers plan to incorporate technology into their curriculums, they must consider their knowledge about what to teach, what the available methods they will use to teach (pedagogy), and to choose which

technology must be used to enhance the learning process. Thus, without a clear purpose and plan for integration without the appropriate technological pedagogical knowledge, technology may hinder the educational systems improvement [43].

2.2. Enhance the classroom technology

Technology is available everywhere these days. It is very hard to imagine our life without the influence of technology devices. In educational sector, we have reached the point where the use of technology is expected by instructors and students.

The study of classroom environments is very important to understand learning atmosphere, goals, and interactions between teachers, students, tools and instructional strategies. Many reports and papers are being written about the use of technology as a teaching and learning tool. However, many researchers focused on the distance learning. Yet, there is another aspect, which focuses on using technology to improve teaching and learning in classrooms environment.

The basic classrooms that use technology depends on a simple network in which there are computers, network wired or wireless connections, and projection system. Instructors use the previous mentioned tools and others to present materials, perform demonstrations, and illustrate courses. Sometimes technology in classroom inherits some disadvantages. Using more time and efforts by instructor to perform the courses requirements, as well as, the different needs between instructors create some conflicts. Finding a balance in applying technology plays a critical role. For instance, provision of technical support must be balanced with knowledge of pedagogy to ensure the successful integration of a technology into the learning experience.

Having the new technologies to improve the quality of education and learning is just the beginning. Here, however, two questions arise: What the instructor can do with all of these resources?. Is it satisfied to keep education and learning closed to classroom environment?. The design of different types of learning environments can depend on the learning objective, target audience, access through physical or virtual or both a of them, and the type of content. It is important to recognize the using of different learning environments and the different effects of the tools and techniques that used to distinguish the difference in learning outcomes as the technology evolves. It is difficult for researchers to perform a meaningful cross-study and conclude a comparison between different conflicts learning environments including distance learning, e- learning, and online learning environment.

2.3. E-learning systems

The learning process needs modern techniques and tools to present, interact, and share the knowledge with others. Electronic learning is becoming an important tool to support the learning and education systems to achieve its goals. It is the kind education that is based on modern methods of communications such as computers and its networks, electronic libraries, various audio, and search engines whether accomplished in the classrooms or at a distance [44].

In generally, e-learning refers to the use of various kinds of electronic media and information communication technologies (ICT) in education. Furthermore, it encompasses all forms of educational technology that involve some form of interactivity; but the question is: Does E-learning intends to replace the traditional learning mode?. Undoubtedly, e-learning can't replace traditional methods of learning like classroom teaching. It aims to create a learning environment where technology is used to facilitate teaching techniques to access resources and services as

well as remote exchange and collaboration. E-learning assists in the transformation of the educational process from the learning level by rote to one that characterized by creativity, interaction, and the development of skills [45][46].

E-learning is viewed as having the potential to: improve the quality of learning, improve access to education and training, reduce the cost of education, as well as, improving the cost effectiveness of education. Education through the use of technologies helps nations to prepare members capable of facing this new information age. Part of the e-learning promise is the connection of the independent groups of learners, and individualized curricula that helps to deliver on demand learning on a global basis. This enables corporations to create development [47][48].

2.3.1. E-learning models

There are two common types of e-learning:

Asynchronous e-learning: It is commonly facilitated by media such as email and discussion boards. It also supports work relations between learners and their teachers. The communications between learners and teachers do not occur simultaneously. Asynchronous e-learning makes it possible to log on to an e-learning environment, and to download any needed contents or documents that served from web server, and to deliver on demand to the learners workstation. In addition, it supports communication by messages between teachers and learners, as well as, posting messages to a discussion groups. It is also called "distributed learning", which is the preferable one for the lower cost of development, reusable components, and reliable for learners [49].

Synchronous e-learning, commonly supported by media, such as, chat rooms, application sharing, white board sessions, video conference and live web-casts. Synchronous e-learning has the potential to support e-learners in the development of learning communities. Asking and answering questions in real time is very helpful in resolving and overcoming frustration and to have a healthy social environment between learners and teachers. Therefore, they feel more comfortable in not being isolated [49].

In our cloud infrastructure lab we plan to build the system depends on merging between both types of e-learning, On one hand, the Asynchronous e-learning used to open a discussion between learners, teachers and administrators using portal and Helpdesk system that have the ability to download any needed contents to help the students in the lab sessions. On the other hand, the synchronous e-learning used the Cloud infrastructure lab system tools to prepare the trainee online on the computer resources using internet connection.

2.3.2. Types of e-learning approaches

There are three types [50]:

- Enhanced approach: the e-learning solutions used to support, facilitate and enhance, face to face, learning by using web-based technology such as course management systems. This approach help in reducing the academic, face to face, seat time.

- Blended approach: this approach is mixed between traditional, face to face, and online learning. It helps to apply a big portion of learning depending on delivered the learning online; it can help in reducing the face to face meeting from 25 to 75% percent [51].

- Online approach: this approach depends completely on virtual learning (VL) which can be realized without any need for learning, face to face, meeting sessions. In exams, however, there are face to face meetings, but this approach can deliver online more than 75% of course content.

2.4. Distance Learning

The term "Distance Education" was first used in the University of Wisconsin-Madison catalog for the 1892 school year [52]. It is the most renowned description almost used when referencing distance learning. It often describes the efforts that used to provide access to learning for those who are geographically distant. Distance learning consists of correspondence education, televised courses, and collections of DVD's and cassette recordings. Slide projectors and microfilm allow students to recall history via photo negatives while satellite TV allowed students to be a part of classes on their own time. With the growth of the internet and large networks, students have an opportunity to utilize asynchronous and synchronous communication tools to facilitate choose for time and place compatible with their own time [53].

Corporations probably become the largest investors and clients of distance learning. Many world big corporations have a serious and urgent need to develop rapid and continuous learning process of their employee's partners and supplier. Therefore, distance learning provides a viable means for the employees upgrading including skills to establish better communication with customers, and to develop products and services rapidly [54]. I experienced HP Company upgrading courses [55]; it is for all employees specifications including all departments. Maintenance and high technology departments must participate in special courses. They, also, must succeed in the final exams in order to keep partnership relation between the most of

employees and the HP Company. This depends on the available devices and technology exists in the market, also, for sales employee's special courses and also courses for upgrading managers skills.

2.5. Engineering Education

It is referred to the activity of teaching knowledge and principles related to the professional practice of engineering. It includes the initial education for becoming an engineer and any advance specializations that follow. Engineering education is typically accompanied by additional examinations and supervised training as the requirements for a professional engineering license. Engineering today is characterized by both a rapidly increasing diversity of demands made on engineering in their professional lives and the ubiquity of products and services the support and manage[56].

Information about engineering education is highly relevant to improve communication between professors, researchers, the students in engineering schools, institutions, laboratories and industry. Technological change is fundamental to the development of education systems. Learning through the context of engineering can play an important role in the implementation of Curriculum for Excellence. It provides challenging and engaging opportunities for personalization and choice, for learning in depth, and for young people to perceive the relevance and coherence of their learning. Young people are supported and challenged to extend and apply their learning in new and unfamiliar situations.

2.5.1. Engineering Pedagogy

Pedagogical strategy is a learning processes which is used in order to achieve certain learning outcomes that can confer competences to the learner, pedagogy and didactic aspects of engineering education. It also covers relevant aspects from more classical engineering courses such as mechanical, manufacturing, industrial, chemical, environmental, civil and systems courses, to more contemporary courses including Nano engineering and bioengineering along with information on sustainable development in the context of engineering education.

Engineering pedagogy is a Multidisciplinary scientific subject which has become one of the main elements of the systems in engineering education. The set of pedagogical principles underpinning engineering education emphasize innovation, invention, creativity, teamwork, perseverance and responsibility. Furthermore, it tries to extend the skills and capabilities of learners through many application of solutions oriented approach, a range of problem solving techniques supported with modeling and simulations, as well as, system approaches, and through the application of high levels of scientific and mathematical understanding [57].

The objective of Engineering Pedagogy is the pedagogical system for training the engineers; the object is to design and realize the professional training contents, organization forms, methods and the process of specialist's personality formation [58]. The basic notions and categories are the same as in general pedagogics: aims, principles, organization form, etc. These categories and notions are enriched with new contents taking into account the objectives of engineering education. The categories specific for Engineering Pedagogy are scientific and technical knowledge, engineering activity, specialist's personality and communication in the process of professional activity [57].

2.5.2. Pedagogical effectiveness in cloud and remote labs

When we designed the Cloud infrastructure Lab we tried to search and collect data about how to make your lab have a good pedagogical effectiveness, such as illustrating and validating analytical concepts, introducing students to professional practice and to the uncertainties involved in non-ideal situations, developing skills with instrumentation, also developing social and teamwork skills in a technical environment.

The Pedagogical effectiveness of different laboratories especially remote and cloud laboratories has been a subject of discussion and surveys [61]. Remote laboratories for measurement and control present an ever-growing subject in the distance teaching of engineering graduates [61]. The Cloud lab can deliver services such as remote access to learning tools over the internet in a cost effective manner to universities systems struggling with reductions in local and state funding. Laboratory classes are widely accepted as a crucial part of an undergraduate engineering degree.

Modern educational methods bring many new challenges from the pedagogical, as well as, from the technical aspect. Laboratories in engineering and scientific education play an important role for the development of students' practical skills, and contribute to their professional development.

Chapter 3

3. Cloud Computing

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3.1. Introduction

IT infrastructures including servers, storage and networks are very important corner in companies' successful stories. On the contrary, they require very huge amount of space in companies' budgets that leads these companies to work on the newest technology in IT solutions. While few years ago typical deployed systems consisted of individual racks filled with few tens of computers, today's massive computing infrastructures are composed of multiple server farms, each built inside carefully engineered data centers that may host several tens of thousands CPU cores in extremely dense and space-efficient layouts [60].

Cloud resources can be described as the latest in a long line of technology advances that have moved us from the details of building and running a data center. Computer end Users used only what they needed and paid only for what they used. It didn't matter where in the world and how you could access your stored information regardless of whether you were using a private or a public terminal.

The cloud itself is a set of hardware, networks, storage, services and interfaces that enable the delivery of computing as a service. Cloud services include the delivery of software, infrastructure, and storage over the Internet, (either as separate components or a complete platform), based on user demand.

Then, what is cloud computing?. In a paper published in 2008 by the IEEE according to Carl Hewitt, cloud computing, "is a paradigm in which information is permanently stored in servers on the Internet and cached temporarily on clients that include desktops, entertainment centers, table computers, notebooks, wall computers, handhelds, sensors, monitors, etc." [62]. The major benefit of the concept behind cloud computing is that the normal user does not require a

powerful computer that is extremely powerful to deal with complex database indexing tasks that server farms can, instead, with the normal use of broadband, users can easily connect to the cloud, which would commonly be referred to, as the center point for contacting with the larger network that cloud computing users from all the world can reap the benefits of using a powerful processing power with neglecting the technical required question of know how [63].

Cloud computing can be defined also as the next stage in evolution of the Internet. The cloud in cloud computing provides the means through which everything starting from computing power to computing infrastructure, applications, business processes to personal collaboration can be delivered to you as a service wherever and whenever you need. Cloud computing presented in different forms: Public Clouds, Private Clouds and Hybrid Clouds which combine both public and private forms, many players support the world of cloud computing including but are not limited to the vendors that providing applications and enabling technology, infrastructure, hardware and integration, also, the partners for these vendors that are creating the cloud services offerings and providing support services to the different customers, and finally the business leaders who are either using or evaluating different types of cloud computing offerings [64].

Many experts expect that cloud computing will reshape information technology and starting already to turn the software industry upside down. Once people start running programs over the internet, they will have no need to install or purchase them on their own computers, this computer revolution leads many big vendors such as Amazon, Google, Microsoft, and IBM to start create and deploy clouds in various locations around the world [7].

Many companies are delivering services from the cloud, such as, Google company that Has a private cloud uses for delivering many different services to its users, including email access,

document applications, text translations, maps, web analytics and much more. Also, Microsoft supported SharePoint online service that allows for content and business intelligence tools to be moved into the cloud, and Microsoft currently makes its office applications available in a cloud. In this context, Salesforce.com, runs its application set for its customers in a cloud, and its, Force.com, and, Vmforce.com, products provide developers with platforms to build customized cloud services.

3.2. Benefits of Cloud Computing

What is the best thing for companies to employ cloud computing?. For cloud computing providers, they are on the cutting edge. Cutting edge means that there are going to be some really good profit margins for them. The competition is scarce in the beginning and, therefore, it is easy to dominate the market. Also, it's the best thing for small business that cloud computing is playing field leveler; it gives small businesses access to new hardware and technology that previously were out of their reach and lets small businesses compete with both other small business and bigger ones [66].

Cloud computing presents IT organizations with a fundamentally different model of operation, one that interested in take the advantage of the maturity of web applications and networks, and the rising interoperability of computing systems to provide IT services. Cloud service providers specialize in particular applications and services, and this expertise allows them to efficiently manage upgrades and maintenance, backups, disaster recovery and failover functions. As a result, consumers of cloud services may see increased reliability, even as costs decline due to economies of scale and other production factors. With cloud computing, organizations can monitor current needs and make on-the-fly adjustments to increase or decrease

capacity, accommodating spikes in demand without paying for unused capacity during slower times. A side from the potential to lower costs, colleges and universities gain the flexibility of being able to respond quickly to requests for new services by purchasing them from the cloud [67].

3.3. Cloud Computing Characteristics

Companies are finding some new important new values founded by companies in cloud computing services. The cloud can overcome many complex constraints from the traditional computing environment including space, time, power and cost. Cloud computing infrastructures make it easier for companies to treat their computing systems as a pool of resources rather than a set of independent environments that each has to be managed.

The cloud reflects the following basic characteristics [64]:

- **Elasticity and have the ability to scale up and down service operations:** Referring to the different required services some users may need the service in a specific period of time in the year such as the peak selling seasons for some companies; on the contrary other users build all its primary platforms and applications on the cloud service. Therefore, the services must be available 7 days a week, 24 hours a day and it has to be designed to scale upwards for high periods of demands and downward for lighters ones.

- **Self-service provisioning and automatic provisioning:** Users and small business companies can get the requested cloud services that meet the workload and applications needed. The user simply requests an amount of computing, storage, software, process

and other required services from the cloud service providers. When a company is about to implement new application, it sends an on-demand request service for the service provider data center asking for addition computing hardware, software, services, or resources. Then, the data center must check in and evaluate the availability of existing resources versus the need to purchase new hardware. Finally the data center staff has to configure the requested resources to meet the new application for the customer. Of course, this on demand process not simple as it is appear but on-demand provisioning capabilities of cloud services eliminate many time delays.

- **Application programming interfaces – APIs:** Standard APIs interfaces needed to be applied on the cloud services to provide the instructions on how two application or data sources can communicate with each other. These APIs interfaces lets the customer more easily link a cloud service, such as, a customer relationship management system with financial accounts management system, without having to restore to custom programming.

- **Billing and tracking service usage in a pay-as-you-go model:** For sure there is no free service, the ideal cloud environment need a billing service that bills the customers. So this service model needs to track the usages that help to calculate the bills.

- **Monitoring and management:** The cloud service provider must include a special monitoring and management service for customers environments, this service is integrated in the environment and able to manage and monitor the physical and IT systems that help to maintain the required service level for the customer organization.

A dash board presented for the customers so they can monitor the level of service they getting from the provider.

- **Security:** The security issues for many companies platforms and applications are the most important subjects needed so these companies must take a leap of faith to trust that the cloud service is safe. Therefore, turning over the critical data and application infrastructure to cloud service provider requires making sure that the information can't be hacked or accessed from others.

3.4. Cloud layering services

Computer architects are normally interested in talk about layers of architecture, which correspond in a certain sense to the layers of a physical building. Once a cloud is established, how its cloud computing services are deployed in terms of business models can differ depending on requirements. The various types of cloud services included into three distinct models which represented by three layers.

The three cloud delivery models are infrastructure as a service, Platform as a service and software as a service with the main idea to make applications available on flexible execution environments primarily located in the internet. Where IaaS refers to sharing hardware resources for executing services, in the PaaS approach, the offering also includes a software program executing such as an application server. In SaaS, complete applications are hosted on the internet accessed through a web browser [68].

Infrastructure as a Service (IaaS) model is the lowest service model in the technology stack, offering infrastructure resources as a service, such as raw data storage and processing

power. It also delivers computer hardware (servers, networking technology, storage, and data center space) as a service.

The consumer can use the IaaS based service offerings to deploy his own operating systems and applications, offering a wider variety of deployment possibilities for a consumer than the platform as a service and software as a service models. “The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g. host firewalls)” as referring to National Institute of Standards and Technology NIST 2009 [69].

Instead of investing in their own corporate server or network infrastructure, companies are able to purchase those resources on a rental basis and use it on demand rather than having their own resources locally. The providers are taking care of the servers, storage and network settings, while the client has virtual instances of that [70].

Amazon Web Services is one example of that. Currently, the most high-profile IaaS operation is Amazon’s (Amazon EC2) Elastic Compute Cloud. It provides a Web interface that allows customers to access virtual machines. EC2 offers scalability under the user’s control with the user paying for resources by the hour [69]. The use of the term elastic in the naming of Amazon’s EC2 is significant. The elasticity refers to the ability that EC2 users have to easily increase or decrease the infrastructure resources assigned to meet their needs. The user needs to initiate a request, so this service provided isn’t dynamically scalable. Users of EC2 can request the use of any operating system as long as the developer does all the work. Amazon itself supports a more limited number of operating systems (Linux, Solaris and Windows) [69].

According to VMware, a pioneer of cloud computing, providing cloud computer resources as infrastructure can reduce hardware and operating costs by as much as 50%, energy costs by 80% and reduce the time it takes to provision new servers by up to 70%. Additionally, it decreases downtime and improves reliability for the whole infrastructure and networks plans [71].

Platform as a Service (PaaS) model offers the services as operation and development platforms to the consumer with the facility to support the development lifecycle from design, implementation, debugging, testing, deployment, operation and support of rich internet applications (RIA) and online services. The consumer can use the platform to develop and run his own applications, supported by a cloud-based infrastructure. "The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations" [72].

Force.com, is an example of platform as a service offered from Salesforce providing a development platform that makes it very easy for developers to build multi-tenant applications. The applications run on the data centers of Sales force, so there is no necessity to take care of maintenance, security and back-ups [73].

Although PaaS has many benefits for customers, it's also has some disadvantages. The major drawback of Platform as a Service is that it may lock you in to the use of a particular development environment and stack of software components. Platform as a Service offerings usually have some proprietary elements (perhaps the development tools or even component libraries). Consequently, you may be wedded to the vendor's platform and unable to move your applications, elsewhere, without rewriting them to some degree. If you suddenly become

dissatisfied with your Platform as a Service provider, you may face very high expenses when you suddenly need to rewrite the applications to satisfy the requirements of another PaaS vendor [64].

For users, **Software as a service** (SaaS) offers the greatest appeal. SaaS offers benefits that are simply not available from applications that already running on your own personal computer. With cloud computing service users potentially have access, from any computer with a browser, to applications that they could never own. Additionally, the burgeoning numbers of SaaS applications enable different users to create and collaborate on projects with people scattered around the globe, this technique simply based on your information in the cloud, where everyone can access it. SaaS applications will not be delivered as one huge chunk of codes, but rather as a set of individual services. Called Service Oriented Architecture, this method of building applications allows you to use the features you need, as you need them, without having to get your arms around all of the available features first [74].

One of the first implementations of cloud services was Software as a Service (SaaS) business applications that are hosted by the provider and delivered as a service. The Software as a Service layer offers purpose-built business applications. For instance, Google Maps, how it's delivered different maps to users which are essentially a map of the world. A multiple of Individual services attached to Google Maps include locating real estate for sale, rent, or lease; hotels and other accommodations; restaurants and other eateries; and points of interest, such as, museums and historical sites. Add to this, the services of driving directions, urban planning, land management and scoping out street level views of many cities, and you've got a robust set of applications that are accessible, informative interesting and available individually [74].

3.5. Cloud infrastructure lab service layer

We built the cloud infrastructure lab to work under the infrastructure as a service layer of cloud computing, and that was the main point in this thesis, but if we want to use this lab under the other layers, it will work with no problems, so if we use it to work under the infrastructure as a service layer, it can delivers any computer resources, such as, (servers, networking technology, storage, and data center space) as a service. Under the platform as a service layer, the IT cloud lab can also deliver the required server specifications with preinstalled operating systems and connected to the required network devices. And finally, referring to software as a service layer the IT cloud lab can help and deliver the required software that installed on the needed platform and server specifications.

Chapter 4

4. Technological Realization of the Cloud infrastructure Lab

Cloud infrastructure Lab required systems, development environment and implementation

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4.1. Introduction

As we discussed before, in sector (1.5.1. Conventional Lab (Hands-on)), in many computer engineering and IT departments at universities, educational labs for instructing operating systems and networks suffer the absence of the costly high-quality IT infrastructure, such as, servers and high-speed network components that are necessary to teach their students the state-of-the-art IT technologies.

Nowadays, it's very difficult to find a lab for the purpose of teaching operating systems and computer networks, including all types of devices that must be available in the same place.

To explain how much we pay to have such a conventional lab. According to my experience, we built a complete infrastructure lab with a normal budget using $200,000 in which this lab includes the following devices:

- Blade server with more than 4 servers, including licenses and fiber SAN switches.
- Backup Tap library coming with backup software and LTO6 tapes.
- Unified threat management device and ASA firewall.
- About 20 PCs, 2 workstation PC and 1 workstation laptop.
- 2 main routers, 2 core switches and 4 (layer 3 switches).
- Preparing a server room with 42U rack, fire alarm, access control systems, smart UPS (10K), CCTV cameras with DVR and 2 air conditions.

It is usually cost-intensively to give company employees or students of IT infrastructure labs the opportunity to get the appropriate needed training on a hybrid IT infrastructure consisting of different operating systems, such as Linux, Windows, AIX etc. These operating systems run on various costly servers that are coupled through different network components and devices manufactured by different companies, such as, CISCO, 3Com etc. Until this point, the training objectives can be achieved without the necessity of traveling. This can happen only by using a simple interface mediating the required lab to be tested or to be studied in the form of a set of experiments to mediate the desired network or operating system training.

In many countries, big companies with many branches can offer many courses sessions for its employees without spending much amount of money and time on arranging a session with all of its requirements, like tickets, hotels and others. Therefore, providing infrastructure lab, as service solutions from a provider company for enterprises, makes it easier regarding expenditures and management. That is because, it is not necessary for these enterprises to invest in buying very expensive infrastructure for teaching and training operating systems and networks [75].

A solution for the previous discussed problems depends on different tools cooperating with each other, to support the idea of building different types of network topologies that depend on the could computing technology.

4.2. Case Study: A simple lab for teaching network topologies

According to my experience, Most of the educational IT infrastructure labs in Palestine are not suitable for teaching IT and computer engineering students. That is because of the absence of appropriate lab equipment, such as, powerful platforms and network components caused through

budget limitations. This leads to enforce trainees are to travel abroad in order to get advanced trainings in IT infrastructures, which requires a lot of money for travelling and living budget. Providing such trainings, as a cloud service, will not only bypass such dilemmas, but also the IT department of an enterprise or the IT academic institutions will save big amount of money, as there is no necessity to purchase such expensive systems.

As an example, having the intention to provide a simple and real experiment of a network topology containing a router, a switch, a server and some personal computers (See Figure 3) for a group of students, will require a very huge amount of computing systems and network devices that necessitate a very big budget without using the cloud computing technology [75].

