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Design of Cloud Services for Cloud Based IT Education

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Abstract

The objective of this article is to facilitate cloud based IT education by developing IT education specific Infrastructure as Service (IaaS). IaaS is one of the main cloud services. This paper considers IaaS development and application in IT education. For IT education, IaaS can be used to reduce cost, enhance security, and provide flexibility. This paper begins with the investigation of requirements for IT education. It then provides design strategies to meet the requirements. Issues in planning and implementation will be discussed. This paper will present a case study to illustrate IaaS for IT education.

Keywords

Cloud; Infrastructure as a Service; Software as a Service; Platform as a Service; Computer Lab

Introduction

In IT education, requirements for IT infrastructure vary from one course to another (Chao, 2008). Meeting all the requirements by different IT courses can be a challenging task. Cloud computing has emerged as the technology that provides a feasible solution for education. As early as 2008, UC Berkeley moved its IT infrastructure supporting software project course to Amazon Web Service (AWS) cloud (Fox, 2009). For the software project course, a small realistic assignment may require 8 to 10 servers. A class of 40 students needs 200 servers if two students are paired as a group. Before the submission deadline, these 200 servers will run at their peak capacity. This will cause a short term surge in usage. After the assignments are submitted, the 200 servers will almost be idle. In the past, it would require an education institution to purchase these servers, network them, install the necessary operating system and application software, and dedicate IT staff members for maintenance. For many smaller universities, it is impossible to support such an IT infrastructure. These universities do not have enough funding for such a large number of servers. They do not have enough manpower for maintenance and technical support. They do not even have space to place these servers and pay for the electric bill. In addition, this is just for one course. In the IT curriculum, there are dozens of courses like this. By using the public cloud such as AWS, the problem can be solved. UC Berkeley subscribed 200 servers for a short time and released these servers after the submission deadline has been passed. In such a way, a university can pay for the usage for a short time and therefore will reduce the cost. The public cloud is well known for its capability to handle the short term usage surge. In addition, there is no need for a university to purchase, install, and maintain these servers. Creating these servers on the public cloud can be done within an hour.

As described by Nicholson (2009), cloud computing is replacing the traditional way of providing software for higher education. Once a higher education institution is cloud powered, it can gain significant flexibility and agility. Nicholson (2009) explored the issues of powering higher education institutions with cloud computing. The main concern is that the data or applications owned by a higher education institution will be physically stored in a third party's data center. The higher education institution has no control over where to store the mission critical data in a third party's data center. Some of the information owned by the higher institution needs to be well protected. The government has strict regulations on protecting students' private information. Higher education institutions often conduct research for the government. The information about government contracts and intellectual properties needs to be protected with high-level security. By the U.S. export

laws, some of the content owned by a higher education cannot leave the country or cannot be accessed by a foreign country. State-funded institutions may not be allowed to outsource government jobs to a private third-party cloud provider located in a different state. In addition to security concerns, a higher education institution also needs to address issues related to service availability, data portability, data content ownership, and maintenance responsibility. Nicholson (2009) suggested that, while looking for new technological advantages, higher education institutions should keep an eye on regulatory factors before decision making.

As a new technology, cloud computing has significant impact on teaching and learning in many ways. Chang and Guetl (2010) investigated the challenges and benefits of cloud computing in experiential and student-centered practices. Through the examples, they demonstrated how cloud computing was used to incorporate the empirical and student-centered learning. They examined the impact of learning behavior, habits and styles of Generation Y by cloud computing.

The advantage of cloud computing is particularly useful for supporting lab activities in the teaching and learning process. The lab activities and content are less sensitive to regulations and security requirements. As labs are upgraded frequently and take a great deal of effort and resources to implement the changes, they can greatly benefit from the flexibility and agility offered by the cloud computing technology. One of the successful stories is the research conducted at North Carolina State University (NCSU) (Stein, Ware, Laboy, & Scha_er, 2013) to improve the K-12 pedagogy. By teaming up with IBM, NCSU developed a cloud architecture to support learning and research. The strong support from an industry leader such as IBM and the rich experience of the NCSU faculty members and IT service made the project very successful.

Some of our education institutions may lack the support from the IT industry. They may be small and short of funding and IT service. Due to the shortage of funding, skilled technicians, and "know-how", frequent updates of research infrastructure and computer labs can become a burden to these education institutions. Additionally, research studies in IT education (such as database, networking, Web development, security, math modeling, numerical methods, bioinformatics, and big data analysis among others) all have their own special requirements for computer labs. Even with the above difficulties, these higher education institutions can benefit from the cloud computing technology. The intention of this paper is to extend the application of cloud computing to IT education. It will first investigate the requirements by IT education. Then, it will identify the cloud technology that can be applied to IT education. The emphasis will be given to the cloud solution for the IT infrastructure which is used to support IT education.

