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Applying Cloud Computing Technology to Build Academic Computing Labs

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Abstract: ***Cloud computing is considered the future of information technology. This technology can help an organization achieve significant savings in IT services and infrastructure costs, as well as enhance IT support for organizational operations. Consequently, businesses with low capital and human resources, find this technology particularly appealing to build information technology systems and infrastructure. Needless to say, cloud computing holds the same potential for the academic computing labs. However, effective application of this technology in this environment requires careful evaluation of issues that are unique to this environment. While there has been research on transitioning software base lab elements to cloud computing, transitioning of hardware based academic labs and in particular computer networking labs has not been sufficiently researched. This paper examines these issues and proposes strategies for successful application of cloud computing in the academic computing labs with the emphasis on hardware and networking laboratories. In particular, the paper emphasizes the use of virtualization technologies to transition hardware based computing labs to cloud environments.***

I. INTRODUCTION

Since its introduction only a few years ago, cloud computing has been heralded as the future of information technology. IT industry research on cloud computing provides significant evidence that this technology can help organizations lower capital expenditures for IT infrastructure and services, help balance the workload of the IT personnel and make qualitative enhancements to the IT support for the organizational operations and decision making. Consequently, many businesses, especially small and medium start-up businesses with low capital and human resources, have chosen to apply cloud computing technology to build and enhance organizational IT resources, services and infrastructure.

Cloud computing is also being increasingly employed to supportoperations of academic institutions as well (Kumar, et al., 2013). However, its use in supporting academic computing labs is still very limited as the academic lab environment has some unique aspects to it.For instance; general purpose academic computing labs are expected to accommodate a large variety of software and hardware requirementsfordifferent courses and programs which can easily result in software and hardware incompatibility issues. Furthermore, when incorporating new technologies, the academic computing labs, like other organizations and entities, will also experience some challenges and issues. This paper examines these challenges and issues and proposes strategiesto successfully employ cloud technology in building and enhancing academic computing labs.The paper also proposes an approach to transition hardware based computing laboratories to cloud environments by using emerging virtualization technologies.

II. THE DEMAND FOR ACADEMIC LABS AT UNIVERSITIES

These days, most students have their own laptops, wireless networks are almost everywhere, and the academic institutions provide wireless connectivity to their computer networks. Thus, it is reasonable to expect that the number of students using the university computer labs will significantly decline. However, the reality seems to be quite different. For instance, in a survey of its 5,721 students, the University of Montanafound that 89.1% of its students own a laptop; however, nearly 2/3rds of its students still use the computer labs frequently(University of Montana, 2012).This survey also investigated the reasons for the persistent high use of the computing labs by the students. Accordingly, (1) instead of carrying 5 to 6 pound laptopseverywhere and being responsible for understanding connectivity to the networks, the students feel more comfortable using the university computer labs; (2) sometimes students need a space to work away from home or dorm, and a computer lab is a good choice; and (3) perhaps the most important reason is that some application softwareare too expensive for the students to purchase and the only viable solution is to use the university labs. Surveys conducted by other universities also support these findings (Schaffer, 2010).Thus, in spite of the increasing ownership of the computer/laptop ownership by students, the demand for academic computing labs has not diminished.

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III. ACADEMIC COMPUTING LAB CONFIGURATIONS

The computer labs may be configured in different ways. This section presents the traditional and cloud-based lab configuration.

A. *Traditional Academic Computing Lab Model*

In the traditional academic computing lab model, alab is configuredas a local area network system, as shown in Figure 1.The database, web and application servers, and other software are installed on the universities computer networks and are managed, maintained and administered by the university IT personnel.

