

Designing Labs for a Sequence of Network Courses

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Abstract

This paper describes the design objectives for a set of networking laboratories to be used in conjunction with a sequence of networking courses. The strong demand from both industry and model curricula provides justification for both conceptual and practical student training. The design of networking labs is complex because of the hardware and software demands in networking. The goal of developing labs that are flexible, affordable, and maintainable is described along with some suggested lab designs and uses.

Keywords: networking, laboratories, lab scheduling, network administration, network infrastructure, network security.

1. Introduction

The importance of networking and telecommunications is at an all time high. This fact is recognized by many computer education curriculum models like IS'97, IS 2002, and ACM Curricula 2001 (Davis, G. et. al., 1997; Gorgone, J. et. al., 2002; Joint Task Force, 2001). The demand from industry is strong and increasing (RHI, 2001). The U.S. Department of Labor, Bureau of Labor Statistics estimates that Network Systems Administrators "... are among the fastest growing occupations over the 2000-10 period." (Occupational Outlook Handbook, p.171) Because of industry demand and curriculum requirements, a sequence of networking courses seems appropriate to provide students with the knowledge and skills needed to succeed in the "real-world."

The amount of knowledge that must be covered in the area of data communications and networking is extensive. Rarely can a single course be designed that covers the top-

ics at sufficient depth. Curriculum models like IS '97 suggest that students obtain level 4 knowledge. Level 4 knowledge is characterized by objectives that include: apply it, implement it, design it, and correct it. (Davis, 1997; p.42) This problem solving level requires a considerable breadth and depth of knowledge. A sequence of courses, each related to a set of topics, is one design that exposes students to sufficient breadth and depth of knowledge.

The topics for a networking sequence range from conceptual, abstract knowledge to practical hands on skills. Students are expected to master network architectures and topologies, communications models (e.g., ISO-OSI, TCP/IP), management techniques, hardware configuration issues, hardware components, security issues, data formats, transmission methods, user's issues, and so on. The topic list is quite large (Davis, 1997; p.80). These topics, which are traditionally presented in lecture format, may

become nothing more than a collection of abstract concepts for the student. Mastery of networking requires not only theoretical knowledge; but also practical hands-on experience.

Students will need access to networking hardware and software to experience and practice these concepts (Madison, 2001; Sivitanides & Dunn, 2001). Even a simple networking lab becomes quite complex as we bring together different technologies that encompass the breadth of networks today. Labs have to provide students with not only adequate technology, but also adequate amounts of time to experiment with and complete their assignments.

Labs to support communications courses require several important design objectives. The labs should be: affordable, maintainable, and flexible. Affordable labs must contain enough equipment to adequately capture the breadth of today's networking environment. Maintainable labs must operate when the students need them without an undue support requirement of the lab faculty or support staff. Flexible labs must be implemented in a manner that allows the students to experience the breadth of operations that they may encounter in the "real world." This paper provides an overview of our goals, designs, and anticipated uses for a set of networking labs and the courses they support.

2. Our Solution

Our solution to these requirements is a sequence of four (4) networking courses with labs: Network Administration, Advanced Network Administration, Network Infrastructure Systems, and Network Security Management. These courses, taught during the junior and senior years, provide a mix of concept-based lecture and practical hands-on labs. This paper focuses on the lab environment and lab activities.

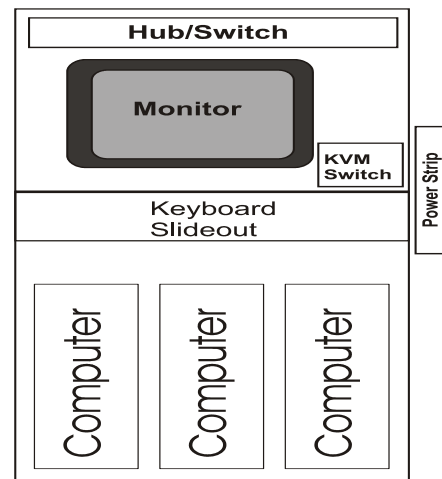
Lab Requirements

Designing and implementing a laboratory for a networking course is a mix of technology, infrastructure coordination, staff and space issues, and scheduling problems. Our solution is designed to facilitate student work and minimize support requirements. Three distinct labs have been

developed: 1) a networking lab, 2) an infrastructure equipment lab, and 3) a security lab.

