Network Instructional Units

William M. Farmer
Richard E. Mowe

Microcomputer Studies Program
Department of Statistics
St. Cloud State University
720 Fourth Avenue South, ECC-139
St. Cloud, MN 56301-4498
{wmfarmer,mowe}@stcloudstate.edu

Introduction

Computer networks are to the Information Age what railroads were to the Industrial Age. Unlike railroads, however, computer networks are implemented today with a diverse multitude of technologies—such as Ethernet, Asynchronous Transfer Mode (ATM), optical fiber, radio, and infrared. These technologies utilize different physical media and different protocols for communicating information. Over the last two centuries, railroad technology has evolved quite slowly: today most trains still ride on a pair of steel rails. In contrast, existing network technologies are evolving at a prodigious rate and new network technologies are continuously being introduced. Moreover, these technologies are used together to form the Internet, a great heterogeneous collection of interconnected networks.

To learn computer networking requires both understanding of theory and hands-on experience with designing, building, and analyzing operational heterogeneous computer networks. Unfortunately, most operational computer networks in the field are designed to work, not to be worked on. For this reason, few undergraduate computer networking courses have the luxury of offering students unrestricted access to real networks used in real situations. Students usually start with a course on local area networks that provides experience with a simple homogeneous network in the laboratory. Advanced networking courses need to give students experience with complex heterogenous networks.

A laboratory network environment for advanced networking courses should expose students to some of the wide range of ideas and technology found in real network environments. Ideally, a laboratory network environment should include:

1. Multiple computers running multiple operating systems such as Unix and Windows NT.

2. Multiple networks involving both routers and hosts and running multiple protocols such as TCP/IP and Novell.

3. Multiple networking technologies, such as Ethernet and ATM, that are used to implement both local area networks (LANs) and wide area networks (WANs) (see [3]).

A major challenge for the networking course instructor is to find an effective and flexible way to offer students a rich network environment in the laboratory which has the elements listed above.

Network Instructional Units

A laboratory network environment can be constructed from two or more modules called *network instructional units (NIUs)*. An NIU is a collection of computers and networking equipment mounted on a movable physical rack. The network environment is made by interconnecting the NIUs using appropriate cabling and other networking equipment such as hubs, switches, routers, and media converters.

A sample NIU might contain four computers (three servers and one workstation); a keyboard, video monitor, and mouse with a keyboard/video/mouse (KVM) switch; four Ethernet network interfaces (one for each computer); an Ethernet hub; and an ATM network interface for one of the servers (see Figure 1). Many network environments can be constructed from NIUs of this kind along with cables and media converters, Ethernet hubs and switches, and ATM switches. Figure 2 shows a network environment constructed from four NIUs containing an Ethernet network at each NIU "site" and a ATM network that connects the NIU sites together. Figure 3 shows a 4-NIU network environment with an Ethernet network and an ATM network in parallel. And Figure 4 depicts another 4-NIU network environment with two Ethernet networks and two ATM networks.

Each NIU could be managed by a group of students. The KVM switch would allow the NIU's four computers to be accessed via the NIU's single keyboard, video monitor, and mouse set. The computers could be configured differently from each other, possibly running different operating systems (such as Windows NT and Linux) and different applications. For instance, the computer with both an Ethernet interface and an ATM interface could be configured as a router.
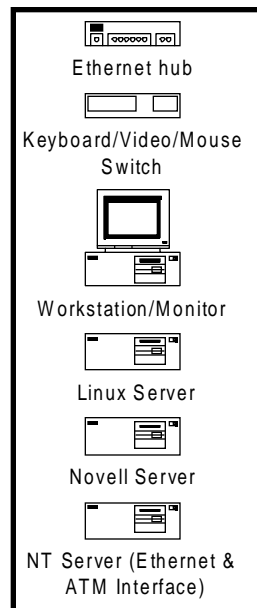

