Design of a Pragmatic Network Communications Laboratory for Engineering Technology

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INTRODUCTION

Unlike most physical sciences where laboratory instruction is accepted as integral to the student's education, data communications and networking are often taught without the practicality of the laboratory section. However a review of the literature shows increasing interest in and merits of including a laboratory in a data communications and networking course. One such early work by Smith [1] emphasized a very basic approach to instruct in network protocol. His approach of limiting communication to the serial port of the PC's allowed for the development of an inexpensive laboratory. A similar approach was presented by Akhtar [2] whose laboratory experiments emphasized different communication protocols. Building on Smith's work, Classen , *et al*, [3] outlined the development of a data communications laboratory emphasizing hands-on experience with algorithms and protocols.

An alternative approach to the expense of an actual laboratory is to use software simulators. However, while useful, this instructional technique limits the availability of important problems and solutions commonly encountered with network systems, as clearly shown in a paper by Mengel, *et al*,[4].

At the Penn State - Altoona, a different approach to data communications and networking laboratory is being developed in conjunction with a traditional class on the subject. This laboratory is designed to meet the needs of a new four year Bachelor of Science program in electro-mechanical engineering technology, BSEMET. The particular emphasis of this program is on automated industrial manufacturing. To achieve this goal, students in this program are educated in the areas of electricity/electronics, mechanical systems, process control and data communications as well as the integrated areas of automation and design.

The purpose of detailing the BSEMET program is to emphasize the difference in the needs of this laboratory as compared to many other programs. As mentioned, the use of network laboratories in support of classroom education is relatively new. The majority of these current papers discuss efforts to educate the students towards advancing the technology as opposed to our program which is designed around implementation and support of networks using current technologies. Consequently, our laboratory is designed around existing off-the-self equipment.

In this paper we detail the design of a new laboratory that emphasizes the pragmatic aspects of data communications and networking systems. The equipment and its setup is introduced and discussed along with the associated laboratory experiments.

DISCUSSION

The general sequencing of the laboratory experiments, Table 1, is designed to loosely follow the seven layer OSI model as shown in Table 2. Because the emphasis of program is on implementation and maintenance of a network, the first laboratory exercises will introduce the students to connectivity and the associated problems in addition to point-to-point transfer.

EXPERIMENT	**TOPIC**
1	Network Cabling Systems (Copper)
2	Optical Fiber Cabling for Network Interconnection
3	LAN Connectivity with Ethernet 10 base-T and IP Addressing
4	LAN Connectivity with Token Ring
5	Asynchronous Transfer Mode (ATM)
6	Multimedia Applications on ATM
7	Router Configuration and Operation
8	Network Setup and Interoperability

Table 1. Experiment sequence and associated topics.

The first experiments introduce the basics of data transmission medium. From the lecture portion of the class, the students are aware of current technologies that offer a variety of choices of cabling schemes for LAN systems. These choices are a function of data transmission rates, reliability, cost, noise immunity and others. Usually the cabling choice is based on the end use of the network and economics. Once the choice of cabling has been made, proper installation and integrity verification are critical to the reliability of the system. The main features of cabling installation are the physical interconnections, which include impedance matching, choices in routing and integrity verification. Beginning with the simplest and most common data transmission medium, copper wire, students develop proficiency in installation of the various types of connectors including BNC, unshielded twisted pair (UTP) and RS232. Additionally, the students are introduced to techniques of line integrity verification and the effects of impedance matching. Finally, character transmission determines the cable integrity.

While for many network systems copper cabling provides a quality cabling solution, there are increasingly more applications where the unique features of fiber optics are required. Examples of these features are ultra high speed data transmission, noise immunity and low signal attenuation for long distance transmission. In this exercise students will install connectors onto the end of a fiber optic spool, Figure 1. Using a PC based optical time domain reflectometer

(OTDR), these connectors are evaluated. Although students will be installing the fiber optic connectors to the working spool, they are not expected to become proficient in this delicate process. Instead, this operation will demonstrate the special care required by fiber optic cable ends and connectors. Continuing with the OTDR and fiber spool setup, the students will be introduced to fiber routing concerns such as macrobending losses.

LAYER	NAME
1	Physical
2	Logical Link
3	Network
4	Transport
5	Session
6	Presentation
7	Application

Table 2. OSI network topology seven layer model.

It is expected that this approach of student manufactured cables will introduce students to real world communication problems associated with poor cabling. Learning about these errors in an actual situation reinforces debugging techniques and introduces errors that are difficult to simulate.

