A Remote Network Laboratory to Improve University Classes

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Abstract: - In the recent years, many lecturers have incorporated remote laboratories in their subjects to improve their university classes. The remote laboratories give support to the practices of a subject. The goal of this paper is to describe the experience carried out in the subject computer networks at the Polytechnic University of Valencia by several lecturers. We have implemented a laboratory that allows remote access to real devices, 24 hours a day, 7 days a week to the students of the technical engineering of telecommunications. This remote laboratory has increased the practice time for each student to work with real devices and have increased their experience in actual real study cases. On the other hand, we have noticed that, after this experience, they are familiarized with the working conditions they will face to when they begin to work as professionals in the real world.

Key-Words: - Remote laboratory, networking classes, university classes.

1 Introduction
Education evolves related to the new technologies, and when we talk about the experimental part, this join is driven more evident. One of the main issues in the University for the next few years is that there will have not to be enough laboratories to practice for all the students.

The laboratory is defined as a place endowed with the necessary means to accomplish investigations, experiments and scientific works and also like the way to experiment or elaborate something in.

Although the experimental practices carried out in the traditional laboratories are important for teaching [1], some inconveniences must be taken into account when it is planned to prepare them:
- Scarcity of experimental resources.
- The lecturer’s schedule is overloaded, so they don’t have enough time to prepare the practices.
- Discouragement of the lecturers because of the complications usually generated in the practical exercises.
- Too extensive programs.
- Groups with excessive number of pupils.
- Methodology behind the times which does not lead to the understanding of the concepts.
- Student’s schedule overloaded.
- Laboratory schedule overloaded [2].
- The devices to do the practices are expensive [3].

Because of all these causes, educational and training professionals have been looking for a mechanism to allow carrying out real practices while avoiding the displacement to the laboratory. The solution has come from the hand of the development of the Remote and Virtual Laboratories [4]. The existence of a great variety of remote and virtual laboratories is unquestionable as well as its benefits [5] [6]. Nowadays, the virtual and remote laboratories have become an important part of the educational curriculum in engineering [7].

The Virtual Laboratory is an interactive multimedia tool that allows accessing to the laboratory from any part of the world without the need of being located in the practice computer. It also improves the learning process of complex Technologies. Its main feature is that it allows specialized access 24 hours a day, 7 days a week. Generally, the software needed to access to the laboratory devices is not installed in the local hard disk so it is needed a previous installation of an executable program. Anyone can access from Internet or from the internal network.

Our work is focused on the development and the implementation of a remote laboratory that has to be able to provide different type of practices with different devices for those practices.

The remainder of the paper is as follows. Section 2 explains why it is needed a remote laboratory in the subject we are teaching, and we will explain the main requirements for a remote laboratory. Some examples of remote laboratories are shown in section 3. Section 4 shows how has been deployed the laboratory and its main characteristics. In section 5, we show the evaluations that have give the students to our deployment. Finally, section 6 presents the conclusions and future research.
2 Problem Formulation

In studies related with new technologies, such as the engineering careers, students should learn about the current technologies available in the enterprise, about the management of the devices that are being used in the network and about the configuration and the use of communication protocols.

As a first step, a telecommunications student must know to set up a network with a set of minimum requirements, such as the number of users, number of delegations, scalability, and access to the Internet network. But, in addition, corporate networks are demanding other requirements such as redundancy to support fault tolerance, security in communications, or Quality of Service (QoS) for the integration of Voice in data network using VoIP technology. All of them contribute to the benefit of the network performance and to offer more services.

In order to achieve professional competitiveness that companies are suing for network administrators. So the telecommunication and computer network students must complete their theoretical training with laboratory practices based on real situations. Moreover, they must be similar to the ones that they will find in the future.

In the topic we are talking about, the use of laboratories with real devices is too expensive and impractical, because their use is limited by the number of students in each practice and by the time allowed to access to the laboratory in school hours.

It is necessary to find solutions to expand the use of the network laboratories, even outside school hours, because it is important for the student formation. In order to achieve this goal, on one hand it is needed to combine different network technologies, both software and hardware, at the same time. And, on the other hand, one laboratory has to be able to allow individual practices, in which a single student works with the complete topology, and group practices, in which the work is distributed among several students and they should be coordinated.

2.1 Remote Laboratory requirements

In order to meet the requirements presented in the previous subsection, we propose the establishment of a remote network laboratory.

A remote laboratory is a group of physical devices that can be driven and controlled remotely, simultaneously or not, by many users, using the same type of interface [8] [9]. These equipments can be didactic laboratory models or real equipments. In these laboratories, specific servers are required to manage the users of the system and the devices of the laboratory.

