Convertible Remote Inter-Networking Laboratory Design for Teaching Purposes

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ABSTRACT − **On-line learning has proven to be a cost effective method of delivering courses to remote students. However in the field of network technology, practical 'hands on' experience is of paramount importance. Procedural knowledge gained during laboratory reinforces learning. Furthermore students must therefore be given the opportunity to configure network devices. Providing sufficient laboratory facilities to supplement a conventional face-to-face classroom is a challenge. Typically remote, on-line students are given access to network devices via the text-based Command Line Interface (CLI). The CLI alone is verbose and many different instructions are needed to understand device operation and the output can also be extensive and complex. Particularly, remote student interaction with the equipment is limited compared with a traditional laboratory model. This paper reviews existing remote access laboratory designs, and explains the new convertible design in details, which address the requirement of remote students.**

KEY WORDS -- Remote access laboratory; computer networking; e-learning; distance learning; computer education

1. Introduction

Online based learning has proven to be cost effective [1], although it may considered as sub-optimal method of education, especially with online courses that require actual practice with equipment. Computer networking is one of the courses that require access to practical equipment. Providing network equipment to student introduced a number of issues, for example, expensive cost of network equipment limits the student accessibility, rapid change in technology made equipment outdate and the student requirement of realistic interaction of equipment for educational purposes.

Most institutions choose to provide simulation tools to online-based computer network students, due to its flexibility. However, the unrealistic limitation of simulation tools may not be enough to the online student. They should have other alternative to learn.

Furthermore, the current literature lacks of investigating in design of physical and remote laboratory [2]. As a specialty, a long distance learning laboratory may need specific design to suit its own circumstance.

This paper will provide a detail discussion of providing a multimedia convertible remote access laboratory for long distance network technology classes. It will describe the problems encountered and solutions to some of specific issues related to long distance learning. Next topic will discuss about the issues that remote laboratory faced. Topics 3 will discuss about the design of physical laboratories in order to be able to convert to remote laboratories. Finally, it will also state the requirement of the remote students.

2. Issues of remote access laboratory

Content of the topic of the paper is explained in Times New Roman 10 points size Functions of the laboratory are to stimulate and emphasize the learning process of theoretical concepts to student. Traditional hands-on classrooms and real laboratories easily supply these functions as they are tangible environments. Simulated environment of remote laboratories, on the other hand, is in the challenging side. Intangible remote laboratories can only focus on visually media. In other words, visual elements may play a significant role [3].

The issue is the less interactive of remote environment. Traditional remote laboratories usually provide fixed pictures or static diagrams of the equipment that the students are controlling; they lack interactivity. If it is possible to simulate such interaction and response from the remote equipment as would occur in the conventional physical layer, it

would be possible to create more realistic surrogates of the real environment. Other engineering disciplines have successfully employed video displays of equipment in their laboratories. However, rarely in the network education field has this element been provided.

The current design of the remote access laboratory extensively focuses on providing text-based Command Line Interface (CLI) to students. Although providing access is considered as necessity factor [4], student also need responsive feedback from equipment. The remote laboratories must provide system responses to allow the user to know the status of the working devices. Text-based CLI response from equipment may be valuable for quick and thorough analysis from a professional perspective. However, text-based information is narrative, verbose and requires users to have the ability to create their own suitable learning models to contextualize the knowledge. The extensive use of the Command Line Interface (CLI) alone in the remote access laboratory extended the pedagogical issues [5].

User interface of the remote network laboratory also needs to incorporate an ability to mimic the changes in physical topology. Literature so far proposed two approaches to the problem of limited physical level interaction in the remote laboratory which are, (1) provide dedicated equipment setup for every task, or (2) provide a logical adjustable topology. The first approach, students can learn by moving from one scenario to other by the pre-configured equipment; this approach is easier to operate in an unsupervised mode. The second approach is to provide a logical adjustable structure which allows the equipment to be reused for different laboratory tasks.

Nevertheless, there are trade-offs of these two approaches. A dedicated solution may incur more implementation costs due to the need of multiple equipment copies in the laboratory. The logical adjustable approach may impede students' development of basic understandings of how equipment may be interconnected. In order to supply a laboratory in this mode, each equipment has to be interconnected physically, which is not a realistic case in the working environment.

Another issue for remote laboratories is the requirement to provide dedicated equipment just for online sessions. Many schools cannot afford to have two sets of equipment for local and remote use. This is particularly emphasized when one considers the maintenance costs on top of the equipment purchasing. The convertible solution of providing locally available equipment to remote students at the non-operating time may be set in place.

3. Design of the remote access laboratory

3.1 Laboratory physical design

Designs of physical laboratory will not only affect how local students learn but a good design may also offer the advantages of creating and rebuilding the whole laboratory in virtual space for remote students. The design needs to provide pedagogical guidance for students as well as successfully challenge them to be familiar with their future working environment. Therefore, the relationship between pedagogical value and real life working experience needs to be balanced; the laboratory design should support both issues.

