Implementing a Wiring Closet Simulator For a Laboratory Based Local Area Network Course

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Abstract

Local area networking is currently found throughout business and industry. Many careers require some understanding of the techniques and technology used in computer networking. This is no longer the private realm of the computer professional. If universities are to properly prepare students for these positions, they must provide education in this area to a wide range of graduates. This instruction can and should involve more than students' listening and writing skills. Students learn quicker and retain more if they actively participate. Laboratory courses are one means of actively engaging students in the topic. In order to present a local area networking laboratory environment that parallels that found in industry, it is necessary to develop apparatus that will present the technology as it appears in industry. Such an apparatus has been created in the Computer Information Systems program at Purdue University's Anderson campus. The design process, layout considerations, and construction of this apparatus will be explored. The rational for use of hands-on teaching methodologies is presented to establish the validity of the device as an instructional tool. A discussion of the integration of the simulator into an existing laboratory course and examples of its use are also presented.

Keywords: LAN, simulator, andragogy, pedagogy

Industry has embraced the personal computer. The PC has placed formidable processing power at the desk of virtually every employee. The single drawback to the individual processing domain created by the PC was the isolation of that domain. In order for the PC to be truly useful it needed to share real-time information with other computers in the organization. Without real-time information sharing, today's decisions were made on yesterday's information. This information sharing need spawned the local area network. Local area networks are becoming an integral part of virtually all businesses and industries. The combination of the computer and the LAN provide an information sharing and processing power that industry has come to rely on for all aspects of its operation, from personal productivity applications such as e-mail to mission critical operations like data warehousing. This interconnection can significantly improve employee productivity and offer other competitive advantages. Recognition of the advantages offered by the LAN is not a recent trend. By the early 1990s, more than 60 percent of all microcomputers in American corporations were networked, a number that continues to rise (Fitzgerald 1996). U.S. businesses are currently spending in excess of $26 billion annually on networking (Meyer 1999). Understanding of the physical makeup of these local area networks is critical to the information systems professional. Other information consumers within the business world will also benefit from an understanding of the connectivity and technology used in local area networks.

Effective classroom presentation of this local area network technology requires a hands-on approach. Students need to directly connect and configure client and server computer hardware to operate in a networked environment. The concrete experience and active experimentation offered in the hands-on approach will complement the abstract conceptualization and reflective observation learning methodology associated with the traditional lecture. In order to experience local area network implementation and configuration firsthand, students need an environment similar to that found in industry. In the case of local area network installations, this environment is frequently a utility closet, service area, or the corner of a mechanical room. The ability to expose students to this environment will greatly enhance their learning experience and better prepare them for the workplace. Common data communications equipment can be assembled in a configuration similar to that commonly found in business and industry. The physical arrangement and installation of these devices can be done in such a manner that it closely resembles the conditions found in business and industry. This paper briefly describes the development of such a wiring closet simulator and its incorporation into a laboratory based data communications course delivered at the sophomore level. While a simulator of this type is most useful in a hands-on course, it can also be used as a visual aid in a lecture only course format.

1. PEDAGOGICAL AND ANDRAGOGICAL RATIONAL

In order to use the computer to its fullest potential in the business setting, some basic knowledge of local area networking is necessary. Recognizing this, many academic departments have included data communications and networking course requirements in their majors. This has created a demand on information systems and computer science programs to offer data communications and networking courses in a service role. In addition to this service role, information systems and computer science departments must provide extensive networking education to their own majors.

Information systems and computer science programs have traditionally addressed this issue by expanding current introductory networking and data communications course offerings and using this capacity to fill the service course demand. These introductory courses are frequently traditional lecture courses originally designed as part of a sequence of data communication and networking courses for majors. Subsequent courses in the sequence provide the hands-on and case study analysis needed for improved comprehension and application skills.

A traditional lecture course often only engages students' listening and writing skills as they download information from a lecture and upload it back on an exam. Learning can involve much more, including comprehension, application, analysis, synthesis, and evaluation (Bloom 1956). Kolb pointed out that information is received through concrete experience, abstract conceptualization, or a combination of the two. Once the information is received, it can be processed either with reflective observation or with active experimentation (Kolb 1984). Learning is enhanced as each of these modes is engaged. Only 20 percent of the information presented is retained if abstract conceptualization is used alone. Retention can reach 90 percent if all four are employed (Stice 1987). Both faculty and students have consistently cited hands-on learning as being crucial to understanding material (Bucciarelli 1998) (Yoder 1998). Unfortunately, these introductory courses are often the only exposure for service courses and associate degree programs. Students limited to the service or associate's degree exposure miss the hands-on portion of the sequence and the educational advantages present of this hands-on experience.