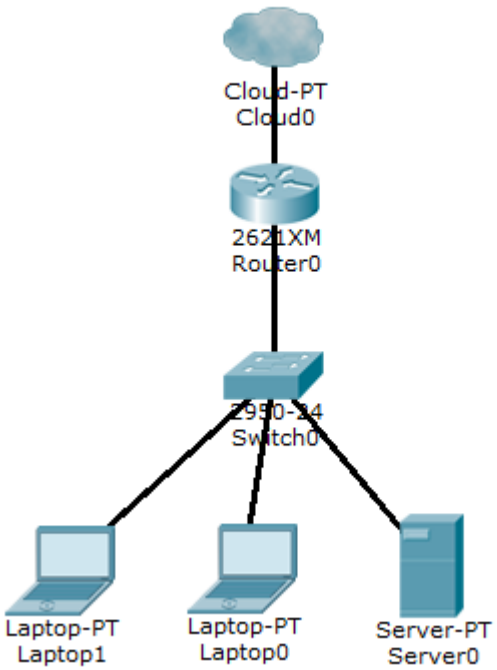

Figure 3. A simple lab for teaching network topologies

Normally for work in a conventional lab, the educational IT institute must provide the appropriate lab equipment needed to configure different network topologies. The required

network skills and configuration needs to build any of the network topologies. However, even simple ones will be more complex for students without practical experience.

To solve the availability of equipment needed for different network topologies, we use computer and server machines by using VMware packages for enterprise solutions. These packages help us provide cloud and virtualization software, as well as, services for building virtual machines. In addition to the ability of VMware packages to support hosting different operating systems for desktop software machines, they are also capable to be the virtualization basis for different server machine using VMware vSphere and VMware server [33]. Network devices are not supported by VMware products, therefore, the researcher use an open source program called GNS3, which allows us to deal with and manage network devices, such as, routers, switches, firewalls and others that are used in our cloud lab. It uses only real operating systems for network devices that are the same as the ones installed on real hardware routers.

4.3. Virtual Machines

A Virtual Machine (VM) is a software implementation of a computing environment (Machine) that executes programs emulating a physical machine in which any operating system or program can installed or run.

The virtual machine typically emulates a physical computing environment which is managed by a virtualization layer, which translates hardware resources needed by the virtual machine, like CPU, memory, hard disk, network and any other needed resources to the underlying physical hardware.

Virtual machines are separated into two major classifications that are mainly based on their use and how they correspond to any real machine [76]:

- A system virtual machine provides a complete system platform, which supports the execution of a complete operating system (OS). These, usually, emulate an existing architecture, and are built with the purpose of, either, providing a platform to run programs where the real hardware is not available for use, or of having multiple instances of virtual machines leading to more efficient use of computing resources, both in terms of energy consumption and cost effectiveness.

- A process virtual machine (also, language virtual machine) is designed to run a single program, which means that it supports a single process. Such virtual machines are usually closely suited to one or more programming languages, and built with the purpose of providing program portability and flexibility. For that, the software which is running inside is limited to the resources and abstractions provided by the virtual machine.

System virtual machine can provide numerous advantages over the installation of OS's and software directly on physical hardware [76][77]:

- Multiple OS environments can co-exist on the same computer and are in strong isolation from each other, ensuring that applications and services that run within a VM cannot interfere with the host OS or other VMs.

- VMs can also be easily moved, copied, and reassigned between host servers to optimize hardware resource utilization.

- Administrators can also take advantage of virtual environments to simply backups, new deployments, application provisioning, maintenance, high availability, disaster recovery and basic system administration tasks.

- The virtual machine can provide an instruction set architecture (ISA) that is somewhat different from that of the real machine.

- The use of virtual machines also comes with several important management considerations, many of which can be addressed through general systems administration best practices and tools that are designed to manage VMs.

Some main disadvantages of virtual machines can be summarized as follows:

- Virtual machine is not as efficient as the real one, when accessing the hardware.

- When multiple VMs are concurrently running on the same physical host, each VM may exhibit a varying and unstable performance, which is highly, depends on the workload imposed on the system by other VMs.

4.4. The Leading Virtual Machine Solutions

Developers and power users often want to test and run different applications created for multiple operating systems on a single machine. Those who have worked in the IT field are usually familiar with how to run many operating systems on a single piece of hardware for just this purpose. In enterprise environments, the primary way to do this is through virtualization. Most modern computers are powerful enough to run the entire operating systems within your

main operating systems, which mean that virtual machines are more commonplace today than ever. Here's a look at the most popular virtual machine solutions.

4.4.1. Virtual Box (Windows/Mac/Linux, Free)

Virtual Box is a general-purpose full-virtualized solution for x86 hardware. It is not only a tool equipped with extremely rich features for providing high performance for enterprise customers, but also the only professional solution that is freely available as, Open Source Software, under the terms of the GNU General Public License (GPL) version 2. Virtual Box is being actively developed with frequent releases, and has an ever growing list of features for supporting guest operating systems and platforms they run on.

Presently, Virtual Box referring to the official website runs on Windows, Linux, Macintosh, Solaris and others. It is capable to host and support different versions of the previously mentioned operating systems.

In order to run Virtual Box on a machine, the following must be fulfilled [78]:

- A powerful **x86 hardware.**
- **Needed Memory.** The size of memory depends on the type of guest operating systems the user wants to run, at least 512 MB of RAM (the more the better). In this context, you will need whatever your host operating system needs to run comfortably, plus the amount that the guest operating system needs.
- **Hard disk space required.** A typical installation will only need about 30 MB of hard disk space; the virtual machines will require fairly huge files on disk to represent their

own hard disk storage. Therefore, to install Windows XP, for example, you will need a file that will easily grow to several GB in size.

4.4.2. Parallels (Windows/Mac/Linux, Premium)

It program is a well-designed software that delivers desktop virtualization to both beginners and advanced virtualization users. While, Parallels is most associated with Macs, there is a version for Windows and Linux systems. With Parallels Desktop, you can run Windows, Linux, MS-DOS and Solaris as a guest operating system on the main operating system.

Parallels solutions help users to run and access applications they need on a variety of platforms. Parallels enterprise solutions include the Parallels Management Suite plug-in for Microsoft System Center Configuration Manager (SCCM) [79]. SCCM 2007/2012 became a universal and comprehensive cross-platform solution to manage Macs and PCs. Additionally, Parallels adding iOS and Android support to Parallels Management to easily manage PCs, Macs, iPads, iPhones and Android devices through one infrastructure management solution.

With parallels workstation, it is possible to install and use 32-bit and 64-bit guest operating systems on host computer, easily share files, devices and other resources between operating systems. Additionally, it is also easy to copy and paste text and drag and drop objects between host OS and guest OS programs, transfer the operating system and all your data from a remote Windows or Linux computer, and use them on your host computer etc. In order to run Parallels Workstation on a machine, the following computer configurations is needed [80]:

1. Minimum 1.66 GHz x86 (32-bit) or x64 (64-bit) CPU that supports the Intel VT-x hardware virtualization technology in order to run 64-bit guest operating systems.

2. A real memory with a capacity of 2 GB RAM minimum. 4 GB RAM or more is recommended.

3. A hard disk space of 350 MB for the Parallels Workstation installation and about 30 GB of hard disk space for each virtual machine.

4.4.3. Windows Virtual PC

Formerly known as, Virtual PC, it is a virtualization program for Microsoft Windows. Virtual PC exists solely to emulate other -usually earlier- versions of Windows [81]. If a user need to run an application that only works under Windows XP or test software for backwards compatibility with Vista or windows 7, Windows Virtual Machine has the solution. It's limited, yes, but for people working in a strictly Windows environment it gets the job done [82].

Windows Virtual PC (successor to Microsoft Virtual PC 2007, Microsoft Virtual PC 2004, and Connectix Virtual PC), is the latest Microsoft virtualization technology. You can use it to run more than one operating system at the same time on one computer, and to run many productivity applications on a virtual Windows environment, with a single click, directly from a computer running Windows 7.

Microsoft released an update to Microsoft Virtual PC, which allows it to run on PCs without hardware support. Windows Virtual PC is available free of charge for certain editions of Windows 7, either pre-installed by OEMs or via download from the Microsoft website.

System requirements for Windows Virtual PC:

1. Computer running Windows 7 (all editions except Starter).

2. **Processor:** Intel®, AMD®, VIA® processors capable of hardware-assisted virtualization, with the setting turned on in the BIOS.

3. **Memory:** 2GB of memory recommended.

4. **Hard disk requirement:** 20MB hard disk space for installing Windows Virtual PC. Additional 15 GB of hard disk space per virtual Windows environment recommended.

4.4.4. VMware (Windows/Linux, Basic: Free, Pro: Premium)

VMware is an American software company that provides cloud and virtualization software and services [83]. VMware known as the biggest pioneer in cloud computing area has a complete package of applications that can host any operating system in a pool with the desired security using special APIs, namely VCloud API which allows programmatic access to cloud infrastructure. The Company's suite of virtualization solutions addresses a range of information technology (IT) issues that include facilitating access to cloud computing capacity, business continuity, software lifecycle management and corporate end user computing device management. Its solutions are based upon its virtualization technology and are organized into three main product groups: Cloud Infrastructure and Management; Cloud Application Platform, and End-User Computing.

Virtualizing a single physical computer is great, but the real power of virtualization comes into play when you build an entire virtual infrastructure, improving application availability and agility while simplifying management. VMware offers the highest performing and most scalable virtualization platform in the industry for even the most resource-intensive business critical applications at the lowest TCO [84]. VMware virtualization solutions are built on a robust

foundation proven in production environments and chosen by over 250,000 customers [85]. VMware pioneered x86 server virtualization over ten years ago and our continuous innovation has brought capabilities to our latest VSphere 5 release that are years ahead of competitors such as Microsoft, Citrix and Red Hat.

VMware's desktop software runs on Microsoft Windows, Linux, and Mac OS X, while its enterprise software hypervisors for servers, VMware ESX and VMware ESXi, are bare-metal hypervisors that run directly on server hardware without requiring an additional underlying operating system.

Some VMware products is listed below ➔

1. Desktop Software:

    - VMware Workstation: Winner of more than 50 industry awards, VMware Workstation is recognized for its broad operating system support, rich user experience, a comprehensive feature set and high performance. VMware Workstation is designed for professionals that rely on virtual machines to get their job done [86].

    - VMware Fusion: Fusion allows Intel-based Macs to run operating systems, such as Microsoft Windows and others on virtual machines. With fusion, it's easier to have access to your windows applications and all files from your old PC directly on your MAC, whenever you need them [87].

    - VMware Player: it is a virtualization software package supplied free of charge; also an advance version of player called player plus which supports more

advance features is supported by VMware group. Player Plus is the best way to deliver a managed desktop to all users, contractors, partners or customers. Instead of buying and shipping hardware, simply provide VMware Player Plus along with a virtual machine containing your standardized desktop image [82].

2. Server Software:

- VMware vSphere (Called "ESXi"): is an enterprise-level computer virtualization product offered by VMware. ESX which is the old version of ESXi is the type 1 hypervisors which run directly on the host's hardware to control the hardware and to manage guest operating systems without requiring an additional underlying operating system.

- VMware Server (Called GSX server): it is a server virtualization program for Windows and Linux that facilitates the remote management, provisioning and standardization of platform.

- VMware vCenter server: it provides a centralized platform for managing your VMware vSphere® environments, automates and delivers a virtual infrastructure with confidence. It has the most important feature that VMware vCenter Server allows for the management of multiple ESX servers and virtual machines (VMs). They can be from different ESX servers through a single console application that we need in our server farm [88].

3. Cloud Management Software:

- VMware vCloud: it is a cloud computing initiative from VMware, which will allow customers to migrate work on demand from their "internal cloud" of cooperating VMware hypervisors to a remote cloud of VMware hypervisors. The goal of the initiative is to provide the power of cloud computing with the flexibility allowed by virtualization [89].

- VMware Go: it is a web-based service to guide users of any expertise level through the installation and configuration of VMware vSphere Hypervisor [90].

4.5. GNS3 Solution

GNS3 is open source (GNU GPL) software that simulates complex networks while being as close as possible to the way real networks perform [91]. It is to note that all of this is achieved without having dedicated network hardware such as routers and switches. GNS3 provides an intuitive graphical user interface to design and configure virtual networks; it runs on traditional PC hardware and may be used on multiple operating systems, including Windows, Linux, and MacOS X. In order to provide complete and accurate simulations, GNS3 actually uses the following emulators to run the very same operating systems as in real networks [86]:

- Dynamips, the well-known Cisco IOS emulator.

- Virtual Box runs desktop and server operating systems.

- Qemu is a generic open source machine emulator, which runs Cisco ASA, PIX and IPS.

The excellent feature founded in GNS3 is the ability to be an alternative or complementary tool to real labs for network engineers, administrators and people studying for certifications such as CCNA (Cisco Certified Network Administrator), CCNP (cisco Certified Network Professional), and CCIE (Cisco Certified Internetwork Expert). It can also be used to experiment features or to check configurations that need to be deployed later on real devices [91].

The unique excellent features included in GNS3 is the instance connection of virtual network to real network equipment that we use it in our experiments to be the main player in build connections between virtual and real equipment using two globally supported methods:

1. The first method is to bind every virtual router interface that needs to be connected to a switch to a dedicated physical interface on your host. Each dedicated interface then is connected to a real switch port.

2. The second method is to create a connection trunk between your virtual network and a physical "breakout switch". Each virtual router interface gets assigned to a VLAN (tagging occurs on the host). The breakout switch receives tagged traffic via the single physical trunk link and distributes the VLANs accordingly to real switches [91].

4.5.1. Connecting GNS3 Solution to a real network

One of the interesting things about GNS3 is that the user can connect any network topology to the real world. In different network courses, such as, CCNA and CCNP courses, the user may need to run an actual Web browser or Cisco's Security Device Manager (SDM) among others to manage the different cisco devices configuration. The user just needs to connect the network topology to a real PC. Additionally, the user could even connect to virtual machines running on

your computer inside VMware or Virtual PC. In our simple experiment in Figure 3, we tried to connect Windows and Virtual machines' server to the network devices including Cisco router and switch using this feature. Connecting a virtual topology running within GNS3 to real devices is very exciting, but again, throughput is going to be limited compared to using real equipment for the entire topology. It only makes sense to use GNS3 in a lab environment and for learning purposes [91]. Using GNS3 provide a very handy ability to capture traffic that is (Network packets) sent between emulated devices. Packets are written to a capture file on disk, which can then be opened with a packet analyzer like Wireshark. See Figure 4 (GNS3, 2013). We can use this feature to troubleshoot network problems, examine security problems and the most important feature is to learn network protocol internals.

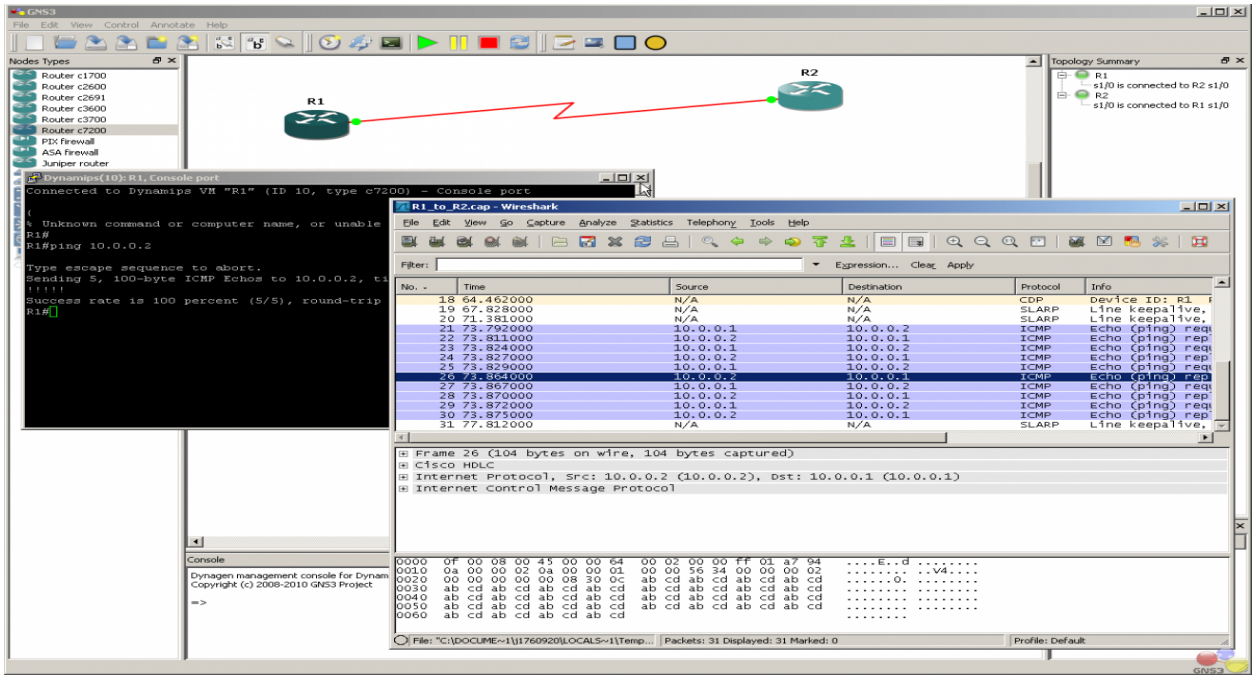

Figure 4: Testing GNS3 and packet captures using Wire shark (Gns3.net, 2013)

GNS3 uses the SVG technology (Scalable Vector Graphics) that has been used to provide high quality symbols for designing your network topologies, as shown in Figure 5. It shows the

implementing of our simple experiment and reflects the connections between a Cisco Router c2600, Ethernet switch, local cloud and the Internet cloud in a very simple way.

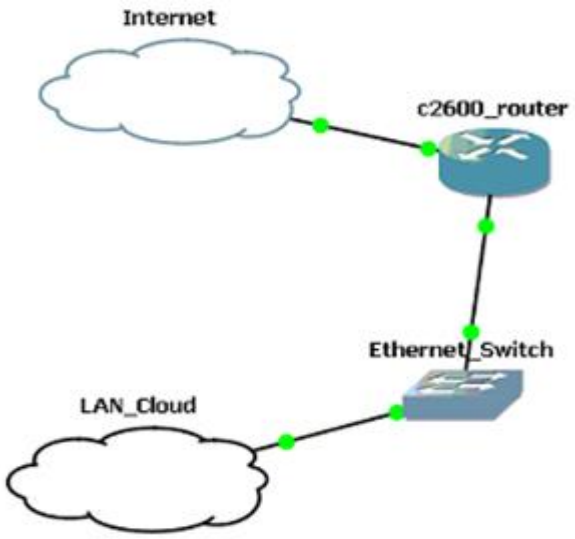

Figure 5: Implementing the experiment on the GNS3

4.6. Cloud environment development and implementation

In planning and development the cloud environment for building IT infrastructure lab, we tried to choose the best useful software and open source packages. Therefore, we tried a dozen of software packages and hosting applications to help us in designing the required cloud environment. Our decision had been made to the VMware packages tools with GNS3 environment which has a Cloud Node Type, that can be easily configured to communicate with any network adapter installed on the computer in which GNS3 is running.

VMware ESX platform and GNS3 play a central role in making the cloud environment very handy, and in allowing us to test and evaluate solutions before live implementation on operational work. By default, each of those platforms is separate; however, both of them have

components which allow integration. This means that it is possible to have virtual machines hosted on VMware ESX to communicate with Network equipment which is running on GNS3. The most important key is that we can build multiple ESX environments including the GNS3 solution and manage it and all virtual machines included by VMware vCenter Server through a single console application.

4.6.1. Building the single ESX Server Environment

At the beginning, we choose to apply the cloud environment on a real server farm, which contains many required network equipment needed by any IT student in order to apply and test both simple experiments and advance network environments. Moreover, the server farm includes many different operating systems hosted on different real servers, virtual servers, network routers, different brand name switches, ASA cisco firewall, unified threat management, storage system and backup library solution that all are to be used in our cloud lab.

We use to host the ESX environment (the new version called "ESXi") on a dell server with the specifications shown in Figure 6.

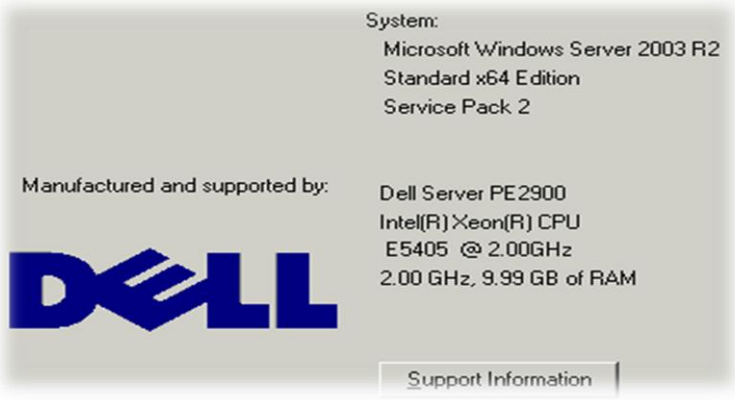

Figure 6: Production Server Specs

Within a virtual machine based on a production server of the IT department of the Ministry of Awqaf, the cloud infrastructure lab was built using a VMware workstation to host the ESX environment with the conclusion that there were no conflicts of the daily work on this server. Fortunately, we had the permission to use this server because it is a 64-bit machine that requires for the ESXi environment. The operating system running on this system is Windows server 2003. The internet used in this lab was a dedicated 8M Microwave link.

From my experience in using the virtual machines, for sure if we use another high performance server with higher specifications like RAMs and CPUs, the performance and workload will be much better and faster in responding time. Also using a higher windows version like windows server 2008 or 2012, will be more stable referring to the compatibility for these windows versions with virtualization more than with windows server 2003. In addition, using a higher speed internet link than 8M will make the trainee more comfortable when dealing with the cloud infrastructure lab.

After having installed the VMware workstation, we build a virtual machine environment to host the ESX server 4.1 using Red Hat Enterprise Linux 5 (also RHL 6 is accepted) with the specifications shown Figure 7.

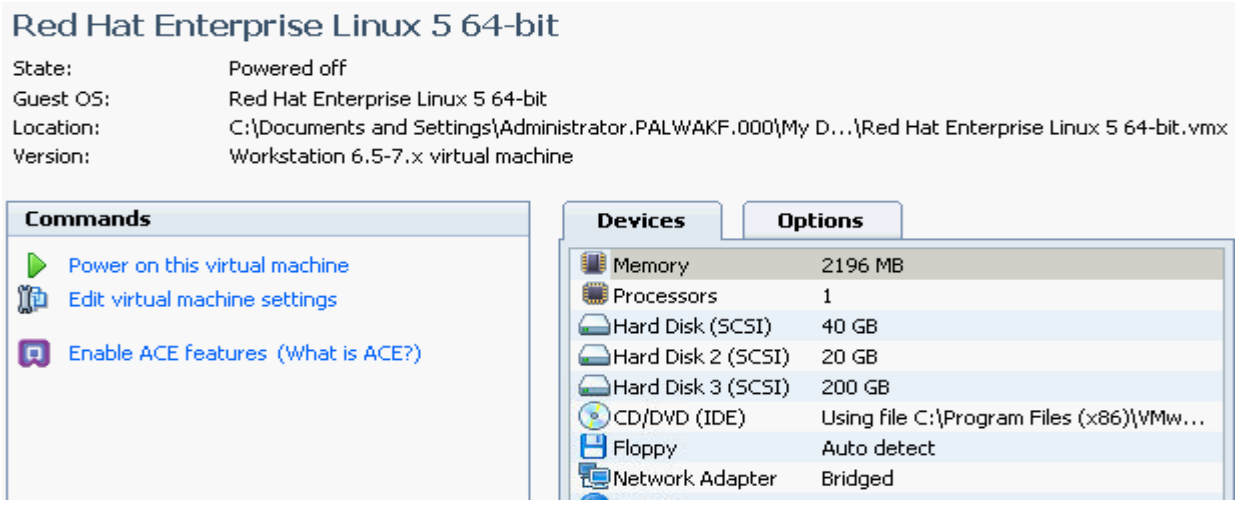

Figure 7: Virtual machine for hosting the ESX

In a further step, the ESX server was hosted on the VMware workstation with a static IP address required for connecting the VSphere client with the server using the graphical user-interface. Figure 8 shows the result after hosting the ESX main screen and Figure 9 shows the ESX console.