There are some papers such as the ones with references [10] and [11] that describe the types of remote laboratories architectures in existence. The access of the users to the devices is generally given through a Web page [12], although there are other implementations that use remote desktops [13].

Generally a remote laboratory consists on several laboratory devices, a camera and a computer application that is able to control the laboratory devices.

The main reason that caused the spread of the remote laboratories world wide has been the increment of the bandwidth at the students' homes, because it allowed enough up and down throughput for the proper operation.

A remote laboratory must meet the following requirements:

- Accessible from the local network laboratory.
- Accessible from anywhere on the Internet.
- Ability to configure a large number of network technologies.
- To access at network devices identical to that used at local laboratory.
- Ability to make individual and group practices.
- Available 24 hours a day, 7 days a week.
- Administration and control of account users.
- Dynamics laboratory reserve through an online tool, as a web server.

3 Related Works

An extensive survey of the remote laboratories of private and public universities and high schools from North America and England is shown in reference [14].

There are a lot of types of subjects where remote laboratories can be applied, but engineering career that the subjects where they are most applied. Although there are many, the following list shows some known examples of running remote laboratories:

- Networking [16].
- Electricity [17].
- Process Control [18].
- Robotics [19] [20].
- Electronics [21] [22].
- Automatic and Control [23] [24].
- Video [25] [26].

As time goes on, new laboratories are appearing and even new type of remote laboratory architectures. Last tendencies in Remote Laboratories are to create Unlikely Collaborative Contexts [15].
4 Remote Laboratory Deployment

Our deployment is based on the Remote Network Laboratory appliance from Cisco System inc. Figure 1 shows the components and the connections between the devices of the proposed solution.

The Server acts as a proxy server. All connections to the laboratory equipment flow through the server.

- The server has two network interfaces:
  - The outside interface (Ethernet 0) attaches the server to the network and faces to the users.
  - The inside interface (Ethernet 1) attaches the server to a control switch and faces to the laboratory equipment and various control devices.

All user connections between the outside interface and the inside interface are related by the proxy, not routed. No connections are allowed unless the user is attending an active laboratory reservation. Because of this proxy, a user only has to open one IP address and two TCP ports to provide access to the server and all equipment of the laboratory behind it. The laboratory only requires one IP address and two inbound TCP ports for all inbound connections. It also starts outbound traffic on ports that are normally open.

   Inbound Ports:
   - TCP 80: Provides HTTP access to the web server interface.
   - TCP 23: Provides Telnet and VNC to the laboratory equipment.
   - TCP 22: Provides SSH for technical support only.

   Outbound Ports:
   - TCP 80: Provides HTTP access to the support services of the server (time, status, backup, software upgrades, etc.).
   - UDP 53: Provides DNS lookups.
   - SMTP 25: Provides SMTP outbound mail.

The control plane that is shown in figure 1 forms the wired part needed to interconnect various devices of the laboratory. The control plane consists of devices that are required in order to run the laboratory properly, but they are not accessible to students and instructors. Control devices are control switches, access servers and switched outlet devices:

- Control switches provide internal connectivity between Server Lab, access servers, remote PC’s, and switched outlet devices. The control switch also provides a network path to download the router’s operative system images (IOS) to the Cisco devices if the flash memory has been erased (or the correct image is not installed).
- Access servers provide console connections to the routers, switches and firewall devices so that users can access these devices from the server.
- Switched outlets provide managed electrical power. It allows the users to turn on and off the devices.

A pod is a group of devices forming a topology that can be used to do several practices. Pod ports connect the devices to the server. During a regular operation, Pod ports are automatically placed in unique or common VLAN to simulate one or several Ethernet segments (depending on what is required by the topology of the pod). When the server must download an IOS image to a device, the server will temporarily place the device in VLAN 1, so it can access the server TFTP server. Pod ports must be consecutive and reside in the same switch. A single control switch can have pod ports for several pods, as long as all pod ports are consecutive on the switch.

The reserved ports of a control switch provide the framework to interconnect the server to the control devices. Reserved ports are usually trunks or access ports in VLAN 1, but may be used to other functions as well. A reserved port is never allocated to the equipment of the pods. Reserved ports are also used by standalone remote PC’s in conjunction with Virtual Network Computing (VNC) software. VNC provides a remote access to the keyboard, the screen and the mouse. A remote PC typically has two network interfaces. One interface is connected to the topology; the other is connected to a reserved port on a control switch. The VNC connection passes through the control plane and through the proxy to a Java-based VNC client window on the user’s PC.

3.1 Remote access to the laboratory

Figure 2 shows the logical topology. There can be seen that both students and instructors can share the access to the real lab equipment in a training environment.

