Remote teaching environment for internetworking students in Thailand

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ABSTRACT: As a result of the Internet whole new dimensions of teaching and learning have opened up. This has the potential to be of major importance to the development of education within Thailand, as it promotes learning opportunities to remote students. Teaching methods, such as using remote access laboratories, simulation and emulation tools, have provided near-hands-on experiences remotely to internetworking students. However there are still many concerns that remain to be addressed, such as access methods and the pedagogical value. A remote access environment has been developed for internetworking students at an Australian university. This newly developed environment will be used by remote access students in Thailand and will incorporate the use of State Model Diagrams (SMDs). SMDs have been applied successfully to normal classroom settings. This paper could be of benefit to educational institutions that may be interested in providing a suitable teaching environment for remote students wishing to study internetworking.

INTRODUCTION

The development of internetworking education in Thai universities is following the international trend to increase the integration of vendor-based certification into their courses. The number of Thai universities registered with the Cisco Network Academy Program (CNAP), as CNAP academies, has increased continuously each year from one institute in 1998, to 37 institutes in 2005. This recently was extended to 55 institutes in 2009 [1]. Cisco is a major internetworking equipment provider. CNAP is now available in 165 countries and there are 9,000 academies worldwide [2]. Furthermore, CNAP offers a number of complete courses along with integrated learning materials via a range of delivery methods. These include self-learning materials via online courses, sets of laboratory exercises pre-tested on their recommended equipment pods, a simulation laboratory through Packet Tracer[TM] software [3] and a remote access laboratory for more advanced courses. Internetworking courses that combine both practical and theoretical topics could be suitable for many of Thailand's universities. However, conducting a CNAP-based course requires access to internetworking equipment. Hands-on experience with real equipment in laboratories is necessary, which may be too expensive for many Thai universities. Simulation and emulation tools can be used to offer near-realistic experience to students but may distract them from differentiating between virtual environments and reality [4]. Furthermore, CNAP notes that:

> *Packet Tracer is not a replacement for lab equipment. Networking Academy recommends the use of physical equipment for hands-on learning. This is a key differentiator relative to other programs. Packet Tracer activities are designed to provide additional learning opportunities to complement the hands-on lab experience* [5].

Hence, hands-on laboratories are still essential for Thai universities. Even though a remote access facility might allow students to use real equipment locally or internationally, it may also have a lack of pedagogical guidance.

In traditional laboratories students have physical access to the equipment. Delivering a course in remote access mode often can be more suitable for distant regions of Thailand, which have problems with equity of access to internetworking education. However, due to the distance barrier, as well as the burden of English language difficulties, the remote Thai student may find the completion of a course delivered in purely distance-learning mode to be a very complex undertaking, despite the CNAP-based courses being available in a range of languages.

On the other hand, a language-independent tool, such as State Model Diagrams (SMDs), has been developed to assist students in building their own conceptual models. It has been used as an alternative representation of the course content, which is in accordance with a constructivist perspective [6]. Different representations of the content can help students to build their knowledge more efficiently [7]. Bruner recommends using a teaching structure that contains multiple

approaches for students, beginning from a fundamental level and increasing detail over time [8]. SMDs follow this approach by presenting an alternative model, at different levels of abstraction, from the fundamental to more detailed levels.

A new remote access facility has been developed in an Australian university, which incorporates the benefit of State Model Diagrams. SMDs have been used for some time to provide logical guidance to students in normal face-to-face laboratories; however, they have not yet been used in remote settings.

HANDS-ON TRADITIONAL NETWORKING LABORATORIES

Traditional laboratories provide a superior experience for students by increasing student involvement, problem-solving skills, motivation and stimulating their interest [9][10]. This first hands-on experience is often more enriching for students than that obtained via simulation tools. Conducting internetworking classes in the hands-on traditional mode is often an ideal solution but may be unrealistic for many institutions. This can be because the setting up of an internetworking laboratory incurs not only hardware costs, but also space, infrastructure, ongoing maintenance, technical support and training expenses [11][12], as well as possible timetabling problems associated with specific room allocation requirements. For example, the hardware costs alone can be of the order of $A300,000 for a complete laboratory suitable for 20 students. Moreover, the provision of physical access to laboratories is incompatible with delivering the internetworking courses to remote students. Therefore, many institutions with limited budgets, located in remote areas, cannot afford to run a laboratory fully within this mode. Thailand's universities may fall into similar categories, lacking sufficient funds to provide large scale internetworking laboratories. This may be an opportunity to promote other approaches of learning delivery to Thai universities. Modern day internetworking equipment can suffer rapid depreciation. For example, over a six-year period, devices can suffer a 90% fall in value. However, during that time many hundreds of students may have gained considerable benefit from using them, as undergraduates, postgraduate and research students.