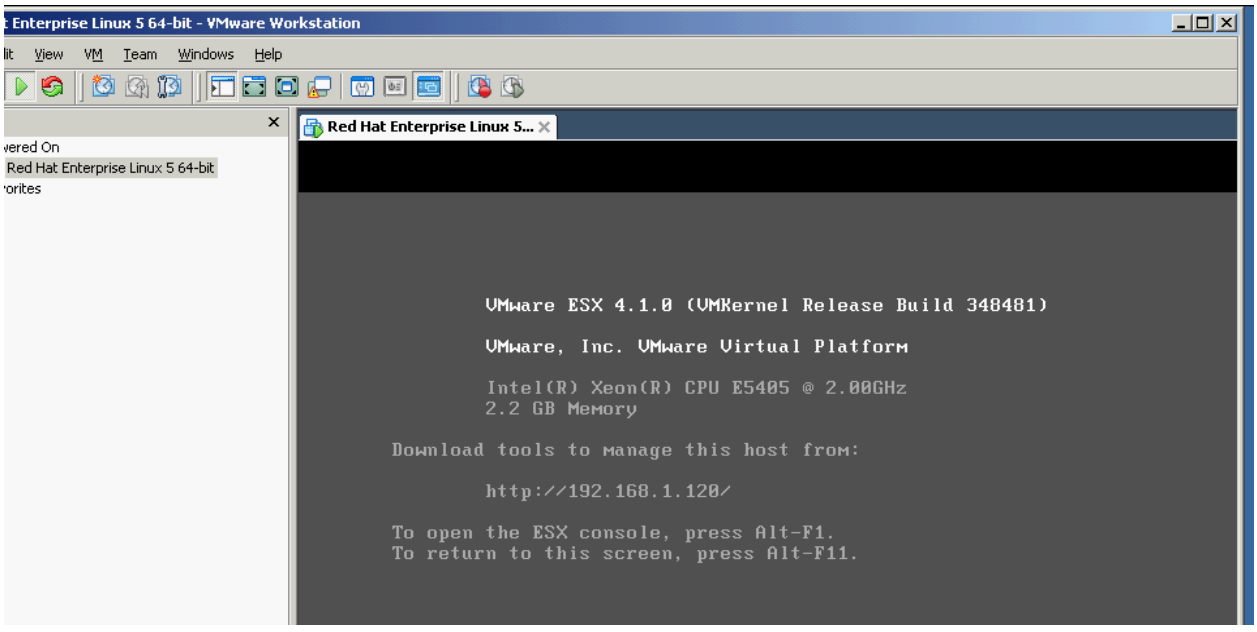

Figure 8: ESX Server installed on the virtual machine

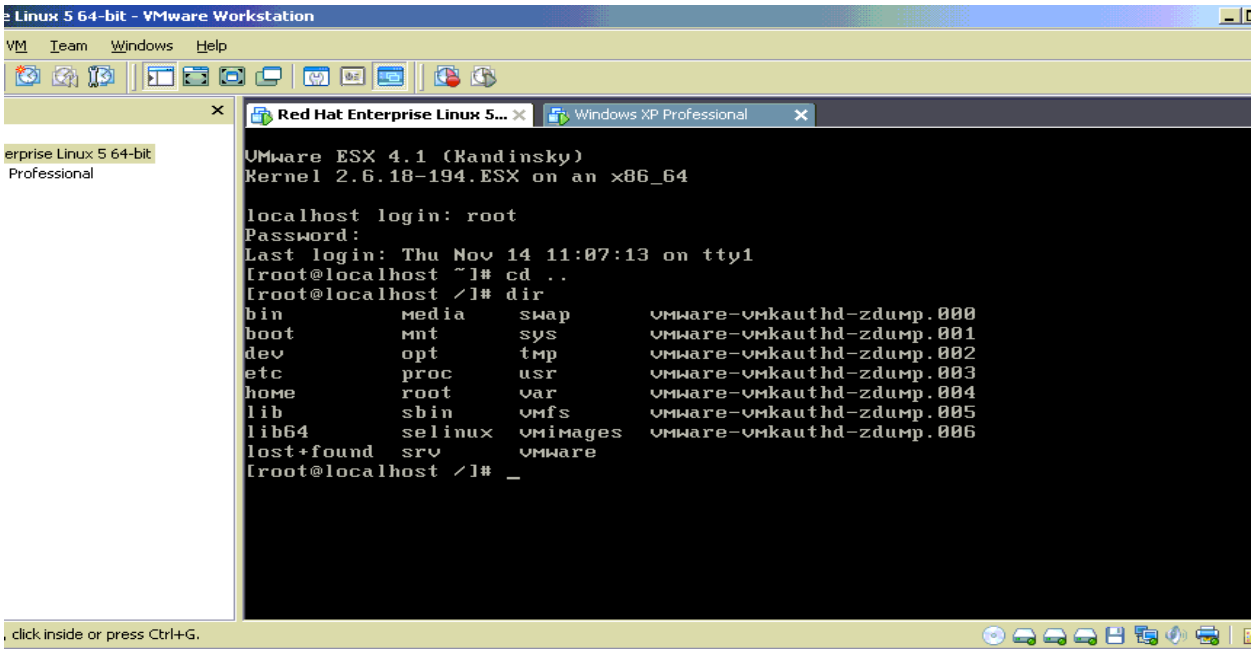

Figure 9: ESX console (command line - TTY)

4.6.2. Preparing the experiment equipment

As shown in Figure 3, the simple experiment contains 1 router, 1 switch, 1 file server, and 2 personal computers connected to the Internet. In the first step, we connected to the ESX server using VMware vSphere client. Figure 10 shows the vSphere window that used from a personal computer founded in the IT department to design the experiment; VSphere remote windows were used to build the required operating systems and the network devices, see Figure 11.

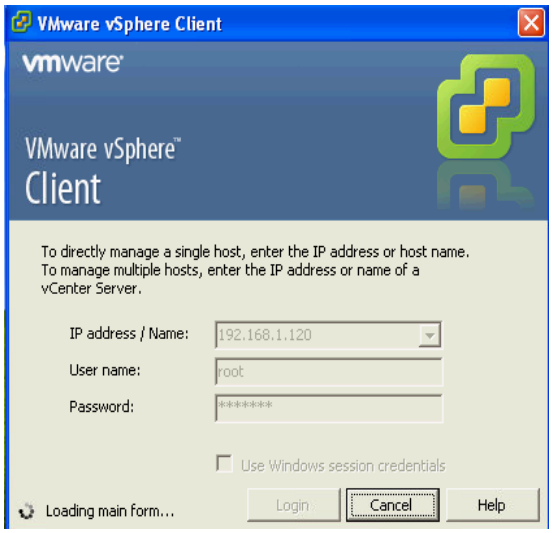

Figure 10: Access the ESX server using vSphere client

We started to build new resource pool which contains all operating systems required for the experiment and we called it Haj_IT pool. We, also, deployed the vShield manager which is a centralized network management component of the build in VMware application vShield that work as an Endpoint offloads antivirus and anti-malware agent processing to a dedicated secure virtual appliance delivered by VMware partners. After that, we installed the required operating systems by building the required virtual machines in Haj_IT pool, and specifying both space and operating system required for each one, see Figure 11. For our experiment, different components were necessary, namely, a virtual machine for Windows server 2003, two copies of Windows XP for two virtual machines, and finally the GNS3 solution required a virtual machine, see Figure 11 and Figure 12.

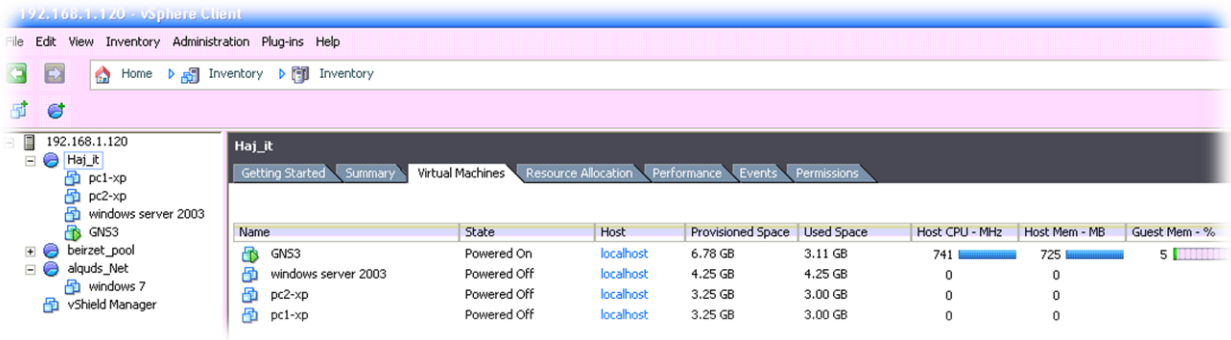

Figure 11: Build the experiment virtual machines

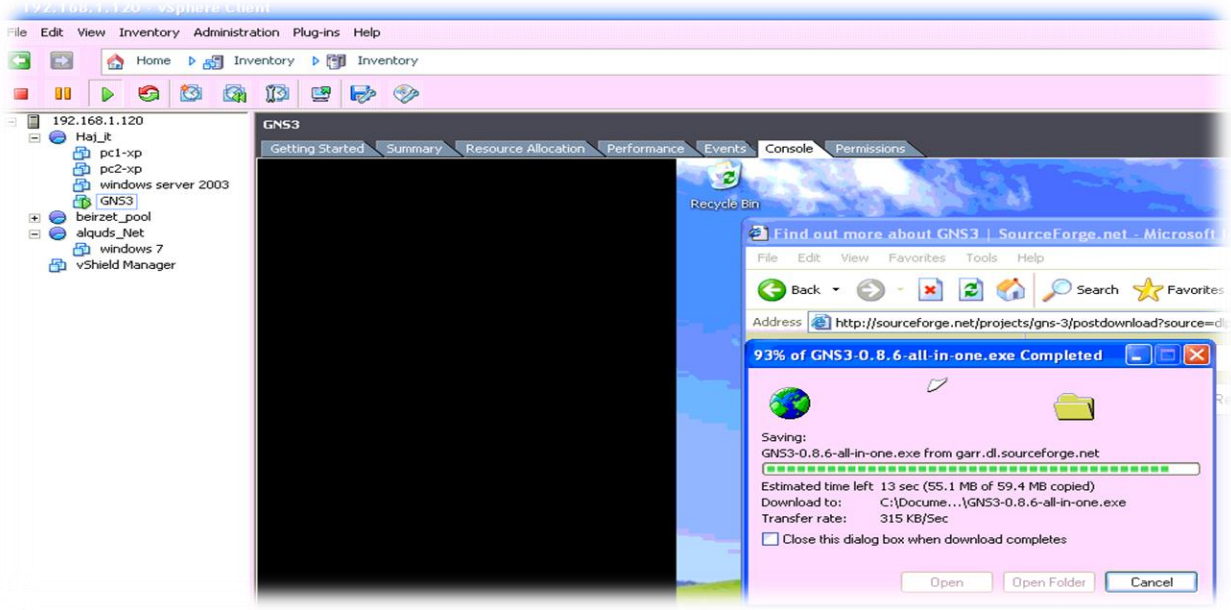

Figure 12: Preparing the GNS3 remotely by IT department

After having installed the GNS3 solution on the virtual machine, it was necessary to download and import all real IOS Cisco packages for different routers and ASA firewalls, for sure with the real Cisco IOS. However, we can do all the needed configurations with no virtual restrictions that we face in virtual routers. Before we start, we should make sure all the images we want to add have been UNCOMPRESSED using Cisco image unpacker binary for Windows. See Figure 13 below.

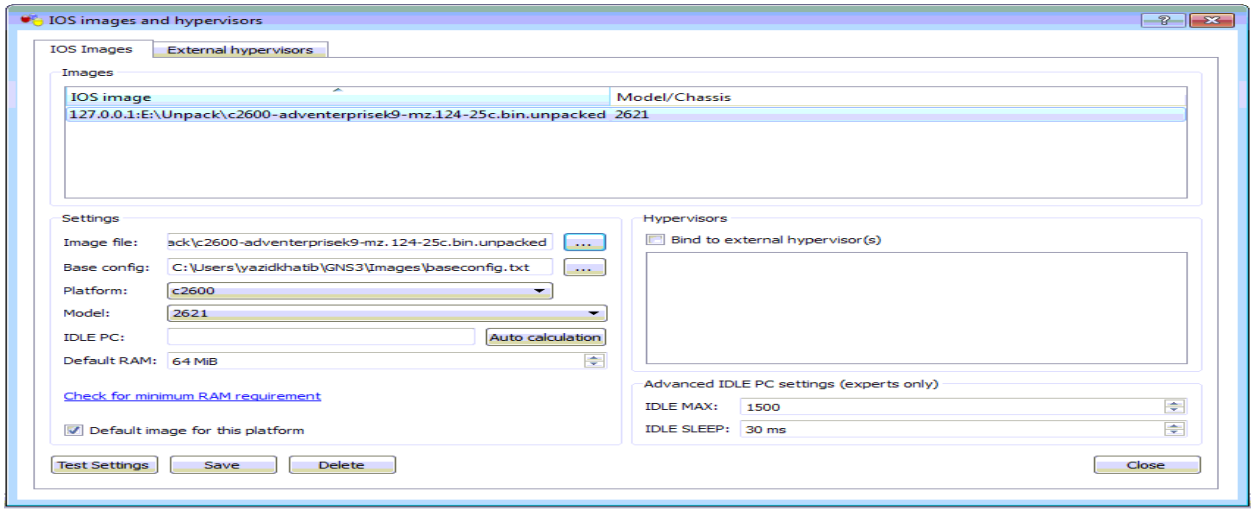

Figure 13: Importing the real Cisco IOS to the GNS3

4.6.3. Implementing the experiment

To design the required experiment, we used in our test the Cisco c2600 router, as an example for using routers, not a specific device that used only with this cloud lab. Hence, we import the router IOS (model 2621), and Ethernet switch to the work desk in the GNS3. Then, we import it through the LAN_Cloud node which used to connect the topology to the real network, and also, to the virtual machines. In this experiment, we connect the network devices to the virtual machines (2 Windows xp, 1 Windows server). Figure 14, shows how all virtual machines can be connected both to each other and to the Internet through a Cisco c2600 router, which is configured to access the Internet through a software Internode node specified for this purpose use.

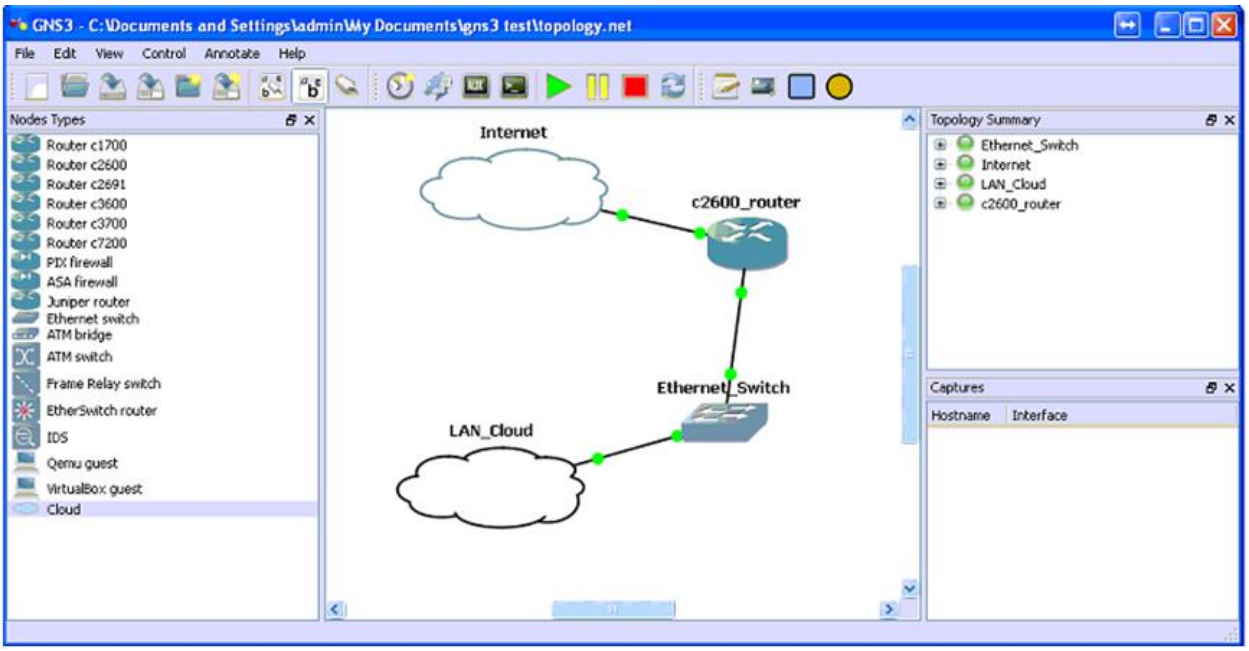

Figure 14: Implementing the experiment in the GNS3

In addition to the previously achieved configuration, all virtual machines in Haj_IT pool can be connected with a VSphere virtual switch, which is also connected to the server service console, in which it enables the system administrator to access and maintain the cloud system, see Figure 15. An extraordinary property of the achieved cloud system is that all built virtual machines can be connected to other external real network devices through the Cisco router c2600 in the GNS3 virtual machine.

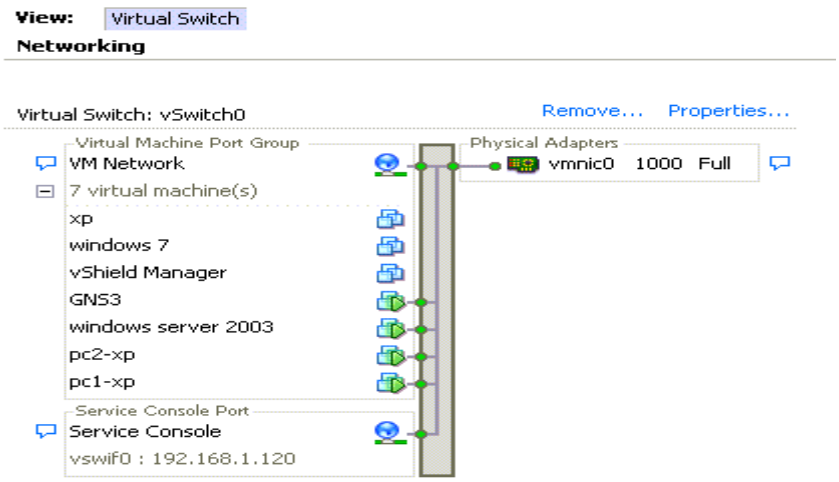

Figure 15: Connect the virtual machines through virtual switch

An IT specialist is needed for any experiment design to prepare and build the infrastructure. Users can connect to the infrastructure and then start configuring and connecting the different virtual machines. Figure 16, shows the different windows necessary to build and configure the cloud lab platform.

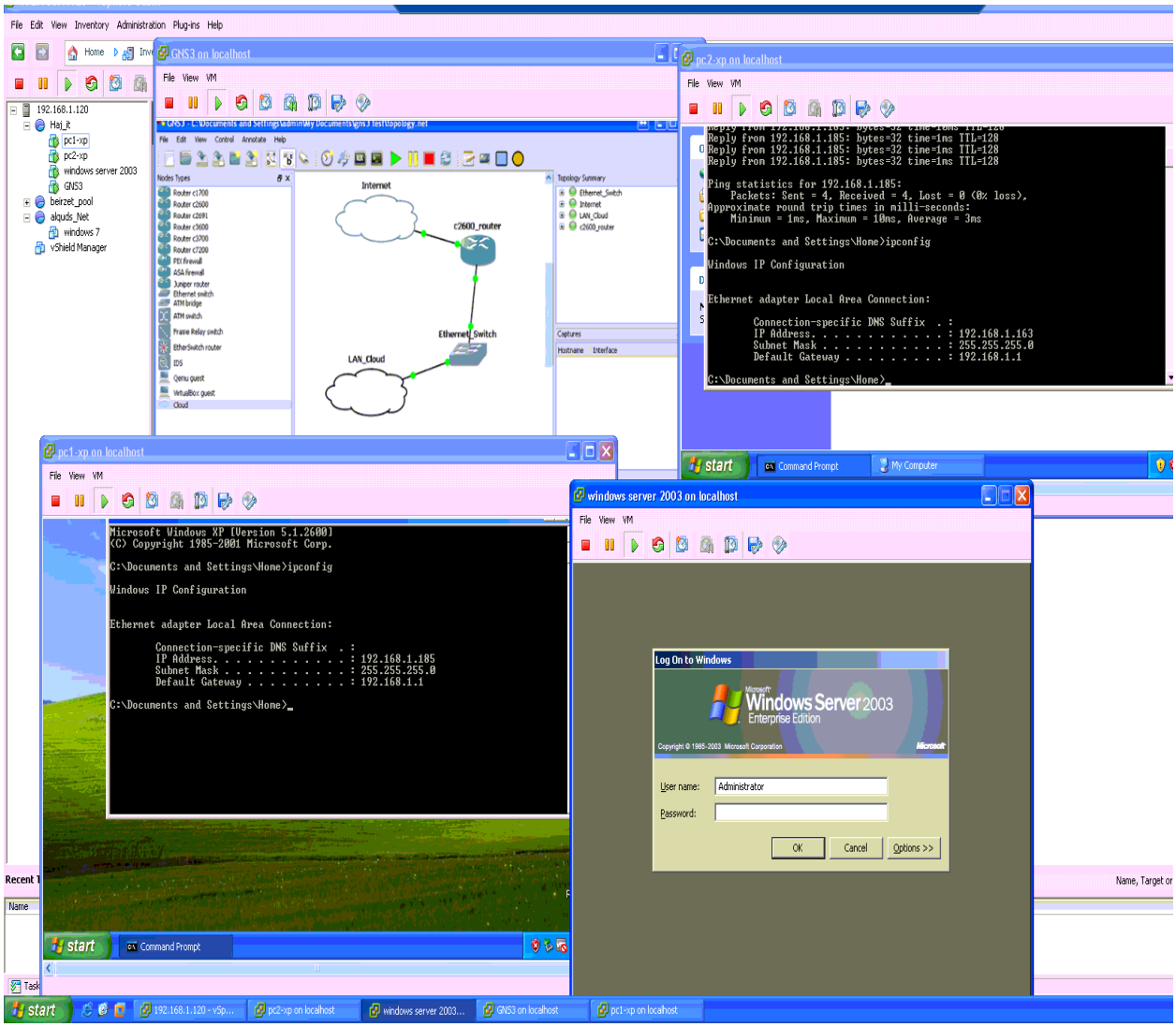

Figure 16: Implementing the cloud lab environment

Figure 16, shows that there are many resource pools called beirzet_pool, alquds_net and Haj_IT. The experiment virtual machines designed and build only in the Haj_IT resource pool. We set the permissions called Haj_IT permission for the required users to work on and test it. In addition, we can set permissions for the supervisor to be with or without the ability to access and help or just monitor the users' configuration for this experiment, see Figure 17.

