AC 2008-1578: NETWORKING LAB SIMULATION USING VIRTUAL TECHNOLOGIES

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Networking Lab Simulation using Virtual Technologies

Abstract

Rapid advances in technologies and the limited budgets always hinder the universities from upgrading their networking lab equipment to a state-of-the-art level. As one of the regional Cisco Networking Academies, East Carolina University spends a large amount of funding purchasing new equipment for the ever changing Cisco networking academy curriculums. Reducing the demand for real lab equipment and deploying simulation based labs can effectively mitigate the current conflicts between the budgets and the requirement of lab availability.

The purposes of this paper are 1. comparing Cisco networking simulation software applications that are available on the market, 2. highlighting the advantages of the novel virtual technology based simulation software over the traditional simulation software, 3. providing a complete solution for teaching networking labs using virtual technology including hardware setup and connection, remote access configuration and software installation, and 4. designing lab topology using DynampisGUI to simulate a full rack of Cisco equipment on a single PC.

I. Background

Laboratory work and hands-on experience are critical aspects of engineering learning. At Technology Systems Department of East Carolina University, we offer a unique ICT (Information and Computer Technology) program which is different from the traditional computer science curriculums. The ICT program emphasizes on delivering hands-on experience and teaches students practical skills that can be used right after they graduate. Many courses within the ICT program provide training for the students to obtain the equivalent industry certificates. The contents and quality of these courses attract a large number of students into the program. The student enrollment was increased rapidly during the past three years, making the ICT program the largest program in the College.

In the meantime, distance education (DE) sections constitute an increasing portion of the student enrollment of the ICT program. Studies have shown that this trend will continue in the future years. To deliver hands-on experience to the online teaching, with a quality equivalent to what students can get from the face-to-face laboratory environment, has been an eminent requirement for further expanding our DE program.

A number of studies on remote computer networking and technology laboratory have been done in recent years. These studies can be classified into four categories.

1. Remote access system and remote lab architecture design

Some studies[1, 2, 3] intend to create remote access methods for the students to join their local machines to the remote labs so that the lab resources can be utilized. VPN is usually used to allow the users to setup a tunnel in the public Internet to transmit information securely in the

encrypted formats. A Lab reservation system is setup for the students to share the lab equipment and available time.

2. Course management and delivery systems for DE classes

A large number of studies[4, 5] have been conducted to investigate the use of the available software or the development of new applications to mange course contents on web-based systems. For example, the widely used asynchronous course management systems are Blackboard[6], Sakai[7], and Moodle[8]. Centra[9] and other tools can deliver lectures online in real-time by using video/audio streaming, Whiteboard technology, application sharing, and remote assistance technique. The free Wiki tools or commercial tools, such as MS Sharepoint, can facilitate collaborations among the DE students.

3. Simulation based lab teaching

Software simulation has been widely used in the engineering fields. The benefits of using simulation in teaching are cost saving and safety. Simulation software can also create an abstract model of the real equipment which concentrates on the essential operations and functionalities of the real equipment. Studies[10, 11] have shown simulation software provides great value to the academic teaching in computer networking and information technology. LabSim[12] is a series of software simulation product used in the academic teaching. It provides simulation environment for the student labs in many major IT software products, including MS Windows Server, Linux, SQL server 2005, security labs, and intrusion detection systems. Boson[13], Packet Tracer[14], Semsim[15], and Routersim[16] are other products simulating Cisco networking lab environment. There are drawbacks of using software simulation teaching networking classes in practice. First, simulation software re-creates environments which are similar to what the real software or equipment provides. Most simulated equipment is highly proprietary. This makes it impossible to re-create all the functions. Therefore, simulation software can only be used to teach the basic concepts or labs with simple topology. Another disadvantage of simulation software is that they are host-based. Remote access and network capacity are not usually provided. Students may install the simulation software to their home computers, but using them on the remote labs is not practical.

4. Virtual machine based remote labs

Virtual technology has been a hot topic in recently years. Academic studies have shown success in bringing industry virtual technologies into class teaching. At ECU, VMware[17] is used to teach operating system and network security classes. Virtual technology allows multiple operating systems running on the same machine simultaneously. These operating systems then communicate with each other in an IP based sub-network. Therefore, a whole network is formed on one computer. A great amount of lab resources are saved.

The objective of this paper is to provide a remote lab solution teaching computer networking classes. The methodology is based on virtual technology. Section II shows the architecture of this solution. Section III discusses the results. Section IV concludes the study and points out the future works.