SIMULATION LABORATORIES

The advantage of face-to-face laboratories is their high degree of realism in a real world networking situation that students experience during their sessions. Simulation and emulation tools, on the other hand, provide the flexibility to carry out experiments at the student's own pace. Delivering the class in simulation mode is flexible in terms of budget. Simulation tools allow the learning process to occur without any limitations on accessing the equipment, the distance from university [13] or even any physical disadvantage of the students [14]. The example of usage of simulation tools can be found in much of the literature [15-17]. It should be noted that it is also possible to use simulation tools within a face-to-face laboratory setting. The provision of appropriate simulation tools also can be an additional expense for institutions or students but Packet Tracer has been available without cost to students enrolled in the associated CNAP courses.

Due to the lack of the physical nature of simulation, the extensive use of logical diagrams can be found in many simulation tools. Packet Tracer [TM] [18], for instance, captures physical and logical learning components by displaying a back panel diagram of virtual equipment and its interconnectivity via logical diagrams. Conceptual diagrams showing network topology are provided within simulation tools. These can be used to compensate for the lack of visualisation of the real equipment [15]. Students' interactions with these diagrams can potentially assist in developing their conceptual understanding [19].

REMOTE ACCESS LABORATORIES

The effectiveness of learning through simulation may depend largely on the accuracy and quality of the simulated tools. Remote access laboratories can compensate for this disadvantage as the students are actually connected to real equipment. The use of remote access facilities, which may depend only on telnet access, could be more suitable for advanced students experienced in handling and cabling actual equipment [12][20-21]. However, beginner usage of such facilities might require more pedagogical guidance. Some hybrid remote facilities blur the distinctions between simulation and remote access to real equipment, by offering facilities to provide remote access to simulated equipment [12][21].

An issue with remote access laboratories is their lack of interaction with physical equipment. The lack of physical access prevents remote users from doing any re-cabling. Students using traditional laboratories have many chances to connect and build up their own network, regularly. Therefore, the physical topology of remote access laboratories is rather fixed or can be modified only by request. Some remote access facilities may choose to have a fixed cabling topology and allow the students to access different slots of equipment as pods [22], as also shown in Figure 1. Another solution may be to choose to provide the facility to adjust the logical connectivity between equipment [12]. The fixed cabling solution may not be suitable to build with a low budget and it loses the flexibility to reuse the equipment. The logical adjustable connectivity solution may create more pedagogical issues, as every piece of equipment is physically interconnected. However, both solutions fail to provide any physical layer interaction, which is an important factor for student learning. Especially novice students, who may not have seen any internetworking equipment, could find it

difficult to distinguish between logical and physical concepts. Therefore remote laboratories' facilities should provide an acceptable degree of physical interaction.
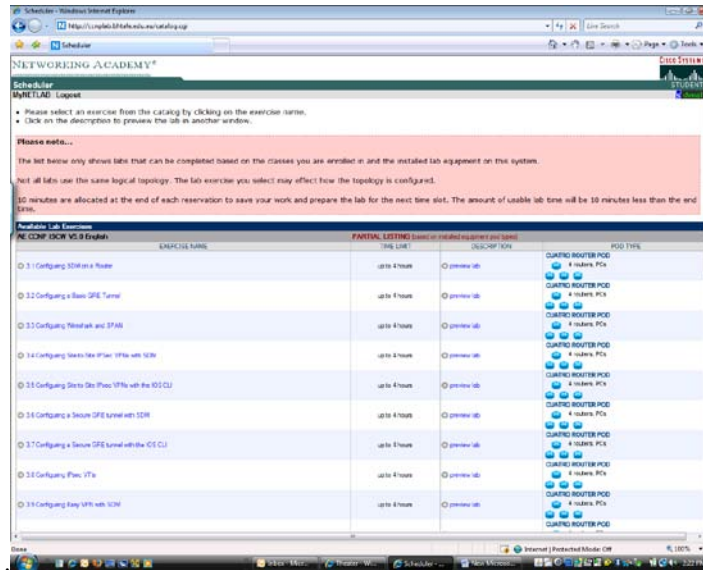

Figure 1: A remote access facility for students to connect to a different equipment pod.

Furthermore, Sivakumar suggests using more visualisation tools to attract beginner-level students [23]. This is an initiative to integrate pedagogical tools as part of an overall framework for conducting Web-based internetworking education.