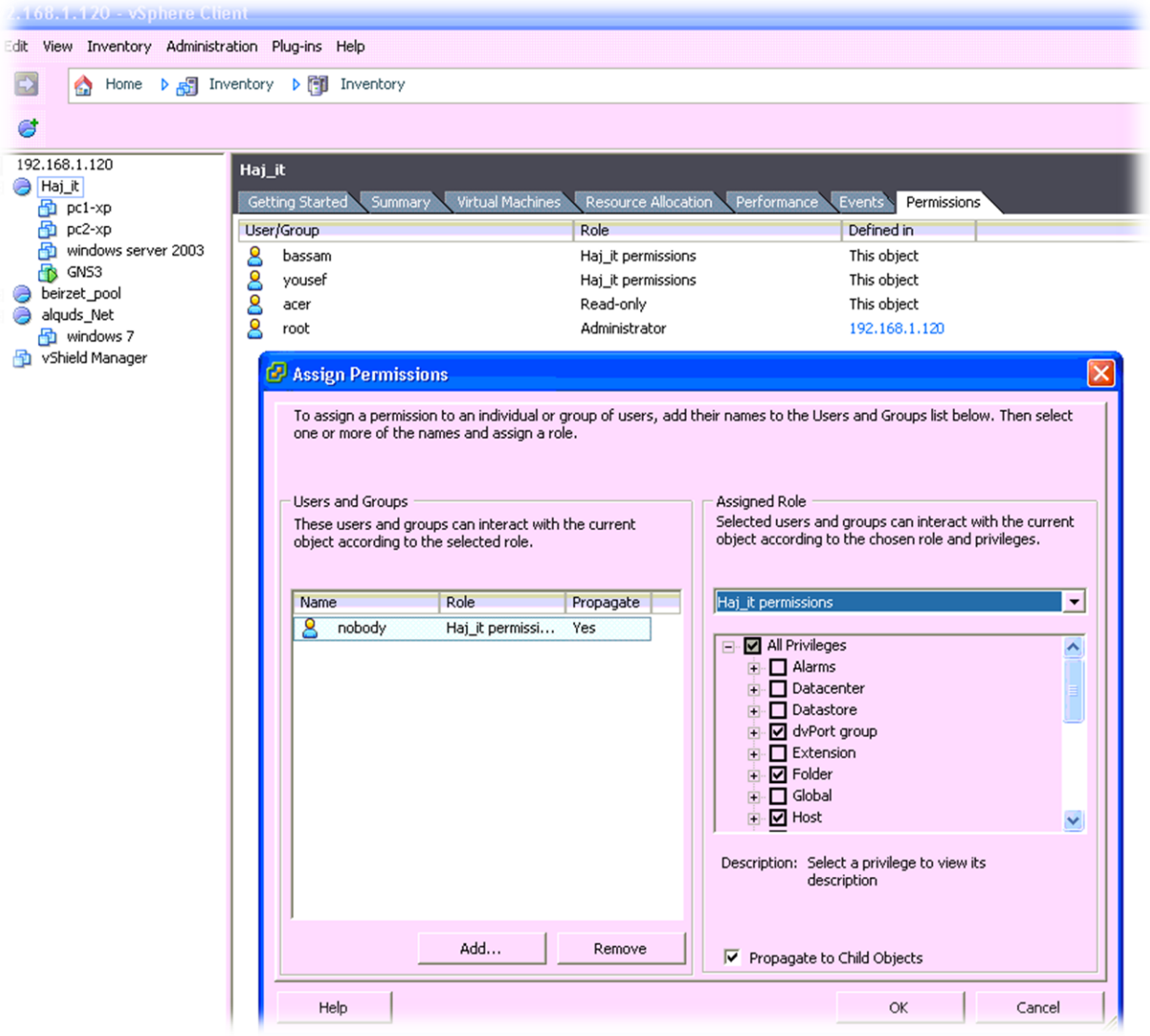

Figure 17: Add permissions for Haj_IT pool users

4.6.4. Cloud lab infrastructure architecture

A detailed architecture of the cloud environment for building IT infrastructure labs is presented in Figure 18. It not only shows the different subsystems and how the information flows within the distributed cloud system, but also presents interactions between the different system users such as system administrators, lab designers and students as well. The scenario for creating

an IT infrastructure lab is discussed in the next section (4.6.5. Cloud infrastructure lab block diagram and its

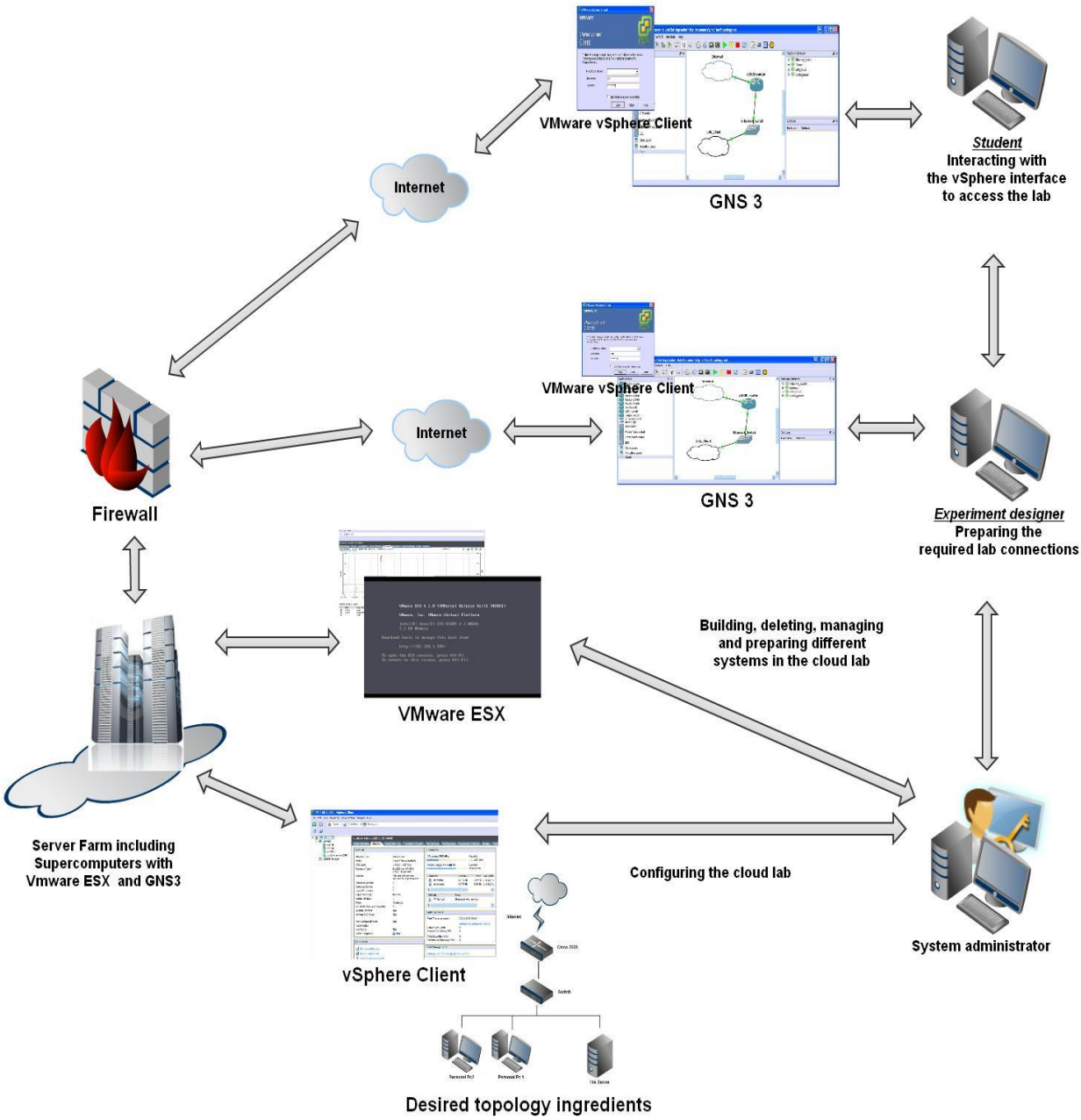

Figure 18: A detailed architecture of the cloud environment for building IT infrastructure labs

4.6.5. Cloud infrastructure lab block diagram and its scenario

Referring to the block diagram, Figure 19, the Cloud lab server farm is built to support the cloud technology. The IT administrators build the ESX environment by installing ESX platform on a powerful host server, and using iSCSI SAN, FC SAN, NAS/NFS and Direct Attached Storage. VMware ESX can facilitate and provide a virtualization layer that abstracts the processor, memory, storage and networking resources of the physical host into multiple virtual machines. The IT administrators can, also, add vCenter server service that acts as a central administrator for ESX hosts connected in the network, in which this service directs actions on the virtual machines and the hosts. VCenter Server helps IT administrators and gives them the ability to manage and control multiple ESX servers and virtual machines from different ESX servers through a single console application. In addition, many important features in vSphere required vCenter server such as VMotion, Storage VMotion, Distributed Resource Scheduler, VMware High Availability and Fault Tolerance.

ESX environment supported network devices by deploying GNS3 solution; it supports the configuration for different network device loaded with real IOS. That is because using a real IOS gives the reality and full functionality to the user. GNS3 also add a great solution to connect the real network devices with the virtual machines to give the ability to build different network topologies depends on different brands. The cloud server farm should be secured by different known security protectors like firewall and unified threat management.

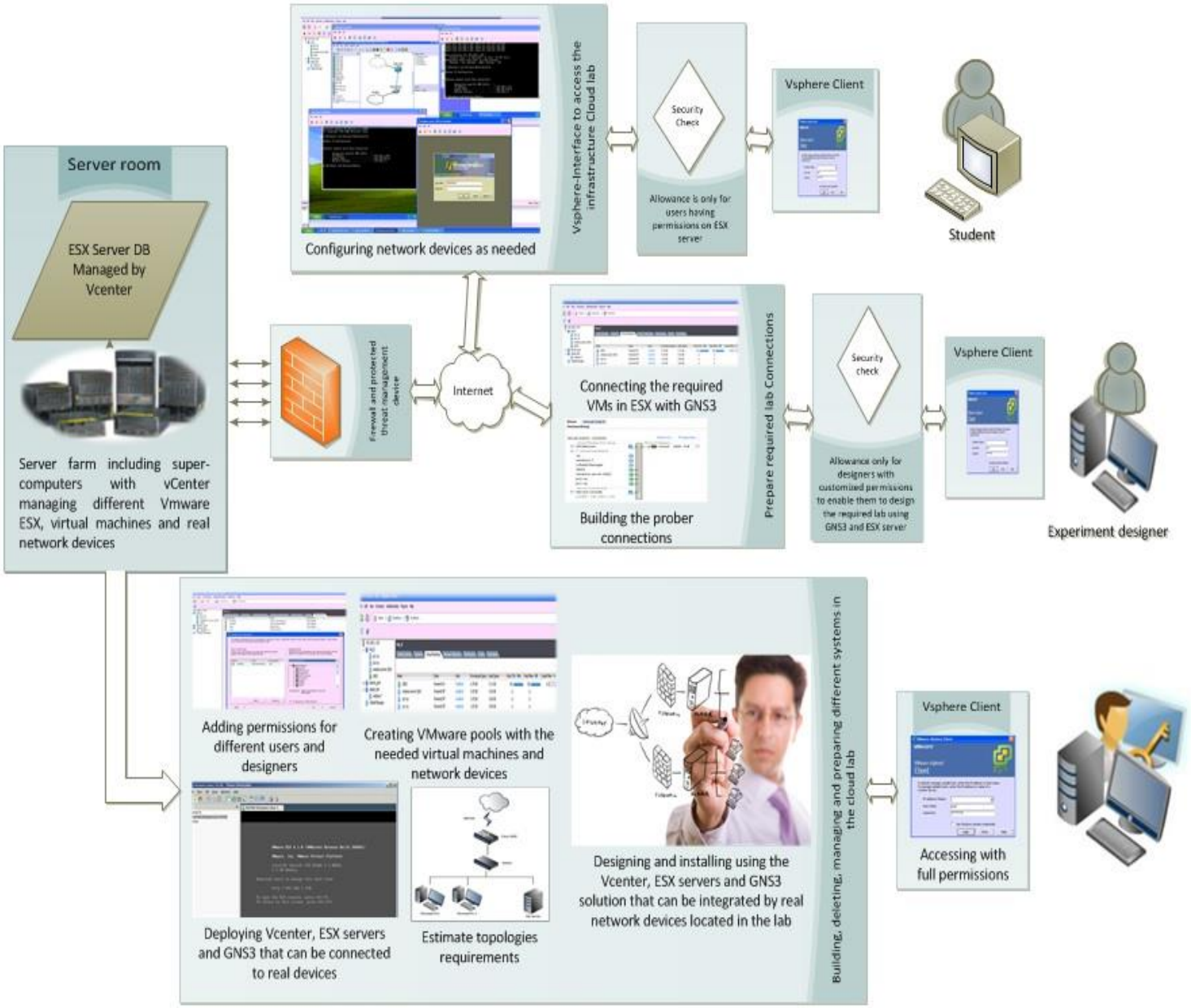

Figure 19: Block diagram for cloud lab infrastructure

In the following, the scenario for creating an IT infrastructure lab is discussed. If the student or trainer in an academic institution, or in a business enterprise intends to build an IT infrastructure experiment sampling the one presented in Figure 3, he must reflect his desires to the cloud system administrator through a facility designated for this purpose, so he can order the

desired design, details of the operating systems required, details of the network devices brand name, specification and the version of the desired IOS installed. In the case of our example, the system administrator must prepare a group of virtual machines containing two images of Windows XP, one GNS3 Windows XP and one Windows Server 2003. The system administrators build all required machines in a specific virtual pool in the ESX server, set the required permissions for the ordered users, and prepare the ordered IOS for the designer in GNS3 solution and check the connections performance and ability to work through the requested topology. In a further step, the designer will import and prepare these devices with the proper real IOS for the c2600 router in the GNS3 solution, preconfigured in a specific virtual machine by the system administrators; he sets the needed connections between all virtual machines and finally writes the instructions. Hence, hints are needed by the user to achieve the required goals. As a result, a student can work on the lab with his tutor by connecting windows XP PC's with the Windows Server 2003 applied as a file server and use the router to access the Internet.

Chapter 5

5. Evaluation and assessment of the Cloud Lab infrastructure

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5.1. Introduction

The journey to the cloud marks a momentous evolution in the IT industry. It is changing the way we all work and manage our systems, regardless of industry or size. One major objective of this evaluation is to show how much it is flexible to do the traditional lab work on the cloud infrastructure lab. We deployed and tested the cloud lab infrastructure environment by building many topologies depending on the available devices in our server farm. Moreover, it was also aimed to reveal through a usability testing based on user questionnaires, the advantages of using cloud lab infrastructure from the perspective of the network engineers. To this end, it will be possible to decide to use the cloud lab infrastructure in future experiments. An obvious way to achieve such a goal is to experiment the cloud approach via a subjective evaluation. One possible approach to achieve this goal is using survey instruments which represent a familiar, inexpensive and generally acceptable evaluation method. This Thesis includes an evaluation of new practical network systems depends on network engineer surveys to measure the achievement of the required practical skills of the students or engineers who have already the experience with traditional labs.

5.2. Profile of Survey and Respondents

For the evaluation, a total of sixty-one IT persons are randomly selected to participate in the survey including ➔

- Twenty one, as Network engineers.
- Twenty five, as IT employees.
- Fifteen Computer and engineering students.

Those IT students and IT workers were enrolled in a lot of network courses, and therefore most of them have a strong background about network topologies, and network configurations. As previously discussed, we used a simple topology; see Figure 3, that includes a router, switch, file server and personal computers that we already implemented in developed the cloud infrastructure lab.

The survey questionnaire revised by two expert network engineers, the expert Cisco trainer, Mr. Islam shahwan, and the expert Microsoft trainer, Mr. Mohammed Foqha. This study has a total number of forty-eight questions, including opened-ended and closed-ended questions. A total of 29 of the survey questionnaire are practical questions, forming the survey questions (Q20-Q48). They are oriented to the goal to measure these evaluation criteria: “usability”, “easy of learning", “sense of reality” and “usefulness”. The other 19 questions are aimed at eliciting basic background information related to the traditional and cloud lab.

In fact, thirty-one of the respondents representing more than half (51%) of the subjects examined the cloud lab had worked and had tested the lab before evaluated it. In the evaluation, they were asked to answer the survey questions after their experience with the cloud lab infrastructure system. The rest of the respondents representing (49%) of the subjects completed (11) questions, were asked about their previous cloud computing knowledge. A further eight questions are aimed at exposing the respondents’ satisfaction about some technical issues.

5.3. Previous knowledge about cloud computing

It is undeniable that traditional labs must be supportive and not substitutive to on-campus labs. In other words, they must serve as a complementary asset to traditional hands-on, enabling students to access cloud lab infrastructure outside the ordinary lab hours in order to enhance their learning concept and theory [44]. In order to understand the current state of cloud computing from the users' perspective, we asked eleven (11) questions about the background and the previous knowledge about cloud computing. Table 1 below shows the presented questions in this section.

Evaluation Criterion	Survey question
Previous knowledge about cloud computing	Have you ever heard about Cloud computing?
	Have you used hands on lab containing all network devices with different brands before?
	Have you used Cloud infrastructure lab containing all network devices with different brands before?
	Has anyone close to you (friends, IT man) ever used Cloud infrastructure lab?
	Has a professor or colleague demonstrated the use of Cloud infrastructure lab?
	How do you feel about using Cloud computing?
	How is your cloud computing background?
	How do you feel about entrusting your data with Cloud lab?
	How do you feel about building a network design using cloud infrastructure lab in general?
	If another type of online cloud infrastructure lab were available, would you consider using it instead of Using hand's on lab?
	If your colleague were to start using cloud infrastructure lab service in network courses learning, would you still appreciate this step?

Table 1: The survey questions about cloud computing previous knowledge section.

In a total, there were sixty-one respondents with a completion rate of 100%. The respondent is asked to choose one of five answers, such as, (Very Dissatisfy, Moderately Dissatisfy, Neutral, Moderately satisfied, Very satisfied) in the questions (Q6, Q8, Q9) and Q7 in different format, while in Q1 to Q5 also Q10 and Q11 the respondents asked to answer (Yes or No) questions.

5.3.1. Findings

In the following, the questions and their result charts are listed. In addition to the statistical results, the number of the respondents and their percentage values for every answer are shown.

- Q1 with ***moderate*** answers. About (43%) 26 respondents heard about cloud computing and 35 respondents (57%) answered NO. See Figure 27.

- Q2 with low answers. About (10%) 6 respondents had experience a traditional lab that contained all network devices; fifty five (55) respondents (90%) answered NO. See Figure 28.

- Q3 with ***low*** answers. About (7%) 4 respondents used a Cloud lab that contained all network devices; 57 respondents (93%) answered NO. See Figure 29.

- Q4 with moderate answers. About (48%) 29 respondents had a close friend worked and experienced a cloud lab and 32 respondents (52%) answered NO. See Figure 30.

- Q5 with ***low*** answers. About (13%) 8 respondents heard about cloud labs by a professor or a colleague and 53 respondents (87%) answered NO. See Figure 31.

- Q6 with ***high*** answers. This question describes the respondent's satisfaction about using cloud computing with the following results ➔ (See Figure 32).

- ✓ About (62%) 38 respondents are very satisfied.
- ✓ About (31%) 19 respondents are moderately satisfied.
- ✓ About (7%) 4 respondents are neutral.
- ✓ Zero (0%) respondents are feeling mod. dissatisfy and also (0%) Zero respondents feeling very dissatisfy.

- Q7 with ***moderate*** answers. This question describes the respondent's background about cloud computing with the following results ➔ (See Figure 33).
  - ✓ About (7%) 4 respondents are very good in cloud computing background.
  - ✓ About (44%) 27 respondents are good in cloud computing background.
  - ✓ About (25%) 15 respondents are neutral in cloud computing background.
  - ✓ About (15%) 9 respondents are bad in cloud computing background.
  - ✓ About (10%) 6 respondents have Zero information.
- Q8 with ***high*** answers. This question describes the entrusting data using cloud computing with the following results ➔ (See Figure 34).
  - ✓ About (57%) 35 respondents are very satisfied.
  - ✓ About (28%) 17 respondents are moderately satisfied.
  - ✓ About (10%) 6 respondents are neutral.

- ✓ About (3%) 2 respondents are feeling mod. Dissatisfy.
- ✓ About (2%) only 1 respondent feels very dissatisfied.

- Q9 with high answers. This question describes the respondent's satisfaction about building a network design using a cloud lab infrastructure. It came out with the following results ➔ (See Figure 35).
  - ✓ About (33%) 20 respondents are very satisfied.
  - ✓ About (54%) 33 respondents are moderately satisfied.
  - ✓ About (10%) 6 respondents are neutral.
  - ✓ About (3%) 2 respondents feel mod. Dissatisfy.
  - ✓ Zero respondents feel very dissatisfied.

- Q10 with high answers. About (95%) 58 respondents want to use the cloud infrastructure lab more than one time and just only 3 respondents (5%) answered NO. See Figure 36.
- Q11 with high answers. About (95%) 58 respondents appreciate to use cloud lab in network courses and 3 respondents (5%) answered NO. See Figure 37.

5.3.2. Data analysis and discussion

Cloud computing is not about buying and developing hardware or software, and thus, it differs from classic heavily centered IT technology concepts. Cloud computing is about offering IT services including applications, platform and infrastructure as a commodity via the Internet. In this section, we apply this survey to analyze and make statistics about cloud computing knowledge background and cloud supporters in our universities and organizations.

Over the past couple of years, cloud computing has been accompanied by a lot of buzz and many in the business community find it hard to judge whether this issue is anything more than hype surrounded by technical jargon. According to our survey, Q1 with moderate answers shows that (57%) of the participants didn't heard about cloud computing. In addition, Q2 and Q3 with low results reveal that about (90%) of the participants used traditional network labs that contain low level network device to test or work in. Question 4 with moderate answers show that about (48%) of participants had friends used the cloud lab. The bad issue, we found in our universities that only (13%) of participants have a professor or colleague demonstrated the use of cloud infrastructure lab. In questions from Q6 until Q11, we found that the participants with high answers indicate they have good feelings toward cloud computing and they trust this technology. These high answers show that cloud computing is the future model of IT, and it is definitely not a hype that will subside.

Table 2, shows the results summary for each question, with mean value and standard division; we calculated the average for the results obtained by all questions in this section. The average of the Mean value for all questions equal (3.26), this value shows that the answers were moderated, and the knowledge about cloud computing not that much in Table 2. The average for the standard division value in Table 2, equal (0.5) and it's, also moderated, so we notice that the

previous knowledge about cloud computing was in average and there is a kind of misunderstanding about the new technologies.

No.	Question	mean	S.D	Grade
1	Have you ever heard about Cloud computing?	2.78	2.004	Moderate
2	Have you used hands on lab containing all network devices with different brands before?	1.38	1.184	Low
3	Have you used Cloud infrastructure lab containing all network devices with different brands before?	1.32	1.090	Low
4	Has anyone close to you (friends, IT man) ever used Cloud infrastructure lab?	2.90	2.014	Moderate
5	Has a professor or colleague demonstrated the use of Cloud infrastructure lab?	1.57	1.411	Low
6	How do you feel about using Cloud computing?	4.56	0.616	High
7	How is your cloud computing background?	3.22	1.099	Moderate
8	How do you feel about entrusting your data with Cloud lab?	4.37	0.903	High
9	How do you feel about building a network design using cloud infrastructure lab in general?	4.16	0.723	High
10	If another type of online cloud infrastructure lab were available, would you consider using it instead of Using hand's on lab?	4.81	0.859	High
11	If your colleague were to start using cloud infrastructure lab service in network courses learning, would you still appreciate this step?	4.81	0.859	High
Average		**3.2612**	**0.50100**	**Moderate**

Table 2: Mean value and S.D value calculated for previous knowledge survey questions

We built Table 3, for a specific reason, it was to show statistics about how the respondents feels toward cloud computing. We made statistics for the closed-end questions in which all possible answers ordered in a five degrees scale. The grade we obtained is ***high*** that shows the good feeling and good reflections toward the cloud computing, so the problem is in prepare and

implement the new technologies, like cloud computing to be a part in our training that included in the university curriculum.

No.	Question	mean	S.D	Grade
6	How do you feel about using Cloud computing?	4.56	0.616	High
7	How is your cloud computing background?	3.22	1.099	Moderate
8	How do you feel about entrusting your data with Cloud lab?	4.37	0.903	High
9	How do you feel about building a network design using cloud infrastructure lab in general?	4.16	0.723	High
Average		**4.0754**	**0.58653**	**High**

Table 3: Calculations for the closed-end with five grade answers in previous knowledge about cloud computing section

Figure 20, shows the survey results for Table 3.