II. Framework and Methodology

The major difference between the proposed lab architecture from the traditional lab setup is that no physical routing equipment is needed; the Cisco IOS (Internetwork Operating System) runs inside virtual machines on the lab PCs using Dynampis[18]. Dynamips is a GPL-licensed Cisco router emulator developed by Christophe Fillot . Dynampis uses the real Cisco IOS as the operating system. It converts a personal computer into one or multiple virtual Cisco devices with full functionalities. The only difference between a real device and its virtual counterpart is speed. In a networking lab for academic uses, speed is a not a major concern because there is no heavy production network traffic involved. Multiple instances can be run on the same computer. A virtual networ, consisting of multiple routers, switches, firewalls, and frame relay switches, can be simulated on a single lab computer. This single computer is therefore used as a remote access server for the students to perform hands-on configuration labs.

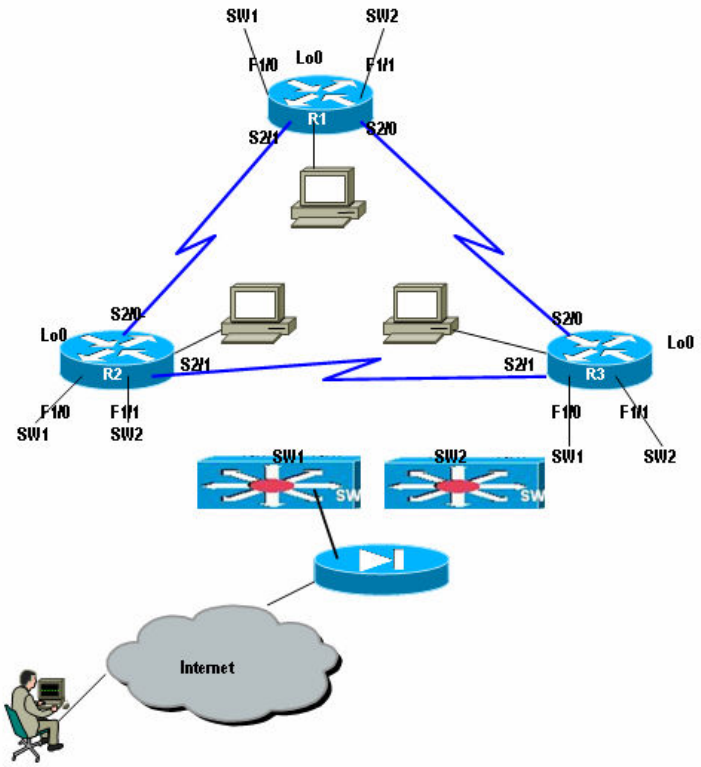

Figure 1. Traditional remote computer networking lab architecture

Figure 1 shows a traditional remote computer networking lab setup. The student logs into the remote lab through VPN and gets access to a central switch or an access server which connects to all the lab equipment. In this figure, three routers connect to each other through the serial interfaces. They connect to two switches through the Ethernet ports. PCs are connected to the routers to test the connectivity and IP settings. This lab topology is suitable for teaching intermediate networking classes. Routing protocols, such as EIGRP, OSPF, RIPv2, and BGP, can be set up on the networks formed between the routers and outside the loopback interfaces. Network analyzers, performance monitors, and network management client tools can be installed and configured on the PCs to analyze the IP packages transmitted in the network. Security tools can also be installed on the network to generate or capture packets for security and intrusion

detection system labs. The setup uses real equipment and emulates the real industry production networks in a remote lab environment. The costs of building and maintaining this type of remote labs are high.And only one student can use the lab at a time.

Figure 2 shows the virtual technology based computer networking lab architecture. The physical routing equipment is eliminated and replaced by virtual devices. The IOS of each device is embedded into the virtual memory of the PCs. A full rack of the routers and switches, as shown in Figure 1, can now be simulated on one PC. Multiple PCs, running the virtual devices, are linked to a central switch for the remote users to connect to. Now each user can have access to a dedicated virtual networking lab.

