Development of Practical Computer Networking Laboratory

Davoud Arasteh

Department of Electronic Engineering Technology
Southern University, Baton Rouge, LA 70813

Abstract

In 2004 Electronic Engineering Technology Department at Southern University decided to develop computer networking and wireless technology laboratory. The driving force was the need for hands-on experience. This is an essential component for a high-quality education in computing and networking technology. We believe creating a technology environment will motivate students to develop a better understanding of theoretical concepts. Hence, these laboratory activities aim to prepare students in computer networking class for the challenges of participating in an exponentially growing technology. Consequently, our primary goal was that students experience the fundamental concepts of wired and wireless networking technology through practical training on hardware components, software configuration, and testing devices. The second goal was to use protocol-analyzing software to examine, analyze, and modify data packets. The third goal was to expand the scope of work to a level to simulate the large-scale network design on simulating software like OPNET®. In order to achieve these goals, we wrote a series of lab practices to guide undergraduate students in their lab work. These activities integrate the aforementioned features. Furthermore, this work can be extended to research oriented activities where a network-programming component, such as socket programming, or modifications of network protocols is required. As a complement to networking activities, we are working on exercises that students can experience the computer security issues and relevant technologies in the same framework. In addition, other motivations were behind the development of a practical computer networking laboratory. The general course framework in networking does not provide direct access to networking equipment and software. This networking lab tries to meet the demand for creating lab-oriented courses in networking by offering an extended set of lab exercises from planning, design, implementation, and testing to software and hardware configuration processes. These are extensible to a broad range of topics. We learn through experience that multi dimensional approach in teaching networking technology requires multi dimensional effort to address all the important aspects of networking science.

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Introduction

The field of computer networking is becoming attractive for the electronic engineering students because of the growing information technology markets and the jobs related to this field. In electronic engineering technology department we have addressed this demand by offering computer systems technology, computer networking and computer security and data protection courses. The EET department of Southern University introduced the enhanced curriculum for computer networking laboratory in 2004 to include the recent technologies in wireless networking.

The rationale for these improvements is the firm believe that exposure to the latest developments will provide students with the information and skills necessary for the major technologies in the industry. One trend that has motivated the enhancement of these laboratory practices is many traditional courses in networking do not provide direct access to networking equipment and software. Increasingly, however, the need for hands-on experience is seen as essential for a high-quality education in networking. Here we try to meet the demand for creating lab-oriented courses in networking by offering an extended set of lab exercises that covers a broad range of topics to prepare students successfully challenge the modern technology concepts. Our course takes a practical approach, which emphasizes how networking concepts are applied in a real network.

Computer networking courses teach networking concepts at a relatively abstract level. Our approach will provide unified powerful tools from pedagogical point of view. Our design for this course aims to expose the students to theoretical concepts as well as practical features of this field. The course consists of lectures, homework problems, course project, and series of experiments. Experiments are designed to reinforce the concepts studied in lectures and essentially form the practical core of the course plan. They are designed to not only complement the lectures and related lecture materials, but also to enhance the understanding of the computer networking students by using software packages like Ethereal and OPNET® simulator which provides a virtual environment for modeling, analyzing, and predicting the performance of information technology infrastructure, including applications, servers, and networking technologies [1, 2, 3]. Working in virtual environment students can validate changes before implementation, understand the impact of changes, and evaluate the network performance under various scenarios.

Students gain insight and understanding of the material through guided observations, measurements and group discussions. Having said this, with the experience gained from the lab exercises, students will become knowledgeable and comfortable with installing, analyzing and configuring networks.

Institutional Description

The Department of Electronic Engineering Technology has about 180 undergraduate students and is one of the fast growing departments in the College of Engineering. The number of students interested in computer networking has been steadily increasing in recent years. In the fall 2005, eighteen undergraduate students have registered for the computer networking course and have declared computer and communication electives as their major area. Sixteen students registered for the networking lab. This makes computer

system technology the most popular area of undergraduate study in the department. The department's mission includes: 1) educating students so that they will be able to pursue a productive career, and 2) providing BS graduates with technical depth in one or more areas of specialization so that they can compete successfully in the marketplace. On the other hand, our near-term goals for the department include; 1) continue to maintain up-to-date undergraduate teaching laboratory facilities, 2) continue to provide our students with a quality laboratory experience, and 3) maintain recognition as one of the accredited undergraduate program within the state. Towards these goals the department has decided to implement new technology equipment for the computer networking and wireless technology lab, while enhancing the analog and digital communication labs with existing equipment from the Lab-volt Company. Our rationale for this endeavor was as follows:

1) The proposed laboratory would allow the students to become familiar with wireless technology and computer networks instruments. Such experience is invaluable in the marketplace, as our graduates would not require extended periods of training. This will make our graduates very attractive to the industry.

