A STUDY TO DESCRIBE UW-STOUT CAMPUS NETWORK

by

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ABSTRACT

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This study is designed to describe the history of the UW-Stout campus network from IBM mainframe computers to the current ATM base network based on a backbone connection.

Data will be from:

1. Interviewed Campus Chief Information Officer (CIO), Joe Brown and the Associate Director of Telecom and Networking Service, Douglas Wahl.
2. Researched Library documents.

Recommendations will be made in terms of the future network needs.

Acknowledgement

The author wishes to thank his investigation advisor Dr. Jonas Amoapim, for his ideas, time, and patience throughout this study.

A special thank you to Nolan Northup for providing useful information and concepts related to the campus network.

Appreciation is given to the Campus Chief Information Officer (CIO), Joe Brown and the Associate Director of Telecom and Networking Service, Douglas Wahl for all of the additional campus network documents.

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CHAPTER I

INTRODUCTION

Statement of The Problem

The objective of this study is to describe and explain the UW-Stout campus network infrastructure and to make recommendations for future network needs.

Research Objectives

The objectives of this study are to:

1. Describe the UW-Stout campus network's history.
2. Describe the campus building connectivity to the backbone

3. Determine the future needs and make appropriate recommendations.

Significance of the Study

The UW stout campus network is primarily established for students, faculty, and staff in order to conduct University-related activities in an efficient manner. The importance of this study is to interpret the UW-Stout campus network in diagram form and word document. The network routes, from building to building will be shown in an entire-campus network map description. Within network devices there are two major areas that include: physical and logical devices. Physical devices are hardware and peripherals. Logical devices include software. Each network component will be explained. The evolution of Stout network went from mainframe to an ATM base. The relationship will be described in correspondence to one another.

Limitations of the Study

The following limitations apply to this study:

1. Campus network, wide area network, (WAN research is not included).
2. Hardware structure, with no analysis of device programming, hardware settings, or protocols.

CHAPTER II

LITERATURE REVIEW

Introduction

The objective of this study is to describe the UW-Stout network.

Computer Network History Review

According to the history topic index in School of Mathematics and Statistics, in United Kingdom, the first numerical techniques calculator

was named Harvard-IBM Automatic Sequence Controlled Calculator or Mark I. It was invented by a Harvard Engineer-Howard H. Aiken, who worked with IBM to create ballistic charts for the U.S. Navy in 1944. The computer size was half the length of a football field. It consisted of 500 miles of wiring. Electromagnetic signals moved mechanical parts processing calculations with a slow speed (3-5 seconds per calculation). A second computer, Electronic Numerical Integrator and Computer (ENIAC), developed in the same era (between 1943 and 1945) was invented by the U.S. government and the University of Pennsylvania. The computer's purpose was to solve computational problems in fields such as nuclear physics, aerodynamics, and weather prediction. The computer consisted of 18,000 vacuum tubes, 70,000 resistors and 5 million soldered joints. ENIAC needed a large power supply. It took the same amount of electricity to operate the computer as it did to light up the city of Philadelphia. However, its calculation speed was 1,000 times faster than the Mark I.

In 1947, three United States research scientists at Bell Laboratories, Shockley, Bardeen, and Brattain invented a solid-state device called a transistor. By 1948, the invention of the transistor enhanced the computer's development. Atransistor replaced the large, power-consuming vacuum tube within televisions, radios, and computers. As a result, the size of electronic machinery has been shrinking. By 1956, the transistor was applied within the computer field. The smaller, faster, and more reliable transistors required less power. The first supercomputers, from IBM and LARC from Sperry-Rand, were made by transistor technology. These computers were developed for atomic laboratories that allowed them to analyze a large amount of data. Only two LARCs were installed: one in the Lawrence Radiation Labs in Livermore, California, for which the computer was named (Livermore Atomic Research Computer) and the other at the United States Navy Research and Development Center in Washington, D.C..

The second-generation computer used assembly language to replace long, difficult binary codes. This newer computer was equipped with printers, tape storage, disk storage, memory, operating systems, and stored programs. For instance, IBM 1401 (See Definition of Terms) was popular and was considered by many to be the "Model T" of the computer industry. The stored program and programming language made this computer more flexible, cost effective, and productive for business use. The stored program was held inside the computer's memory, which helped the computer perform specific functions. If the program needed a different set of instructions for a different function, a quick replacement could be made. COBOL (Common Business - Oriented Language) and FORTRAN (Formula Translator), were higher-level computer languages and that made it easier for computer programmers. The computer language used words, sentences, and mathematical formulas. Formulas helped to format the program computer rather than using binary machine codes. New types of Career developments included: programmers, analysts, and computer systems' experts. The software industry literally began with second-generation computers.

Transistors use less power. Their relatively small volume generates an abundance of heat, which often damages the computer's sensitive internal components. The first integrated circuit, made by Jack Kilby, (Texas Instruments), was larger and not as complex as those of today's integrated circuits. It was designed in July 1958, which consisted of a small piece of germanium that held a transistor and a few wires together. The integrated circuit is composed of millions of tiny transistors that are placed upon a piece of silicon. This is approximately the size of a fingernail. The size of computers became smaller, more powerful, less energy was required, and more energy efficient. The development of a third – generation computer provided the use of an operating system which allowed computers to run multiple programs simultaneously.