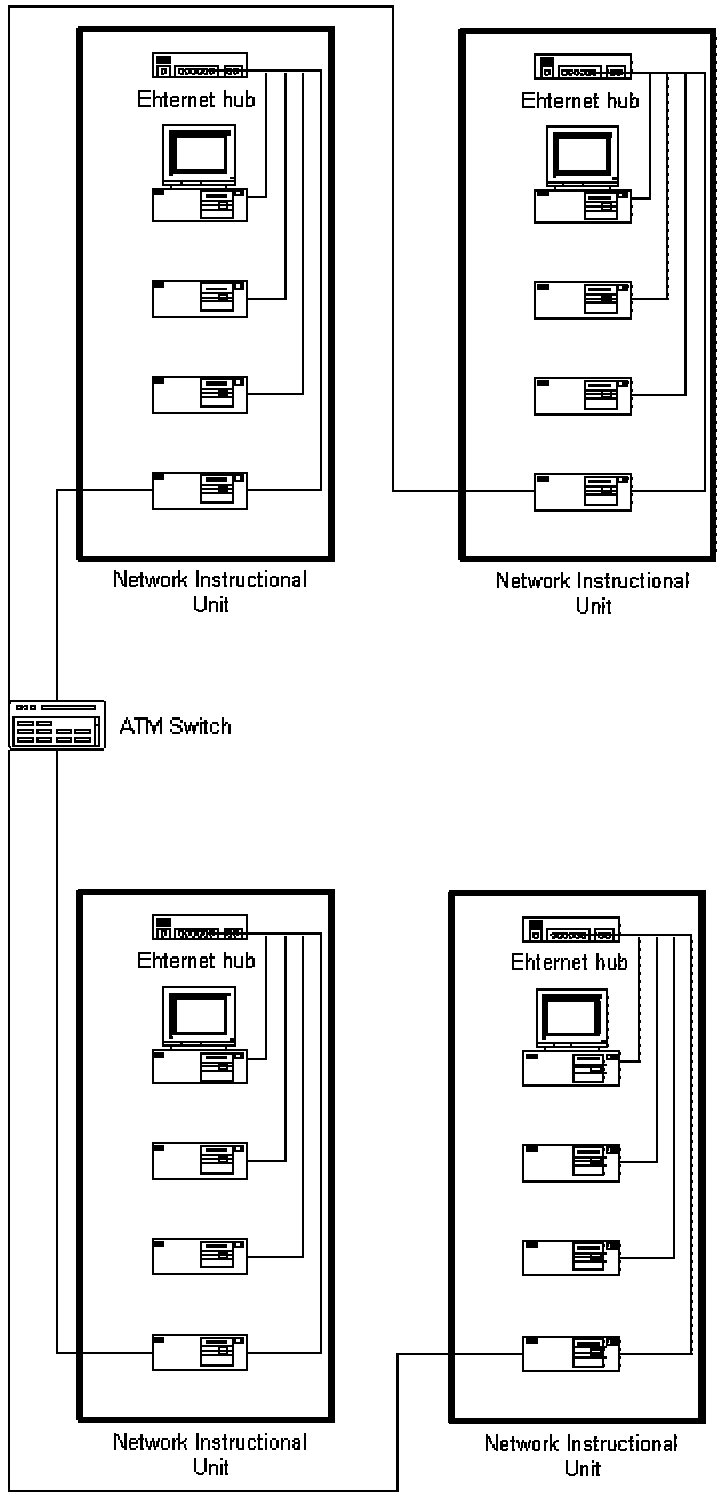Figure 1. One Network Instructional Unit on a Movable Physical Rack.
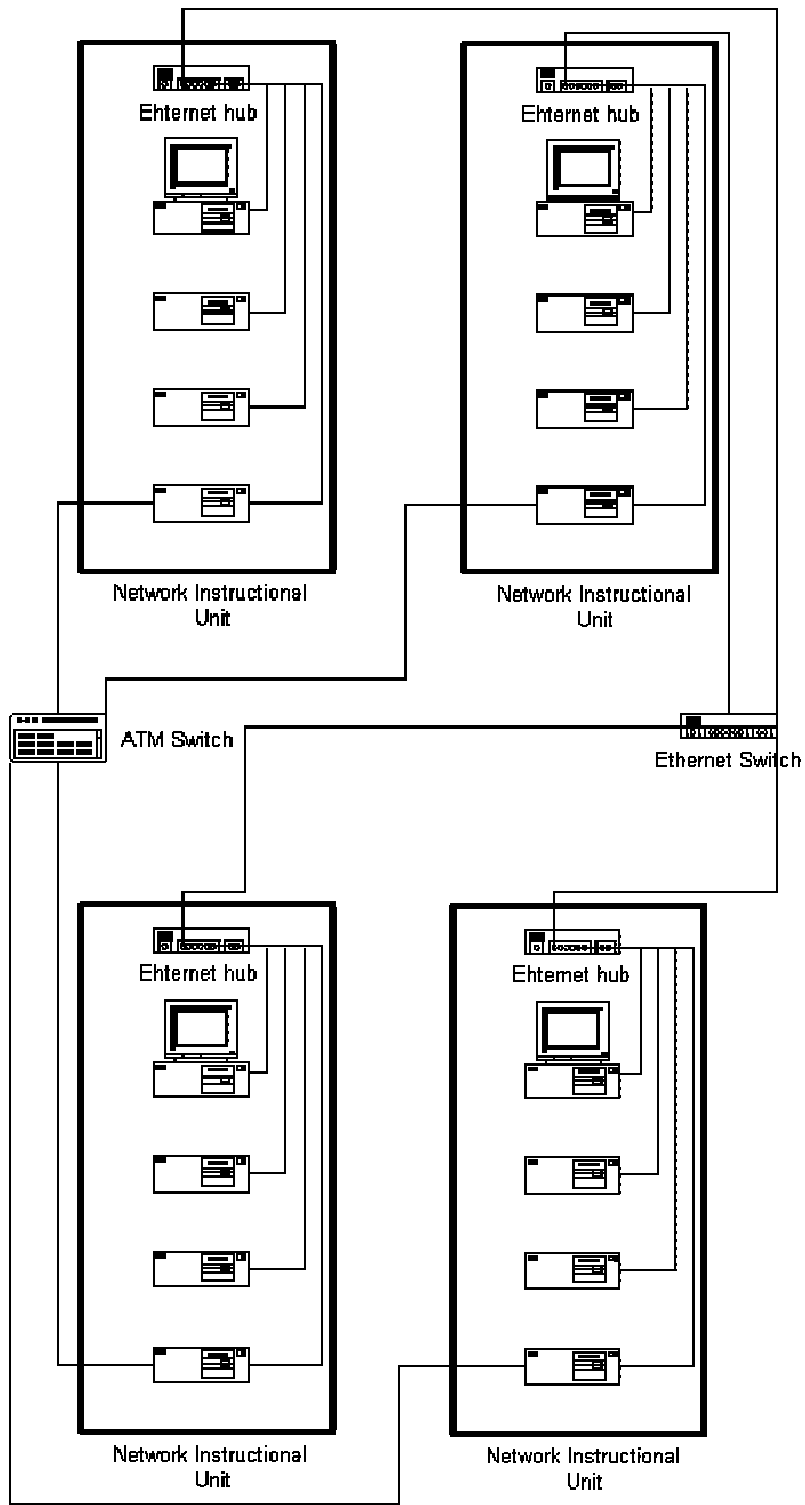