The problems associated with the lack of a hands-on component are further complicated by the presence of the non-traditional students. Non-traditional student learning differs greatly from traditional student learning. The traditional lecture format used in most college courses is even less effective with non-traditional students (Goodnight 1999). Non-traditional students require an active role in their learning and must be self motivated, while traditional students are more accepting of external control and motivation. Knowles has developed the concept of the learning continuum, in which traditional and non-traditional students fall at opposite ends (Knowles 1980). Hands-on course work is needed to engage the non-traditional students and better engage the traditional students in the learning process.

The Anderson campus of Purdue University suffered from the situations described above. The campus offers an Associate of Science degree in its Computer Information Systems and Technology (CIST) program, as well as a Bachelor of Science degree in Organizational Leadership and Supervision (OLS). The CIST A.S. graduates take only the first local area networking course. The OLS B.S. graduates receive the same course in the service role. As a part of Purdue's Statewide Technology initiative, the Anderson campus has historically served non-traditional students. The prominence of the Purdue name and the recent admissions restrictions present on Purdue's main campus in West Lafayette, Indiana have also brought a significant traditional student population to the Anderson campus.

To address this lack of hands-on experience, the faculty has developed a laboratory-based introductory data communications and networking course. The goal is to improve overall learning by incorporating a hands-on methodology in the 200 level data communications course. To achieve this, the faculty converted this course from the pure lecture format to a lecture and laboratory format. By doing so, the hands-on component was added as a series of laboratory exercises. In conjunction with the development of the laboratory component of the course, a complete data communications laboratory had to be assembled. In the course of development of this laboratory, an apparatus was created to simulate a data communications wiring closet installation similar to that typically found in business and industry.

2. DESIGN AND CONSTRUCTION

Construction of the LAN wiring closet simulator began with a review of the course model. Course objectives and desired learning outcomes were used to identify the role the simulator would play in the delivery of the laboratory component on the course. Relevant learning outcomes identified were

- Recognize common LAN devices
- Understand the connectivity of common LAN devices
- Physically cable common LAN devices
- Configure common LAN devices

The learning outcomes list indicated that the simulator should provide students with the necessary equipment to install and configure a simple local area network of several client workstations and one or more servers. The simulator would provide the connectivity and network devices needed to connect a group of computers into the above indicated client/server environment. Based on this definition of the simulator's function, the following devices were identified as the minimum required to successfully meet the objectives.

- 2 hubs
- 1 punch down block
- 1 section of cable raceway
- Several electrical boxes

These devices were specifically selected because they represented the minimum needed to adequately provide students the needed exposure to LAN devices, connectivity, and configuration. The devices were arranged per Diagram 1. Each hub contains 12 RJ45 ports for unshielded twisted pair connection and one BNC connector for coaxial cable connection. The hubs operate at 10 MBps data transfer speed. The punch down block supports 12 connections in either the T568A or T568B unshielded twisted pair wiring standard. The conduit is a simple surface mount design with open slots in the sides to allow easy routing of the cables from the conduit to the various computers, hubs, and other devices. The electrical boxes are standard electrical outlet boxes used in many electrical applications.

The various devices were arranged such that the top and bottom of the grouping represented the termination points of a LAN connectivity segment. The various components of the complete network connection will flow from the top of the unit to the bottom. A typical connection will originate at the hub. The hub will be connected to a punch down block via a patch cable. The punch down block will in turn be attached to a length of cable that runs through the facility (represented by the short section of conduit) to an RJ45 jack mounted in a wall box (represented by the electrical box) at the location of the specific computer. The computer is attached to the jack via another unshielded twisted pair jumper cable. This top-down flow allows students to build their LAN connections in segments as they learn about the various devices, connectivity, and related technology and standards. The top-down flow provides visual reinforcement to the concept of individual segments and how these individual segments combine to form the complete link.

