THE DESIGN AND IMPLEMENTATION OF A HETEROGENEOUS COMPUTER NETWORKING LABORATORY[1]

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ABSTRACT

This paper presents the experiences gained by the authors in the design and implementation of a heterogeneous computer networking laboratory. Hopefully, this laboratory model would better prepare any computer science department's curriculum to meet the challenges presented by the rapid advancement of telecommunication technology.

INTRODUCTION

Computer Science mentors are confronted with the formidable task of not only trying to balance application and theory but also to keep up with the rapid advancement in technology. Our society is rapidly evolving into one that will continuously demand faster communication on a relatively slow expanding bandwidth. During the past decade, telecommunications have undergone an extraordinary acceleration due to the vast improvement in both the physical and logical structure o computer networks.

This paper presents the experiences gained by he authors in the design and implementation of a versatile networking laboratory. Hopefully, this laboratory model would better prepare any computer science department's curriculum to meet the challenges presented by the rapid advancement of telecommunication technology. The heterogeneous networking laboratory is characterized by the following attributes:

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a) It is adaptable to five (5) different network architectures: Ethernet, Fast Ethernet, Asynchronous Transfer Mode (ATM), Gigabit Ethernet, and Fiber Distributed Data Interface (FDDI) on a token ring that will be configured either concurrently or separately.

b) It is configured to handle streaming multimedia and distributed application components that exist in the local area network.

c) It is designed to handle very high bandwidth web traffic and secure communication protocols.

d) It is scalable and adaptable to new networking technology.

THE CURRICULAR NEED

During the past decade, telecommunications have undergone an extraordinary acceleration due to the vast improvement in both the physical and logical structure of computer networks. The physical aspect of this improvement is characterized by the rapid deployment of fiber optic cables, high-frequency channels, infrared media, and ISDN lines. The improvement on the logical side is manifested by the ten-fold improvement of the widely used Ethernet protocol into Fast Ethernet and even by a hundred-fold increase as manifested by Gigabit Ethernet. Coupled with this is the introduction of new protocols such as those that integrate voice, data, and video. This phenomenon entails the augmenting of the traditional curriculum suggested by the 1991 ACM Curriculum [2] with increased emphasis on technical skills. Fox and Reynolds best describe this curriculum issue in their Information Technology Curriculum Vision [7], which calls for the additional pedagogical emphasis on networks, databases, multimedia, and intelligent systems. The increasing emphasis on networking and telecommunications needs in the undergraduate curriculum is clearly seen in the knowledge and learning units of the IS'97 model curriculum [3]. The versatile networking laboratory will support course work similar to the model course as described in the IS'97 curriculum guidelines [3].

The authors have long recognized the value of the involvement of the undergraduates in research and project development. Prior to the current academic year, the authors were supervising twenty (20) undergraduates involved in seven (7) different projects. Topics included multimedia development, computer-based tutorial modules, intelligent advising, virtual reality modeling, neural network design and implementation, and computer-based intelligent assessment tools.

The aim of this project is 1) to address the need for students to acquire a working knowledge of both basic and advanced computer networks, and 2) to stimulate undergraduate research in advanced computer networking, in multimedia systems, and in systems design and programming. Five (5) computer science courses are being redesigned with both theoretical and practical emphases. Students will learn the theory of network structure, architecture, and performance from the lecture part of the courses. They will then apply this knowledge to a real network in this heterogeneous networking laboratory. We believe that the introduction of a well-designed computer networks course supported by a well-equipped networking laboratory into

our undergraduate curriculum will better train our students for both industry employment and graduate education.

This laboratory will have a direct impact on five (5) of our computer science courses: CS300 (Microcomputing), CS417 (System Modeling and Simulation), CS441 (Computer Systems Programming), CS450 (Computer Networks), and CS499 (Special Research Topics).

THE DESIGN OF THE LABORATORY

The design of the versatile computer-networking laboratory is predicated on the following notions:

a) to provide our students a hands-on experience in installing and managing an advanced heterogeneous computer network,

b) to establish a pedagogical computer network system that is scalable and adaptable to new networking technology,

c) to be able to conduct research on a controlled networking environment, and

d) to be able to apply and/or simulate theoretical networking concepts.

Furthermore, our design is dictated, in part, by the following laboratory activities that will be used to support the classroom lectures. Some of these activities were modeled after published descriptions of laboratory projects [1, 4, 5, 6, 8, and 9] that were indirectly supported by an NSF grant and were well received by undergraduates. The other activities are adaptations and implementations of exemplary materials and projects from previously funded NSF grants such as those described in [8, 9, 12, 13, 14, and 15].

THE LABORATORY ACTIVITIES

The laboratory activities were identified and categorized according to course suitability.