Figure 2. ATM Network of NIUs.
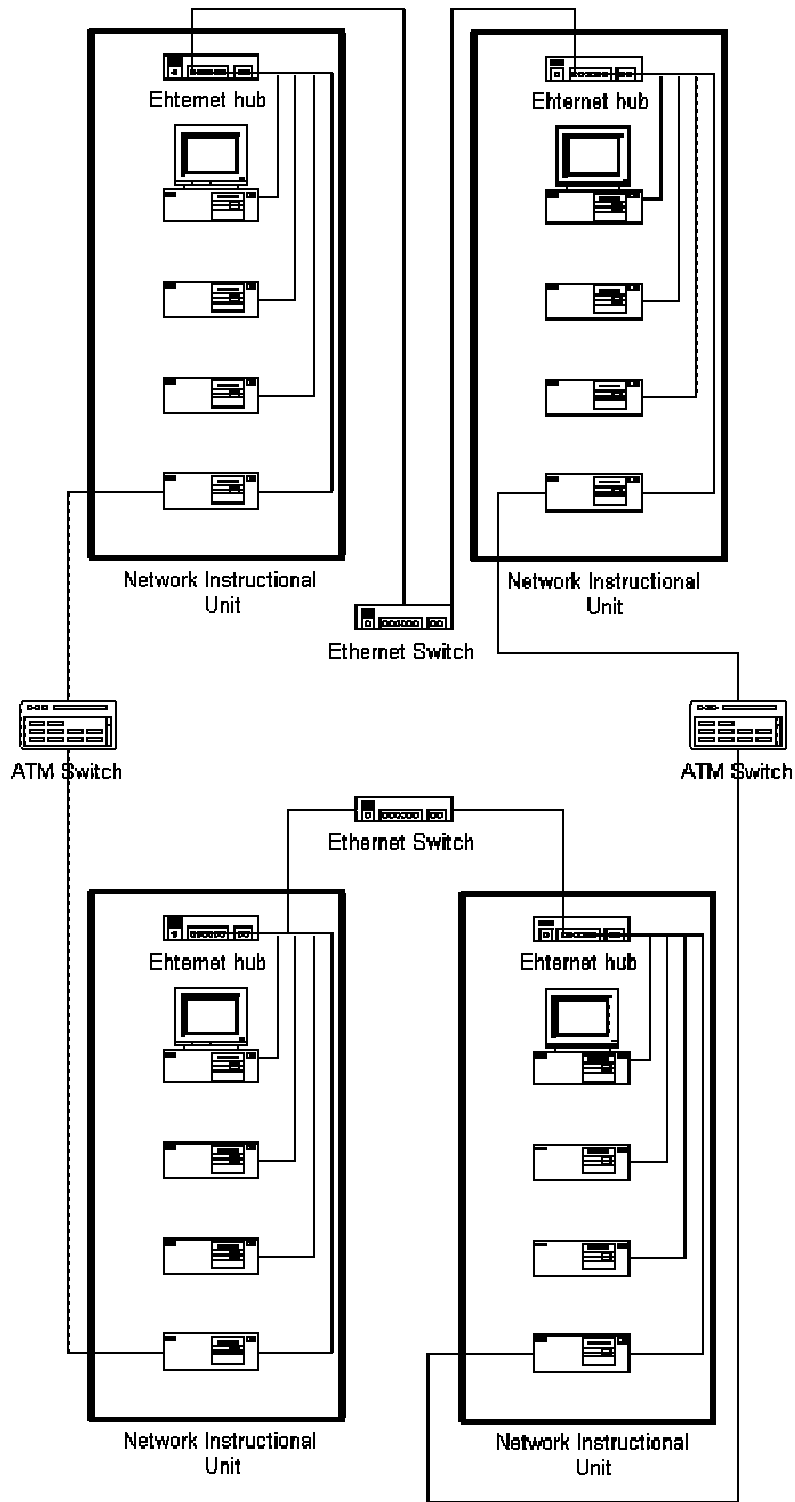
Figure 3. ATM and Ethernet Network of NIUs.

