

# Transforming Traditional Labs into Virtual Computing Labs for Distance Education

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**Abstract**—The demand for on-line courses continues to rise in academia because (1) on-line courses remove time barriers that would otherwise restrict a student from pursuing academic endeavors, (2) they remove the distance barriers for academia in reaching potential students and (3) they can to some extent alleviate budgetary and physical constraints on the academia in imparting education to students. The on-line instruction mode rather easily accommodates courses in some disciplines such as history, sociology, and political science. However, it posits significant adoption challenges for courses that require hands-on computing experimentation such as computer networking, system administration, web application development and database administration. Nevertheless, given the demand for on-line courses, there is a need to devise strategies that would allow students to conduct computing experiments through remote access. This paper presents an approach to transform traditional computer labs into a virtual lab environment. Such transformation allows students to remotely conduct experiments that involve software and hardware interaction. The methodology presented here can be applied to a large number of computing courses encountered in Management Information Systems and Computer Sciences disciplines.

**Keywords**—On-line Lab, Computing Lab, Distance Education, Virtual Presence, Remote Access Labs

## I. INTRODUCTION

Distance education is rapidly becoming an alternative to the traditional methods of education. Through distance education students enjoy reductions in commuting time, flexible learning schedules as well as education opportunities at geographically disperse locations. Distance education affords students to have access to university resources free from time and location barriers. Using distance education technologies, teamwork and group projects can easily be scheduled and executed. With the help of the Internet and computing technologies, high level of interaction between students and instructors as well as among students become possible.

According to recent surveys, distance education and on-line learning programs are growing much faster than their face-to-face counterparts. In 2004, online enrollment in U.S. universities increased to 2.34 million with an overall increase of 18% from previous year [1]. More universities are using computer technology to augment their course offerings [2, 3, 4, 5]. National Center for Education Statistics reports that, in academic year 2001 – 2002, 56 percent of all two-year and four-year degree granting institutions offered some form of distance education [6].

Distant education has three important components that must be separately considered in designing on-line

courses. The first component is the on-line teaching of the course material. The second component includes student assistance, grading, student advising, etc. The third component includes activities pertaining to project and laboratory support [2, 7].

Transitioning from a face-to-face instructional environment to technology-supported environment is still a significant paradigm change with its own difficulties [8]. While some academic disciplines lend themselves readily to distance education because of the nature of these courses and availability of online training and services tools such as BlackBoard™ and WebCT™, other disciplines such as computer science and management information systems pose significant challenges in switching to distance education due to difficulty in providing the required laboratory support.

In general, design of traditional computing labs poses challenges from many aspects such as funding, lab space, support staff, etc. Consequently, it becomes necessary to design traditional labs in versatile and flexible ways to support diverse computing courses [9, 10, 11, 12, 13, 14, 15]. Support of distance education and remote experimentation is another factor that exacerbates the laboratory support issues for small and large institutions. Deployment of distance education courses poses many challenges for certain computing courses that require hands-on experimentation. While for some computing courses the experimental work can be performed using personal computers, many others require support of dedicated lab environment.

This paper presents a model to transform traditional computing labs into distant education labs. The model is primarily intended for courses in Management Information Sciences (MIS) and Computer Sciences (CS) disciplines. However, this model can be applied to other computing disciplines as well. The concepts and strategies presented here are based on the experience and insights gained in developing the computer network lab at the university of Houston-Clear Lake (UHCL).

## II. VIRTUAL LAB DESIGN METHODOLOGY

The approach presented in this paper seeks to transform a traditional MIS or a CS lab into a distant education lab via the concept of virtual lab presence. Virtual lab presence can be defined as creating an environment in which the remote presence of a student and her home computer is transformed into a virtual presence in the computing lab whereby the student can conduct the same computing experiments from home as she can in a traditional lab setting. To facilitate understanding virtual lab presence concept, the types of experiments performed in a traditional MIS and CS computing lab are presented

next. These experiments can be classified into three general categories:

- Software Experiments
- Hardware Experiments
- Hybrid (Software and Hardware) Experiments

Software experiments require interaction with one or more software systems such as an operation system or a software application. A student working on a Java programming, a web development or a database development experiment is considered to be conducting a software type experiment since she only needs to interact with the software running on computing systems via her key-board, video monitor and mouse (KVM) interface.