Category I : Common Development Projects for Computer Networks and Microcomputing courses

Activity 1: Desktop Networking
Installing and administering a Novell Netware Server
Installing and administering a Windows NT Server
Installing and administering a Unix Server

Activity 2: LAN Troubleshooting
Searching for faults in LAN cabling and connections.
Testing LAN network interface cards.
Monitoring and decoding LAN protocols
Monitoring networks using SNMP and RMON

Category II: Development Projects for the Special Research Topics course

Activity 1: Desktop Computing
RPC programming in Windows NT

Sockets programming in Windows
NetBIOS protocol (Microsoft/IBM) programming
SPX/IPX protocol (Novell) programming

Category III: System Modeling and Simulation Development Projects

Activity 1: Client Server Computing
Install and configure a Parallel and Distributed
Computing environment using MPI.
Simulate a computationally bound server
Simulate an I/O bound server
Model scalability of Client/Server architectures and applications

Activity 2: Network Simulation and Performance Analysis
Simulate and analyze performance of different protocols for heavy network congestion
Simulate and analyze performance of different protocols for light network congestion
Develop recommendations for protocol based on projected congestion

Category IV: Special Research Topics Development Projects

Activity 1: Network Performance Analysis
Designing software-based network simulation models
Designing hardware-based network simulation models
Developing a network visualization system

Activity 2: Distributed Computing Environment (DCE)
Implementing distributed applications
Implementing the Distributed Component Object Model Protocol

Activity 3: Security

Setting up and testing a prototypical electronic commerce

Setting up and testing secure firewalls

Category V: Computer Networks Development Projects

Activity 1: TCP/IP Protocol
Analyzing network packets
Writing a connectionless client for the TFTP service
Writing an asynchronous message-based Windows client.
Developing an application protocol

Activity 2: Fast Ethernet LAN
Installing and Testing 10/100 adapters
Installing and configuring drivers
Making and Testing UTP cables
Reconfiguring a traditional Ethernet to partial Fast Ethernet
Reconfiguring a traditional Ethernet to full Fast Ethernet
Network Testing with LAN analyzer

Installing mixed speed switches
Benchmarking a Fast Ethernet network

Activity 3: ATM LAN
Installing and Testing ATM network adapters
Installing and configuring ATM network drivers
Benchmarking an ATM network
Network Testing with LAN analyzer
Integrating ATM with Ethernet/Fast Ethernet

Activity 4: FDDI LAN
Installing and testing the FDDI kit and network adapters
Installing and configuring FDDI network drivers
Benchmarking an FDDI network
Network Testing with LAN analyzer
Integrating FDDI with Ethernet/Fast Ethernet

THE IMPLEMENTATION

The authors have five (5) computers from previously completed grants which are used as nodes in the networking laboratory. These computers are multimedia ready and, together with the a Sun Enterprise 250 server, should be able to provide the necessary computing power to simulate simultaneous heavy network traffic of distributed multimedia, intranet web communication, and internet access. Two of these computers are running under Linux, the other two under Windows NT/2000, the fifth computer is running Novell Netware. The Department has an SGI O2 workstation that is attached to the versatile network to simulate heterogeneous networking scenarios. An iMac is also acquired to complete the network setup. These computers will act as clients to the Enterprise 250 server. Figure 1 in the Appendix depicts the actual network implementation.

The Sun Microsystem Enterprise 250 multimedia server system was selected over the other Unix-based systems due to its well-documented scalability to symmetric multiprocessing, adaptability to present and emerging network architectures, and most importantly, its reliability and serviceability. These features will be required during the network bandwidth saturation tests, the distributed multimedia simulation, and the internet/intranet traffic simulation. The Enterprise 250 system acts as the dedicated web server of the entire network where all notes, laboratory manuals, and activity assignments reside. The external DAT tape drive is used to make a backup of the system and different network configurations and setup for easy transition from one activity to the other. The 10/100 Ethernet cards and switch are used for those activities that will require the standard and fast Ethernet network configuration. The ATM cards and the OC-3 switch module are used in a similar manner but with the ATM configuration. The StackPro SNMP/Rmon Management module will allow us to monitor the network performance and activity more closely and efficiently. The Link Builder FDDI kit and adapters are used for the FDDI configuration. The NetSense/Observer software tool is a specialized tool for network monitoring and is our primary tool for peeking into the networking environment. Windows

NT/2000 and Novell Netware are the two network operating systems that are used to configure a true heterogeneous networking environment. The LAN tester kit is used for troubleshooting simulated network problems

CONCLUSION AND FUTURE WORK

Finding the appropriate balance between theory, practical experience and research is difficult in all computing courses. [2, 3 and 6] This is especially true in the areas of networking and systems. This paper outlines the configuration of a versatile laboratory to support courses in these areas. The laboratory gains its versatility by heterogeneously combining different operating systems, network protocols, cabling schemes and equipment into one environment. The versatile laboratory supports activities in several areas of instruction. The activities are designed and structured to provide practical experience while illustrating theory and research areas.