Lab Requirements for IT Education

To benefit from cloud computing, one needs to know the requirements for IT lab courses' hands-on activities, where and how to provision the cloud service to meet the requirements. The first step is to investigate the needs of the IT courses. Basically, the IT courses can be categorized as below:

- **Type 1**: Courses that require hands-on practice on computer software, such as computer programming and multimedia development. For this type of course, the computer lab can have a single server with the required software packages installed. Students can remotely access the software installed on the server.
- **Type 2**: Courses that require hands-on practice on a client-server structure. Database systems and application development are such courses. For these courses, we can configure students' computers as the clients to communicate with the server. If the hands-on practice is performed on multiple servers or the students are divided into multiple groups and each group has its own server, it is necessary to have a computer lab constructed with multiple servers on the client-server architecture.
- **Type 3**: Courses that require hands-on practice on the server side. This may require the re-configuration of operating systems and networks. There are many such courses in the IT curriculum such as system administration and network management. For this type of course, a fully functioning IT computer lab is necessary. Students have to be the administrators of the computers in the lab.

In IT education, computer labs are necessary to support the hands-on practice for all these types of the IT courses. For an IT education program to be accredited by the Accreditation Board for Engineering

and Technology (ABET) (ABET, 2005), the IT education program must meet the requirements for computer labs. To be able to support all the three types of IT courses, the computer labs must overcome some challenges, frequently upgrading to catch up with the rapidly changing IT industry trend, supporting various needs of IT courses, and enforcing security measures.

To catch up with the IT industry trend, IT textbooks are updated frequently. The computer labs designed to support the IT courses are often short lived. IT education programs are required to reconstruct the IT infrastructure to support the new content covered by the IT courses. The reconstruction of the IT infrastructure physically is time consuming and expensive. Many small universities can hardly keep up with the demands. Since cloud computing provides Infrastructure as Service (IaaS), it can greatly help small IT programs with reconstructing the IT infrastructure.

All the three types of IT courses have their own particular requirements on the IT infrastructure to support their hands-on practice. The IT infrastructure created to support one IT course may not be used to support to another IT course. For example, the IT infrastructure constructed to support a networking class cannot be used to support a Web development class. As the network configuration is modified by the networking class, the students from the Web development class will not be able to access the Web server. It is impossible for a small IT education program to support so many IT infrastructures physically. With cloud computing, virtualized IT infrastructures can be built in a fast and easy way. IaaS is flexible enough to create various types of IT infrastructures to support all types of IT courses.

There is a great concern when teaching IT courses, especially for those Type 3 IT courses where students are required to have the administrator's privilege for network and system configuration. When a computer lab is physically connected to the university's network, the network services developed by the students can mess up the services provided by the university's network. The virtual IT infrastructures can effectively resolve this problem. The virtual networks can be isolated from the university's network so that no network traffic can pass from the students' virtual networks to the university's physical network.

Cloud Service Design

Depending on the requirements and the existing IT infrastructure of an education institution, the cloud computing environment can be constructed with different approaches. There are three types of cloud computing services available (ZDNet, 2010).

- **Software as a Service (SaaS)**: This is a cloud service that allows education institutions to subscribe online software hosted by a cloud provider. If proprietary software is used, the education institutions need to pay for the usage of the software. Some of the well-known software packages provided by SaaS are Google Apps and Microsoft Office 365.
- **Platform as a Service (PaaS)**: This is a service that provides a Web-based application development platform. It can be used by an IT course to design, develop, test, deploy, upgrade, and host Web-based applications. It allows application developers to form a community to carry out collaborative work on a project. Server operating systems, databases, middleware, Web servers, and application development environments are provided remotely by PaaS providers. Microsoft Windows Azure is this type of service.
- **Infrastructure as a Service (IaaS)**: This is a cloud service that provides an IT infrastructure that consists of servers, networks, data storage and other necessary tools properly configured to form a virtual computing environment that fulfills the hands-on practice requirements of an IT course. Amazon Web Service (AWS) provides this type of service.

As cloud solution designers, we need to make decisions on the selection of cloud services and cloud computing platforms based on the types of IT courses.

- For Type 1 IT courses, SaaS is adequate to get the job done. If the required software is available from the public cloud provider, our research team doesn't have to do much. If it is not available, we can subscribe a server from AWS and install the required software. In most cases, the cost of subscribing a server is affordable. Another option is that the research team develops a private cloud to provide such a service.
- For Type 2 IT courses, PaaS is the one to use. Windows Azure and SQL Azure can be used for database system and application development courses. Some of our IT courses require application development with open

source tools such as Apache, MySQL, Perl, and Firefox; the research team can provide the computing service through a private cloud. Although subscribing public cloud services from Windows Azure or AWS can also solve the problem, the cost for storage, networks, and servers can add up to a significant amount. This solution should be considered only when an education institution has inadequate IT infrastructure to support its Type 2 IT courses. PaaS provides an ideal platform for group projects. It enhances interaction among students and instructors.