   It allows the students to have more time to use the laboratory, so they get the maximum use of the laboratory equipment. It provides scheduled 7 days x 24 hours access to the laboratory equipment. The session sharing feature supports instructor led classroom lectures, team collaboration, and individual student practice. Students can be grouped into teams and work together from different locations. Moreover it is easy to use and manage.

   Students and instructors can access to the laboratory equipment through a Virtual Private Network (VPN), against a public IP address of the Polytechnic University of Valencia.

3.2 Remote Lab Network Topology

The laboratory devices are part of the topology and users can interact with them either directly through the console or through the network. The basic router pod is shown in figure 3. It includes three routers: R1, R2 and R3. The devices meet the minimum requirements for interfaces, IOS, RAM, and Flash.
One of the main features that doesn’t have other remote laboratories is that our laboratory is able to have multiple types of pods in the same deployment. The basic router pod is able to provide several topologies. The server can alter the topology and reposition the PC’s by manipulating the VLANs on the control switch. This is done automatically based on the selected laboratory exercise. Instructors can change exercises and topologies during instructor led class reservations.

5 Evaluation

The laboratory remote network has been used in degree courses with students of Communications from the E.P.S of Alcoy belonging to the Polytechnic University of Valencia, and, also, with graduate students from the Master of Corporate Networks.

In order to look for the benefits and drawbacks of our deployment, the students full fill an evaluation survey. We saw and analyze both degree and postgraduate student’s opinion on the next items:

1. Can you easily access and use the remote laboratory from the facilities of the University?
2. Can you easily access and use the remote laboratory at home through your Internet connection?
3. Using the documentation and instructions given for remote laboratory management, are you able to perform all the remote laboratory is able to do?
4. Are you doing more practice exercises since the remote laboratory has been set up?
5. Does the remote laboratory allow the same practice exercises than the real one?
6. Do the remote laboratory practice exercises clarify the theoretical contents?
7. Has the remote laboratory been an instrument to acquire knowledge about the theoretical content?
8. Is the remote laboratory an indispensable tool for teaching in telematics engineering?
9. Has been the experience of working with the remote laboratory good and stimulating?

Each of the items in the survey was rated from 1 to 5, where 1 means strongly disagree and 5 fully agree with the evaluated item. Figure 4 shows the results of the students in the telecommunications degree of EPS of Alcoy survey. Figure 5 shows the results of the postgraduate students from the Master of Corporate Networks survey.

The results obtained for items 1 and 2 show that it is easy to access and use the laboratory from inside of the Polytechnic University of Valencia and from Internet. Item 3 shows us how much are the students satisfied with the documentation and with the instructions received about the remote laboratory. Although we paid attention to the issue, it seems that it must be improved. We deployed a workbook to guide the students to specific practices related to the theoretical content. Despite of this, students are demanding additional information to realize any general practice.

Item 4 results are striking and illustrate how remote laboratory do not have the main issues given in the classical laboratory: to adjust schedules.
This is not surprising, since the high availability of remote laboratory allows the student to conduct his own time planning and adjusts his schedule as he deems appropriate.

In item number 5, we see that the practices with the remote laboratory are equivalents, in a fairly high percentage, to those performed in a classical laboratory. However, this item has the lowest values of the survey. It is probably due to the lack of physical contact with the real network devices. It is therefore necessary to complement the remote laboratory practices with at least one or two conventional practices to enable students to have direct contact with the devices, to manipulate interfaces and wires, to make direct connections with the real devices. These are experiences that cannot be acquired through the remote laboratory.

The results obtained in items 6 and 7 are, in our opinion, the most important ones. Thanks to the availability of the remote laboratory, the students believe they have better knowledge of the course contents. It happens because they do not see the theory and practice as two separate parts of the course, but each other are complemented. –it is due to they have more access to the laboratory at any time and from anywhere, allowing the students to resolve the doubts they have while they are studying the contents at home. Accessing to the remote laboratory they can check the concepts and protocols operation on the devices.

According to the information provided by item 8, the remote laboratory is not essential for teaching networking courses, but it improves the class.

Finally, item 9 shows that a new tool to support the teaching of new technologies, promotes, stimulates and gets rich the student's experience.

6 Conclusion
An experience with a remote network laboratory is highly positive. Both from the instructor and from the student point of view. It gives important benefits for both. The main benefits are the following ones:
- Distance blended learning
- Provide scheduled laboratory access
- Increase the student’s laboratory time
- Promote work in teams
- Menu-driven system administration
- Automates laboratory management and cleanup tasks
- Recover erased flash and passwords
- Share sessions with the students
- Record and assess student laboratory work
- The number of devices and topologies available through the remote laboratory can be increased.
- It has high flexibility to adapt to different kind of practices.

One of the main contributions of this paper has been to show a flexible remote laboratory that is able to work with different practice exercises with different devices at the same time.

References:


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