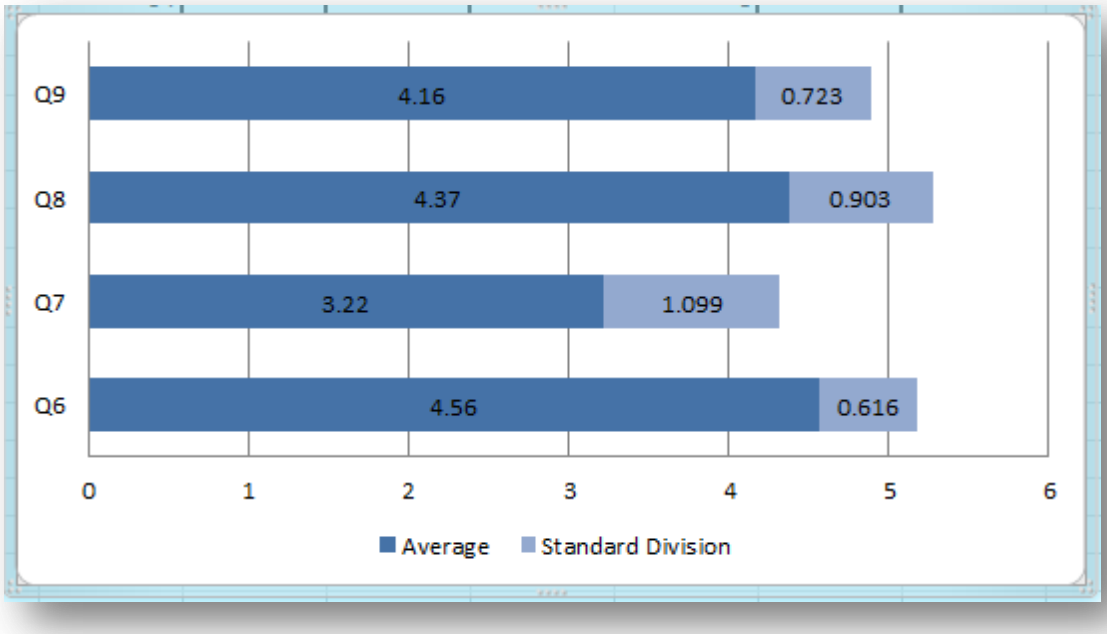

Figure 20: Survey results for questions (6, 7, 8, and 9).

5.4. Satisfaction

This survey section includes eight questions that were used to evaluate the satisfaction of the respondents regarding how much they are satisfied with the traditional lab. Moreover, they are also, about the current hardware and software of the traditional labs. In addition, we asked about the future plan scheduled for employees to have different network training courses supported by the respondents' organizations. Table 4 below shows the presented questions in this section.

Evaluation Criterion	Survey question
Satisfaction	Do you face a lot of troubles in the traditional lab?
	After carrying out an experiment in the traditional lab, do you wish that you can have more time to exercise more on it?
	How satisfied are you with network hardware devices available for use in your lab, including all types of routers, switches, firewall and other network technologies?
	How satisfied are you with network software available for use in your lab, including all operating systems and different IOS brands?
	Choose the hardware devices and software that you urgently need to deal with it?
	Does your company/colleague provide sufficient training in the use of new hardware and software that you need to do on your job/study?
	If a new technology available in the world for training, will your company/colleague put these new courses in future training plan for employees/students?
	Please indicate the types of training you have had over the past years?

Table 4: The survey questions about cloud lab satisfaction.

In a total, there were sixty respondents with a completion rate of (98%). While in Q14, and Q15, the respondents are asked to choose one of the five answers (Very Dissatisfied, Moderately Dissatisfied, Neutral, Moderately satisfied, Very satisfied), in Q12, Q13, Q17 and Q18, they asked to answer (Yes or No) questions. And finally, in Q16 and Q19, the respondent answered open questions with multiple selections.

5.4.1. Findings

In the following questions and charts, we listed the section required questions along with the statistics including the number of respondents, and the percentage result for every answer.

- Q12 with ***high*** answers. About (95%) 57 respondents faced a lot of troubles in the traditional lab and 3 respondents (5%) answered NO. See Figure 38.

- Q13 with ***high*** answers. About (98%) 59 respondents wish to have more time to exercise in traditional lab and only 1 respondent (2%) answered NO. See Figure 39.

- Q14 with low answers. About (98%) 59 respondents describes how the respondents are satisfied with the current hardware available in their lab. It comes with the following results ➔ (See Figure 40).

    - ✓ Zero (0%) respondents are very satisfied.
    - ✓ About (10%) 6 respondents are moderately satisfied.
    - ✓ About (5%) 3 respondents are neutral.
    - ✓ About (47%) 28 respondents are mod. dissatisfied.
    - ✓ About (38%) 23 respondents are very dissatisfied.

- Q15 with ***moderate*** answers. About (98%) 59 respondents described how the respondents are satisfied about the current software available in their lab. It comes with the following results ➔ (See Figure 41).

    - ✓ About (2%) 1 respondent are very satisfied.

- ✓ About (7%) 4 respondents are moderately satisfied.
- ✓ About (13%) 8 respondents are neutral.
- ✓ About (65%) 39 respondents feel mod. dissatisfied.
- ✓ About (13%) 8 respondents feel very dissatisfied.

- Q16 is an open question. About (98%) 60 respondents chooses the required hardware and software needed urgently in their labs. It comes with the following results ➔ (See Figure 42).
  - ✓ No one needed a basic router.
  - ✓ About (12%) 30 respondents needed powerful router.
  - ✓ About (4%) 9 respondents needed manageable switch.
  - ✓ About (23%) 55 respondents needed powerful server.
  - ✓ About (6%) 14 respondents feel very dissatisfied.
  - ✓ About (21%) 51 respondents needed Linux server.
  - ✓ About (21%) 50 respondents needed Firewall.
  - ✓ About (12%) 29 respondents needed UTM firewall.
  - ✓ About (1%) 2 respondents needed wireless access point.
  - ✓ About (0%) 1 respondents choose other and list programmable UPS.

- Q17 with ***Low*** answers. About (5%) 3 respondents said that their companies/colleagues provide sufficient training to them and 57 respondents (95%) answered NO. See Figure 43.

- Q18 with ***Low*** answers. About (5%) 3 respondents say that there is a future plan for training in their companies and 57 respondents (95%) answered NO. See Figure 44.

- Q19 is an open question. About (98%) 60 respondents choose the types of training courses they had over the past years. It comes with the following results ➔ (See Figure 45).

    - ✓ About (35%) 47 respondents took network configuration course.
    - ✓ About (19%) 26 respondents took different OS's courses.
    - ✓ About (1%) 2 respondents took wireless course.
    - ✓ About (4%) 6 respondents took network security courses.
    - ✓ About (37%) 50 respondents took building courses.
    - ✓ About (2%) 3 respondents took UTM course.
    - ✓ About (1%) 2 respondents choose other and listed ethical hacking and no courses.

5.4.2. Data Analysis and discussion

We apply this survey to analyze and make statistics about the respondent satisfactions in different subjects to identify and examine in depth the troubles, hardware and software available in traditional labs, and also, the future plans about training and dealing with new technologies available in the market. Therefore, the used survey questionnaire consists of a group of questions (Q12-Q16) for gaining an imagination about the students' opinion about difficulties they faced in traditional labs; in Q12 and Q13, we found that about (95%) to (98%) of respondents faced a lot of troubles including the time needed to exercise in a traditional lab. In addition, in Q14 and Q15, the participants with low answers are not satisfied about their labs network devices, also with moderate results closed to low about the software including OS available in labs. Q16 is aimed to collect the most needed network devices by participants; as a result, we found that the heavy servers and firewalls that needed a big budget are the most wanted devices. Q17 and Q18 with low results are aimed to collect data about the training courses offered for the participants, and the future deal with new technologies. About (95%) for each question shows that our companies and colleagues are not taking a step forward in dealing with new technologies. Finally, in this context, using Q19 we collect data about the training courses taken by the participants, and the result shows that network training are the most common courses with about (37%) and (35%).

Table 5, shows the results summary for each question with mean value and standard division; we calculated the average for the results obtained by all questions in this section. The Mean value average for all questions equal (2.697), this value shows that the answers were moderated in Table 5. The average for the standard division value in Table 5, equal (0.47) and it's also moderated, so we notice that the satisfaction about cloud computing in these questions was in

average and closed to low, these results reflect the bad situation in the respondents labs and insufficient training courses they got.

No.	Question	mean	S.D	Grade
12	Do You face a lot of troubles in the traditional lab?	4.80	0.879	High
13	After carrying out an experiment in the traditional lab, do you wish that you can have more time to exercise more on it?	4.93	0.516	High
14	How satisfied are you with network hardware devices available for use in your lab, including all types of routers, switches, firewall and other network technologies?	1.87	0.911	Low
15	How satisfied are you with network software available for use in your lab, including all operating systems and different IOS brands?	2.18	0.813	Moderate
17	Do your company/colleague provide sufficient training in the use of new hardware and software that you need to do on your job/study?	1.20	0.879	Low
18	If a new technology available in the world for training, do your company/colleague will put these new courses in future training plan for employees/students?	1.20	0.879	Low
Average		**2.6972**	**0.47587**	**Moderate**

Table 5: Mean value and Standard division value calculated for all satisfaction survey questions

We built Table 6, for a specific reason, it was to show statistics about how the respondent's satisfaction about the hardware and software available in the labs they used. We made statistics for the closed-end questions in which all possible answers ordered in a five degrees scale. The grade we obtained is *low*, this answer shows that the respondents were not satisfied about the current labs they used and this make them in the last row in the IT revolution.

No.	Question	mean	S.D	Grade
14	How satisfied are you with network hardware devices available for use in your lab, including all types of routers, switches, firewall and other network technologies?	1.87	0.911	Low
15	How satisfied are you with network software available for use in your lab, including all operating systems and different IOS brands?	2.18	0.813	Low
Average		**2.0250**	**0.81003**	**Low**

Table 6: The Mean value and S.D value for close-end questions with five grade answers for satisfaction section

Figure 21, below shows the survey results for Table 6.

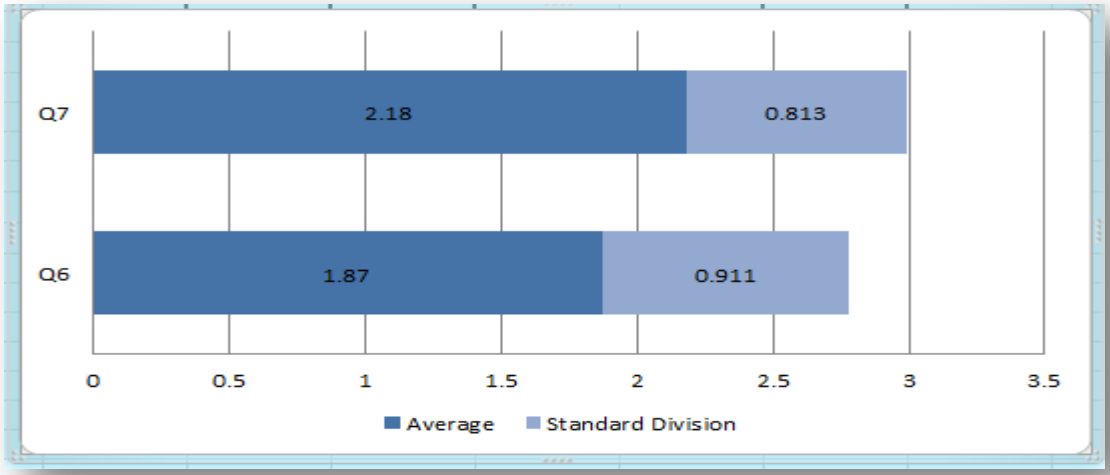

Figure 21: the survey results for Q7 and Q8.

5.5. Usability

This evaluation criterion "Usability" includes ten (10) questions; in this context we build a questionnaire used to evaluate the usability and interaction with the cloud lab infrastructure. With these questions, it is possible to reveal how much cloud lab infrastructure is user-friendly and easy to use. Moreover, we can measure the participant's satisfaction about the experiment time, assistant needed through the experiment, ability to function correctly and also to switch between different windows to gain the expected results. In addition, we asked about the training ability and apply different topologies. Table 7 below shows the presented questions in this section.

Evaluation Criterion	**Survey question**
Usability	Do you find the cloud infrastructure lab easy to use/easy to understand?
	The usefulness of system functions.
	Personal gain from using the system.
	You don't need the assistance of the experiment tutor in most of the activities.
	While using the cloud infrastructure lab, you were motivated to continue carrying out the experiment.
	You don't have problems with the assigned time.
	Moving between network devices and operating systems and applying required configuration is without hindrance.
	Ease of interaction with the system.
	The cloud lab infrastructure makes it easy to design and exercise on any network topology.
	Using this system, you can have the ability to (the respondent selects multiple choices).

Table 7: The survey questions about cloud lab usability

In a total, there were thirty-one respondents with a completion rate of (100%). The respondent is asked to choose one of five answers such as (Strongly Disagree, Disagree, Neutral, Agree, Strongly agree), for most of the questions, except for the questions Q21 and Q22 a Likert-scale with the values high, moderately high, neutral, moderately low, and low were used. Finally, in Q29 the respondent answers an open question with multiple selections.

5.5.1. Findings

In the following questions and charts, we listed the section required questions, in addition to the statistics that include the number of respondents and the percentage result for every answer.

- Q20 with ***High*** answers. About (50%) 31 respondents describe how they found the cloud infrastructure lab usability. It comes with the following results ➔ (See Figure 46).

  - ✓ About (10%) 3 respondents with strongly agree.
  - ✓ About (84%) 26 respondents with agree.
  - ✓ About (3%) 1 respondent with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ No one with strongly disagree.

- Q21 with ***High*** answers. About (50%) 31 respondents describe the usefulness of system functions. It comes with the following results ➔ (See Figure 47).

  - ✓ About (19%) 6 respondents with high.
  - ✓ About (61%) 19 respondents with moderately high.
  - ✓ About (13%) 4 respondents with neutral.

- ✓ About (6%) 2 respondents with mod. low.
- ✓ No one with low.

- Q22 with ***High*** answers. About (50%) 31 respondents describe the personal gain from using the system. It comes with the following results ➔ (See Figure 48).

  - ✓ About (20%) 6 respondents with high.
  - ✓ About (57%) 17 respondents with moderately high.
  - ✓ About (13%) 4 respondents with neutral.
  - ✓ About (7%) 2 respondents with mod. low.
  - ✓ About (3%) 1 respondent with low choice.

- Q23 with High answers. About (50%) 31 respondents describe the needed to have assistance from the experiment tutor. It comes with the following results ➔ (See Figure 49).

  - ✓ About (10%) 3 respondents with strongly agree.
  - ✓ About (68%) 21 respondents with agree.
  - ✓ About (16%) 5 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ About (3%) 1 respondent with strongly disagree.

- Q24 with ***High*** answers. About (50%) 31 respondents describe how they were motivated to continue carrying out the experiment. It comes with the following results ➔ (See Figure 50).

  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (65%) 20 respondents with agree.
  - ✓ About (10%) 3 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ About (3%) 1 respondent with strongly disagree.

- Q25 with High answers. About (50%) 31 respondents answered about if they were have problems with the assigned time. It comes with the following results ➔ (See Figure 51).

  - ✓ About (23%) 7 respondents with strongly agree.
  - ✓ About (58%) 18 respondents with agree.
  - ✓ About (16%) 5 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ No one with strongly disagree.

- Q26 with High answers. About (50%) 31 respondents described moving between network devices, and OS's and applying configuration without hindrance. It comes with the following results ➔ (See Figure 52).

- ✓ About (16%) 5 respondents with strongly agree.
- ✓ About (61%) 19 respondents with agree.
- ✓ About (10%) 3 respondents with neutral.
- ✓ About (13%) 4 respondents with disagree.
- ✓ No one with strongly disagree.

- Q27 with ***High*** answers. About (50%) 31 respondents described the user interaction with system. It comes with the following results ➔ (See Figure 53).

- ✓ About (27%) 8 respondents with strongly agree.
- ✓ About (57%) 17 respondents with agree.
- ✓ About (13%) 4 respondents with neutral.
- ✓ About (3%) 1 respondent with disagree.
- ✓ No one with strongly disagree.

- Q28 with ***High*** answers. About (50%) 31 respondents answered about that cloud lab infrastructure, makes it easy to design and train on any network topology. It comes with the following results ➔ (See Figure 54).

- ✓ About (19%) 6 respondents with strongly agree.
- ✓ About (65%) 20 respondents with agree.
- ✓ About (16%) 5 respondents with neutral.

- ✓ No one with disagree.

- ✓ No one with strongly disagree.

- Q29 is an open question. About (50%) 30 respondents answered that they have the ability to route network packets, analyze network performance, test devices workload, configure network devices etc., using this system. It comes with the following results ➔ (See Figure 55).

  - ✓ About (12%) 13 respondents were agreed that they can do routing network packets.

  - ✓ About (13%) 14 respondents were agreed that they can analyze network performance.

  - ✓ About (21%) 23 respondents were agreed that they can test devices workload.

  - ✓ About (27%) 29 respondents were agreed that they can configure network devices.

  - ✓ About (25%) 27 respondents were agreed that they can test new network brands.

  - ✓ About (2%) 2 respondents choose other and listed additional abilities (the first respondent added new system ability "the ability to fast switch connectivity" and the second respondent added "the ability to connect devices with each other faster than traditional lab").

5.5.2. Data Analysis and discussion

Cloud computing is evolving from a discussion topic towards real implementation in many organizations. After implementing the cloud lab infrastructure, we apply this survey to analyze and make statistics about the cloud lab infrastructure usability in different subjects. Therefore, the used survey questionnaire consists of a group of questions (Q20-Q26); we measure the participant's satisfaction about many different subjects. In Q20 with high answers, about (83%) of the respondents found that the cloud lab was easy to understand and use. In this context, Q21 and Q22, with high answers show that the system was useful and the participants gain new knowledge and experience from using the system. The survey Q23 and Q26 with high answers expose that during an experiment session, there was no necessity for the instructor help which means that system design and its functional structure is designed in such a way that the user will be supported in a correct manner through the cloud lab system. In Q24 and Q25 with more than (58%) for both questions, the participants agreed that the system motivated them to continue carrying out the experiments without the necessity to be assigned with additional time to finish. We used Q27 and Q28 to test the interaction with the system and the easiness in building topologies; the results with high answers reveal that the system give the required flexibility to move on and carry out the experiments.

Finally, Q29 is aimed at collecting data about what abilities that can be gained by using this system. Therefore, the participants choose with high results many listed abilities including testing, analyze, routing and configure different network devices.

Table 8, shows the results summary for each question with mean value and standard division; we calculated the average for the results obtained by all questions in this section. The Mean value average for all questions equal (3.899), this value shows that the answers were high. The

average for the standard division value in Table 5, equal (0.62) and it's also high, so we notice that usability and usefulness of system functions is good.

No.	Question	mean	S.D	Grade
20	Do you find the cloud infrastructure lab easy to use/easy to understand?	4.00	0.516	High
21	The usefulness of system functions	3.94	0.772	High
22	Personal gain from using the system.	3.83	0.950	High
23	You don't need the assistance of the experiment tutor in most of the activities/	3.77	0.805	High
24	While using the cloud infrastructure lab, you were motivated to continue carrying out the experiment.	3.94	0.854	High
25	You don't have problems with the assigned time.	4.00	0.730	High
26	Moving between network devices and operating systems and apply required configuration is without hindrance	3.77	0.845	High
27	Ease of interaction with the system.	4.07	0.740	High
28	Cloud lab infrastructure makes it easy to design and train on any network topology.	4.03	0.605	High
Average		**3.8996**	**0.62087**	**High**

Table 8: Mean value and Standard division value calculated for usability survey questions

Figure 22: below shows the survey results for Table 8.

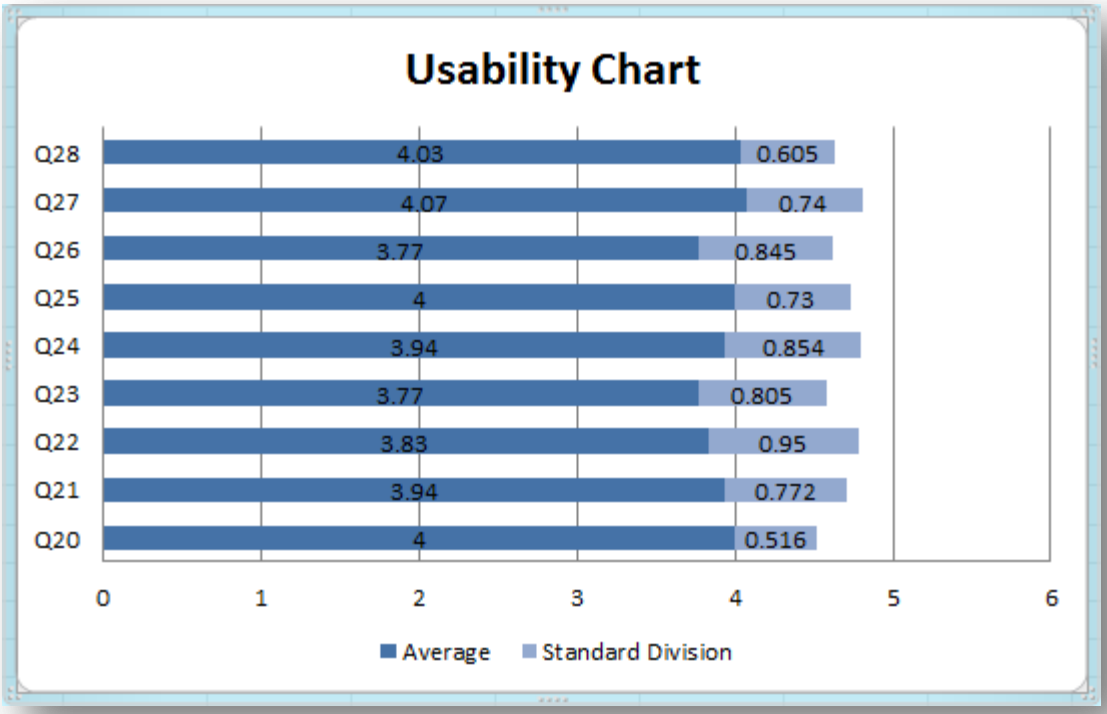

Figure 22: Survey results for cloud lab usability

5.6. Ease of learning and sense of reality

This survey section includes eight (8) questions; it is used to evaluate the satisfaction of the respondents regarding how much they are satisfied with the ease of learning, and sense of reality founded in the system. Table 9 below shows the presented questions in this section.

Evaluation Criterion	Survey question
Ease of learning and sense of reality	Navigation was easy.
	Ease of learning to use the system.
	I would take another IT learning experience if relevant to my learning needs.
	Learning through the cloud lab increases access to many new network brands
	You felt that cloud lab infrastructure is real and not virtual
	The configuration for different network devices in cloud lab infrastructure is identical to their real equivalence
	Although you are being far from the cloud lab infrastructure, you have felt yourself to be in control of it
	You would like to have a webcam (clock, a device, a screen, etc.) at the side of the lab server, in order to improve your interaction between the users and the cloud lab

Table 9: The survey questions about cloud lab ease of learning and sense of reality.

In a total, there were thirty-one (31) respondents with a completion rate about (100%). The respondent is asked to choose one of five (5) answers (Strongly Disagree, Disagree, Neutral, Agree, Strongly agree).

5.6.1. Findings

In the following questions and charts, we listed the section required questions, in addition to the statistics included the number of respondents, and the percentage result for every answer.

- Q30 with ***High*** answers. About (49%) 30 respondents describe the system navigation as shown in the following ➔ ➔ (See Figure 56).

  - ✓ About (13%) 4 respondents with strongly agree.
  - ✓ About (83%) 25 respondents with agree.
  - ✓ About (3%) 1 respondent with neutral.
  - ✓ No one with disagree.
  - ✓ No one with strongly disagree.

- Q31 with ***High*** answers. About (50%) 31 respondents describe the ease of learning to use the system. It comes with the following results ➔ (See Figure 57).

  - ✓ About (23%) 7 respondents with strongly agree.
  - ✓ About (65%) 20 respondents with agree.
  - ✓ About (10%) 3 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ No one with strongly disagree.