Laboratory design should be an isolated learning environment from the real world or production network. Since there is a risk that student's mistakes in trail-error learning process can interfering real working traffic, the laboratory should be designed as a closed learning sand-box. Especially in computer security courses which needed to be involved with malicious network traffic, the benefits of having an isolated laboratory are more emphasized [6].

Many institutions provide separated set of equipment to groups of student in workstations, as a traditional laboratory fashion. For example, this separated set could be consisted of two routers two switches and a set of computers. Students who are conducting each laboratory activity may involve the extra time to prepare equipment setup, apart from cabling their network equipment.

Other institutions may use alternative fashion by sharing centralized network equipment rack, instead of providing them separately. Each student workstation is permanently cabled to the patch panel which can be able to connect to any shared network equipment. One of the advantages is to save the space [2]. Another advantage is in maximizing the potential for reuse of the equipment to build a more complex network; it will also reduce the amount of time needed for setting up and removing the equipment [7]. The racked equipment will also simulate a working environment. Student may have good chances to experience misconfigurations, confusions and easily resulted as disturbances to the neighboring network, which is realistic and cannot be simulated with the traditional laboratory fashion.

Our physical design of the laboratory followed the second fashion, in which the network equipment has been placed in the center of the laboratory. Twenty computers in workstations surround the centralized rack to provide equal accessibility. Figure 1 shows the logical topology and physical equipment layout. The equipment is isolated from the production university network and facility. However, it also

allows each workstation to reconnect to the production network for educational purposes, such as distributing lab documents through the Course

When a remote laboratory is being configured as a particular network topology, some of these multiple connections will be disabled, leaving the enabled
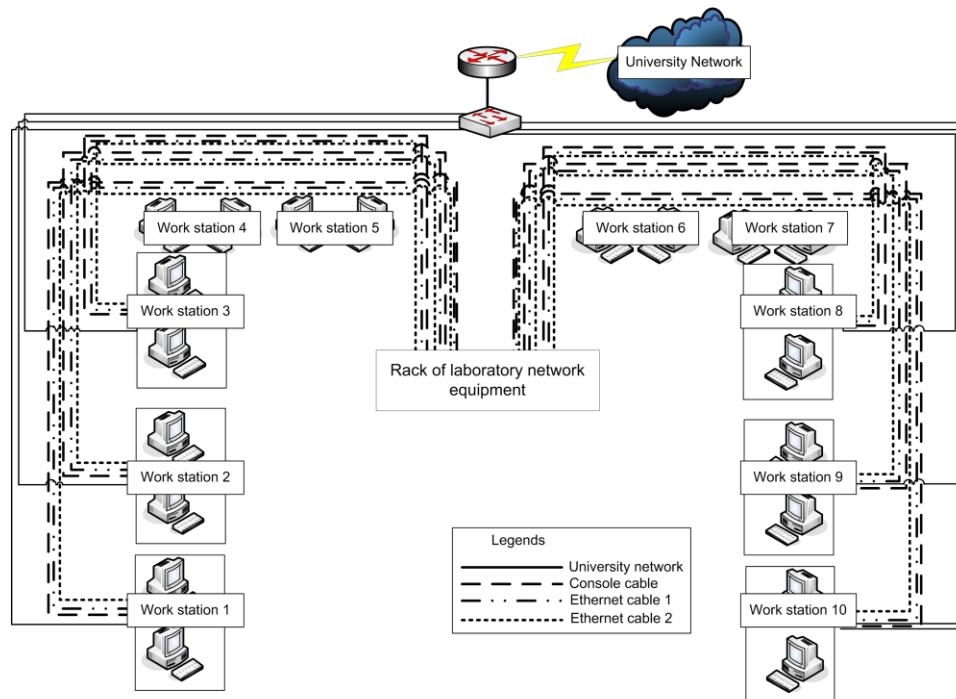

Figure 1. A figure shows the logical topology of the equipment layout in the laboratory

Management System (CMS)

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This physical design does not only benefits local students, but also gives the advantage for remote students of seeing the way in which the equipment would be structured in industry. However, this set-up cannot stimulate the ability of remote students to learn by creating mistakes.

3.2. Permanent remote access laboratory designs

Physical design of the remote access laboratory may differ from the traditional face-to-face laboratory. Traditional face-to-face laboratories need space for students accessing the equipment and extra room for changing or re-configuring the network structure. Sufficient space is essential. On the other hand, remote access laboratories do not share this concern. The equipment used in a remote access laboratory is normally locked in a restricted place. It normally has a fixed network wiring which physically links every piece of equipment. Furthermore, this physically fixed link normally provides multiple connection paths between equipment to support numerous network designs.

connections as a virtual network, which is equivalent to a physical network of the same logical structure. Normally the enabling and disabling processes of these connections may be completed through specific equipment. For example, according to Rigby [8], their virtual patch panel equipment allows the laboratory to be converted and available as multiple purpose lab structures.