2) At present we offer six undergraduate courses in the communication computing area. These are Computer Systems Technology, Analog Communication, Digital Communication, Computer Networking, Computer Security and data protection, and Advance topics in computer technology. LabVolt laboratory equipments accompany communication system courses. LabVolt Analog Communications Training System Model 8080 and LabVolt Digital Communication Training System Model 8085. Computer networking and computer security and data protection are both technical elective courses and had no significant laboratory experiments associated with them. Because of this necessity we planned to equip these laboratories for our undergraduate program so that the curriculum has significant practical components.

3) Enhancing the communication and computing lab in a direction that would allow undergraduate students to obtain hands on design experience in several areas of communication and computer systems. In particular, research efforts involving implementation of wired and wireless LAN has been undertaken in one of the large-scale senior design project where computer-networking lab has provided an infrastructure for student design project.

These advance laboratories are expected to increase the visibility of the Department of Electronic Engineering Technology in this important field. These labs will be showcase to attract more students into the area of computer systems technology and result in attraction and retaining of student from Louisiana and neighboring states.

Laboratory Technical Description

The computer networking lab exercises are designed for a set of equipment, which consists of Cisco routers, Microsoft PCs, Linux PCs, Ethernet hubs, access points, wireless network interface cards, and additional cabling equipment. The software packages either purchased or downloaded from web sites. The software required for the Linux PCs has been obtained under the GNU Public License without cost and that there is no restriction on distributing the software. For network traffic performance evaluation studies OPNET software package is used. This package is installed on College of Engineering networked computers where students can access the software for simulation exercises.

The equipment of the networking lab is house in large room with a storage room and two racks. Networking laboratory is not connected to the Internet, thereby avoiding security issues and preventing interference with the College of Engineering network. Following describes the technical specifications of some of the equipments and devices.

- 3COM Network Adapter 3COM 3C920 Integrated Fast Ethernet.

- PCMCIA Card with Texas Instrument® PCI-4451® card Bus Controller.

The 10/100 PC Card will connect the notebook computer to an l0BaseT or l00BaseTX network. Ready to run in both half and full duplex modes, the 10/100 PCMCIA Card supports speeds of 10 Mbps, 20 Mbps, 100 Mbps, or 200 Mbps. The card adjusts its speed and duplex to almost any 10BaseT or 100BaseTX network automatically. The Texas Instrument® 10/100 PC Card includes a 32 KB buffer for fast file transfers, low voltage operation, hot swap compatibility, advanced error correction, 16-bit architecture, and complete software suite.

- The Cisco Catalyst™ 2600 Series Ethernet

Switch provides industry-leading performance and end-to-end network integration. The Catalyst™ 2600 switch has up to twenty five l00BaseT switched Ethernet ports (including the AUI switch port on the back panel), each port providing users, or groups of users, dedicated l00-Mbps bandwidth to resources within the network. These ports connect to other 100BaseT-compatible devices, such as single workstations and l00BaseT hubs. The switch also has two l00BaseT switched ports, and is designed for plug-and-play operation, requiring only that you assign basic IP information to the switch and connect it to the other devices in your network.

- Cisco Catalyst 3550 Multi-layer Switch

Hardware includes 24 auto-sensing 10/100 Ethernet ports, 2 GBIC-based Gigabit Module slots. Configuration supports Layer 3 routing, auto-negotiation of speed, and duplex operation on 10/100/1000 Ethernet ports.

- 3COM SuperStack® 3 Baseline 10/100 Switch 24-Port

This switch does not need sophisticated management capabilities with 24 auto-negotiating ports, for determining the speed and duplex mode of the connected equipment.

- Cisco 2500 and 2600 Series Routers
- Cisco PIX Firewall
- Wireless Access Point

The Wave2Net Wireless Access Point is used as the wireless equivalent of a hub, splitting and distributing 11 Mbps connections to as many as 256 wireless clients through 2 adjustable dipole high-power antennas. It features network management software, USB console support, roaming, and supports advanced WEP security.