- Q32 with High answers. About (50%) 31 respondents describe the ease of learning to use the system. It comes with the following results ➔ (See Figure 58).

  - ✓ About (16%) 5 respondents with strongly agree.

- ✓ About (74%) 23 respondents with agree.
- ✓ About (6%) 2 respondents with neutral.
- ✓ About (3%) 1 respondent with disagree.
- ✓ No one with strongly disagree.

- Q33 with High answers. About (50%) 31 respondents answer the question "Learning through cloud lab increases access to many new network brands". It comes with the following results ➔ (See Figure 59).
  - ✓ About (32%) 10 respondents with strongly agree.
  - ✓ About (58%) 18 respondents with agree.
  - ✓ About (10%) 3 respondents with neutral.
  - ✓ No one with disagree.
  - ✓ No one with strongly disagree.

- Q34 with ***High*** answers. About (50%) 31 respondents answer the question "You felt that the cloud lab infrastructure is real and not virtual". It comes with the following results ➔ (See Figure 60).
  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (65%) 20 respondents with agree.
  - ✓ About (13%) 4 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.

- ✓ No one with strongly disagree.

- Q35 with ***High*** answers. About (50%) 31 respondents answer the question "The configuration for different network devices in the cloud lab infrastructure is identical to their real equivalence". It comes with the following results ➔ (See Figure 61).

  - ✓ About (26%) 8 respondents with strongly agree.
  - ✓ About (58%) 18 respondents with agree.
  - ✓ About (10%) 3 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ About (3%) 1 respondent with strongly disagree.

- Q36 with *High* answers. About (50%) 31 respondents answer the question "Although you are being far from the cloud lab infrastructure, you have felt yourself to be in control of it". It comes with the following results ➔ (See Figure 62).

  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (65%) 20 respondents with agree.
  - ✓ About (3%) 1 respondent with neutral.
  - ✓ About (13%) 4 respondents with disagree.
  - ✓ No one with strongly disagree.

- Q37 with ***High*** answers. About (50%) 31 respondents answer the question "You would like to have a webcam (clock, a device, a screen, etc.) at the side of the lab server,

in order to improve your interaction between the users and the cloud lab". It comes with the following results ➔ (See Figure 63).

- ✓ About (35%) 11 respondents with strongly agree.
- ✓ About (52%) 16 respondents with agree.
- ✓ About (13%) 4 respondents with neutral.
- ✓ No one with disagree.
- ✓ No one with strongly disagree.

5.6.2. Data Analysis and discussion

Another criterion to evaluate the interaction with the cloud lab system is to measure the ease of learning and sense of reality, which serves as examination of the reality strength of real world and virtual world in the manufactured environment. We apply this survey to analyze and make statistics about the respondent satisfactions in different subjects. According to Q30 and Q34-Q36 results, participants with about (83%) think that the navigation was easy during the experiment steps, in this context; about (65%) of participants in Q34 in addition to (58%) in Q35 and (65%) in Q36 felt that cloud lab closed to real lab and can be configured, in a same manner as the real lab. We measured the ease of learning in the cloud system using Q31-Q33 and the recorded high scores for the previous questions show that the system has the ability to help participants in different network issues and gain network experience.

Finally, it is clear that the survey question Q38 about adding some modifications, such as, a Webcam has a relatively high results which shows that about (52%) of participants think that it is

necessary to have access to real devices for example through a live webcam because they would feel like they were doing real experiments and led to a deeper engagement with the task.

Table 10, shows the results summary for each question with mean value and standard division; we calculated the average for the results obtained by all questions in this section. The Mean value average for all questions equal (4.23), this value shows that the answers were high. The average for the standard division value in Table 10, equal (0.617) and it's also high, so we notice that ease of learning and sense of reality of the system is good and the respondents welcoming any future technology used the cloud computing technology.

No.	Question	mean	S.D	Grade
30	Navigation was easy.	4.10	0.403	High
31	Ease of learning to use the system.	4.06	0.680	High
32	I would take another IT learning experience if relevant to my learning needs.	4.03	0.605	High
33	Learning through cloud lab increases access to many new network brands	4.23	0.617	High
34	You felt that the cloud lab infrastructure is real and not virtual	4.00	0.683	High
35	The configuration for different network devices in the cloud lab infrastructure is identical to their real equivalence	4.00	0.894	High
36	Although you are being far from the cloud lab infrastructure, you have felt yourself to be in control of it	3.90	0.870	High
37	You would like to have a webcam (clock, a device, a screen, etc.) at the side of the lab server, in order to improve your interaction between the users and the cloud lab	4.23	0.669	High
Average		**4.0524**	**0.50184**	**High**

Table 10: Mean value and Standard division value calculated for ease of learning and sense of reality survey questions

Figure 23: shows the survey results for Table 10.

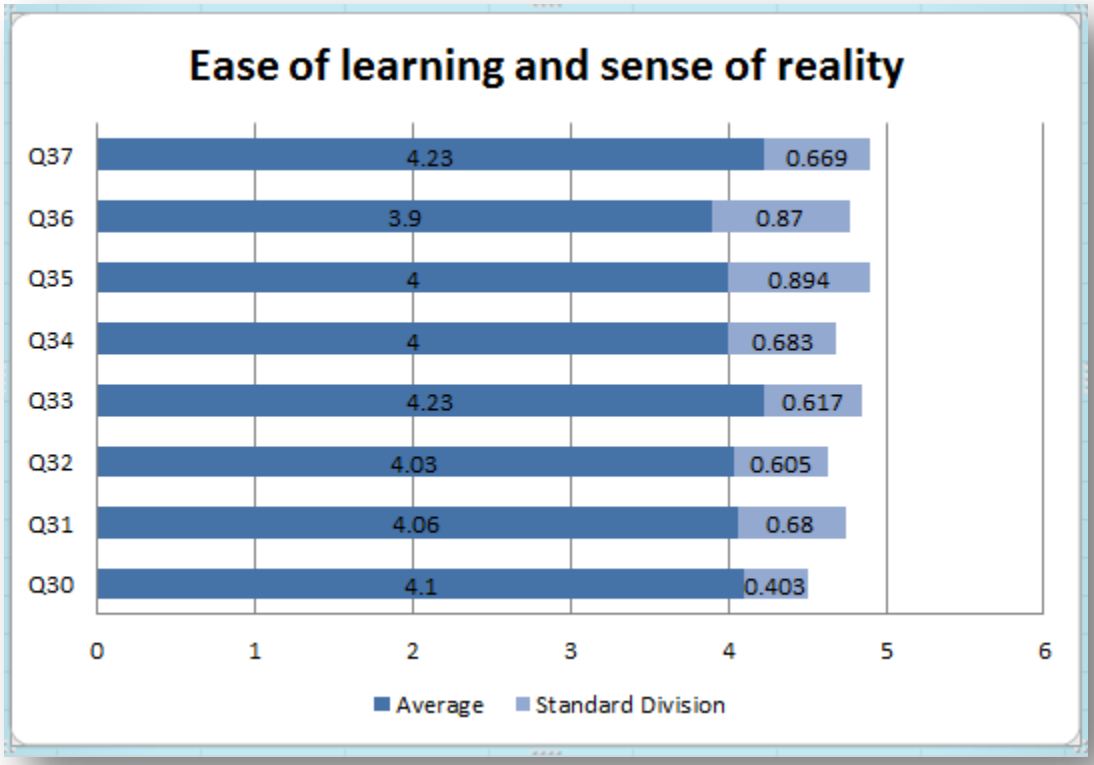

Figure 23: Survey results about ease of learning and sense of reality while using cloud lab.

5.7. Usefulness

This survey section, "Usefulness of the system", includes eleven questions; it is used to evaluate the usefulness of the system, and to test if the system satisfies the participants' experiments needed. Table 11, shows the presented questions in this section.

Evaluation Criterion	Survey question
Usefulness	The system's impact on increasing the individual's job opportunities.
	The system's impact on increasing the individual's job satisfaction.
	Using this system, you can have the ability to learn new skills and knowledge.
	I would like to use the cloud lab infrastructure in other subjects
	Using this system you can have the ability to understand the problem and try to solve it.
	Using this system, you can have the ability to deal with new network devices and apply network configuration commands.
	Using this system, you can have the ability to test and check new network devices before purchasing them.
	Building network topologies virtually and using this system decreases the amount of time necessary for the configuration session.
	Using this type of system minimizes the workload of the trainee while carrying out the tasks of the IT infrastructure activities
	With this system, we can check the appropriateness of the IT infrastructure consisting of network devices, servers and operating systems.
	You think that cloud infrastructure labs serve as a complement to hands-on labs

Table 11: The survey questions about cloud lab usefulness.

In a total, there were thirty-one (31) respondents with a completion rate of (100%). The respondent is asked to choose one of five (5) answers (Strongly Disagree, Disagree, Neutral, Agree, Strongly agree).

5.7.1. Findings

In the following questions and charts, we listed the section required questions in addition to the statistics included the number of respondents and the percentage result for every answer.

- Q38 with High answers. About (50%) 31 respondents answer the question "The system’s impact on increasing the individual’s job opportunities". It comes with the following results ➔ (See Figure 64).

  - ✓ About (13%) 4 respondents with strongly agree.
  - ✓ About (74%) 23 respondents with agree.
  - ✓ About (6%) 2 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ About (3%) 1 respondent with strongly disagree.

- Q39 with High answers. About (50%) 31 respondents answer the question "The system’s impact on increasing the individual’s job satisfaction". It comes with the following results ➔ (See Figure 65).

  - ✓ About (16%) 5 respondents with strongly agree.
  - ✓ About (68%) 21 respondents with agree.
  - ✓ About (13%) 4 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ No one with strongly disagree.

- Q40 with High answers. About (50%) 31 respondents answer the question "Using this system, you can have the ability to learn new skills and knowledge". It comes with the following results ➔ (See Figure 66).

  - ✓ About (23%) 7 respondents with strongly agree.
  - ✓ About (71%) 22 respondents with agree.
  - ✓ About (6%) 2 respondents with neutral.
  - ✓ No one with disagree.
  - ✓ No one with strongly disagree.

- Q41 with high answers. About (50%) 31 respondents answer the question "I would like to use cloud lab infrastructure in other subjects". It comes with the following results ➔ (See Figure 67).

  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (68%) 21 respondents with agree.
  - ✓ About (6%) 2 respondents with neutral.
  - ✓ About (6%) 2 respondents with disagree.
  - ✓ No one with strongly disagree.

- Q42 with high answers. About (50%) 31 respondents answer the question "Using this system, you can have the ability to understand the problem and try to solve it". It comes with the following results ➔ (See Figure 68).

  - ✓ About (23%) 7 respondents with strongly agree.

- ✓ About (68%) 21 respondents with agree.
- ✓ About (6%) 2 respondents with neutral.
- ✓ About (3%) 1 respondent with disagree.
- ✓ No one with strongly disagree.

- Q43 with High answers. About (50%) 31 respondents answer the question "Using this system, you can have the ability to deal with new network devices and apply network configuration commands". It comes with the following results ➔ (See Figure 69).

  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (68%) 21 respondents with agree.
  - ✓ About (13%) 4 respondents with neutral.
  - ✓ No one with disagree.
  - ✓ No one with strongly disagree.

- Q44 with High answers. About (50%) 31 respondents answer the question "Using this system, you can have the ability to deal with new network devices and apply network configuration commands". It comes with the following results ➔ (See Figure 70).

  - ✓ About (19%) 6 respondents with strongly agree.
  - ✓ About (74%) 23 respondents with agree.
  - ✓ About (3%) 1 respondent with neutral.

- ✓ About (3%) 1 respondent with disagree.
- ✓ No one with strongly disagree.

- Q45 with High answers. About (50%) 31 respondents answer the question "Building network topologies virtually using this system decreases the amount of time necessary for the configuration session". It comes with the following results ➔ (See Figure 71).
  - ✓ About (23%) 7 respondents with strongly agree.
  - ✓ About (67%) 20 respondents with agree.
  - ✓ About (7%) 2 respondents with neutral.
  - ✓ About (3%) 1 respondent with disagree.
  - ✓ No one with strongly disagree.

- Q46 with High answers. About (50%) 31 respondents answer the question "Using this type of system minimizes the workload of the trainee while carrying out the tasks of the IT infrastructure activities". It comes with the following results ➔ (See Figure 72).
  - ✓ About (26%) 8 respondents with strongly agree.
  - ✓ About (61%) 19 respondents with agree.
  - ✓ About (13%) 4 respondents with neutral.
  - ✓ No one with disagree.
  - ✓ No one with strongly disagree.

- Q47 with High answers. About (50%) 31 respondents answer the question "With this system, we can check the appropriateness of the IT infrastructure consisting of network devices, servers and operating systems". It comes with the following results ➔ (See Figure 73).

    - ✓ About (19%) 6 respondents with strongly agree.
    - ✓ About (71%) 22 respondents with agree.
    - ✓ About (10%) 3 respondents with neutral.
    - ✓ No one with disagree.
    - ✓ No one with strongly disagree.

- Q48 with high answers. About (50%) 31 respondents answer the question "You think that Cloud infrastructure labs serve as a complement to hands-on labs". It comes with the following results ➔ (See Figure 74).

    - ✓ About (29%) 9 respondents with strongly agree.
    - ✓ About (58%) 18 respondents with agree.
    - ✓ About (6%) 2 respondents with neutral.
    - ✓ About (6%) 2 respondents with disagree.
    - ✓ No one with strongly disagree.

5.7.2. Data Analysis and discussion

The criterion “Usefulness” achieved a relatively high value, which means that the participants find the cloud infrastructure lab useful and satisfy their experimentation needs. We apply this survey to analyze and make statistics about the respondent satisfactions in the usefulness criterion. The high values we had from Q38 with about (74%) and Q39 with more than (68%) shows that the participants agreed that the system will move them a step forward in their career, and increase the job opportunities and satisfaction. The participants give the system with high results in questions (Q40 with about (71%), Q42 with about (68%), Q43 also with (68%), and Q44 with more than (74%). The explicit approval that using this system can give them the ability to learn new skills and knowledge "Q40", understand the problem and try to solve "Q42", deal with new network devices and apply configuration commands "Q43", and finally the system give them the ability to test and check the new network devices before purchasing them "Q44". In Q41, we notice that the system encourage the participants with about (68%) to move forward and give the agreed about test and use the cloud lab in other subjects. Q45 with about (67%) of participants agreed that the usefulness of system interface and the ease way in build the network topologies virtually can decrease the amount of time necessary for configuration session. Increasing the workload for the trainee is a very important issue in systems, so in Q46 we asked the participants if the system decreases the workload while carrying out the tasks of the IT infrastructure activities; regarding to this question, we found that about (61%) of the participants agreed with Zero (0%) percentage for disagree and, also, Zero (0%) percentage for strongly disagree. Having a system helps the IT person to test the network devices before purchasing and thus gives him a good decision without doing mistakes. In Q47 with about (71%), of the participants agreed that this system can help them to check, test and find the appropriate network

devices required for their labs. Finally, about (58%) of the participants think that the cloud lab infrastructure can serve as a complementary to hand's-on labs.

Table 12: shows the results summary for each question with mean value and standard division; we calculated the average for the results obtained by all questions in this section. The Mean value average for all questions equal (4.0), this value shows that the answers were high. The average for the standard division value in Table 12 equal (0.49) and it's also high, so we notice that usefulness of the system is good.

No.	Question	mean	S.D	Grade
38	The system's impact on increasing the individual's job opportunities.	3.90	0.790	High
39	The system's impact on increasing the individual's job satisfaction.	3.97	0.657	High
40	Using this system, you can have the ability to learn new skills and knowledge.	4.16	0.523	High
41	I would like to use cloud lab infrastructure in other subjects.	4.00	0.730	High
42	Using this system. You can have the ability to understand the problem and try to solve it.	4.10	0.651	High
43	Using this system you can have the ability to deal with new network devices and apply network configuration commands.	4.06	0.574	High
44	Using this system, you can have the ability to test and check new network devices before purchasing them.	4.10	0.597	High
45	Building network topologies virtually using this system decreases the amount of time necessary for the configuration session	4.10	0.662	High
46	Using this type of system minimizes the workload of the trainee while carrying out the tasks of the IT infrastructure activities	4.13	0.619	High
47	With this system we can check the appropriateness of the IT infrastructure consisting of network devices, servers and operating systems.	4.10	0.539	High
48	You think that Cloud infrastructure labs serve as a complement to hands-on labs	4.10	0.790	High
Average		**4.0528**	**0.49392**	**High**

Table 12: Mean value and Standard division value calculated for usefulness survey questions

Figure 24: below shows the survey results for the previous Table 12.

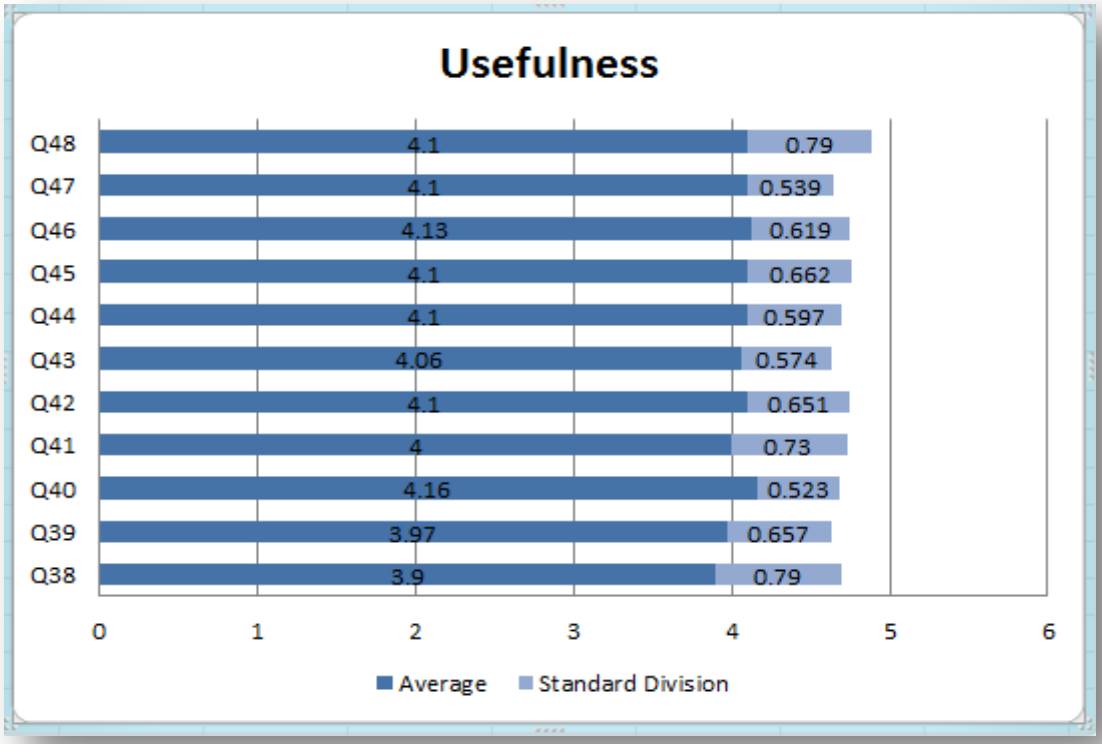

Figure 24: Survey results for cloud lab usefulness

Chapter 6

6. Future work, Conclusion and Appendix

Contents

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6.1. Reflection and Future work

There is a huge potential for future research to go deeply and deeply, using the cloud computing technology in IT solutions. For this specific research, it was important to possibly reach the respondent's representative. This research at hand indeed deserves further research. Cloud Computing is a revolutionary IT trend that will change a lot of companies' IT infrastructure and make the usage of their IT more efficient. This technology topic can attract many potential companies that want to invest more in this topic and/or even would like to implement a cloud solution.

From my opinion, we need to take a step forward in develop our labs with new infrastructure technologies because the satisfaction about the existing technologies including hardware and software founded in the respondent labs was too low as discussed in section (5.4). The unstructured interviews were picked to firstly qualitatively analyze the insights of the companies, and due to the fact that a limited amount of companies actually had experience with cloud computing solutions. However, as one of the interviewee's experts assured, cloud computing solutions will get more and more attractive to companies within the next two or three years.

The cloud infrastructure lab can support the conventional lab operation and solve the problems we may face in different types of labs as we mentioned in unit 1. In our perspective for future work we will proceed in this field and try to finish the following points ➔

- Write a new IEEE transaction publication paper including the evaluation results.

- Build a production server farm based on the Cloud lab infrastructure.

6.2. Conclusion

Initially, this study provided a broad theoretical and technical explanation about different types of lab technology, educational technology and cloud computing with their particularities. Many advances in information technology during the last two decades have made cloud computing a reality but with some challenges remaining. Providing computer resources as an infrastructure services faces problems in securing and controlling cloud data and finding optimal design for compatibility between all network devices that can be supported. With all information and communication available these days, it is possible to provide cloud computer resources that can be used in different activities and experiences.

It is a desire that through providing cloud computer resources, educational labs for IT infrastructures will be taken step forward without taking care about how to work on up to date devices or supercomputers. Users face real experiments as they are in a real lab with lower risks, secured and customized access through offering software applications, data storage and processing power that are available as a service over the Internet.

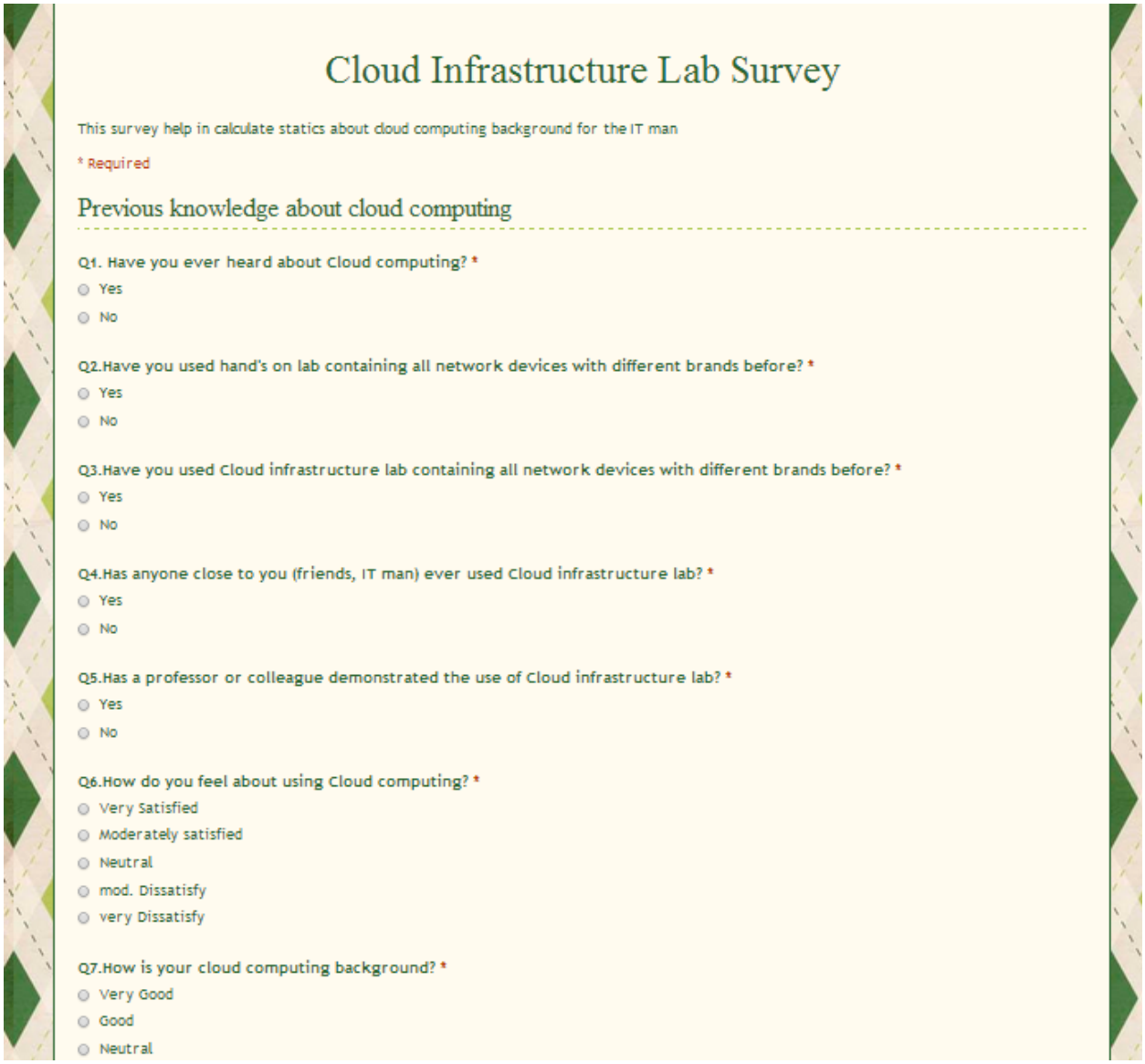
This solution is not oriented only for IT students at universities, but also for employees in the IT branches located in far places as well. Not doing so leads to restrict the improvement of their skills in world new technologies and new software applications that found in the main IT building. Cloud lab infrastructure will give the different trainee groups, the computer engineering, and IT students and employees responsible for IT affairs, the opportunity to work, to examine different IT infrastructures consisting of different operating systems, such as Linux, Windows, Solaris, platforms that are coupled through different network components and devices manufactured by different companies such as CISCO, 3Com and to achieve hybrid solutions.