Although permanent remote access laboratories require less space and provide more flexibility for network topology creation, they require extra sets of equipment dedicated to a singular purpose. Commercial training institutions may be able to afford these permanent laboratory setups, while educational institutions such as universities may not. Universities may consider other options of providing convertible remote access laboratories.

3.3. Alternatively convertible remote access laboratory

Convertible remote access laboratories benefit from using the existing structure of traditional face-to-face laboratories. The general design of traditional laboratories allows the creation of various network topologies and allows them to be re-designed to

provide access to students outside the university. However, there are various factors that need to be considered before choosing to conduct online classes using the laboratory in this mode.

1. Time available to build, re-build and configuring the laboratory to provide an access to externals
2. Time slot for the externals to use the facility
3. Equipment available
4. Bandwidth of the remote site / traffic permission
5. Language/cultural translation
6. Availability of rewiring equipment and pre-configuration time
7. Number of remote students
8. Accessing style and visualization of laboratory equipment to the externals
9. Pedagogical issues of teaching materials

The laboratory was operated in a traditional face-to-face mode; it needs time to reconfigure and provide the access to the externals. Generally, the availability of the lab outside the peak hours was suitable for utilizing the equipment. However, the providers should also consider the availability of the lab after the configuration. For example, utilizing the lab in the night time is a good alternative.

Using shared equipment with day-time laboratory sessions means that equipment is likely to be broken from extensive use during normal class times. Therefore re-using them at night may not permit staff to count on 100% utilization.

Providing a different mode of access to the remote site means that there is a need to consider the bandwidth factor, especially as a developing country's communication infrastructure may not be as effective as that offered by the developed country host. As such a host laboratory provided in [9], may satisfied the higher bandwidth standard of a well-developed country. Text-based user interfaces are suitable for small bandwidth consumption; however, they may create confusion in a laboratory setup. On the other hand, graphical interfaces may help because of their ease of use but may consume more bandwidth. Using high bandwidth media in a slow communication channel may lead to time-outs and lack of response.

Not only bandwidth but also the traffic types allowed to be used for communication to-and-from the remote institution are needed to be defined. Both the laboratory hosts and remote sites have to agree upon the allowed types of traffic. CLI driven software, such as hyper terminals or Putty, require specific ports for security reasons; hence both sides need to allow this traffic to flow in and out of the system. Similarly, GUI configuration tools require IP connectivity to the configuring systems.

The convertible laboratory can be set up into two modes. First, simple mode, it could be structured as a fixed topology lab. In this case, remote users will not be able to change the logical structure of the lab. It requires less effort and is straightforward to build. Second, the laboratory could be constructed to provide multiple and dynamic network topologies. By using a virtual connection, such as VLAN, the laboratory's logical connectivity can be changed to provide a different logical network. The second option may involve another process to adjust the logical connectivity before the laboratory is usable.

Another factor of concern is the number of remote students. A larger class may need help from a virtual machine to provide equivalent access to the facility. However, with a smaller number of students, the normal PCs in the laboratory can be used as remote terminals. Also a booking management system may need to be implemented to facilitate teaching with the laboratory in asynchronous mode.

The ways in which remote students access the laboratory is another issue that also needs to be considered. The laboratory can be configured to provide normal text-based access via CLI or another hyper terminal program. This method provides direct access to the equipment. Alternatively, the users may access the laboratory via desktop sharing software. The advantage of this alternative is that it permits the other GUI based configuration tools, which normally are prohibited by the traditional text-based methods, to be used during the laboratory session. The pedagogical value of tools must also be considered carefully when implementing such laboratory.

4. Requirement of remote students

Remote students may require more class attention than traditional on campus students as influential factors from presence in a real environment are missing. The learning environment may need to build this attraction and also provide immediate responses to capture students' attention. Therefore, connection speed and the response rate of the environment becomes an indicator of a good or bad learning environment.

In a traditional network laboratory, students can interact with their tutor and ask for immediate comments regarding their current configuration. However, in a remote access laboratory, which normally is operated in an unsupervised mode, an extra task for students is incurred when it is necessary to save or copy the configuration in order to ask for feedback. In a synchronous mode remote laboratory, an immediate response from the remote tutor may be gained. The laboratory should provide the facility for both tutor and students to see the same configuration at the same time.

5. Conclusion

Distance learning of computer networking requires remotely available laboratories. Providing such laboratory may infer extra burden of cost to educational institutions. Many institutions choose to adopt simulation tools as a solution of this requirement, which is partly successful. This paper discussed the alternative physical laboratory design that can be also used as a remote laboratory as a second purpose. However, the evaluation of this laboratory is beyond this paper and set as a work in progress.

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