As with any laboratory development project, funding was an issue. The course in which the wiring closet simulator was to be used was not originally a laboratory course. Thus, there were no funds allocated to obtain or develop laboratory equipment. Alternative sources had to be located. One source that proved to be very helpful was the network and computer support unit within Purdue's School of Technology. Most large institutions have a unit similar to this at the university level, if not the school level. This group provided the hubs, conduit, cabling, and other assembly hardware. Most of the equipment and supplies were outdated or scrap. Twelve port 10 MBps hubs are relatively small and are often replaced with hubs offering more ports or greater speed. These smaller devices are ideal for a simulator. They demonstrate the technology without the bulk associated with larger units. The slower data transfer speeds are not critical since the goal is installation and configuration, not the actual performance of the completed network. The technology and techniques for cabling and device configuration are the same for

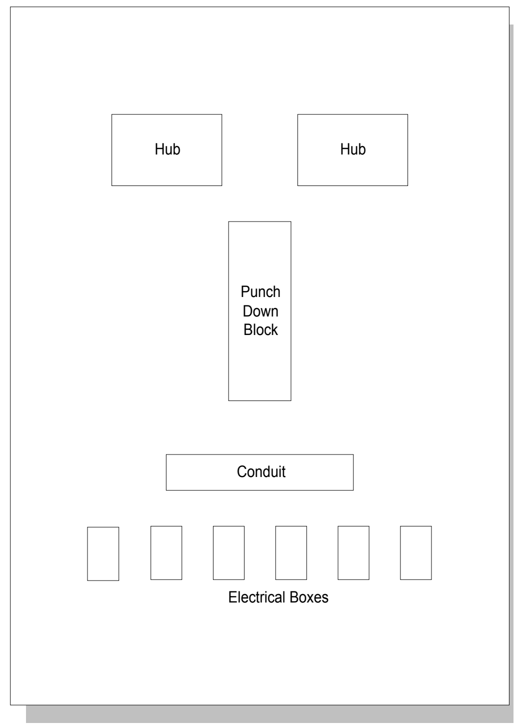

Diagram 1

older, slower equipment and the newer, faster equipment. The goals of installation and configuration can be met with this older equipment. The network support unit readily offered these units for the project, as they had no other use for them. Similarly, they provided a short section of conduit. The piece was too short for any practical use, but it fit well into the space of the simulator. They also provided short pieces of cable and assorted mounting hardware. The short cable represented ends of spools and other short segments that were too short to be of use in jobs they performed. Establishing a good working relationship with someone in the computer and network support group can provide access to equipment that is potentially useful in the laboratory.

Another source of equipment is local business and industry. Some of the computers in the networking laboratory were donated by local businesses. Local business also provided networking equipment such as cabling, connectors, and other mounting hardware for the laboratory. Donations provide businesses an outlet for their older equipment while offering certain tax incentives and positive public relations opportunities. While this equipment is marginal for actual business applications, it is more than adequate for simple network installation and configuration. Again, the system does not need extensive processing power since no applications will be deployed on it. All that is needed is the ability to support current networking technology and standards. Not all devices were donated. The punch down block, for example, was purchased using the laboratory's general operating budget.

The devices were mounted on a sheet of 5/8-inch plywood. Each device was mounted with fasteners that could be easily removed and replaced so the individual devices could be used in lecture demonstrations then returned to the simulator for laboratory use. Initial plans called for the plywood to be carefully cut, sanded, and painted. However, in the final assembly, the mounting surface was left rough and unfinished. LAN wiring installations in business and industry are rarely found in neat, clean, painted and polished locations. The rough surface, lack of finish, and rough cuts used in the simulator were consistent with conditions found in industry and better illustrate conditions that students were likely to encounter in the real world.

The physical dimensions of the mounting surface are not critical. The size of the mounting surface should provide sufficient area to mount and access the various devices. Any suitable material can be selected for the mounting surface. Plywood was selected for this specific application for two reasons. The piece of plywood used was donated, which helped to reduce the cost of the unit. Also, plywood is durable and rigid. In normal use the simulator will have considerable forces placed upon it. The activities involved in punching down wires are particularly rigorous. Plywood is able to withstand this very well. The plywood backing was fitted with a pair of sturdy legs to further stabilize it during use. These legs allow it to sit firmly on the floor or a table during lecture demonstrations and laboratory usage.

If the simulator will be used only for lecture demonstration, more lightweight construction methods can be employed. Lecture demonstrations will place less stress on the unit, requiring less rigidity and allowing the use of lighter construction materials. The use of lighter materials will also make the unit easier to transport.