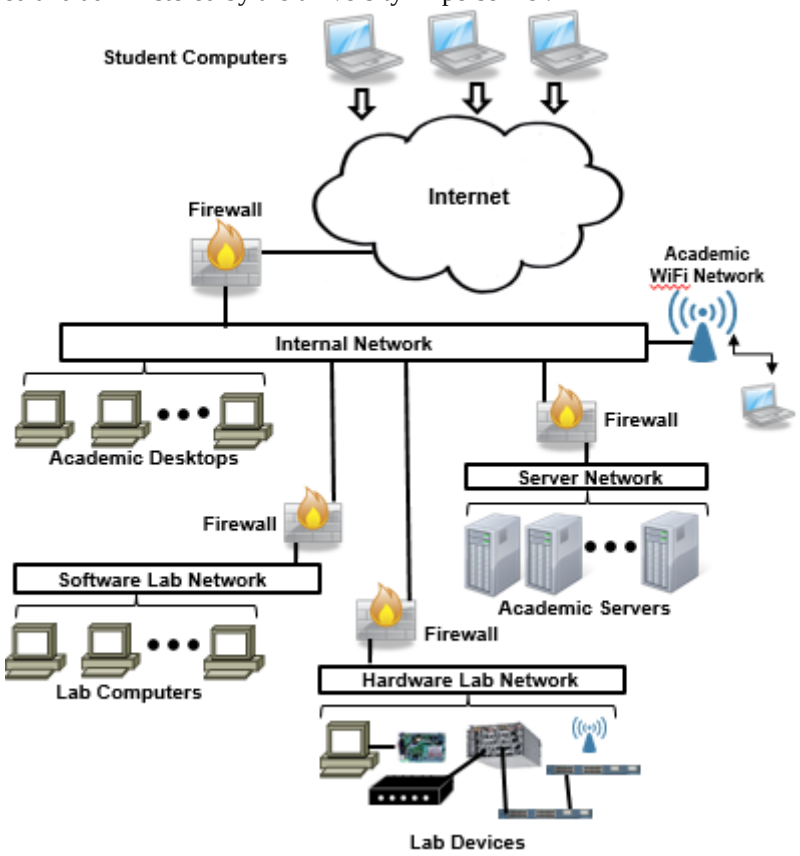

Fig 1: Traditional lab model

Every student is given a username and a password to access the system. However, since the lab resides within the university, the students log into the university network through the lab computers or through their laptop using the wireless connectivity provided by the university. When logged into the university networks, the students can use all the applications that are installed on the university networks and have their own storage space to store their data, documents and files. The storage space can then be accessed from any computer lab in the university but only from theuniversity lab computers.

In some courses, such as computer networks, computer security, database administration and system administration, the students may need to access the entire network as an administrator.However, access at this level means that the students have the rightto affectthe security orprivacy issues of the entire system. Consequently, one serious mistake can jeopardize the whole system. For this reason, such courses must be supported by specialized labs wherein any possible effect on the network can be prevented, and at the same time the students can attempt the required exercises and projects without any concerns for jeopardizing the network.Nevertheless, during a lab session, the lab equipment and network states are modified; therefore, alab administrator withadvanced computing skills must maintain and restore the whole system to the original statusfollowing each session(Yan, 2011). Consequently, such specialized labs should be configured with the following design guidelines (Yan, 2011):

- Low lab administrative and maintenance cost
- Ease in maintenance and recovery

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- High lab availability
- Open lab environment

B. Virtual Computing Lab Using Cloud Computing Technology

Figure 2, shown on the following page, models an academic computing lab configuration based on the cloud technology. The lab data center is setup and stored on the cloud server which is managed, maintained and administered by an external service provider. All applications are also setup on the cloud.

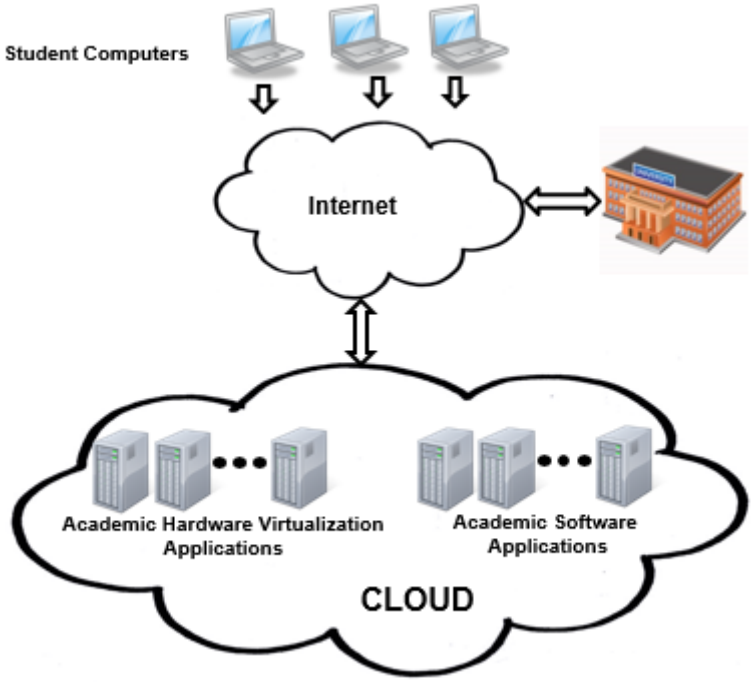

Fig 2: Cloud computing lab model

The Students are given usernames and passwords so that they can access the lab by using a virtual web desktop on the web browser.