Networking Clusters

A normal computer lab requires one workstation per student. A network lab requires a networking cluster which includes three computers and support equipment to allow a complete and independent operating network. Figure 1 provides a diagram of our networking cluster. Because of the amount of required equipment, we assign student teams to each networking cluster.



Approximate Dimensions
26" w x 24" d x 54" h

Figure 1. Network Cluster

In an effort to reduce floor space, we have stacked the monitor, keyboard, and other peripherals atop the three computer towers. The cabinet is open on the front and back allowing access to both sides of the equipment. A single switched keyboard and monitor further reduce the space requirements. Our cluster is constructed out of 3/4 inch oak cabinet plywood; however, several commercial stands are also available with similar features.

In normal use, one of the computers serves as the server, while the other two are configured as workstations. This configuration provides flexibility in installation and configuration of a network (Leone, 2002).

Networking Lab

This lab can serve both the network administration and advanced network administration courses. Figure 2 diagrams the basic lab layout. This lab provides twelve networking clusters, interconnectivity cabling (hubs, switches, and routers), and a gateway to the Internet. Students will be able to install and configure a network using their networking cluster. With an operating network, students can interconnect their system into larger configurations within the lab. Using a lab gateway, students will be able to configure their network to access the Internet.

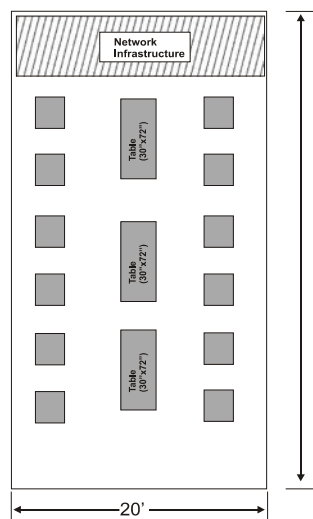


Figure 2. Basic Network Lab Layout

Security Administration Lab

Developing a lab for network security requires operating networks and the supporting infrastructure (hubs, routers, switches, etc.) as well as security equipment like firewalls and packet sniffers. Figure 3 diagrams the security lab layout. To keep all of the security experimentation isolated within the lab, all student work will be done within the lab. The lab will not have connections to the Internet. To simulate an external attack, students probing a secured system will be connected on one side of the lab router while the secure system is

connected on the other side. Lab rules will prohibit most types of physical system attacks (e.g., dismantling a machine), even though the lab layout would allow it to occur.

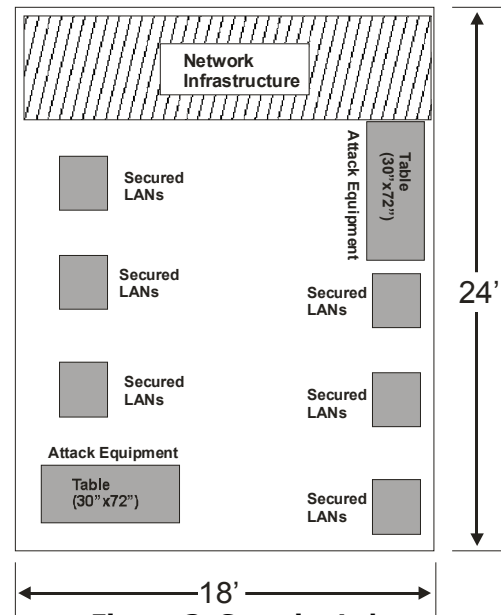


Figure 3. Security Lab

This course and its lab requires a considerable focus on the ethical requirements of networking professionals. Tools and techniques must be isolated within the lab and students must understand that these skills must be appropriately used to protect the client.