3. INTEGRATION INTO COURSEWORK

The wiring closet simulator quickly became the focal point of networking laboratory activity. Much of the laboratory work centered on the connectivity of the network devices to the computers. Other than the installation and configuration of the network software on the computers, all laboratory exercises incorporated the simulator. Below are some examples of specific laboratory activities that employed the simulator.

- <u>Unshielded Twisted Pair Cabling:</u> Many of the components on the simulator are interconnected with unshielded twisted pair cables. Each student builds at least one unshielded twisted pair cable. Students use wire stripping and RJ45 connector crimping tools to assemble the jumper cables from a length of Category 5 cable and RJ45 connectors. Students then use commercial cable testing equipment to verify that their connectors are properly attached and that the appropriate cabling standard has been maintained. The student-built cables are used to construct physical network links in subsequent laboratories.

- <u>Coaxial Cabling:</u> Each students constructs a coaxial cable from a length of RG58 cable and two BNC connectors. Students use coaxial strippers and BNC crimping tools to attach the BNC connectors to the coaxial cable. Each cable is tested to verify proper connectivity. The coaxial cables are first used to create a simple peer-to-peer network. In subsequent exercises the coaxial cables are used to simulate the bridging of two LAN segments by connecting hubs together via the BNC ports.

- <u>Peer-to-Peer Network Setup Using Coaxial Cabling:</u> Students use the coaxial cables built in a previous laboratory exercise to interconnect computers and establish peer-to-peer communications. Students install and configure network interface cards in the computers. The students then configure Windows to use the network interface cards to communicate with other computers on the network. Lastly, the students configure Windows to share various peripherals and storage devices. The students test the system to verify connectivity by installing and configuring applications software to access and share resources via the established peer-to-peer network.

- Peer-to-Peer Network Setup Using Unshielded Twisted Pair Cabling: Students use cables built in previous laboratory exercises to convert the coaxial-based peer-to-peer network described above into an unshielded twisted pair network. Students replace the computer-to-computer coaxial cable spans with unshielded twisted pair cables that connect the network interface cards in the computers to the hub. Students observe the physical and logical topologies employed, and discuss the advantages and disadvantages of each. The students test the system to verify that no functionality was lost as a result of the media conversion.

- Punch Down Cabling: Each student is required to install an unshielded twisted pair cable in the punch down block. Students use a common punch down tool to attach one end of a length of category 5 unshielded twisted pair cable to a conventional punch down block. They install an RJ45 connector on the other end of the cable. Students use a second unshielded twisted pair cable constructed in a previous laboratory exercise to jumper between the punch down block and the hub. Students verify that network functionality is not lost because of the media change.

- Keystone Connector Installation: Each student connects a Keystone cable connector to the opposite end of the cable attached to the punch down block. The RJ45 connector previously installed is removed. The cable is routed through the conduit section and the Keystone connector is mounted in an electrical box. This type on installation is typical of that found in a business setting. Students then re-connect a computer to the previously established peer-to-peer network via this new cable system. The unshielded twisted pair cable that had been used to connect the computer directly to the hub is used to connect the computer to the Keystone jack. System operation is again verified.

- LAN Segment Bridging: Students use coaxial cables built in previous laboratory exercises to bridge the hubs together. The BNC connectors on each hub are interconnected with the coaxial cable to allow communications to occur between the hubs. Through this exercise students gain knowledge of the technology needed to interconnect LAN segments. Students verify that previous LAN functionality has been maintained and that communications between computers attached to different hubs is possible. As previously indicated, computer applications are used to verify communications.

- Client/Server Conversion: Cabling similar to that described above is used to introduce a server into the LAN. Students connect the server to the existing LAN via a Keystone/punch down block/ unshielded twisted pair jumper connection. The students install and configure a server operating system on the computer and establish a client/server LAN. Students reconfigure Windows on the peer-to-peer computers to allow them to function as part of the client/server network. User accounts are established, and applications software is reconfigured to access resources through the server. Functionality is verified through the applications already present, and performance comparisons are conducted.