North Carolina State University (NCSU) was one of the first universities to apply the cloud technology to building the laboratory called the virtual computing lab (VCL) in 2004 and the number of users of the lab has significantly increased since the inception of the lab(Murphy, 2009; Schaffer, 2010).

As with the traditional academic lab networks, when the users log into a virtual lab network, they can use all the applications that are installed on the cloud, and each userwill also have a storage space to savetheirdata, documents and files. This configuration offers the advantage that, via the virtual web desktop, the users can turn their own web browsers into the virtual computer that has all the applications installed on the cloud server. The users can use all these applications as if the applications were set up on their own computers. They can also choose to store the data, documents and files on the cloud storage spaces or easily transfer them to their personal computers.

IV. BENEFITS AND CHALLENGES OF VIRTUAL COMPUTING LABS

The virtual lab environment offers advantages in terms of usage and availability of resources to both the students and their faculty, while offering economic benefits to the university. At the same time, these labs do not come without their own set of unique challenges. This section discusses the pros and cons of virtual computing labs.

A. *Advantages of Virtual Computing Lab*

A traditional computing lab may be required to support computing exercises and projects for different courses and instructors; furthermore, the same lab may also be used as a teaching lab. Thus, the lab may require a diverse set of hardware and software to provide effective computing support to students and faculty. Consequently, developing and maintaining such a lab can be an expensive undertaking. What further complicates this situation is the fact that the

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hardware and software evolve at a rapid pace, which can render a lab obsolete in a short time, and thereby trigger the upgrading/replacement cycle again. Ignoring or postponing the required upgrades/replacements may have considerable negative impact on the effectiveness of the lab support,as well as diminish the overall quality of the instruction provided (Yan, 2011).

In the traditional computing lab configuration, a student needs to go to the lab to use an application.However, these labs typically have fixed hours of operations which can create a limitation for the students working on large projects that require long, continuous time on computer.Stopping the work on the project and coming back the next day to resume the work can interrupt the student's flow of thoughts.Consequently, providing access to the application via a virtual computer lab satisfies the software license terms while allowing students to continue to access the application from their own computers.

Furthermore, users can only access the application and local network viauniversitycomputers in a university computer lab. Employing cloud technology on the networked lab resources allows students to access all resources on the entire network from their own computer or from any lab at the university. Thus, cloud technology enables efficient and easy lab access to the users and at the same time allows different components of the university to share the cost and thus reduce the overall costs to the university.

A virtual lab offers numerous benefits.First; the virtual computer lab gives the studentsan open and flexible environment. Since the student connectivity is virtual, the students can be given the administrator or root level access and privileges to work on exercises and projects at this level.However, all applications and devices are on the cloud and under the cloud provider management; therefore, after each lab class, the lab administrator needs only a short time to reset the lab systems to its original status.Second, a significant amount of time is saved when the students or instructors begin the request of a new application and the application is installed. An instructor can quickly install the new application needed for the course.

Third, virtual labs prevent traffic jams and ease the burden of time and space. The students can access the needed software and hardware in the virtual environment; they don't have to be physically present in the lab. This helps students by alleviating the lab hour restrictions and also helps reduce the physical demand on the lab resources. And, lastly, it is cost-effective for the university to have software access based on the number of users on the virtual lab, rather than the number of the physical computer on the laboratory (Murphy, 2009).

B. Technical Challenges to Virtual Computing Labs

One issue that can significantly affect the benefits of the cloud-based academic computing lab is the internet speed. The quality of interaction with a virtual lab is dependent on two factors: (1) the internet connection speed and (2) the number of users accessing the lab simultaneously.

First, while the connection speed of the traditional computer lab is stable, it can vary on the virtual labconnection and thereby adversely affect the user interaction. Although the virtual computer labs now usually have backup methods, a weak or lost connection can still result in lost work. Second, the number of users accessing the lab simultaneously can also pose a problem. Whenever there are too many connections to one application, the cloud lab needs to create a new image of the application for the users. However, the larger number of images results in slower response time by the server. One solution is to configure a fixed number of the application images to ensure acceptable application response time.In this configuration, when a student needs to use the application; he or she needs to make a reservation to access to the image. However, this solution creates another problem. That is, when the number of users reserved for using the application increases, the queue overflows and the waiting time of a user to access the application increases. This problem further deteriorates around the mid-term and final exam times when lab usage increases (Murphy, 2009), resulting in student reluctance to use the lab (Schaffer, 2010).