Infrastructure Lab

A lab to support communications infrastructures is filled with expensive equipment. Complex routers and switches allow students the opportunity to configure and operate this type of equipment. (Gowan, 2001) Infrastructure equipment is responsible for seamlessly integrating all the different forms of communications technologies. Standard leased wire (T1/T3), standard copper wire (Ethernet), coax, optical, and wireless technologies must be available in the lab to allow students to configure various connectivity scenarios. Figure 4 provides an infrastructure lab equipment block diagram.

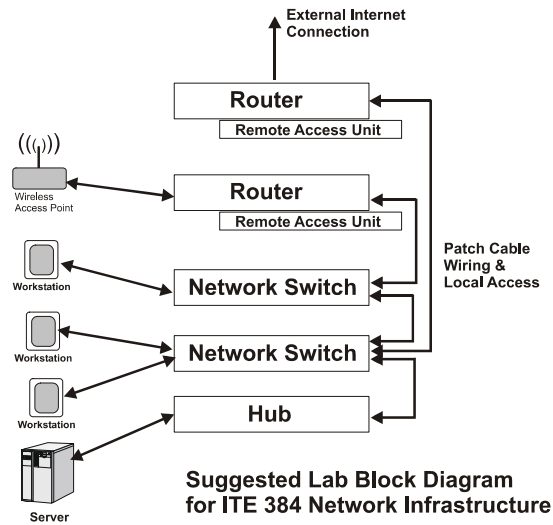


Figure 4. Infrastructure Lab

Fortunately, this equipment, while costly, does not require extensive floor space. Most of this equipment can be rack mounted further reducing floor space requirements. In many business installations this equipment is located in wiring closets with limited physical access.

Students will initially configure the equipment by physically plugging patch cables between various ports to provide the needed connectivity that this equipment provides. By providing remote access capabilities, students will be able to monitor and operate the equipment from other locations reinforcing remote management principles and limiting their need for physical access to the lab facilities.

Other Design Issues

Internet Connectivity: Today's world is connected. Remote connectivity, maintenance, and management are becoming common tasks for network professionals. The ability to provide both on-site and remote management opportunities is an important teaching/learning objectives for these labs. However, meeting this requirement adds an additional level of complexity to the lab design and operation.

Emerging Technology: Because of the increasing importance of wireless and optical technology, these technologies should be included in the design of these

labs. Integrating this technology into the lab's infrastructure will provide students with up-to-date skills.

Space: There is never enough space for labs. The issue of space relates directly to the number of workstations, the number of students a lab can serve, lab scheduling, and lab operation. The goal of two person teams assigned to each networking cluster is a reasonable goal. Our experience with larger team sizes (3 or 4 students) has shown that some team members may not have adequate lab experiences.

3. Lab Usage

Lab usage presents several unique problems and issues.

Lab Scheduling

The design of the lab depends upon the method used to schedule lab use. Two methods of scheduling are appropriate for the anticipated assignments in these courses: open scheduling and fixed scheduling. Choosing a method depends upon several factors such as: class size, staffing, project durations, student access, and lab budget.

Open Scheduling: This approach assigns a networking cluster to a lab team for the duration of each assignment. Because of the complexity of some assignments (e.g., network installation) students may not complete an assignment at one sitting. Under open scheduling, they will return at their convenience and complete the assignment. To increase the utilization of this approach, each assignment is assigned a fixed deadline which students are required to meet.

Fixed Scheduling: This approach provides fixed lab periods for students to work on their assignments. At the end of each lab period, the current state of each team's system (networking cluster) will have to be saved so that it can be restored at the next lab period. Operationally, at the beginning and end of each lab session, students would run a series of scripts to restore or save their current work.