The second category of experiments is hardware only experiments. Building a physical computer network using hubs, switches, routers and cabling is an example of hardware experimentation. Modifying the hardware configuration of a computer by replacing its hard disks, video cards and various I/O cards is also an example of hardware experimentation.

The third experiments category, hybrid experiments, combines some level of hardware experimentation along with significant degree of software experimentation. A student studying a UNIX system administration course may have to work to a certain degree at the hardware level but also significant amount work is done at the software level. Experiments in many network courses and network security courses fall into this category since students must first complete the physical wiring required for the network and subsequently work with the software systems to configure and monitor various network components.

The MIS and CS coursework experiments are predominantly software or hybrid category of experiments. Therefore the emphasis of this paper will be only on those two categories. As indicated earlier, virtual lab presence creates an environment where software and hybrid experiments can be supported remotely. Consequently the following factors form the key elements in this process:

- Secure remote access to the lab facilities over the Internet
- Virtual lab support via lab portal
- Software experiment support with virtual KVM/CLI environment
- Hardware experimentation support
- Virtual Lab Support Procedures

#### A. *Secure Remote Access to the Lab Facilities over the Internet*

The virtual lab presence seeks to allow only authorized students to access the lab facilities. This is tantamount to permitting students into a physical lab environment only if they are enrolled in that course. Secure remote access component of the virtual lab design seeks to create an environment where the student's home computer appears as if located inside the lab. Furthermore, secure remote access ascertains that the student is authorized to access the departmental laboratory facilities by proper strong authentication methods. This "virtual presence" is achieved using a set of network technologies including a firewall and a virtual private network (VPN) server. Authenticated access to the facilities is provided via an

Authentication, Authorization and Accounting (AAA) server.

VPN server creates an environment where student's computer is virtually placed on the same network where laboratory computers and equipment reside. A student's computer is allowed to become part of the laboratory network only after verifying the credentials supplied by the student against an authentication server database (Figure 1). A firewall also ensures that student's computer is allowed only a set of permitted operations on the laboratory network. These operations will be discussed in the next section.

For virtual presence, client VPN software may have to be installed at student's home computer. However, many new VPN concentrators use web browsers as client side applications eliminating the need for installation of additional VPN software on student's home computer. AAA server holds the student account information. It assists in authenticating students for virtual presence and it also allows access to different virtual labs based on authorizations.

#### B. *Virtual Laboratory Support via Lab Portal*

The next step in the virtual presence operations is to allow the student to the particular computing lab that she needs to enter. Conceptually virtual laboratory access is very similar to allowing a student to access, for example a database lab, only if she is enrolled and authorized to work in that lab. The Lab Portal provides a visual depiction of different lab facilities. On the lab portal there is an entry point (i.e. a link) for each virtual lab facility. Some examples of those lab facilities are database laboratory, application development lab and network laboratory. The Lab portal, with the assistance of the AAA server, allows the student to "enter" into the laboratory based on her credentials and authorizations. Once granted access to a particular laboratory, the student is presented with a pictorial view of the lab with all the servers and computers as icons which can be individually accessed. Subsequently, the student selects required computers and or network systems in the lab to conduct her experiment.