STATE MODEL DIAGRAMS

Models such as SMDs have been used successfully in traditional laboratory settings but they are yet to be used in the remote teaching environment [6][24]. Transferring knowledge from experts to novice-level students cannot occur simply as transmitting a series of words and explanations. Unless the students and teachers share the same vocabulary with the same scope of meaning, students may be exposed to the risk of misunderstanding whole concepts. This may be of particular concern in distance-learning environments where students may lack interaction with the physical laboratories and equipment and have developed only limited conceptual models. Unfortunately, students may build incorrect mental models of equipment as *black boxes*, without any understanding of internal structures. SMDs [6][24-26] were developed to represent the network device information in a conceptual manner [25]. Therefore, they may be usefully applied to more restricted teaching environments, such as remote access laboratories. In a simple network topology from Figure 2, which contains only two routers and PCs, SMDs can conceptually present the internal information from the routers as shown in Figure 3. The overlaid diagrammatical information shows three Open System Interconnection (OSI) layers which can help students identify the concept and eventually assimilate the knowledge of equipment functionality.
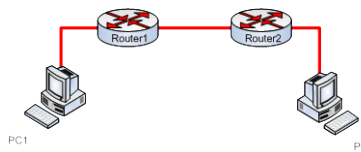

Figure 2: Example of a simple networking topology.

Figure 3: Internal information of a router, presented in an SMD.

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By comparison, the command line interface (CLI) may need several inputs to obtain the same information. For example, at least three commands *show ip route*, *show ip arp* and *show ip interface brief* need to be entered to the router to acquire this information, as shown in Figure 4. Furthermore, the result of the command may not provide any helpful visualisation information for the students. This could prevent them from building their own conceptual model, which is an important step in learning.

```
Router1#
Router1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, FastEthernet0/1
R    192.168.2.0/24 [120/1] via 192.168.10.2, 00:00:08, FastEthernet0/0
C    192.168.10.0/24 is directly connected, FastEthernet0/0
Router1#
Router1#
Router1#show ip arp
Router1#show ip arp
Protocol  Address          Age (min)  Hardware Addr   Type   Interface
Internet  192.168.1.1            -    0060.479A.EE02  ARPA   FastEthernet0/1
Internet  192.168.1.2           11    0007.EC9C.586C  ARPA   FastEthernet0/1
Internet  192.168.10.1           -    0060.479A.EE01  ARPA   FastEthernet0/0
Internet  192.168.10.2          13    0006.2A10.EE01  ARPA   FastEthernet0/0
Router1#
Router1#
Router1#show ip inter
Router1#show ip interface bri
Router1#show ip interface brief
Interface          IP-Address       OK? Method Status            Protocol


FastEthernet0/0    192.168.10.1     YES manual up                up

FastEthernet0/1    192.168.1.1      YES manual up                up
Router1#
Router1#
```

Figure 4: Result of several CLI commands from one laboratory router.

PRELIMINARY REMOTE INTERNETWORKING LABORATORY

The remote access laboratory environment, as presented here, attempts to provide a rich learning environment. Instead of merely providing access to local equipment for remote users, this laboratory setting will also include interactive video of real controlling devices, interactive SMD conceptual diagrams, interactive voice communication between tutor and students and a facility to gain remote access to the equipment. Normally, the laboratory is operated as a traditional face-to-face classroom during a semester. It consists of 20 routers, 20 unmanaged switches, 10 managed switches and 20 PCs, together with an interconnecting cabling infrastructure. This allows the students to have the flexibility of building many different network topologies. During the semester in standard teaching times, these devices are often fully booked. However, at other times, especially during semester breaks, these devices are largely not utilised. Apart from staff conducting research, this empty laboratory may be regarded as a lost opportunity in terms of investment.

The laboratory can be adjusted to provide a service for external students by allowing students to log-in from outside. The direct remote access of external students to networking devices can be achieved through an access server. This allows students to have full control over the devices while maintaining the interconnection. Also, this access server will require remote users to identify themselves by username and password to provide some degree of laboratory security. The configuration uses a Radius server to handle this secured authorisation process. Only a limited number of students can use the laboratory at the same time. Remote students can log-in to the devices through secure shell (SSH) sessions.

As many examples of remote access laboratories focus upon connection to the local laboratory equipment [12][14][22], one can assume that remote access laboratories may be conducted only in asynchronous mode, which is one-way communication. In this context, delivering the laboratories in an asynchronous mode means students individually learn by using the facility at their own individual pace, independently from any other students and local facilitators. However, remote access laboratories can be conducted also in a synchronous mode by facilitating two-way communications. A meeting application, such as WebEx, can be used in this case. It can handle basic communications between remote students and local tutors [27]. The communication elements are voice and video stream. Therefore, the remote students not only can interact with logical control through SSH sessions but also are able to interact with the physical equipment via a request to the local facilitators. Introducing video streaming of real equipment will help them link the logical and physical concepts.