Figure 4. Two ATM and Two Ethernet Networks.

As modules, NIUs can be combined to form different network environments to suit the demands of different networking courses. Since the equipment of each NIU is mounted on a movable rack, network environments can be quickly reconstructed and moved from place to place. For instance, the network environment shown in Figure 2 can be converted to the network environment shown in Figure 3 or 4 in just a matter of minutes. Since each NIU is composed of independent, replaceable components, an NIU can also be easily updated or augmented as new networking technology becomes available. NIUs offer a long-term solution to the problem of giving students access to state-of-the-art networking environments. They also give students greater freedom to experiment with different networking schemes and configurations and to test their own ideas.

Laboratory Exercises

An NIU-based network environment could support a wealth of laboratory exercises dealing with a wide variety of issues.

Advanced Local Area Network Course

Assume that the students have had a LAN course in which they gained familiarity with protocols and installed and configured a Windows NT server. In an advanced LAN course, the students set up and configure multiple servers.

The Novell NetWare server uses Novell Directory Services (NDS), which is an implementation of the X.500 directory service. NDS makes it possible to access all the Novell-related resources with one login and provides contexts for grouping users who share the same rights and login scripts [6].

The Windows NT Server uses the Dynamic Host Configuration Protocol (DHCP) to dynamically allocate IP addresses. The Internet Information Server (IIS) functions as a Web and FTP server [5].

Below are a list of possible laboratory exercises for such a course.

Exercises for one NIU as shown in Figure 1

Exercise 1. Install Novell NetWare on one of the NIU computers. Configure the NDS for a sample business. Install users in the various contexts.

Exercise 2. Install Windows NT Server on one of the NIU computers. Add appropriate service packs. Install TCP/IP with a static IP address. Add the DHCP service. Finally, install the IIS. Configure the Web and FTP servers. Create a simple Web server for the sample company. Note: Each NIU group should install TCP/IP for a different domain.

Exercise 3. Install Linux on one of the NIU computers. Add the Domain Name System (DNS) service. Make entries for each of the NIU computers (including the alias for the Web server).