#### C. *Software Experimentation Support With Virtual KVM/CLI Environment*

Upon "entering" the required lab, a student, wishing to perform a software experiment, may have to work with one or more software systems available on one or more computers. It should be noted that these computers are physical computers in the physical lab space for that course. Virtual KVM Environment simply allows the student's home computer appear as the KVM for any of the laboratory computers via a set of access protocols known as Remote Desktop Protocol and Remote Terminal Protocols. UHCL MIS department uses Microsoft Remote Desktop Protocol for GUI remote desktop access and Secure Shell (SSH) and telnet protocols for CLI based remote access.

With the support of the virtual KVM environment, the student can conduct the same software operations remotely as they are possible locally in the lab facility. Student's computer needs RDP, telnet and SSH protocol support. Remote Desktop Protocol and telnet protocol are inherently provided in Microsoft operating systems. Tools supporting SSH client protocol can be found as share-ware on the Internet. SSH server protocol is mostly

used with UNIX based server systems and network equipment. Telnet is a required protocol for network experiments.

#### D. *Hybrid Experimentation Support*

Remote hybrid experimentation is relatively more involved than software experimentation. A student who plans to conduct a remote hybrid experiment needs the aid of a Teaching Assistant (TA) for the hardware configuration support and experimental coordination. The students planning for a hybrid experiment are required to prepare an experimental hardware and software configuration plan and provide it to the TA via email prior to the experimentation. For example, for a network experiment, the plan can be the topology drawing of the experimental network and the detailed description of the wiring, interconnecting the network devices in the experiment. Furthermore, the students would need to reserve a time slot for experimentation with the TA, if the student would require TA's assistance during experimentation.

The software aspects of the hybrid experiments are quite similar to software experiments depicted earlier. The student must first establish a secure VPN session from her home computer for virtual presence. Once the virtual lab presence is established, the student needs to "enter" the required laboratory using the Lab Portal. Inside the laboratory, the student is presented with the pictorial view of the lab with the servers and client computers as "clickable" items. Clicking any item will launch the necessary virtual KVM protocol to start the remote desktop protocol or SSH protocol at student's computer. As explained later in the scenarios section, access to the network devices are provided via "reverse telnet" servers which allow console sessions to such devices.

#### E. *Virtual Lab Support Procedures*

Providing online assistance to students for virtual presence is quite critical for the success of the virtual lab environment. Students should be familiar with the guidelines, policies and technical aspects of the virtual experimentation. For this purpose, at the beginning of each semester, students are provided with written procedures explaining general virtual lab concepts and VPN access procedures and concepts. They are also provided with the VPN credentials for authentication.

Additional procedural and technical support is also provided on the Lab portal. Detailed procedures for each kind of laboratory environment are separately provided.

Remote access procedures, remote desktop protocol configuration and utilization details, sign-on and sign-off procedures are examples of the procedures provided via the Lab Portal.

### III. VIRTUAL LABORATORY EXPERIMENTAL SCENARIOS

This section provides two scenarios to illustrate the concept of virtual lab presence. The first scenario explains a software experiment and the second scenario illustrates a hybrid experiment.

#### A. *Scenario 1: Software Remote Experiment*

Figure 1 shows the settings where a student wishes to perform a web application development experiment remotely. In this experiment, the student needs to develop a web server application and configure it to operate in conjunction with a database server. It is assumed that Srv-1 is the web server being developed by the student and Srv-2 is the database server that will be operating in conjunction with the web server. Student also needs to access the workstation WS-1 to test the operation of the web-database application.

Student must first establish her virtual lab presence by setting up a VPN connection to the lab VPN concentrator using the credentials provided to her at the beginning of the semester. Subsequently, the student must access the lab portal to "enter" into web application development laboratory. When the student clicks on the web application development lab icon, her credentials are checked against the authentication server to ascertain that she is authorized to "enter" the lab facility. Once authorization is approved, she is presented with the layout of the lab.

As the first step, she needs to build the web server. Therefore, she clicks on Srv-1 icon on the lab portal and starts a remote desktop session to Srv-1. She can also start a second remote desktop session to Srv-2 to work on the database development concurrently. Once server based development work is completed, she starts a remote desktop session to workstation WS-1 to test the operation of the web application.