In this thesis, we have surveyed the state-of-the-art of cloud computing in our country, covering the respondent's background and respondent's satisfaction about conventional IT labs. In the evaluation, we used several criteria for assessing our cloud infrastructure lab, such as system usability, ease of learning, sense of reality and finally the usefulness of the system. The survey statistics reveal that the cloud infrastructure lab will support with great manner the traditional labs in our companies and universities.

As the development of cloud computing technology is still at an improvement stage. We hope that our work will support cloud computing research and provide a better understanding of the design challenges of cloud computing, and pave the way for further research in this area.

6.3. Appendix A

A screenshot for the online survey used for the system evaluation ➔



Cloud Infrastructure Lab Survey

This survey help in calculate statics about cloud computing background for the IT man

* Required

Previous knowledge about cloud computing

Q1. Have you ever heard about Cloud computing? *
- Yes
- No

Q2.Have you used hand's on lab containing all network devices with different brands before? *
- Yes
- No

Q3.Have you used Cloud infrastructure lab containing all network devices with different brands before? *
- Yes
- No

Q4.Has anyone close to you (friends, IT man) ever used Cloud infrastructure lab? *
- Yes
- No

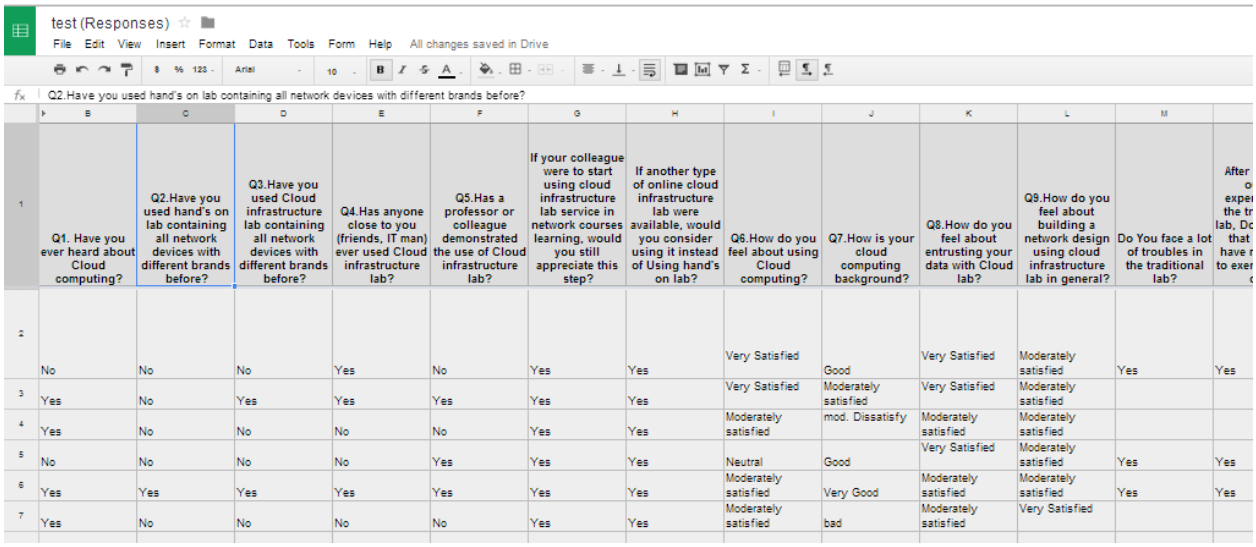
Q5.Has a professor or colleague demonstrated the use of Cloud infrastructure lab? *
- Yes
- No

Q6.How do you feel about using Cloud computing? *
- Very Satisfied
- Moderately satisfied
- Neutral
- mod. Dissatisfy
- very Dissatisfy

Q7.How is your cloud computing background? *
- Very Good
- Good
- Neutral

Figure 25: Online survey for cloud lab infrastructure

A screenshot for the responses sheet ➔



test (Responses)

File Edit View Insert Format Data Tools Form Help All changes saved in Drive

Q2.Have you used hand's on lab containing all network devices with different brands before?

	Q1. Have you ever heard about Cloud computing?	Q2.Have you used hand's on lab containing all network devices with different brands before?	Q3.Have you used Cloud infrastructure lab containing all network devices with different brands before?	Q4.Has anyone close to you (friends, IT man) ever used Cloud infrastructure lab?	Q5.Has a professor or colleague demonstrated the use of Cloud infrastructure lab?	If your colleague were to start using cloud infrastructure lab service in network courses learning, would you still appreciate this step?	If another type of online cloud infrastructure lab were available, would you consider using it instead of Using hand's on lab?	Q6.How do you feel about using Cloud computing?	Q7.How is your cloud computing background?	Q8.How do you feel about entrusting your data with Cloud lab?	Q9.How do you feel about building a network design using cloud infrastructure lab in general?	Do You face a lot of troubles in the traditional lab?	After o expe the tr lab, Do that have to exer
2	No	No	No	Yes	No	Yes	Yes	Very Satisfied	Good	Very Satisfied	Moderately satisfied	Yes	Yes
3	Yes	No	Yes	Yes	Yes	Yes	Yes	Very Satisfied	Moderately satisfied	Very Satisfied	Moderately satisfied		
4	Yes	No	No	No	No	Yes	Yes	Moderately satisfied	mod. Dissatisfy	Moderately satisfied	Moderately satisfied		
5	No	No	No	No	Yes	Yes	Yes	Neutral	Good	Very Satisfied	Moderately satisfied	Yes	Yes
6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Moderately satisfied	Very Good	Moderately satisfied	Moderately satisfied	Yes	Yes
7	Yes	No	No	No	No	Yes	Yes	Moderately satisfied	bad	Moderately satisfied	Very Satisfied		

Figure 26: responses sheet collected the responders answers

6.4. Appendix B (Evaluation results)

6.4.1. Previous knowledge about cloud computing criteria results

Figure 27: Question 1 results.

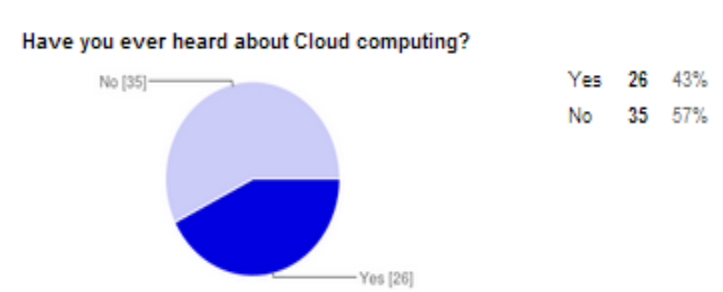


Figure 28. Question 2 results.

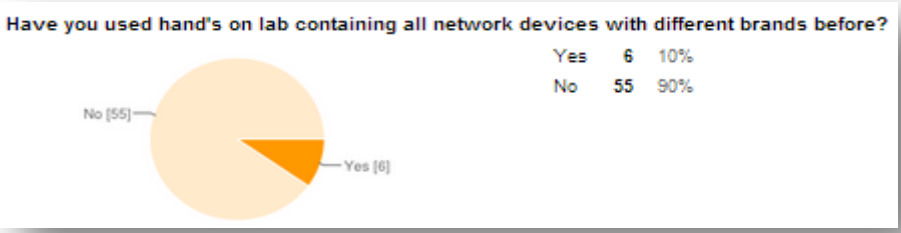


Figure 29. Question 3 results.

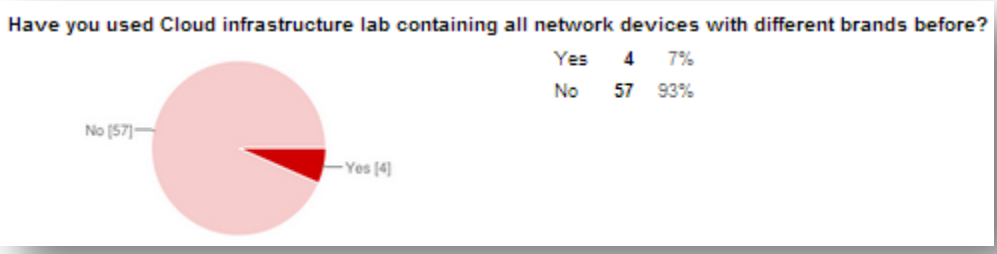


Figure 30. Question 4 results.

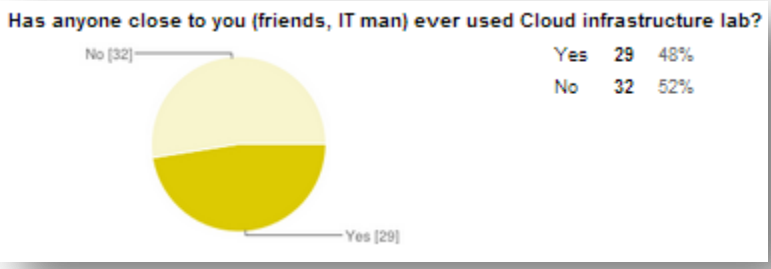


Figure 31. Question 5 results.

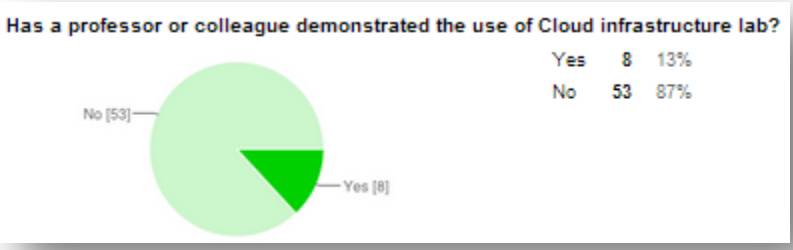


Figure 32. Question 6 results.

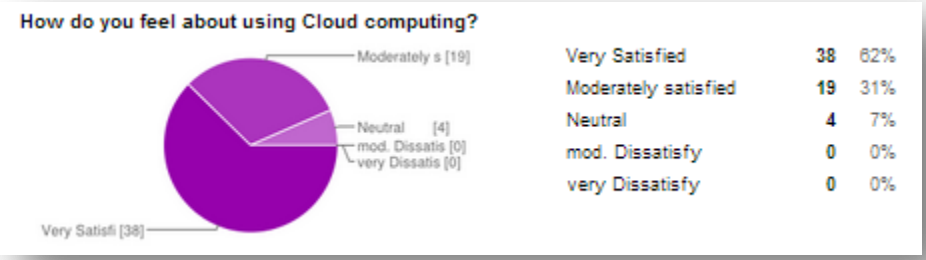


Figure 33. Question 7 results.

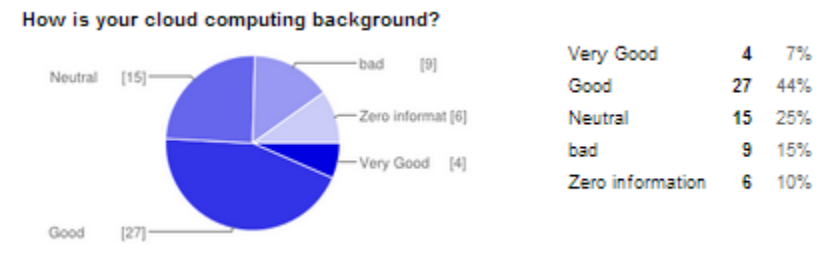


Figure 34. Question 8 results.

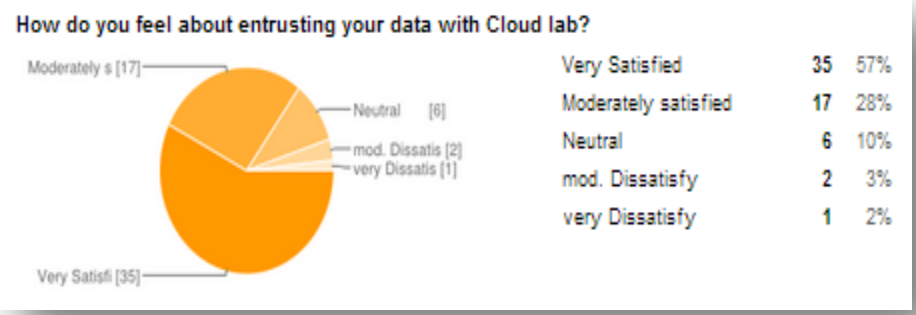


Figure 35. Question 9 results.

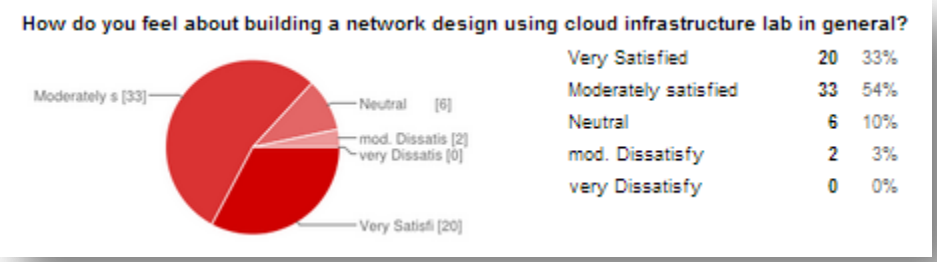
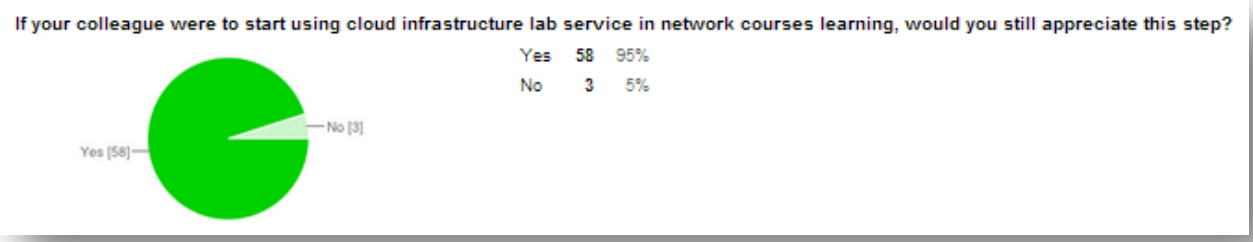


Figure 36. Question 10 results.

Figure 37. Question 11 results



6.4.2. Satisfaction criteria results

Figure 38. Question 12 results.

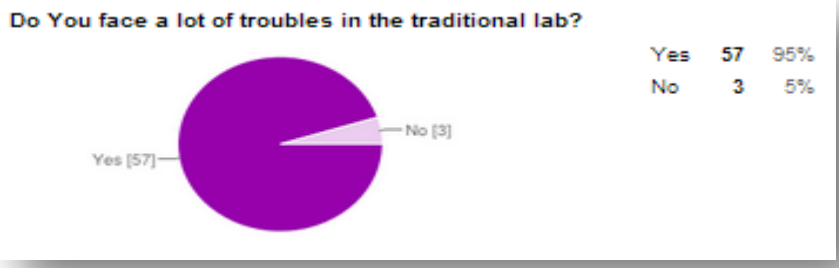


Figure 39. Question 13 results.

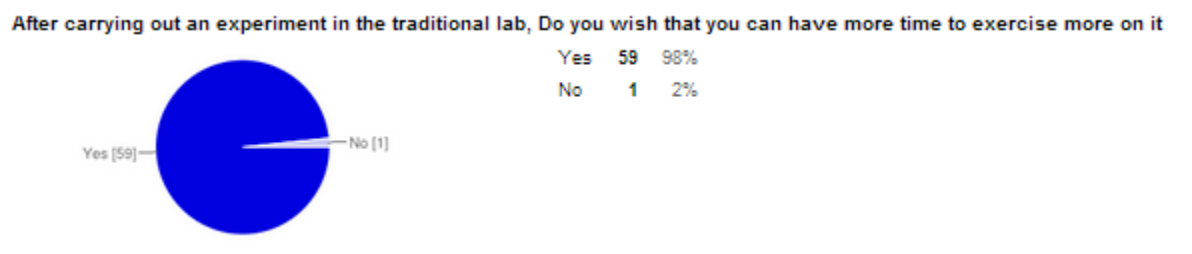


Figure 40. Question 14 results.

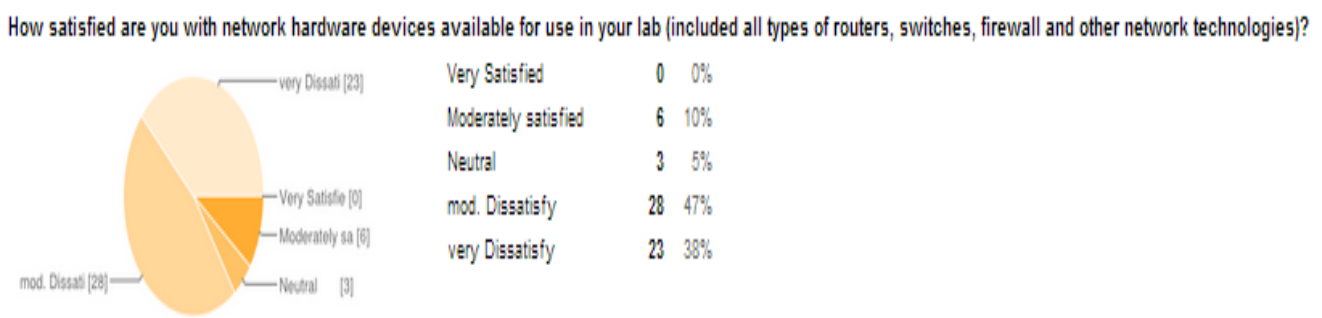


Figure 41. Question 15 results.

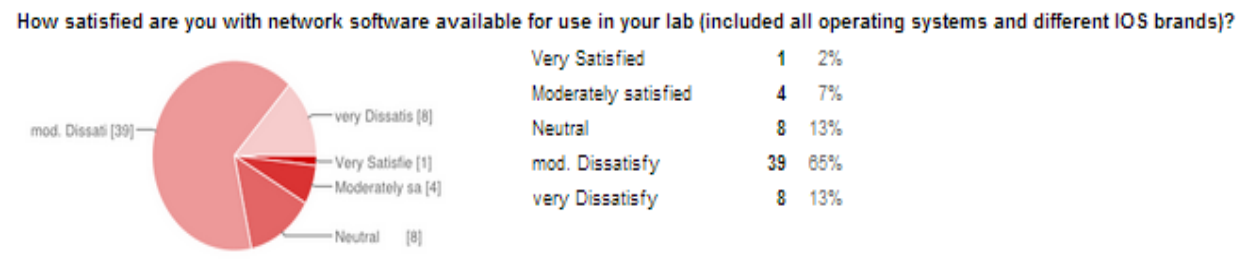


Figure 42. Question 16 results.

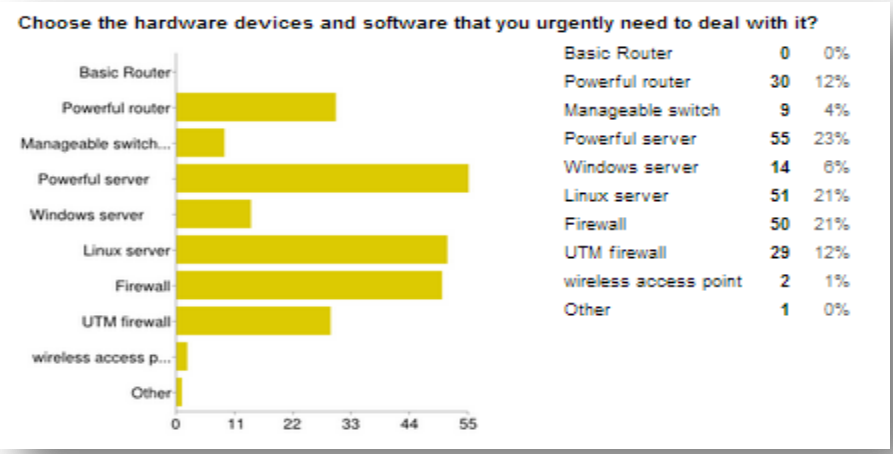


Figure 43. Question 17 results.

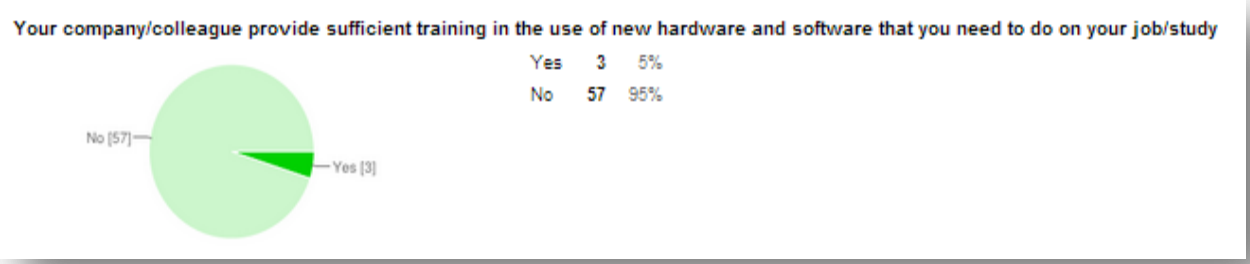


Figure 44. Question 18 results.

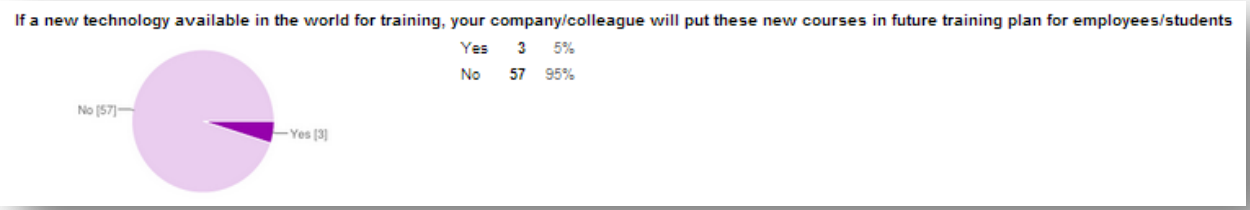
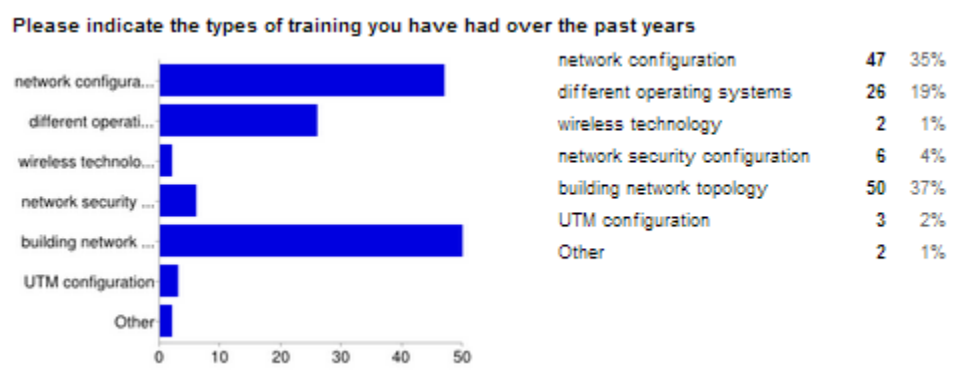


Figure 45. Question 19 results.