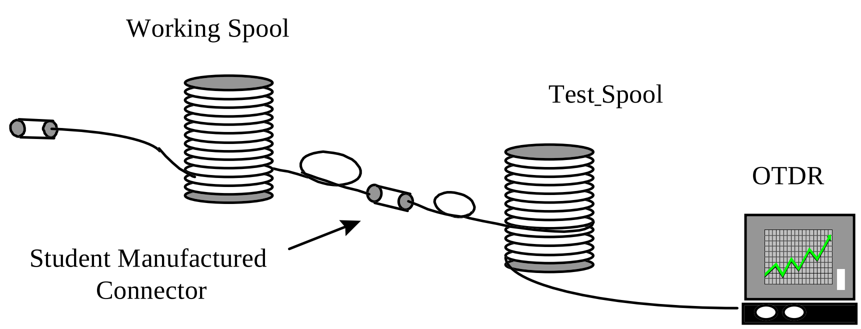

Figure 1. Fiber optic communication test setup.

The next set of experiments focus on LAN connectivity. There are a variety of different network transport systems in use today that follow specific protocol that manage the communication between computers. The physical data transport system can be broken down into the network topology, network access and the network cabling transport subsystems. The three most common topologies are bus, ring and star. Network access is accomplished by the network interface card (NIC) using such methods as broadcast or contention, token passing and polling methods. Students will work with these common network topologies and network access methods through the following exercises on Ethernet, token ring and asynchronous transfer mode (ATM) network transport systems.

Ethernet is one of the most common forms of network data transport in use today. It uses a bus topology and is a broadcast network system that functions by a node listening to the communication on the network, and when quiescent, the node sends its message. Once the data has been sent, the device listens for possible collisions with other data. This data collision possibility implies that only one packet of data can be sent at a time. This Ethernet function of listening, sending and verifying is performed by a network interface card (NIC) installed in each computer on the network. For unique identification of the sender or receiver, each NIC has a media access control (MAC) hardware address. Further network addressing which allows internet and intranet communication is provided through the interface protocol (IP) address. The IP address is then mapped onto the MAC address via a process called binding. The physical transportation of the data between computers occurs over a variety of cabling types, such as coaxial, shielded or unshielded twisted pair and fiber optic cables.

This experiment introduces the students to hardware, addressing and file transfer protocol and system analyses of Ethernet systems. The students will load the network interface card drivers and perform IP address binding to the NIC specific MAC address. Using either coaxial or unshielded twisted pair (10 base-T) connections, students will run diagnostic performance test on the network using the standard ping (packet internet groper) and a Netranger network analyzer. The ping performs connectivity tests and the analyzer monitors the data transfer and the network MAC addresses. This allows for the specifics of file transfers between machines to be monitored and analyzed. Intentional equipment malfunctions will be incorporated into the network system requiring students to perform additional troubleshooting using the network analyzer.

Token ring is a LAN protocol that was proposed by IEEE in 1969 and first implemented by IBM in the early 1980s. This technology uses a passing token arrangement between network devices to control data transfer. Data is sent by the device which possesses the token. Once data transmission is complete or a specific period of time has elapsed, the token is passed onto the next network device that wishes to transmit data. Token ring can operate at 4 to 16 Mb/s, depending on the implementation. The physical medium used to transport token ring protocol is normally on a IBM type cable or unshielded twisted pair (UTP). Token ring technology uses multi-station access units (MSAU) as the central connecting hub for the network. Newer technology has produced token ring switching, which increases throughput performance of the network.

In this lab experiment, the student will be expected to configure a network computer for token ring with an MSAU as the central hub for operation at 16 Mb/s. Students will also make the necessary UTP cable connections for proper operation of the token ring network. Each computer on the token ring network will be configured with TCP/IP network transport protocol. Network integrity will be checked with the ping command. Higher level file transfers will also be run to ensure network operation and will be monitored with the analyzer. Network throughput can be done by using the Netperf utility program. Netperf is a freeware program that measures throughput between two networked computers. Some simple trouble shooting principles such as malfunctioning cables and improper computer configuration will also be investigated.

Asynchronous transfer mode, ATM, a new cell based data transfer technology, is based on a statistical multiplexing method to achieve extremely high speed data transmission rates. Each cell contains a 53 byte body, of which 48 bytes contain the information to be transferred, and a 5 byte header. This small cell size coupled with the high speed statistical switching hardware not only offers high speed data transport (up to 622 Mb/s), but efficiently handles delay sensitive information such as video and voice.