Another aspect of enriching the remote laboratory environment is its suitability for a broad range of students. The command line interface (CLI) alone may not be suitable for novice students because the command responses are not conceptually displayed [26]. The CLI responses are text-based, and verbose, which tend to give too much information to novice students as the function was designed and developed for experienced practising internetworking professionals.

The effective use of the CLI also relies upon students' ability to search for specific information, which prevents them from building conceptual understandings [24]. Although this is a very useful skill for more developed students, it may inhibit the progress of many beginners in this field. This, in fact, points out a possible advantage of simulation tools over the traditional face-to-face laboratory, because the logical responses of the commands can be displayed easily in the form of simulated diagrams. Any changes in logical settings may be more difficult to notice when using only physical equipment. Therefore, the remote access laboratories, which attempt to benefit from using physical equipment, tend to suffer from this issue in a similar manner. SMDs have been introduced to traditional laboratories as a solution to this problem [6][24]. However, with the limitations of communication methods in a remote teaching environment, paper-based SMDs alone may not be suitable for conducting classes in remote access mode. Therefore, the next step forward is to introduce the SMDs in the form of software in order to reduce the role of facilitators as much as possible.

SMD software was implemented for the purpose of capturing real-time data from networking devices and presented as a conceptual model for the students. Using this software, students can interact with the equipment and check experimental results. One of the laboratory PCs is designed to host this software. The software needs a physical interconnection to the controlled devices in order to receive their internal network information. Therefore, in order to provide the same interactive ability to the remote students, the host PC needs to be connected to the experimental network on one end, and to the outside network, on the other end. The solution is to install multiple network interface cards (NICs) and configure the host PC to redirect only a small amount of the internal network equipment's data.

Due to the limitation that the software has to be locally installed and physically attached to the experimental network, providing access to the software for the remote students becomes a challenge. One solution is to share the control of the application through a communication channel. This allows the remote students to be able to control the application and at the same time reduces the distribution issues related to the software. Figure 5 shows the laboratory setup which allows the remote students to control the internal equipment pods while seeing the real equipment interconnection through a video stream and at the same time accessing SMDs as displays of conceptual models.
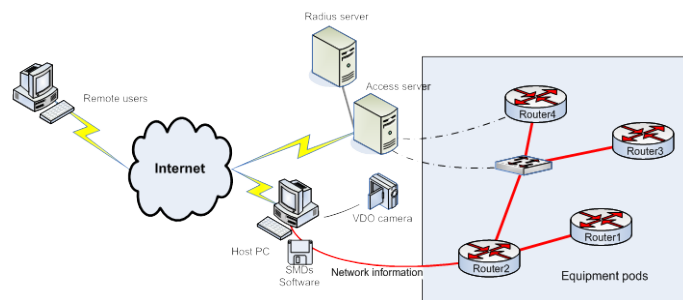

Figure 5: Connection diagram of host PC and access server to the pods of experimental network equipment.

When students log-on to a meeting session, they can see and control the SMDs through a shared application. At the same time, they can program the equipment in the pods by using the CLI interfaces. Figure 6 shows the learning environment that students will see during the lectures or laboratory sessions. The SMDs and video stream will allow the students to see an experimental result from both logical and physical points of view.
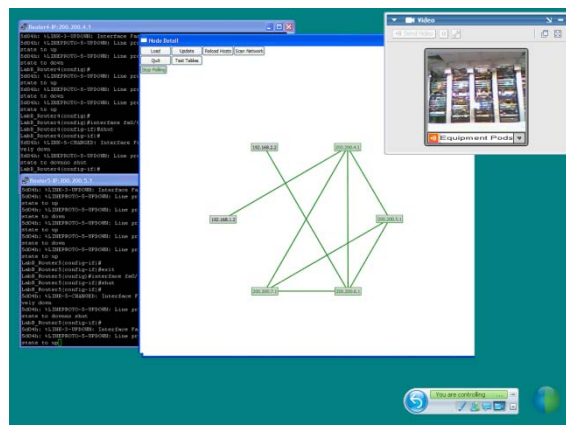

Figure 6: User's screen capture of the remote learning environment with SMD software running to assist students.

CONCLUSION

The preliminary remote access facility presented in this paper will benefit Thai universities by attracting a broader range of students to internetworking courses. This solution can be used by setting up a common facility between universities. It will reduce the overall investment cost of networking equipment and also allow the facility to be centrally maintained.

The students can benefit from various sources of information, such as video stream, CLI components and visualisation from the diagrams. It will help them to have a near first-hand experience which is closer to traditional laboratories. However, further research steps need to be taken to evaluate the suitability and usage of the laboratory itself.

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