- Type 3 IT courses post a great challenge to the research team. IaaS provided by a public cloud may not be the solution. For example, a networking class of 20 students may require 60 servers for hands-on practice, three servers for each student to form a local network. Subscribing 60 servers from Amazon can be too expensive for a small education institution in a rural area. From our experience, the cost for subscribing 4 virtual servers and some storage space for four months is $1,186. The IaaS provided by a public cloud has another drawback. It is not easy for students to reconfigure the server's IP address, which will disconnect the students' access to the cloud. This research project mainly focuses on the development of a private cloud that can handle the hands-on practice for Type 3 IT courses.

As the analysis indicates, the support for Type 3 IT courses is the most difficult to implement. The Type 3 IT courses require IaaS, which is the most expensive among SaaS, PaaS, and IaaS cloud services. In addition, the Type 3 IT courses may need the IaaS service for an entire semester. Subscribing IaaS for a short time from a public cloud provider may not be the solution for this case. Therefore, the solution is to provide IaaS on a private cloud. The logical design of IaaS provided by a private cloud is illustrated in Figure 1. Depending on the requirements of an IT course, IaaS can provide the IT infrastructure specially designed for the required hands-practice.

Although the private cloud has some initial cost, once established, there are significant savings on computer lab construction. It is also flexible and safe enough to meet other requirements for hands-on practice. In addition, we do not need to pay subscription fees for using the private cloud. Physically, the private cloud is constructed on our private network with cloud servers and storage devices. To support an adequate number of virtual networks with virtual servers, the physical host server needs to have enough RAM and hard drive storage space. If the funding is available, the data center can be built on a set of hard disks configured as an RAID 10 system for better reliability and performance.

If the budget is limited, one may consider using open source cloud software such as Ubuntu Enterprise Cloud or an education priced cloud capable operating system such as Windows Server 2012 R2. When there is not enough RAM and hard drive storage space for an entire class, the instructor may encourage the students to access the IaaS service at different times.

To access the cloud service, the students need Internet connections, PCs, or mobile devices. Nowadays, most households have Internet connections through TV cables, Satellite, or DSL. Today's 3G and 4G mobile networks can also be used to access the Internet. When connected to the Internet, the PCs or mobile devices can be used to access the IaaS service anywhere and anytime. When constructed, the private cloud can be accessed through a VPN, private cloud client software, or hybrid cloud technology remotely through the Internet.

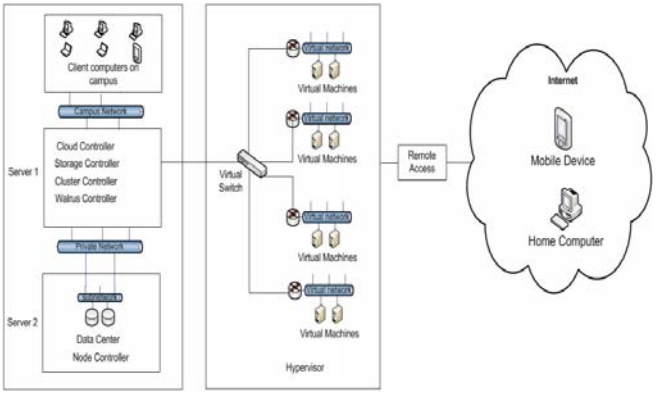

FIG. 1. CLOUD ARCHITECTURE

IaaS Technology

Infrastructure as a Service (IaaS) provides the virtualized IT infrastructure. It provides equipment such as storage, virtual machines, virtual networks, and networking tools. The key technology for virtualization is the hypervisor which is the software used to create, host, and manage virtualized computing resources. There are two types of hypervisors, the bare metal hypervisor and the embedded hypervisor. The bare metal hypervisor runs directly on the hardware of the host computer. Microsoft Hyper-V, VMware vSphere, and Citrix

XenServer are this type of hypervisor. The embedded hypervisor runs like a piece of software on an operating system. VMware Workstation is this type of hypervisor.

The implementation of vSphere requires a powerful server and the licensing cost may be too high for a small business. Therefore, VMware offers a lower-cost package for small businesses and the VMware Academic Program (VMAP) package which includes vSphere, Workstation, vCloud Suite, and other software for an annual subscription fee of $250 for education institutions. Microsoft Hyper-V is included in Windows Server 2012 which is free for students and faculty members. The full version of XenServer is not free. The free XenServer version supports only up to 4 virtual machines and 4GB of RAM. When creating the IaaS service, an education institution may consider either vSphere or Hyper-V. Especially, as Hyper-V is relatively easy to use and takes fewer resources, it is a good choice for small education institutions to implement IaaS. For more advanced features, vSphere should be considered.