This lab experiment will expose students to high speed, statistical ATM switching and performance. Students will first configure an OC-3 card, which is an optical network interface card (NIC) that operates at 155 Mb/s, for IP protocol in each computer. Students will also configure the ATM switch for IP operation. As indicated by the OC-3 card, optical fiber (62.5μm) will be the cabling medium. Fiber cable integrity will be verified using the OTDR. Network integrity will be checked using the ping command and also through interrogation of the switch port assignments. Network data throughput tests will be run using the ping command along with the Netperf utility.

Delay sensitive data suffer in performance and quality when transmitted over traditional networks such as ethernet and token rings LANs. This is mainly due to the variable length packets native to these architectures. When large packets, such as those found in large file transfers, are transmitted on these networks coincident with voice and video sessions, the voice and video become choppy. ATM's small cell structure and guaranteed throughput on vendor switches alleviates this contention problem. The small cell also prevents large file transfers from chewing up the network bandwidth. These features of the ATM make it one of the fastest growing technologies in the telecommunications field today. All ATM switches are based on statistical multiplexing. Instead of time slots for data, the switch architecture is based on the probability of cells arriving and leaving. Buffering or short time storage and high speed buses are designed around this probability so that delay is minimized and throughput is maximized on an ATM switch.

Many telecommunications service providers, in conjunction with the ATM Forum (ATM standards body), are developing quality of service standards for transmitting delay sensitive data, such as voice and video. In this scenario, low priority data, such as data from file transfers, are marked as such and stored in a low priority queue on the ATM switch. Conversely, delay sensitive data are marked as high priority and given precedence over low priority data when received by an ATM switch. In this manner, the throughput of delay sensitive data can be guaranteed to reach its destination in a timely manner.

During this experiment, students will investigate switch throughput and multimedia applications on the ATM network. The ATM switch will be configured for LANE, LAN emulation that allows communication between ATM and Ethernet, so IP multicasting used in IP video conferencing can be used. Each multimedia PC will be equipped with free-ware tools used on the Mbone. The Mbone is the Internet's multicast backbone where audio and video conferencing is common. These free-ware tools include: SDR, the session director which is used to establish multimedia sessions; VIC, which is the Video Internet conference tool and VAT, the audio tool. A two member team with one PC will establish a VIC and VAT session with three other teams and their PCs. This will result in two, 4-team video conference sessions. The conference tools will be set to their highest possible transmission speed. Each team will then be required to send 100 MB of network data via the Netperf tool to a PC on the same conference and also to the other conference session. The performance of the conference sessions will be noted during the data transfer test. The throughput of the data will be checked with the Netperf statistics output. The conference sessions will then be terminated and the Netperf test will be run again. The results will be compared to the previous test. The results should indicate an increase in throughput since delay sensitive data was not present on the network during the second test. The ATM switch will also be queried to check throughput on its network module ports.

Deploying a network solution which provides total connectivity is an essential skill for network engineers. The ability to bring a LAN on line and interconnect it with another LAN via a wide area network (WAN) link is a quality lacking in many network engineers today. Most network engineers possess either LAN skills or WAN skills.

This experiment will reinforce and test the students' current network skills. As a team, the students will connect two separate LAN systems with a WAN interconnect link (T1 link). They will be expected to produce an IP network design prior to configuring any network equipment. Once the IP design is reviewed and approved by the instructor, one half of the PCs will be configured with an IP address on an Ethernet segment and the other half will be configured for a 16 Mb/s token ring segment. Two different routers, a Cisco 4500-M and a Cisco 2501, will be used to connect individually the Ethernet and the token ring to the wide area network interface router, Kentrox CSU/DSU. The students will run network connectivity tests using the ping command during each phase of the network setup. The final phase of the network testing will be to send data packets from a PC on one LAN to a PC on the other LAN via the WAN link. Once this is accomplished, students will then use the Netperf utility to check data throughput from one LAN to the other. The router ports can also be queued during this test to specifically view packet throughput.

In the next part of the experiment, the Cisco 4500-M router will be configured and connected to the campus network. The students will then test their internet connectivity by using the ping command to send data packets to a specific internet site, such as www.cisco.com. In the final part of the experiment, the instructor will introduce network problems into the system through cable malfunctions and equipment misconfigurations. The students will use the skills they have developed to determine and resolve these network problems.

SUMMARY

A data communications and networking laboratory has been outlined. The particular design addresses the specialized needs of a four year engineering technology program. The laboratory is designed to be taught in conjunction with a lecture section. The laboratory as currently presented stresses utilization of off-the-shelf equipment. While this masks many of the underlying features of the network system, it offers opportunity to address other very pragmatic concerns associated with the day to day maintenance and installation of network systems. Additionally, this hands-on laboratory will support several other classes in machine automation and production design.

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