The software experimentation scenario presented here simulates an experiment performed physically in the lab. Of course, remote access labs require the necessary coordination activities to prevent resource conflicts in the laboratory as is the case in traditional lab settings.

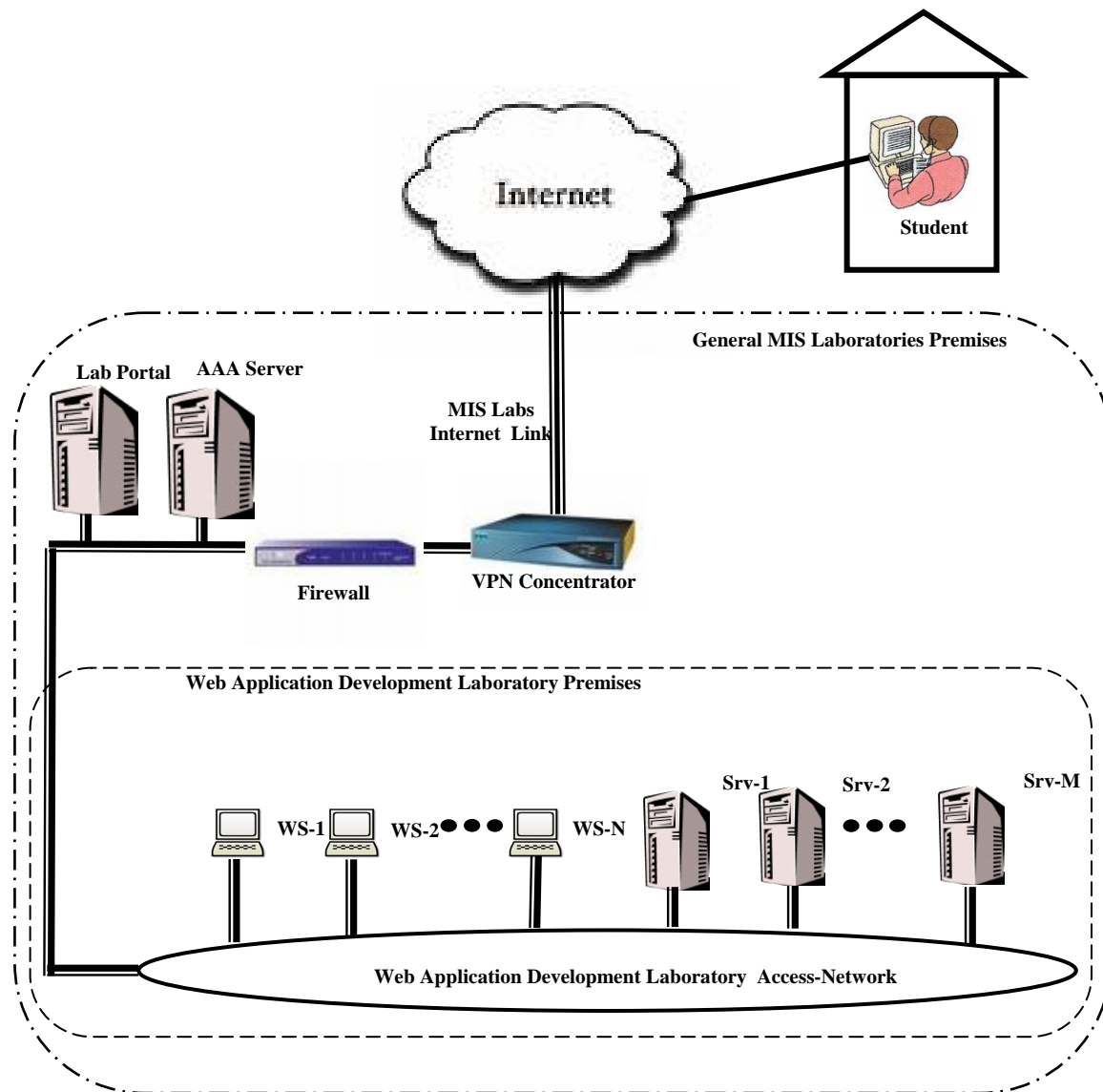


Figure 1. Software Experiment Support

*B. Scenario 2: A Hybrid Remote Experiment*

Computer network experiments constitute good examples to illustrate hybrid experimentation support in the virtual lab environment. A student who plans to conduct a network experiment in a virtual laboratory environment needs TA's aid for the experimental network wiring. The network drawing must be sent to the TA by the student a-priori. In a typical experiment, students may configure a number of routers, switches, firewalls, desktop computers and servers remotely. Figure 2 presents the Virtual Laboratory environment for a computer network experiment. In this scenario, the purpose of the remote access server (RAS) is to allow console sessions to

network devices. The RAS device provides a bridge between the telnet session to the student's computer and console session to the network device. These devices are sometimes referred to as "reverse telnet servers."

The experimental network consists of two routers, R-Exp-1 and R-Exp-2 and three Ethernet hubs, Hub-A, Hub-B and Hub-C. There is only one server, Srv-1, utilized in this experiment. The experiment also uses three desktop computers as client systems on the experimental network. In such an experiment, this server may be a web/DNS server that needs to be configured by the students.