The challenge for the authors will be in continual development of activities and exercises that leverage these facilities. Future work will include:

Wireless and mobile protocols [8],
xDSL and cable modem technology, and
security and encryption.

The application of computer networking is growing tremendously. Students and industry are clamoring for courses with more hands-on experience. The versatile laboratory and the associated activities outlined in this paper represent an ongoing effort to meet these needs.

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APPENDIX

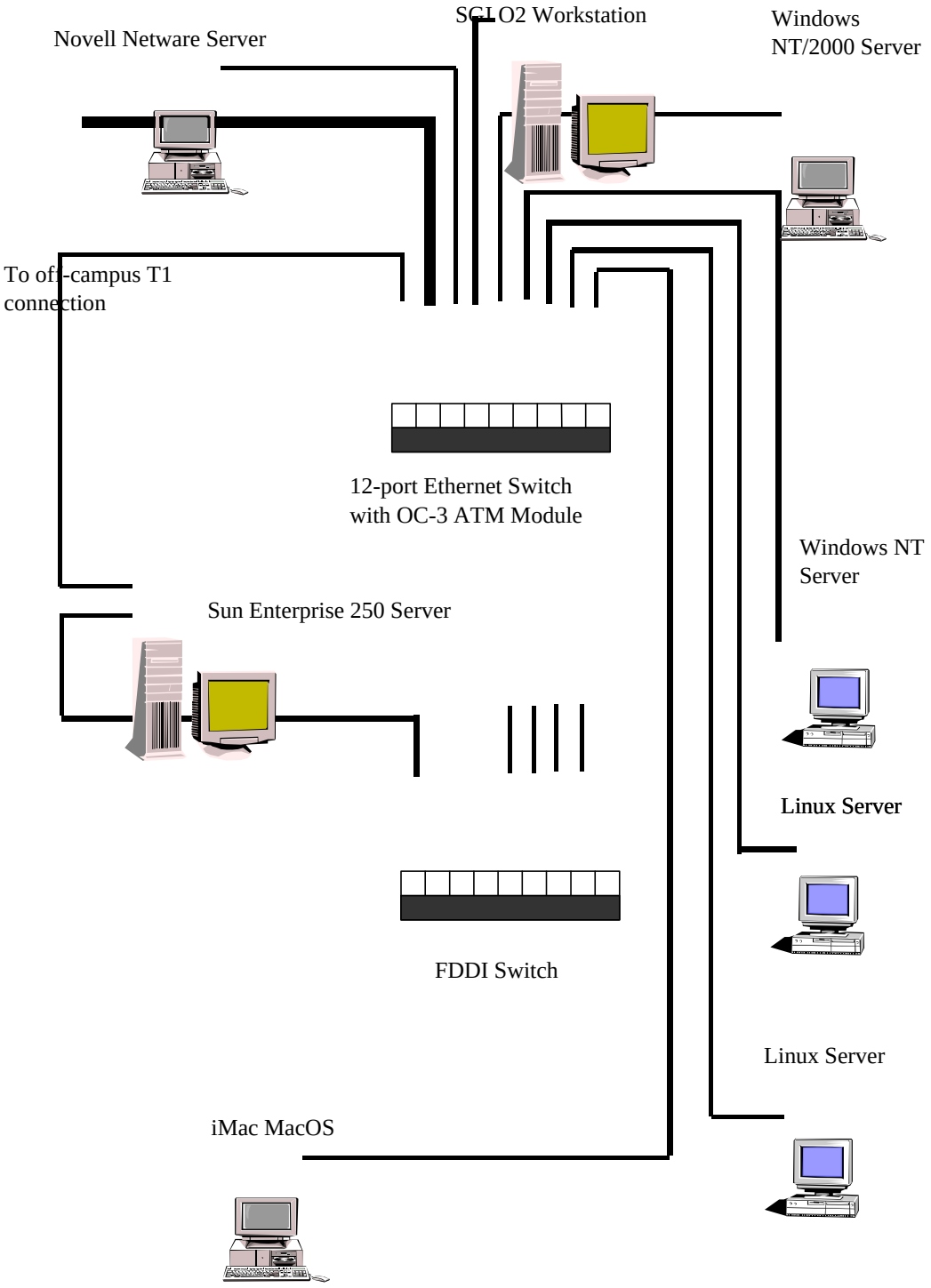

Figure 1: The Heterogeneous Computer Networking Laboratory Implementation