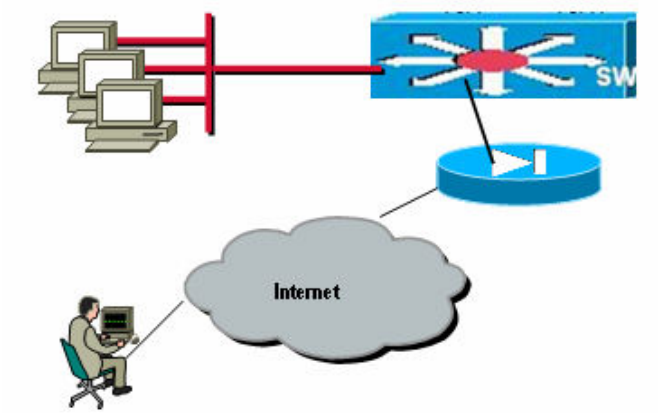

Figure 2. Remote computer networking architecture by using virtual technology

In a testing lab, 8 PCs were set up with Dynampis to accommodate a graduate networking class of 8 students. Each student has her/his own dedicated computer to configure the virtual routing equipment. This lab setup can easily fit into a large undergraduate networking class. And the remote virtual lab can be shared among classes.

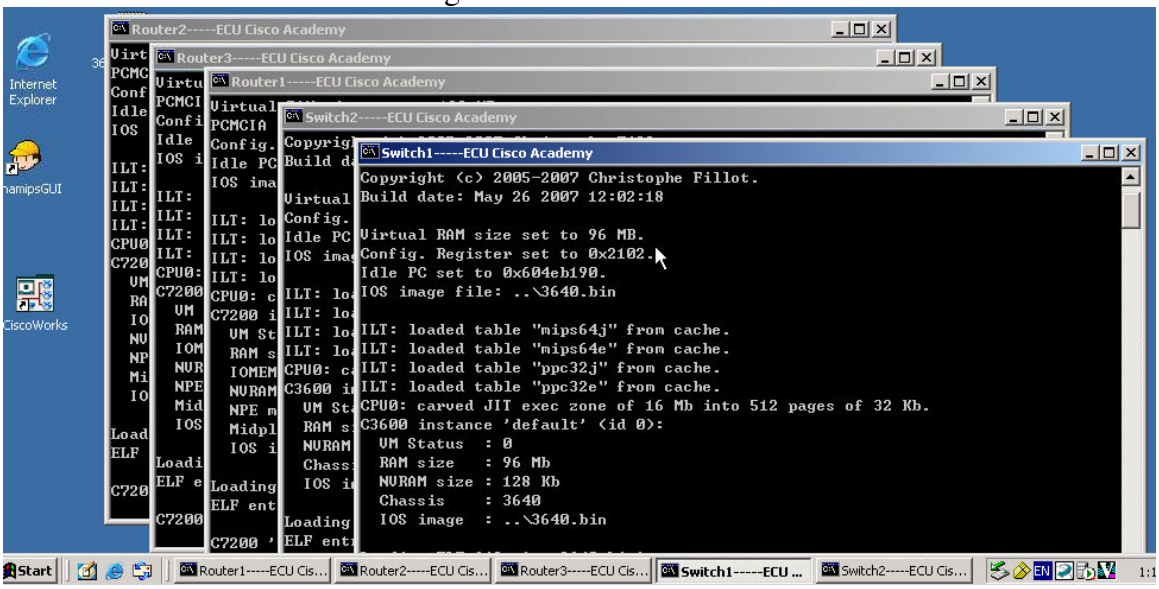

Figure 3. Dynampis server setup

Figure 3 is the screenshot of a Dynmapis server for the topology illustrated in Figure 1. In each instance window, the size of the virtual memory used by the IOS, IOS version, and equipment type are listed. As shown in the figure, an emulated Cisco 2600 series router only uses 64MB of memory. An emulated Cisco 3640 router with switch modules uses 96MB of memory. A lab PC with Intel P4 3.0G CPU and 2GB RAM is capable of hosting complicated routing and switching topologies that are taught in the upper level graduate courses.

In this simulated network environment, the virtual cabling process is reduced to be incorporated into a simple text file. The connectivity configuration file for Dynamips is shown in Figure 4.

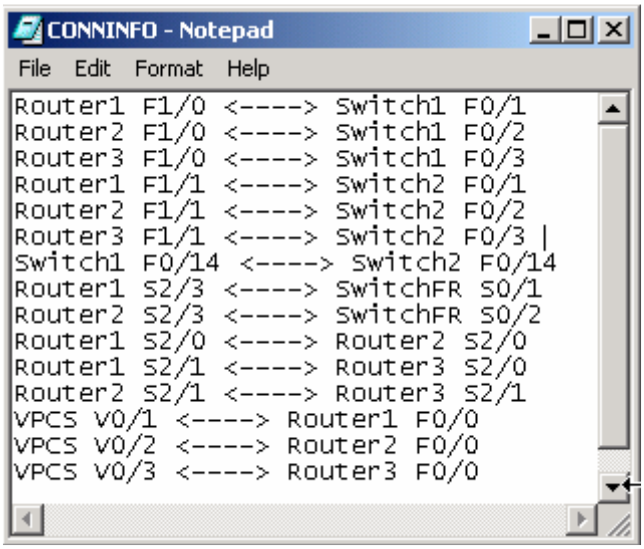

Figure 4. Configuration file for the cabling and connectivity of the network shown in Figure 1.