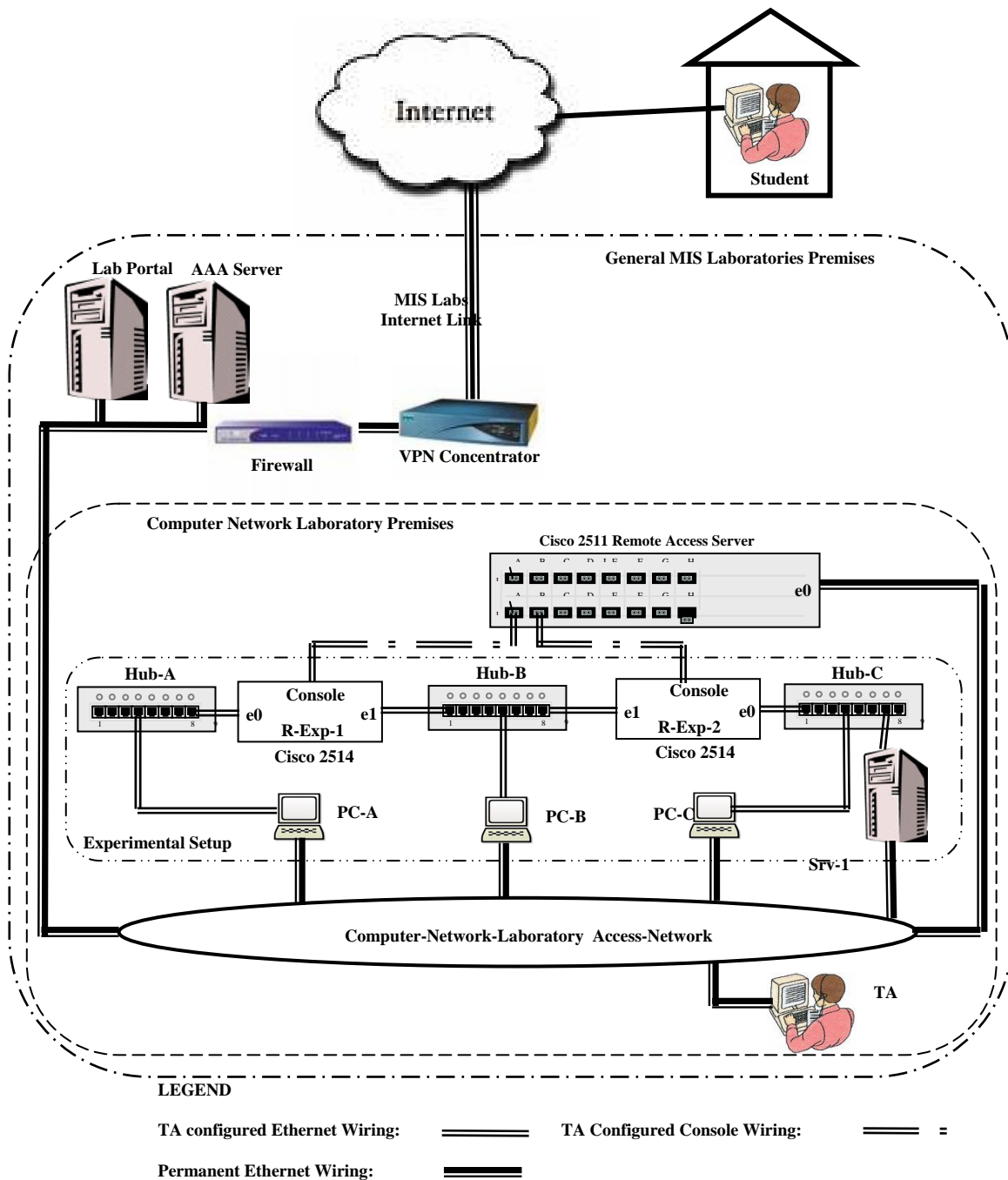


Figure 2. Hybrid Experiment Setting

As part of the experiment, the student needs to configure the routers R-Exp-1 and R-Exp-2, the PCs PC-A, PC-B and PC-C and the server Srv-1 remotely. The student needs the assistance of the TA for the physical wiring of the devices. As described earlier, virtual lab experiments require careful adherence to operational procedures as well as technical procedures. The students must follow the steps outlined below to conduct a hybrid network experiment:

1. Reserve an experiment time slot with the lab TA via email.
2. Provide the TA a network drawing for the experiment. The drawing provides connectivity diagram for routers, hubs, servers and workstations.
3. At the beginning of the reserved time slot, initiate a VPN connection to the laboratory network using the UserID and password provided at the beginning of the semester.
4. Access the Lab Portal and select the Network Laboratory as the desired lab.
5. "Enter" the network laboratory.

6. Initiate an over-the-Internet voice/video channel, such as Skype™, telephone/video session with the TA. As the TA connects the network devices per network drawing, student provides directions to the TA about the desired connectivity.
7. Initiate a reverse telnet (RAS) session to the Remote Access Server.
8. Initiate console sessions from the Remote Access Server to the experimental routers (R-exp-1 and R-exp-2).
9. Configure the routers as needed remotely.
10. Initiate remote desktop sessions to computers (PC-A, PC-B, PC-C, Srv-1) one at a time. Configure each workstation and server as required per experimental procedure.
11. Test the experimental network operation by accessing the routers, workstations and servers remotely, over the configured network as needed. Collect necessary data remotely for experiment report.
12. Coordinate with the TA for re-wiring needs if necessary.
13. Restore the network devices, desktop computers and servers to their default configuration.
14. Coordinate with the TA for the disassembly of the wiring at the end of the experimentation.

#### IV. CONCLUSION

Many colleges and universities are supplementing their programs with distance education courses. Providing computing courses within the distance education paradigm still poses significant challenges due to the laboratory component involved in such courses. This paper presents an approach to transform traditional computer labs into virtual labs. The paper recognizes two categories of experimental setups where slightly different approaches are needed. The first category is software based experimentation. The second category is hybrid experimentation where software and hardware experiments need to be conducted within the same experiment. The design relies on the concept of "virtual presence" whereby the student and her home computer appear as if located inside the lab. The lab design presented in this paper can be used for majority of MIS and CS courses. Furthermore, the approach presented in this paper can also be employed in other computing courses as well.

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