Hands-on Laboratory Based Networking Courses

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Abstract

Today computer and information science graduates are expected to have a working knowledge of network based applications. Also, the demand for network and computer systems administrators has created potential employment for graduates that have completed course work in networks and systems administration.

At the University of Illinois Springfield (UIS), we have developed and offered courses to provide our students with an opportunity to master a working knowledge of the basic fundamentals of network applications and systems administration. These courses include hands-on laboratories on topics related to network administration, introduction to network concepts, configuration of routers in a WAN environment, and client server programming. The laboratory classes require the students to demonstrate a working knowledge of configuring network hardware and software, administering a network, configuring security for a network and programming a client server application.

The laboratories used by the students include Linux and Microsoft based Microcomputers that are connected to the Internet and to a LAN with switches and routers. The laboratories include patch panels, conduit, routers, switches and microcomputers. In the network administration class students install and configure a Microsoft 2000 server based network. The Cisco Networking Academy Curriculum with hands-on laboratory exercises is used to introduce students to the fundamental concepts of networks and configuring routers in a WAN environment. The students are given network specifications and are required to design and implement a working solution by configuring routers and switches. After students have configured the network they must perform tests and collect data to insure the system is configured properly. In the network programming laboratories students write client server code that runs on Unix platforms in the Unix and Internet domains.

In this paper the author will delineate the curriculum, laboratory configurations and laboratory exercises. The presentation will include pictures and web links for those desiring information related to implementing a similar curriculum.

A Need for Hands-on Networking Laboratory Classes

The author reviewed several papers presented in previous Special Interest Group on Computer Science Education (SIGCSE) Conference Proceedings related to teaching networking courses [1, 3-6]. Based on these articles, there appears to be a trend toward incorporating more hands-on hardware and software laboratories into the networking classes. Some of the papers [3,4] make direct references to requests from the private and public sector to expand the computer science curriculum to include more networking and information security courses. In particular, the President's Commission on Critical Infrastructure Protection (PCCIP) [2] emphasized the need for developing new curriculum in the area of information security.

In an effort to expand the computer science curriculum to include laboratory based networking courses, faculty members at universities are developing and offering new courses. Martin Levin developed a data communications laboratory at Grand Valley State University (GVSU) with funding from a National Science Foundation (NSF) grant [5]. The laboratory at GSU provides students with hands-on experience with various Local Area Network topologies, cabling, and implementations on WANs by different vendors. Laboratory exercises included data collection to test and evaluate network performance. Barr, Yoo and Cheatham developed a hands-on laboratory that provides students with experience capturing and analyzing network traffic [1]. Bruce Elenbogen at the University of Michigan Dearborn has utilized an NSF grant to build a laboratory that provides students with hands-on experience implementing and managing a network. The students install the network software, create user accounts, setup domains, manage networked devices, backup systems, monitor network performance and implement security software [3]. Brad Richards at Vassar College has developed a hands-on laboratory to provide students with experience examining network protocols [6]. Hill, Carver, Humphries and Pooch at Texas A&M University College Station developed a networking laboratory for teaching advanced networking concepts and security [4]. The laboratory is used by graduate students to implement a security test bed environment. The students are divided into two teams with one team responsible for providing security while the other team attempts to breach the security and cover-up their access in the security logs.

At the University of Illinois Springfield (UIS), the author has developed two networking laboratories designed to provide students with hands-on networking experience. Currently there are four networking courses being offered by the UIS Computer Science Department. The classes include: Introduction to Networks, Routing in a WAN Environment, Network Administration and Network Programming. In the fall 1999 UIS entered into an agreement with Cisco Systems Incorporated to become a regional and local Cisco Networking Academy. As a regional academy, we recruited ten schools to become local Cisco Networking Academies. We provide training and technical support to

the local academies. We are also a local academy and offer the Cisco Certified Network Associate (CCNA) curriculum to our students. For more information about the Cisco Networking Academy program please visit the author's web pages at http://www.uis.edu/~mims. The Computer Science Department received a set of five routers and two switches donated by Cisco to use in the Regional Academy to provide training to local academy instructors and for use by our students. We use this equipment and an additional five routers and five switches to instruct our students in the Introduction to Networks and Routing in a WAN Environment courses. We use Pentium based systems running Microsoft's 2000 server and Linux in the laboratories for teaching Network Administration and Network programming. Pictures of the laboratories may be viewed on the author's web site at http://www.uis.edu/~mims/networkinglabs.

Introduction to Networks

This course began as a data communications type class with laboratories that used PCs connected via serial ports with software that networked computers via serial communication. The course has been redesigned and we currently offer the Cisco Networking Academy to students taking Introduction to Networks. In this course students are provided with on-line access to the CCNA curriculum. The curriculum is excellent and utilizes audio and video to deliver the course content. On-line quizzes and tests are included for each learning objective. Feedback is provided to students after they complete a test. The feedback indicates areas of weakness where additional help is needed. Cisco Press publishes a textbook that is coordinated with the curriculum Cisco Networking Academy Program: First–Year Companion Guide, Second Edition.