If anything goes wrong with the virtual equipment, for example, a router is down, an interface is unable to come up, or the IOS freezes, the instructor or the students can log into the lab PC and restart the instance of the faulty device. This releases the burden of the instructor to fix the hardware problem on site. Fast recovery and easy backup are among the advantages of the virtual lab over the traditional approach. In the meantime, the full capacity and functionality of the simulated equipment are delivered. Both the instructors and the students can modify the connectivity file and reconstruct the topology of the virtual labs.

III. Results and Discussions

The remote virtual lab was used in a graduate level DE networking class. The students performed eight routing protocol labs.. The first four labs on Interior Routing Protocols were conducted in the traditional lab settings. The students had to reserve the lab time slots each week. There were always time conflicts because most DE students have daytime jobs and can only do the labs during the limited hours at night.. Weekend is the most desirable time for them. . The last four labs on advanced Interior Routing Protocols and Exterior Routing Protocols were conducted on the virtual machines.

A student survey will be conducted at the end of the semester. The survey will contain questions about the virtual technology based lab experience, such as ease of lab access, lab availability, lab stability, improvement of learning, ease of using and managing lab equipment, and general

satisfaction. Since this course is still in process, the result of the survey is not currently available. The initial feedback from students is very positive. .

The virtual networking lab provides the following benefits. First, the lab availability is greatly improved. In the testing class, each student has a set of virtual lab equipment available any time through the semester. The lab reservation system used in the past years is no longer necessary. Second, the hands-on experiences are very "real". The students could barely tell any differences between the simulated and the real lab environment. The students still log in to the lab network though a VPN concentrator, and connect to the individual devices through an access server by using Telnet. Even the port numbers on the access server which are used to connect to the console ports on the individual devices were not changed. During the lab, students experienced improved equipment performance because the virtual machines were completely software based, and time was saved from eliminating the hardware self-testing process. And finally, the students were learning more by creating their topology and virtually cable the equipment. Several student projects were done this way. Cabling a remote networking lab is impossible on the traditional remote lab because the students do not have access to the physical equipment.

As for maintenance, the virtual lab eases the instructors from cabling the labs. Each topology and virtual machine files can be saved on the hard drive. A typical lab topology takes a storage space from 200 to 300 MB. A file server can be setup to store these files. The labs can be set up by downloading these files to the lab PCs at any time when the topology needs to be changed. The virtual lab also simplifies the troubleshooting process. There is no need for on-site troubleshooting because the connectivity is software based. The hardware failure or "layer I" problems are completely eliminated. All the operation and configuration are done through remote access.

IV. CONCLUSIONS AND FUTURE WORKS

The proposed remote networking lab architecture based on virtual technology showed great advantages over the traditional labs using real equipment. This lab is particularly helpful in teaching DE classes. Students can gain the same level of hands-on experience.. The students are able to virtually re-cable the lab equipment, change the lab topology, and implement new design with by adding new virtual lab equipment. The virtual lab delivers of the full functionalities of the real equipment. This lab solution is mostly suitable in teaching because the network traffic is light and the lab PCsare usually powerful enough to handle the load.

As a Cisco Networking Academy, ECU is teaching a full curriculum of both CCNA (Cisco Certified Network Associate) and CCNP (Cisco Certified Network Professional) levels. The success of the proposed lab solution may generate positive influence on more than 700 Cisco academies nationwide.

Future works will be done to explore the virtual technology in remote lab teaching. In 2007, Eagle Server solution was proposed by Cisco to teach network services. The Eagle Server is a Linux based machine, providing DHCP, mail, FTP, Web, and many other services to the lab equipment in the network including routers, switches, security devices, and PCs. We are working on integrating the free Dynampis virtual Cisco device simulation with other virtualization applications, such as VMware, which is used to host the Linux based Eagle server. If the

integration is successful , a high end lab with network equipment and servers will be fully emulated on just one single PC by collaborating different virtual technologies. The results can be fascinating and very valuable in academic teaching.

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