C. Economic benefits of the Virtual Lab

A virtual lab offers several economic benefits. First, while the hardware systems may need to be enhanced with the increase in the number of students using the lab, it’s not necessary to increase the staff to support the system. A small staff can support a diverse set of applications and services in a virtual lab. Second, it can save the students a significant amount of money because it is nolonger necessary for them to purchase the software for their personal computer. The students can always access the licensed applications on the virtual environment and practice on them as if they were

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installed on their own computers.Lastly, virtual lab can also support theonlinecourses and distance education programs at the university. There are a number of e-learning software programs from many reputable software developers such asWebCT and Blackboard - developed by University of British Columbia, Adobe E-Learning, Microsoft E-Learning, and others that can be employed for online courses and distance education.

D. Economic Challenges of Cloud Computing

While cloud computing offers economic benefits, it also presents some economic challenges that must be carefully examined before integrating this technology in the labs. The first issue is the licensing costs of some applications on the cloud server such as Microsoft Office, Adobe Creative Suite, SPSS, and others. According to a survey of conducted by University of Montana, the top software applications in use on campus are Microsoft Office (78%) and Adobe products. Research into the cost of licensing applications on a virtual server for concurrent use by campus constituents, regardless of user computer ownership, showed that most software vendors are not amenable to cost-effective licenses to users in a virtual environment. Furthermore, some service providers require the users to pay extravagant fees to use the software hosted on their server that has been paid for license. These costs make the idea of cloud computing lab uneconomicaluntil the virtual lab licensing cost is more affordable (University of Montana, 2012).

V. VIRTUAL COMPUTER NETWORKS LAB EXAMPLE

In university environments, a number of opportunities already exist for transition from brick-and-mortar based labs to cloud base labs. It should be noted that many software applications that are used by computer science, management information science and computer information science departments typically operate on server based systems with desktop clients which may be computers at university premises or personal computers owned by students. Server based software include database programs, enterprise resource planning (ERP) programs, web application development and deployment tools. Lab elements that are candidates for transitioning to cloud also include some hardware based laboratory elements.

Hardware based elements, which historically posed an obstacle to transition of academic computing labs into clouds, are becoming easier to transition, thanks to progress made in hardware virtualization. Virtualization refers to abstraction of a form of technology away from its original environment (Kulshreshta and Verma, 2010). Virtualization is becoming more common place in cloud technology as Infrastructure as a Service (IaaS) (Hossain, 2013). Today it is possible to build software objects such as servers, client systems, networking and networkable devices that represent various hardware elements in computing environments (Agarwal 2013; Rodriguez, et al., 2012).

An example of hardware virtualization is virtualization of networking devices and components. While computing platform virtualization on clouds has been studied for educational use [Khan, Seetha and Pandey, 2012), virtualization of networking elements in education has not been researched sufficiently. With the current virtualization technology, it has become possible to conduct computer network and computer network security course experiments using virtual networking software that can run on desktops and servers. Such software products allow students build exact replicas of hardware based networks using software tools. Some companies that provide such software tools include Cisco Systems, Inc. and Boson Software, LLC. Such software tools allow student to build complex computer networks using various network components such as routers, switches, hubs, servers, client computers, cables and WAN emulation devices to be represented as software objects in the virtualization tool. The available software tools provide a convenient virtual laboratory environment for many networking experiments and network security experiments. At the University of Houston-Clear Lake, students utilize Boson software to build complex computer networks and test them using server based software at the university premises.

The software items listed above, whether used for software experiments or virtual hardware experiments, can easily be transitioned from computing systems on university premises to cloud computing allowing variety of cost savings in terms of physical real estate and in terms of installation, maintenance and administration of servers that hold those applications.

VI. CONCLUSION

The traditional academic computing labs play a significant role in supporting the student learning at the universities.The changes in academic environment, evolving computing technology and teaching modes mandate changesin the configurations of the labs to remain practical and relevant. The cloud-based computing labs offer students flexibility in accessing the lab resources from outside the university at any time. With the advent of virtualization technologies, not

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only software labs and applications but also hardware based labs such as network laboratories can now be transitioned to cloud environments. Such flexibilityprovides them the ability to continue to work on their homework and projects outside the lab hours as well as at their convenience, preference and choice. Furthermore, it allows them work on projects with rights and privileges that are not feasible in the traditional computing labs. The universities gain the benefit that they can accommodate more students with virtual configuration than with the traditional lab configuration, and it relieves the lab personnel from many management and administration functions that are performed by the cloud service providers. Importantly, this technology can better support the online academic environment than the traditional computing labs. Nevertheless, cloud based labs also pose challenges that need to be addressed. An important challenge in the adoption of this technology remains in terms of the additional licensing fees that may need to be paid in order to accommodatealarger number of users. Furthermore, the students may also be required to pay fees to the services providers. Nevertheless, the benefits mayfar outweigh the costsfor universitiesto not explore the configuration of academic computing labs that might become the norm in the future.

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