The middle section of Figure 1 demonstrates an IaaS service implemented with hypervisor. A large scale of IaaS may have a pool of hypervisors together to support a large number of virtual machines and network devices. IaaS may provide a virtual machine image library for users to choose. This is a desired feature for IT education. Each course has its own required virtual machines. The image of each virtual machine can be saved in the library. When needed, the specific image design for an IT course can be used to generate virtual machines required by the IT course. IaaS may also provide a virtual network to link the virtual machines, a virtual hard disk to store files, an IP address for Internet access, a firewall for security, and remote access mechanisms. IaaS provides these resources depending on the demands of an IT course.

The features of IaaS are ideal for developing computer labs that require various computing resources and frequent updates. A small education institution lacks funding to support a large scale IaaS service. However, it does not require a lot of resources to accomplish computing tasks. Its IaaS can be built on well-defined circumstances. It can have better understanding of its student population and better control on simultaneous logins. The IT courses on a small education institution have fewer requirements when compared with a large university's needs. The following case study demonstrates the process for implementing IaaS for a small education institution.

Case Study

Both private and public clouds can provide IaaS. When IaaS is subscribed from a public cloud provider, it is not necessary for an education institution to develop its own IaaS. The virtual network and virtual machines will be provided by the public provider. Some public cloud providers also provide software including operating system and application software. In such a case, instructors can create their computer labs on top of the subscribed IaaS.

As mentioned earlier, some IT courses such as networking require a large number of virtual networks and virtual machines. It may be too expensive for a small education institution to subscribe the IaaS service from a public cloud provider. In such a case, constructing a private cloud is a good choice. In many cases, a small university may already have an Internet accessible network in place. Therefore, developing a private cloud by using an open source cloud development package such as Ubuntu Enterprise Cloud can be an inexpensive and flexible solution. The education institution can also consider an academically supported cloud development package such as Microsoft System Center 2012 R2 or VMware vCloud Suite. Although Ubuntu Enterprise Cloud is free, it requires powerful servers to host the private cloud. The purchase of new servers can add to the cost significantly. On the other hand, once a private cloud is created, the education institution does not need to pay a public cloud service provider for the IaaS service. The private cloud developed with Ubuntu Enterprise Cloud is compatible with the public Amazon Elastic Compute Cloud (EC2). Such a private cloud can be transferred to the public cloud EC2 with minimum effort.

As a case study, let us consider the procedure of creating a private cloud to provide the IaaS service to support multiple IT courses such as networking, web development, Java programming, database systems, and security management. Instead of physically creating several computer labs to support these IT courses, an educational institution can implement the private cloud to provide the IaaS service. Depending on the cloud solution design described earlier, the development of Ubuntu Enterprise Cloud can be implemented with the following strategies.

1. Install the Ubuntu Cloud Server on two computers, one is used as the cloud controller

and the other one is used as the node controller. Used as servers, these two computers should have large enough RAM and hard disks. Depending on the number of classes to support and the number of virtual machines to be used in a class, when the private cloud is configured to use RAM dynamically, the cloud can use the RAM efficiently. For a networking class with 30 students, each student uses two virtual machines and each virtual machine requires 1GB RAM and 60GB hard disk space. The host server may need to have 48GB RAM and 4TB hard drive space. Since networking is a Type 3 IT course, it has the largest demand for virtual machines. To support Type I and Type 2 IT courses, a few virtual machines should be adequate.

2. Create computer images for different types of IT courses. Each image is designed to meet the hand-on practice of an IT course. It includes a virtual machine installed with all the required operating system and application software. The image is used to generate a number of virtual machines depending on the class enrollment.

Each image needs to be uploaded and registered to the cloud controller. Once it is registered, create enough copies of instances of the image designed for the IT course depending on the enrollment of the class. Figure 2 shows the created virtual instances.

Conclusion

Theoretically, students should have complicated and high-level thinking skills to solve all the problems that occurred in the PBL. This study adopted a teaching strategy consisting four stages consisting of planning, concept learning, structuring, and designing to guide students who accomplished a PC AVG in one year. This teaching strategy is feasible. The authors found that in the PBL, students learned new knowledge and skills by modeling the core learning examples and connecting newly learned ones with the prior ones. This process definitely develops their programming capabilities for game design. In discussions, when design students attain the ability of programming, they usually have worked on the project continuously in solving the programming problems. In addition, programming is usually difficult and boring for design and art students. However, in this study, the authors found if the mentoring teacher can guide students by using suitable modeling examples, they can combine their visual design ability with programming to create a PC AVG. Using the PC AVG as the programming subject will motivate students to learn interdisciplinary subjects and also lead them to advanced skills, such as advanced array, functions, and algorithms of programming.

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