6.4.3. Usability criteria results

Figure 46. Question 20 results.

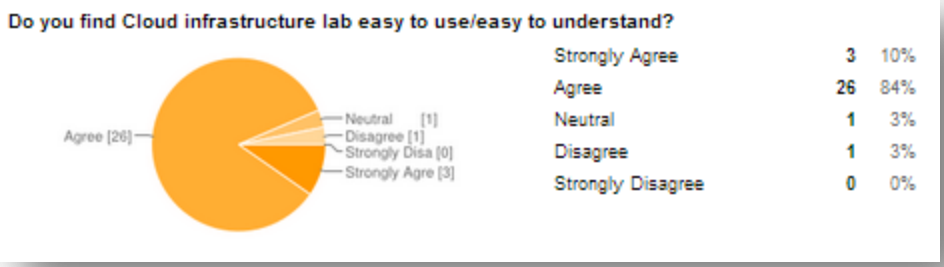


Figure 47. Question 21 results.

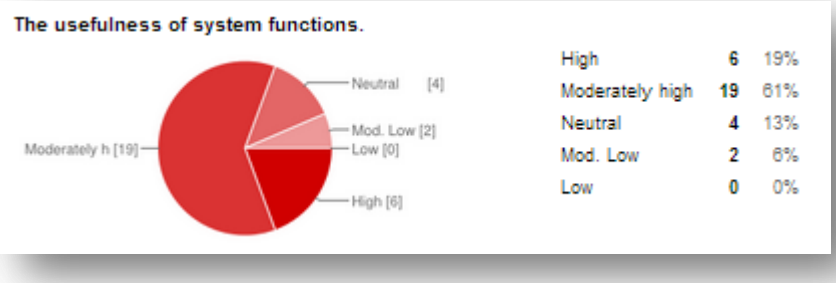


Figure 48. Question 22 results.

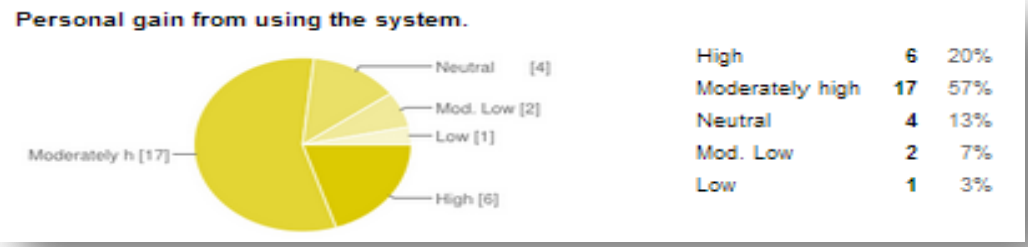


Figure 49. Question 23 results.

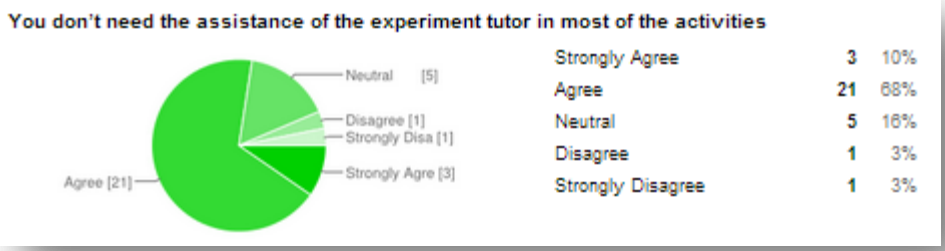


Figure 50. Question 24 results.

Figure 51. Question 25 results.

Figure 52. Question 26 results.

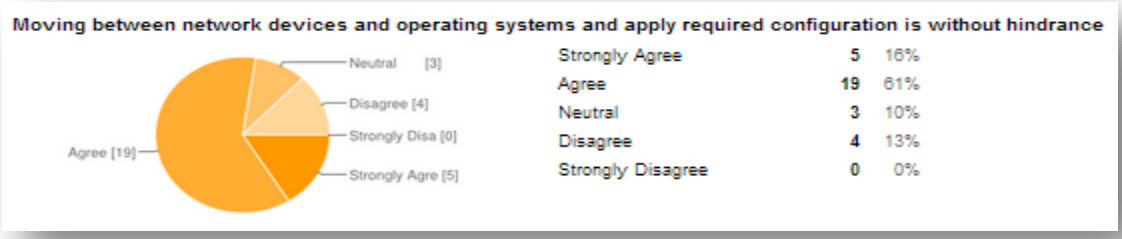


Figure 53. Question 27 results.

Figure 54. Question 28 results.

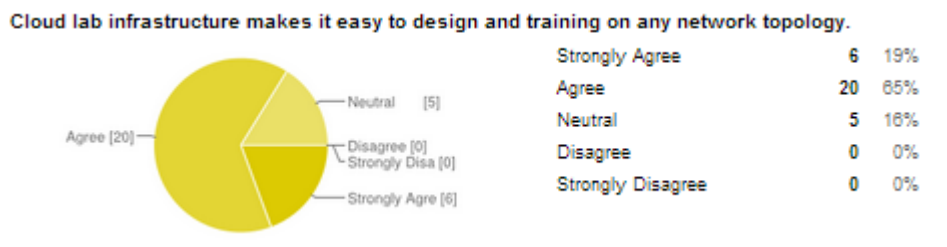
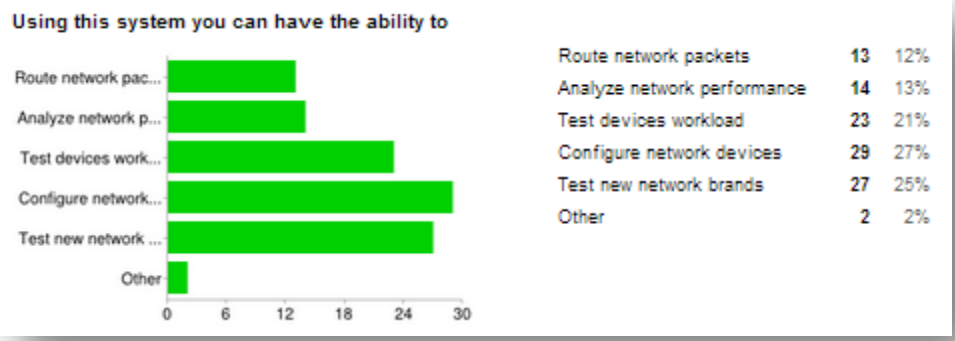


Figure 55. Question 29 results.



6.4.4. Ease of learning and sense of reality criteria results

Figure 56. Question 30 results.

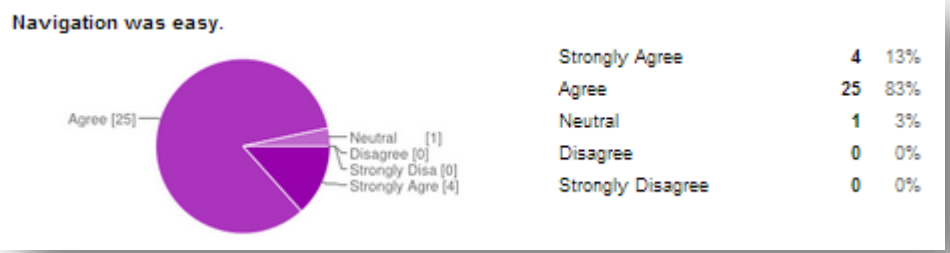


Figure 57. Question 31 results.

Figure 58. Question 32 results.

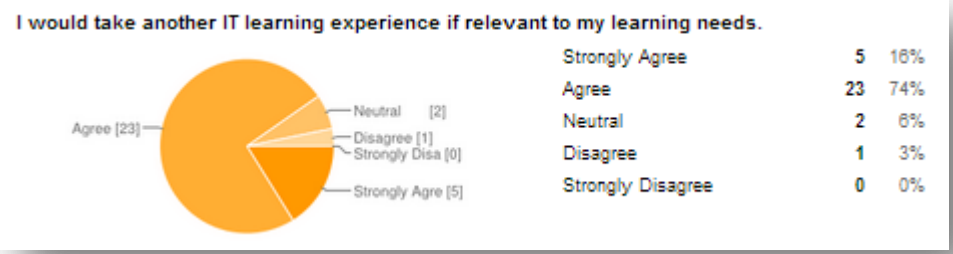


Figure 59. Question 33 results.

Figure 60. Question 34 results.

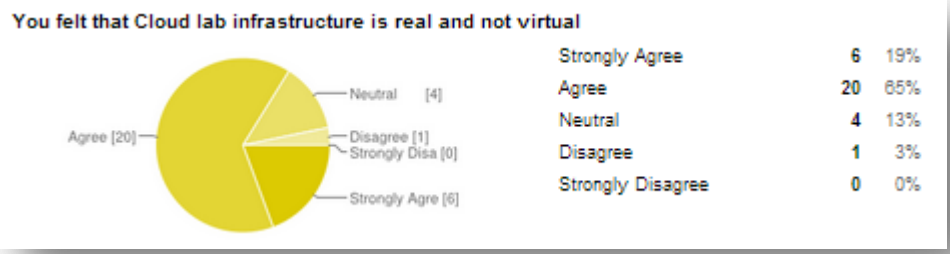


Figure 61. Question 35 results.

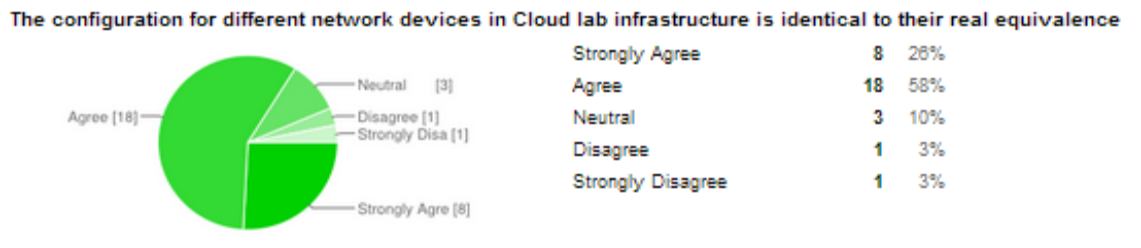


Figure 62. Question 36 results.

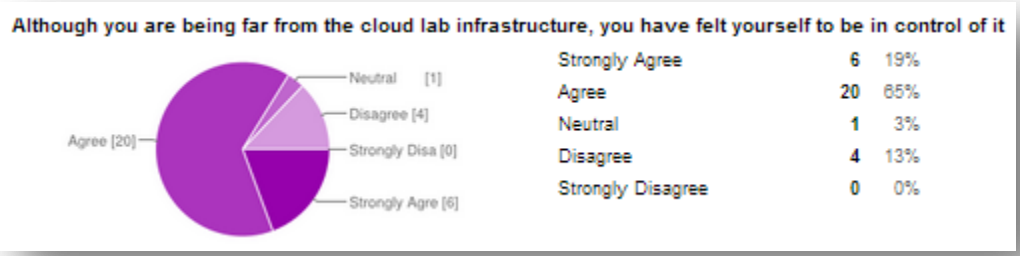
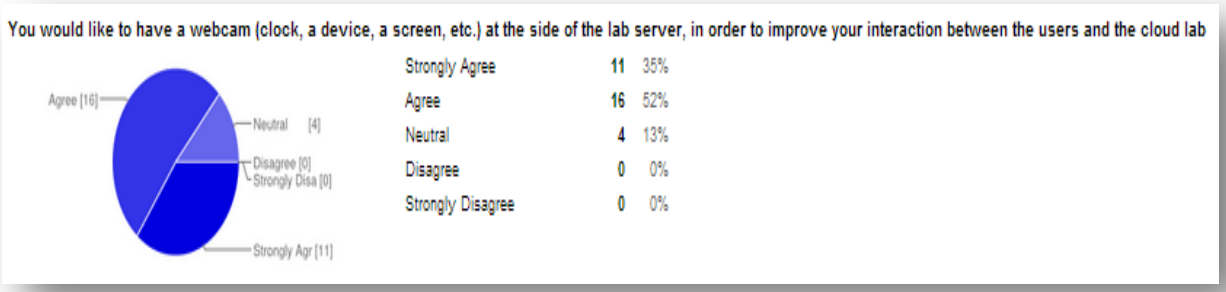


Figure 63. Question 37 results.



6.4.5. Usefulness criteria results

Figure 64. Question 38 results.

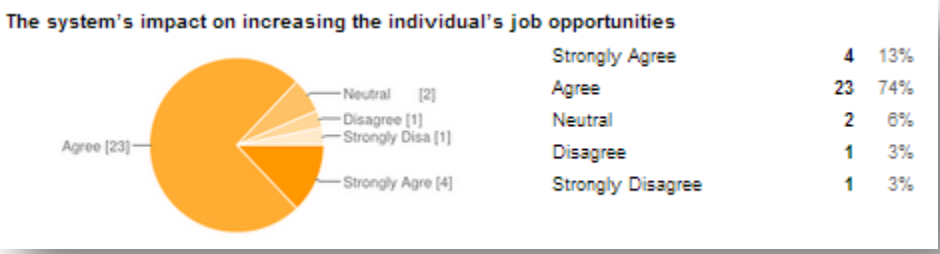


Figure 65. Question 39 results.

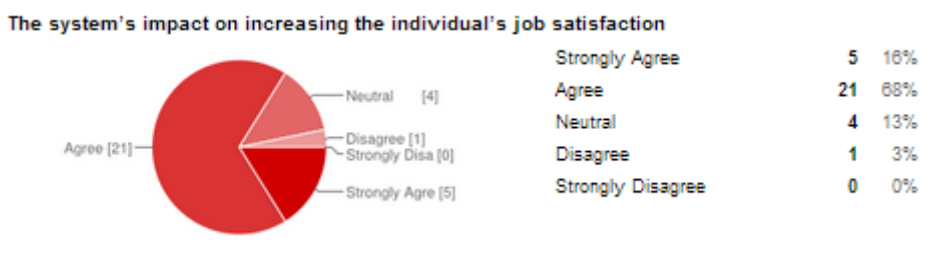


Figure 66. Question 40 results.

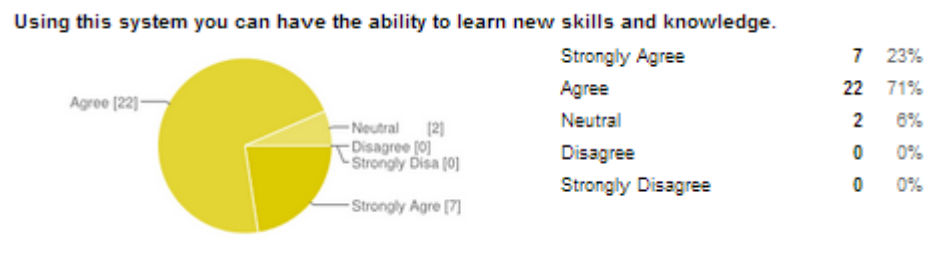


Figure 67. Question 41 results.

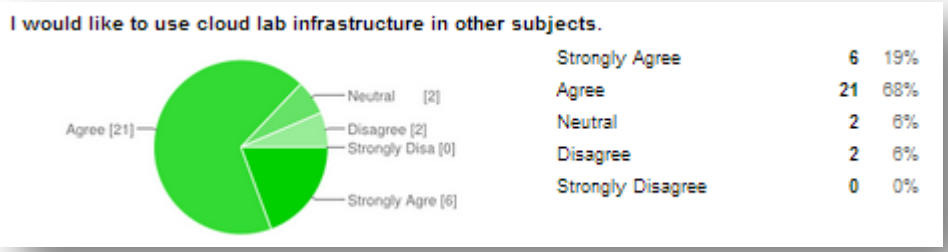


Figure 68. Question 42 results.

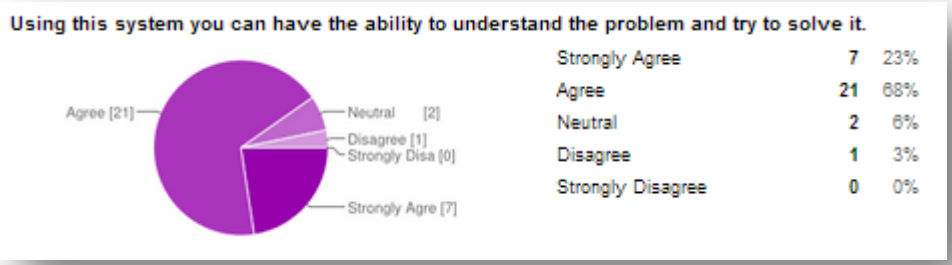


Figure 69. Question 43 results.

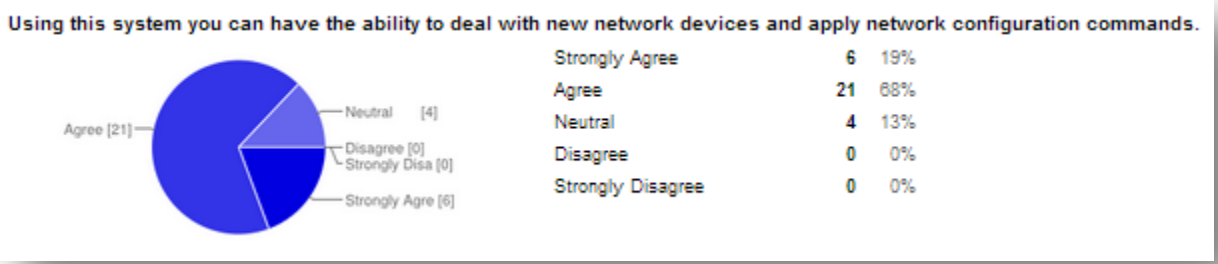


Figure 70. Question 44 results.

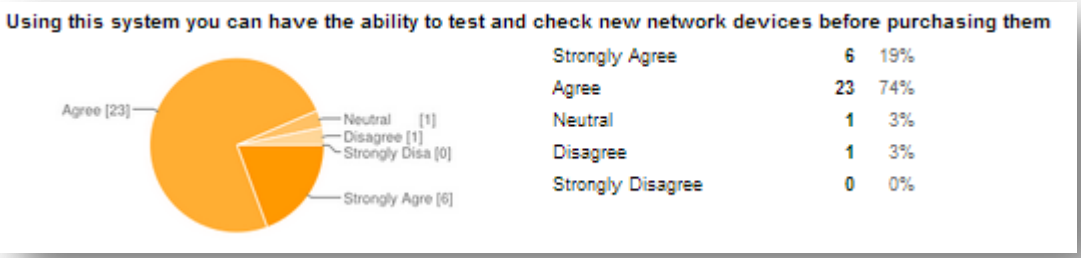


Figure 71. Question 45 results.

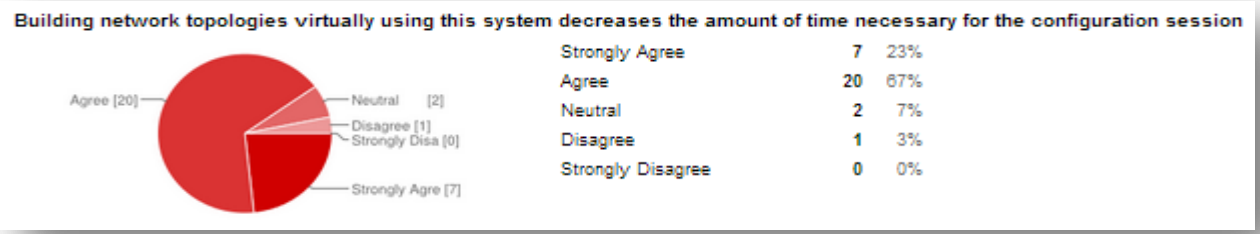


Figure 72. Question 46 results.

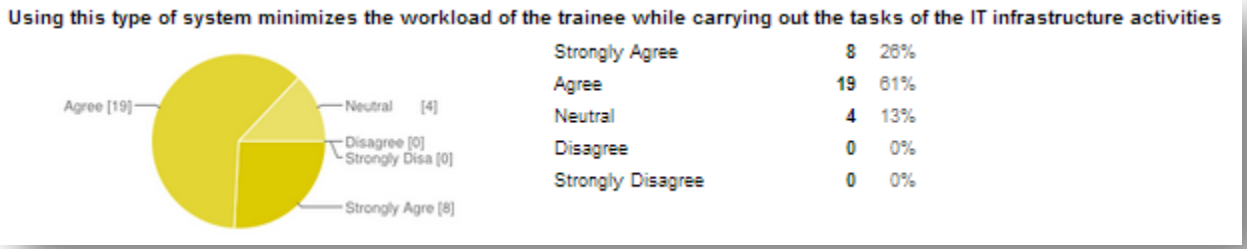


Figure 73. Question 47 results.

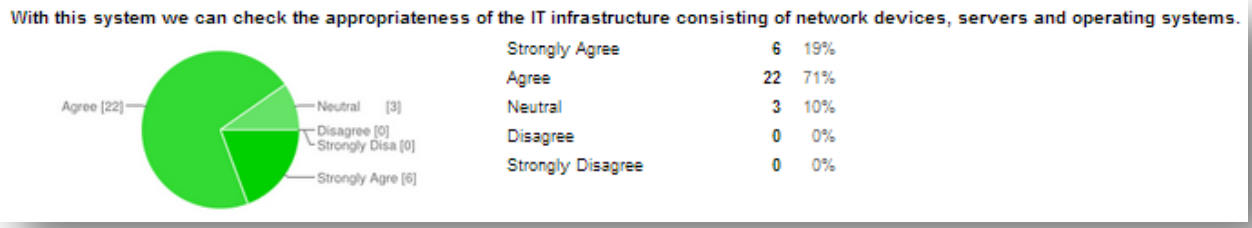
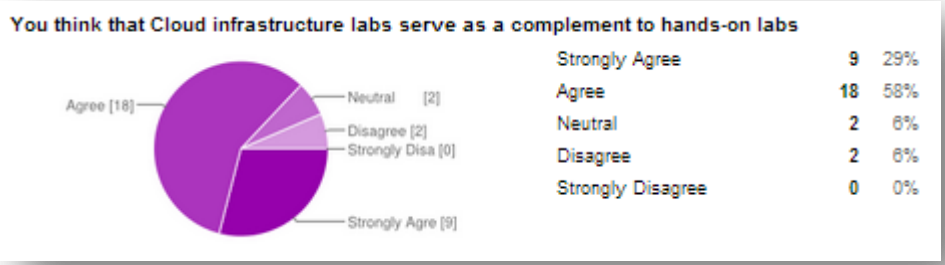


Figure 74. Question 48 results.



6.5. Appendix C (Computer Resources as a Cloud Lab Service-IEEE 2012)

We published a scientific paper in the Global Engineering Education Conference (EDUCON), 2012, IEEE in Morocco/Marrakech, this paper now available on the IEEE Xplore digital library with the following abstract ➔

Abstract—A prototype of a remote lab for providing cloud computer resources in optimal manner to achieve an infrastructure lab service is discussed. It has the ability to offer training sessions for different operating systems and networking techniques that are used to build hybrid IT infrastructure solutions. Topologies consisting of machine servers equipped with different operating systems such as Linux, Windows, Solaris etc. that are coupled with each other through different network components and devices, presents an IT infrastructure solution. Such a laboratory will solve many of the problems facing students in developing countries, as academic institutions are not equipped with the appropriate platforms and network components for teaching IT. Moreover, IT departments of business enterprises or IT academic institutions will save big amounts of money as there is no necessity to purchase such expensive systems. Currently, the first prototype is being built using VMware ESX server, VMware vSphere client, GNS3, among others. The

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