- Windows Network Troubleshooting: After the LAN has been established and verified by the students the instructor purposely "breaks" the network. The instructor frequently removes network access protocols from one or more of the networked computers. Another disabling technique involves deleting network interface card device drivers. Working cables are replaced with shorted or improperly constructed cables. Various networking devices are disabled by unplugging power or loosening connections. The students, using checklists developed during the initial setup processes of the laboratories described above, must diagnose and correct the problems. The students use the installed applications to verify the restoration of normal network operation by demonstrating communications and data sharing.

In addition to its use in the laboratory, the wiring simulator has also proven to be a useful lecture tool. Individual components can be removed from the simulator and taken to a lecture for demonstrations. During subsequent laboratory activities, students get hands-on access to the same equipment previously observed in lecture. The complete wiring closet simulator can be moved into a lecture setting to illustrate the interaction and interconnection of the devices employed. This option is particularly useful in non-laboratory courses, where the demonstration is the only exposure to the networking devices the students receive. This allows presentation of the devices in a real world setting so students can observe their actual connection and function.

4. IDEAS FOR IMPROVEMENT

The faculty has identified several areas that could improve laboratory delivery. Hubs, and network interface cards (NICs), along with the cabling technology described previously, are the only network components currently included in the laboratories. Students need exposure to other devices commonly found in network installations. Switches are becoming more common in business and industry as a tool to control network throughput by isolating LAN segments from one another and still allowing communications between segments when needed. Wide spread incorporation of the Internet and wide use of Internet technologies in LAN and Intranet systems have made routers a common and vital device in many business LAN installations. Knowledge of the router's function, connectivity, and configuration is becoming more and more important to business data communications. Bridges and gateways are two more networking devices that could be included in the networking laboratory, although extensive work in configuration and management of these devices might be beyond the scope of most 200 level courses.

Exposure to additional media types would also enhance the laboratory experience. Currently, only twisted pair and coaxial cable are deployed in an Ethernet environment. Addition of such media technology as fiber optic, DSL, ISDN, and T-1 would help laboratory exercises parallel real world installations.

One specific improvement in the physical construction of the wiring closet simulator is currently being investigated. The component mounting surface is being redesigned to more closely resemble an actual wall, complete with studs and a wall cavity. This construction method will allow students to experience the routing of cables through walls. The simulator could be made more realistic by the inclusion of insulation and other obstacles commonly found in a wall. This would help illustrate the challenges of cabling.

Many local area network courses also include other telephony topics. Industry is trending toward the integration of voice, data, and image transfer via a single system. The inclusion of such teleconferencing and voice systems would broaden the application base of the apparatus. Central office and PBX simulators are available and could be integrated into the simulator to expose students to these additional aspects of the data communications field.

5. RESULTS AND CONCLUSIONS

The wiring closet simulator has been used in the laboratory component of the course for three complete semesters. Students, especially non-traditional students, enjoy the challenge of the hands-on activities and appreciate the real world parallels the simulator offers. Student responses on written course evaluations have been very positive. They specifically cite the laboratory component and the actual cabling and connectivity exercises as informative, useful, and engaging. The students express a sense of ownership. This is collectively their network, and each student has his or her own personal segment within it. Students feel that the simulator adds significantly to the overall laboratory experience, and further enhances the learning and retention benefits of the hands-on laboratory activities.

The simulator has worked well in small classes, having enrollments of 15 students or less. As is the case with most laboratory courses, groups larger than this might present a problem. Physical access and laboratory management become issues with larger groups. Also, the number of connections the various networking components can support currently limits the number of users. Adding larger networking components capable of supporting more users will increase the size, bulk, and cost of the simulator. This will, in turn, reduce the usefulness of the simulator as a lecture demonstration device by making it more difficult to transport. Larger groups would most likely require additional simulators so students could get access to the apparatus to complete assigned exercises in a reasonable time. This will add to the cost and increase laboratory management issues for the instructor. Limiting laboratory enrollment or using multiple laboratory sections will be necessary to maintain the accessibility and portability of the apparatus.

Based on the student response and the enthusiasm demonstrated by students, the faculty has deemed the simulator a success. They plan to continue to use the simulator in the lecture and laboratory components of the course in future semesters. The simulator has proven popular and successful with both traditional and non-traditional students, making it a valuable tool for use in mixed student populations.

Information systems curricula must be in a constant state of change if they are to keep pace with change in computer technology and the information systems industry. The challenge to the faculty is to incorporate these changes into the wiring closet simulator to support the laboratory methodology and maintain the benefits of hands-on learning.

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