- Laptop Computer

This Laptop Computer features Microsoft Windows XP Professional Operating Systems, Mobile Intel (R) Pentium (R) 2 GHz CPU, 20 GB hard disk drive, 512 MB RAM, DVD/CD-ROM, and PCTEL 2304 WT V.92 Modem.

- Desktop Computer

This computer features Microsoft Windows XP Professional Operating Systems, 2 GHz CPU, 20 GB hard disk drive, 512 MB RAM, DVD/CD-ROM, and V.90 Modem.

- Handheld Wireless Receiver

A handheld, wireless receiver designed specifically for sweeping and optimizing LANs. The instrument measures coverage of direct sequence CDMA networks which allows the user to measure and determine the Access Point, Packet Error Rate and RSSI signal levels aiding in locating the hub and access points throughout a building. It detects and differentiates from narrow-band multi-path interferences, such as microwave ovens and frequency hopping systems. It also features a display, keypad, and battery pack for true portability works with any IEEE 802.1 lb DSSS access point.

- Accessories

AUI/RJ-45 transceiver, RJ-45 to DB25 Adapter, Aironet Client Utility, Cisco Aironet 2 dBi Diversity Omni directional Antenna, LAN ProNavigator® Data and Coax Network Tester, RJ45 Network Cables - 50' , CAT5e cable, Data SureStrip™ twisted pair cable cutter/stripper, Surepunch® punchdown tool with combination 110/66 blade, CrimpALL® Ergonomic Series crimper.

Figure 1 shows different perspectives of computer networking laboratory in Electronic Engineering Technology Department.

Figure 1 Electronic Engineering Technology Department Computer networking lab

Laboratory experiments

Labs accompanying the lectures provide step-by-step procedures for installing, configuring, testing and troubleshooting both wired and wireless local area network hardware and software. Student will gain hands-on experience working on networking equipment and acquire useful networking skills. The primary goal is to put computer networking into practice that is how individual network component configured and how networked systems interact. In these series of experiments our primary purpose is the study of networking concepts, technologies, and protocols in operation as well as some basic configuration techniques. In our approach we tried to integrate some of the professional training certification programs with and fill the gap that exists between the experts in configuring or troubleshooting networks. The networking lab emphasizes on both insight and skill development. From router configuration knowledge provided in the labs to some basics of router configuration and system administration is covered to provide the basic knowledge and experience in this area. Advance topics can be learned in professional training programs that already exist outside of universities and colleges.
Since tools for simulation of networks have an important place in networking education the Networking lab also uses these tools for simulation or emulation of networks.
Labs are organized so that students can understand all aspects of the configuration of a lab experiment and can complete the lab setup themselves. Each lab consists of many parts with corresponding lab exercises. Students work in groups of two. They are responsible for recording their observation and analyze the lab objectives.

- Lab 1, “Network cables assembling and testing”

This lab introduces three types of cabling, i.e. twisted pairs, coaxial cable, and fiber optic. Students assemble connectors to a twisted pair cable using crimping tool, and then they test the cable to ensure properly wired connections. This is important because many of the network installation problems are related to cabling errors.

- Lab 2, “Network cards installation and test”

This lab shows how to install and configure the network card into a PC expansion slot of a client computer. Connect the client computer to the network. Install the cable and document all network connections on a classroom LAN network.

- Lab 3, “LAN configuration”

Once the network operating system and the physical hardware is installed and configured, shares must be set up on the workstations. The lab introduces how to locate the network configuration screen used with Windows XP and configure a workstation with a unique computer name and configure a hub with an IP address. Each workstation becomes a client for Microsoft Networks, and File and Print Sharing is enabled. The basic elements will be in place to share files between workstations on the LAN. In this procedure students examine the user-level access control, that is, access is granted based upon access privileges granted to a single user or a group of users. Another lab activity is the configuration of a client computer for print sharing.

- Lab 4, “Wireless Networks”

In this lab students will install and configure the Cisco Aironet Wireless Access point, which allows laptops and other mobile computer systems wireless access to a network, and perform a link test to assess the performance of the RF link. Also students learn how to implement a strong network security by changing the Service Set Identifier (SSID), and establish a strong Wi-Fi Protected Access (WPA) pass-phrase on the router or access point. Then configure all the wireless computers and devices on the network to associate with the SSID of WPA-enabled router or access point using the same WPA pass-phrase. Another activity in this lab is using Aironet Client Utility to perform user level diagnostics on Cisco Wireless LAN Adapter Card. Students upgrade firmware, look at the current device status, as well as view the current device statistics. Also perform a link test to assess the performance of the RF link at various places in area. The results of the link test can be used to determine the RF Network coverage, which can be used to figure out the required number and placement of Access Points to eliminate ‘dead spots’, where low RF signal levels can result in the loss of the connection between the Cisco Wireless LAN Adapter Card and the Access Point.