Exercise 4. Install Windows NT Workstation on one of the NIU computers. Add the Novell client. Install TCP/IP connecting to the DHCP server to obtain an IP address.

Exercises for multiple NIUs as shown in Figure 3

Exercise 5. Connect the NIUs with an Ethernet switch. Students work together to create an NDS tree for a large business. The tree spans the four NIUs and connects the four Novell servers as one logical server.

Exercise 6. Install LAN emulation on the Windows NT server on each NIU. Open communication between the servers and the ATM switch.

Exercise 7. Install routing on the Windows NT server. Ensure that all the machines of the NIUs can ping the ATM switch. All parts of the NDS tree from Exercise 5 should be visible to all the NIUs.

Exercise 8. Reconnect the NIUs as shown in Figure 4. The computers of one NIU communicate with one neighboring NIU via an Ethernet switch and with the other via an ATM switch. Communication with the nonneighboring NIU involves routing through both an Ethernet and ATM switch.

Wide Area Network Course

Wide area networks could be simulated using ATM networks as in Figures 2-4. ATM is an important networking technology which may well be the dominant WAN technology in the next few years. It is a technology that networking students should intimately understand. With a network environment like that shown in Figure 3, students could conduct experiments that analyze the performance of ATM and compare it with the performance of Ethernet.

Network security

The main concern of network security is how to protect a network from attack via the Internet. A network environment for studying this problem could consist of three regions:

1. An *interior region* representing the network to be protected constructed from one or more NIUs.

2. An *exterior region* representing the Internet constructed from one or more NIUs.

3. A *firewall region* separating the interior and exterior regions constructed from one NIU.

The firewall region would contain the computers for protecting the interior region from the exterior region and the computers that need to be "exposed" to the Internet. The former group would include computers acting as routers, packet filters, and proxy servers, etc. The latter group would include computers running Web servers, FTP servers, mail servers, etc. (See [1] and [2] for more information about network firewalls.)

Exercises could be developed for testing the adequacy of the firewall. They could involve attacks on the interior from the exterior and countermeasures initiated by the interior against the exterior.

Packet Routing

Suppose that a network environment running TCP/IP is constructed from several NIUs. In order for IP packets to be transmitted between any two computers in the environment, each computer must have a correctly configured routing table. These tables can be either static or dynamic. Static tables are configured by hand by system administrators, while dynamic tables are configured automatically by routing protocols.

An exercise in static routing is to have each group of students configure the routing tables of the computers they are in charge of. They will learn that to achieve effective IP traffic flow across a network environment requires a high degree of cooperation between the routing tables. One missing or misconfigured entry in a single routing table can completely disrupt IP traffic flow.

An exercise in dynamic routing is to run one or more dynamic routing protocols such as the Routing Information Protocol (RIP), the Exterior Gateway Protocol (EGP), or the Open Shortest Path First Protocol (OSPF) (see [4]). Then students could modify the network environment and observe how the routing protocols reconfigure the routing tables.

Conclusion

NIUs provide a cost-effective, flexible way of introducing students to key networking concepts and technology. They also provide an effective way of organizing networking equipment so that network environments can be easily and quickly constructed and modified. By allowing many different network environments to be constructed, NIUs provide a basis for many different kinds of networking laboratory exercises.

The Microcomputer Studies Program at St. Cloud State University in St. Cloud, Minnesota is now in the process of assembling a set of NIUs as shown in Figure 1. These NIUs will be used to support the networking courses that constitute our Network Modeling and Simulation major that was begun in 1999.

References

[1] D. B. Chapman and E. D. Zwicky, *Building Internet Firewalls*, O'Reilly, 1995.

[2] W. R. Cheswick and S. M. Bellovin, *Firewalls and Internet Security: Repelling the Wily Hacker*, Addison-Wesley, 1994.

[3] D. E. Comer, *Computer Networks and Internets*, Prentice Hall, 1999.

[4] D. E. Comer, *Internetworking with TCP/IP, Vol. I: Principles, Protocols, and Architecture*, Prentice Hall, 1995.

[5] M. Minasi, *Mastering Windows NT Server 4, Fifth Edition*, SYBEX, 1998.

[6] C. Zacker, M. Applebaum, S. Miles, J. McKee, R. Kresge, B. Lawrence, *Special Edition Using Intranetware*, QUE, 1997.