Topics covered in the first half of the course include: Computer Hardware Basics, OSI Model, Local Area Networks, Network Design, Cabling, IP Addressing, Routing Concepts, Router Configuration and Basic Network Trouble Shooting, Security and Management. The laboratory assignments have been developed by Cisco Networking Academy personnel. The lab assignments include building and testing cable, using Fluke Network Inspector and Protocol Inspector software to view network traffic, and the basics of IP address classes and subnetting.

The second half of the course focuses on basic router configuration, routing protocols, address resolution protocol (ARP) and reverse address resolution protocol (RARP). The laboratory exercises introduce students to basic router commands and the function of routers in a network. At the end of the semester students are given a diagram of a network requiring five routers and eight networks. The students are required to develop a set of subnetted addresses using a single class C address. Threaded case studies are included with the Cisco Networking Academy Curriculum and provide students with experience designing and implementing a complete network for a school district.

Routing in a WAN Environment

This course covers the second half of the Cisco Networking Academy Curriculum. The first half of the course covers advanced subnetting, layer two switching, Virtual LANs (VLANs), upgrading router memory and software, characteristics of switches, managing switches, routed and routing protocols, access control lists. Students spend considerable time in the laboratories configuring VLANs and access lists in the first half of the course. They also continue the work they began on the threaded case study from the Introduction to Networking course. The curriculum is on-line and there is a textbook published by Cisco Press Cisco Networking Academy Program: Second–Year Companion Guide, Second Edition

The second half of the course includes topics related to WANs. Students complete laboratories on Integrated Digital Services Network, Point to Point Protocol, Frame Relay Encapsulation, Packet Switched and Circuit Switched Connections. Students complete the threaded case study. Students are assigned a final laboratory exercise in which they are given a diagram of a small school district requiring three routers and a class C address. They must design a network with the correct number of subnets and implement the network design with the proper access lists to provide the security specified in the assignment.

The Cisco Networking Academy Curriculum includes a CCNA exam review. After completion of the two courses, Introduction to Networks and Routing in a WAN Environment, students should be prepared for the CCNA examination.

Network Administration

This course was first offered in the fall semester 1998. We used Pentium 90 and 100 Mhz. machines that were obtained with an NSF grant for networks and parallel processing. We have since replaced those machines with Pentium 200 and 300 Mhz. systems.   The class is presented in a lecture and laboratory format. Typically a lecture will be presented on the class day preceding the day students complete the laboratory assignment.   Students have access to all the software used in the course and may make copies for use on their home computers. The software is made available by Microsoft to computer science departments at an annual cost of $750. For details on the MSDN** agreement visit the web site http://www.msdnaa.com/products/descriptions.asp. Topics covered in the class include: Domains, Installation System Requirements, Installation Process and Trouble Shooting, Adding User and Group Accounts, Managing File Systems, Security, Managing Networked Devices, Network Protocols, Remote Access, Internet Information Server, Performance Monitoring and Optimization and Trouble Shooting Techniques and Tools. Students complete laboratory exercises for most of these topics. Previous laboratory exercises for this class may be viewed at http://www.uis.edu/~mims/csc470networkadmin. We are working on a new set of laboratory exercises for the Server 2000 and they should be available by the end of the spring semester 2002 at the same web site address.

Network Programming

This is a graduate course that focuses on client server networking application interfaces that run in the Unix and Internet domains. Lectures are presented on the following topics: Introduction to the OSI Model, TCP and UDP Transport Layer Protocols, Introduction to Sockets, Elementary TCP Socket Functions, Client Server TCP Examples, I/O Multiplexing, UDP Sockets and Name and Address Conversions. Students in the course are given a client server application project to implement in both the Unix and Internet Domains. A typical laboratory assignment is given on the author's web site at http://www.uis.edu/~mims/csc583networkprogramming.

Conclusion

The incorporation of hands-on laboratories has enhanced the networking courses at UIS. Students provide feedback in the form of teaching evaluations and on-line evaluations of the Cisco Networking Curriculum. These evaluations have been very positive. Students have also indicated they are better prepared to enter the job market after taking the networking courses and completing the hands-on laboratories. Several of the students have earned their Microsoft MCSE and Cisco CCNA certifications.

It is the author's opinion that adding the laboratories has been the primary reason we have seen an increase in the number of students taking networking courses. A large percentage of students enrolling in the Introduction to Networking course continue in the their course work taking Routing in a Wan Environment and Network Administration. It is the hope of the author that others will find the work we have done with networking laboratories beneficial and are eager to share our findings with others.

References

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