- Lab 5, “Wireless IP Networks”

This lab shows how to configure a wireless network interface for IP networking and what can happen when a network configuration errors occurs. Another subject of study is the address translation of IP addresses to MAC addresses using ARP. The final lab exercise exposes students to signal strength problems of common wireless networks.

- Lab 6, “Cisco Switch configuration”

Topics covered in this lab include the recognition of the status of each port on the switch and the purpose of each connector on each switch, terminal emulation setup to access the switch configuration settings. Also become familiar with Cisco IOS command modes, configure the switch with a unique IP address and test the switch in a LAN for its functionality.

- Lab 7, “Router configuration”

This lab introduces the concepts of IP forwarding and routing between IP networks. The lab exercise show how to set up a Windows PC and a Cisco router as an IP router and reveals the similarities of IP forwarding and routing tables on a Widows PC and a Cisco router. Students learn how to interpret and manually edit routing-table entries in a network with multiple IP networks and IP routers. Since this is the first lab that uses the Cisco routers, there is a component that shows how to access the console port of a Cisco router from a Windows PC and how to issue configuration commands on a Cisco router.

- Lab 8, “Client-Server Network Configuration”

Students are introduced to the installation of Window 2003 Server tools on a Windows XP Professional workstation and set up a user account on the Windows 2003 server. Also create and manage networked groups, and manage the security policies of users and the network.

- Lab 9, “Network Design”

The lab demonstrates the basics of designing a network, taking into consideration the users, services, and locations of the hosts. This is important because OPNET simulator can be used to optimize the design of a network by refining the initial design. Students explore the how different design formats can affect the performance of the network. Steps include, creating a new project, initialize the network, configure the services, configure a subnet, configure all departments, configure the servers, choose the statistics and configure the simulation, duplicate the scenario, run the simulation and view the results.

- Lab 10, “Routing Information Protocol”

The lab explores a routing protocol based on the distance-vector algorithm using OPNET. The goal of the lab is to configure and analyze the performance of the Routing Information Protocol (RIP) model. Here students study how RIP provide a distributed, dynamic way to solve the problem of finding the lowest-cost path in the presence of link and node failures and changing edge costs. A lab exercise with the routing protocol RIP explores the analysis of the routing tables generated in the routers based on distance-vector algorithm, and how RIP is affected by link failures.

- Lab 11, “Protocol Analyzer”

The objective of this lab is to introduce the students to the techniques for using a protocol analyzer to examine how networking packets are transferred and exchanged in a TCP/IP network. Student will develop an understanding of the protocols in packets transfer and corresponding protocols like Address Resolution Protocol (ARP), and Internet Control Message Protocol (ICMP). Ethereal software is used to capture, decode and analyze the packets. Students learn how to detect, identify and correct some of the network problems.

Conclusion

In this paper we have described the experiences accumulated in teaching a senior level course in computer networking laboratory. To relate the relatively abstract level of networking concepts to real world practices, we developed a dynamic lab-oriented approach, which provides practical experiences in networking hardware, device configuration, testing and troubleshooting. Also we take advantage of OPNET simulator software to virtually implement networks while analyzing their performances under various traffic models. In addition, whenever packet manipulation is required network protocol analyzer like Ethereal software is used to capture network packets for monitoring and detection. We are in the process of extending these laboratory activities to network security and data protection course materials. A bonus that comes from this type of practical teaching is that lab sessions were very enjoyable for students. It had substantial positive impact on the overall performance of students, which were reflected on their level of involvement in lab assignments and active attendance in lab sessions as well as class discussions.

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DAVOUD ARASTEH
Davoud Arasteh serves as an assistant professor of Electronic Engineering Technology at Southern University of Baton Rouge. He has an extensive experience in curriculum development on senior level and laboratory environments. His research interests include Mobile Computing, Network Security, Nonlinear Dynamical Systems, Computer Vision, Condense Matter Physics, and Technology Based Engineering Education. He is the chair of departmental curriculum committee and is a member of ASEE, IEEE, IEEE Computer Society and SPIE.