Saving the networking cluster state requires significant hardware either in the cluster

hardware or in the lab infrastructure. The networking cluster solution requires two hard disks so that the image of the smaller master drive could be saved to a larger slave drive. The network solution requires a high-capacity imaging server that can store each networking cluster's state on the lab server's drive. The network solution also requires high-speed connectivity to allow the entire lab to be serviced in a reasonable time period.

Sample Lab Assignments

Using the lab effectively is as important as designing and installing the hardware. The richer the lab environment, the richer the student lab experiences will be. Developing the lab experiences requires an understanding of the lab hardware and software, the course objectives, the student's knowledge level, and the amount of available setup time. To provide students with a breadth of experiences several different lab scenarios seem relevant. For the different courses a few sample lab activities are describe below.

Net Admin & Infrastructure Courses

Normal Operations: Activities such as network installation, user and resource management, and monitoring of the network environment should be provided. Some of these labs are simple in their design but complex to execute (i.e. hardware and software installation). A monitoring lab will require simulating normal network operations (e.g., logins, file usage, printing). This can be accomplished by modifying network log statistics or running simulated activities on the network. These types of labs would be completed on an individual networking cluster.

Debugging/Troubleshooting: The configuration of an individual networking cluster is changed to reflect a failed condition(s). Students will then be given access to the cluster to troubleshoot and diagnose the problem. Students will be expected to correct situations that are within their control and report on all others. Additional more complex scenarios could be designed in this lab environment.

Timed Labs: This type of lab mirrors real-world activities because it simulates some of the pressure on a network

professional to restore operation as soon as possible. Students are presented with a malfunctioning network situation and given a fixed amount of time to diagnose and repair the problem. Students may repair or reconfigure the system to restore some or all of the operational capabilities. Evaluating this type of lab adds more complexity to this assignment because observation is one of the best methods of evaluating this skill. Evaluating several teams simultaneously may prove problematic.

Network Security Administration Course

Developing security labs provides some dilemmas: to adequately test system security we must attack the system. Training students for security requires them in looking at systems for the security flaws. Building a secure system is only part of the solution; the systems must be monitored to determine if it actually provides security. Configured secure systems must defend all attacks for some period of time. Because of the skills taught in this course and its labs, there must be a constant ethical component to reinforce the importance of properly using these skills.

Lab Operation: We will assign three student teams to each networking cluster. Each team is assigned one of three responsibilities: defense, attack, or monitor. The Defense team will design and implement a security system while being monitored by the Monitor team. After the security deadline, the Attack team will be given access to the system, allowed to collect information, and breach the system, if possible, while being monitored by the Monitor team. The Monitor team's responsibility is to ensure that the lab rules are followed by both teams. At the conclusion of a cycle period (several weeks), the teams will complete reports on their outcomes, change team responsibilities, and repeat the lab with new responsibilities. Each team will rotate through all three responsibilities.

4. Our Current Status

Implementing this plan is a large undertaking for a department. There are issues of space, equipment purchase and installation, development of faculty skills, implementation of course and lab materials, and coordination with the university's computing infra-

structure to contend with. Our department has begun the process with a two-year time frame. Our first lab offering is currently scheduled for the Fall 2003 semester. Network infrastructure and network security courses will follow in the Fall 2004 semester.

Hardware/Space

The networking cluster prototype was completed during the summer semester. The rest of the units will be built by the campus cabinet shop. The networking lab space will be remodeled during the summer semester. Upon completion of the remodeling and electrical wiring, the networking lab and portions of the advanced networking lab will be installed. The infrastructure and security labs are awaiting space.

Course/Lab Materials:

During the summer, lab procedures and support software will be developed and tested for the specific hardware installations. Specific labs and lab instruction handouts will be developed by a current faculty member. The development and refinement of course outlines and labs for the infrastructure and security courses is ongoing. An additional faculty member will be sought to bolster existing faculty skills for these courses.

The ambitious nature of these designs and the need to provide students with the most up-to-date skills makes this project worthy of effort in all areas to overcome the problems and make these designs a reality.

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