After the development of integrated circuits, the chips size became smaller which made it possible to fit hundreds of transistors onto a single chip. This process was called Large Scale Integration (LSI). Ultra-Large Scale Integration (ULSI) increased the number of transistors into the millions. With the increased performance, batch processing was largely replaced by online processing. Online terminals were used in parallel communication with the main computer. But many terminals were teleprinter devices that used serial data communication.

In 1971 Intel developed the Intel 4004 chip. This integrated microprocessor chip had a central processing unit, memory, and input and output control on one single chip. The chip was designed and manufactured to meet individual needs. In the mid-1970's, computer manufactures began to direct computers from large businesses to general consumers. The microcomputers were designed with user-friendly software for common users. Programs such as word processing and spreadsheet programs become wildly use.

Pioneers in this developing field were Commodore, Radio Shack, and Apple. The minicomputers were able to communicate with the large computer. Their location could be anywhere within the same work area, and could function as the central computer. These computers began appearing not only in the home of some employees, but also on office desks. By the end of the 1970's, salesmen began carrying portable computers. Salesmen could enter the order from a customer's office to the main computer through the telephone line (Jones Telecommunication).

In 1981, IBM developed its personal computer (PC) for home, office, and school use. In addition, the PC became affordable. The number of PC's increased from 2 million in 1981 to 5.5 million in 1982. Three years later, Apple Computer introduced a new operating system with a user-friendly Graphical User Interface. Users were allowed for the first time, to move screen icons using a mouse. As a result, users did not to have to remember complicated commands. Therefore, computers became more popular in the workplace. Some personal computers replaced CRT terminals serving as both terminals and local processing devices. These compact computers became increasingly powerful by networking and sharing memory, software, data, and communication.

Satellite communication was introduced during the wireless age of the 1980's. A company could lease bandwidth from a satellite company

that connected multiple site locations together with a network of low-speed teletypewriter-like terminals (Held, 1996).

In the beginning of the 1990s, computers were initially used for spreadsheets, word processing, sales, and marketing information databases. During the same time, people realized the capability and productivity of computers and shared resources. Different formats of adapter cards were introduced for installation in each personal computer to transfer network signals. Networks enable users within a building or campus to communicate with one another, and share hardware resources such as printers and plotters. They could also share the LAN- attached computer, called a server. A server is a computer or device on a network that manages network resources. Servers are computers with a large amount of memory and high-speed processors. A server can share the host resource with other LAN-attached devices. As a result, the users are called "clients". Any computer connected to the network can access resources stored on servers. The three most common types of servers used on campuses and various different organizations are file servers, mail servers, and application servers (Held, 1996).

UW-Stout Computer Network Review

The earliest computer system and network documents that could be found were dated back to the mid-1960's. From the mid 1960's to the late 70's, Stout had mainframes and terminals that connected from building to building.

The first mainframe computer was an IBM 1620 batch-process computer that was shared between UW-Eau Claire, UW-River Falls, and UW-Stout in 1967. This computer was physically moved from campus to campus at six-week intervals on a pre-arranged schedule. IBM computers were gradually upgraded from IBM 1620 in 1967, IBM 1410 in 1967, and to IBM 1130 in 1968 (See Definition of Terms).

UW-Stout had its first formal access to an interactive computing system in 1972. It consisted of a timesharing terminal that connected a dedicated port on the UW-La Cross campus computer. At the same time, Digital PDP-11/40 (See Definition of Terms) computer provided services to the Stout campus with four terminals and then upgraded to Digital PDP 11/70 in 1982.

In 1997, UW-Stout acquired the services of Dr. Raymond K. Neff. He was a network consultant and made recommendations for improvement of network infrastructure, organizational structure, and computing capabilities to meet future growth needs. After his investigation, Dr. Neff recommended that the network organization should include:

1. Data, voice, and video transmission service network.
2. The operation of all central computers, including one to library automation and administrative information systems.
3. Offering information technology services for campus units via a charging system.

Upon Dr. Neff's recommendations, Stout decided to integrate the network into an ATM base network with data, video, and voice services.

<u>Why Stout Campus Network is based on Asynchronous Transfer Mode (ATM)</u>

What is ATM:

ATM was originally conceived as an asynchronous transfer mechanism for Broadband Integrated Services Digital network (B-ISDN). It is composed into cells of equal length.

Each cell contains 53 eight-bit bytes that are called “octets”. Five of the bytes constitute the header and carry both source and destination addressing information. The remaining 48 bytes carry the " information payload."

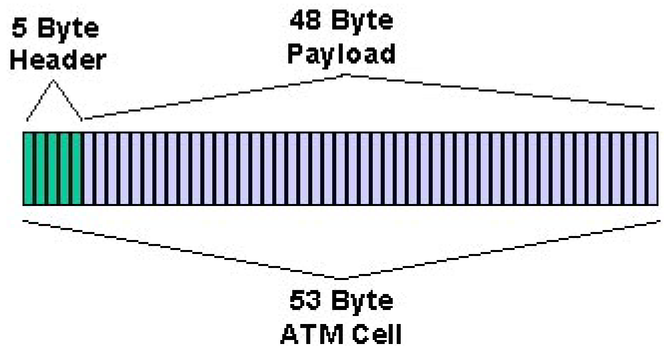


Figure 1: Typical ATM Cell

The 48-octet information cell that was chosen by the standards committee was as: a) it is acceptable for voice networking, b) it is short enough to avoid delay problems inherent in longer protocol data units, c) it is adaptable to forward error correction, d) it minimizes the number of bits that must be re-transmitted in the case of a transmission error, and e) it works well with carrier transport equipment.

ATM is a standard form of cell relay similar to frame relay and X.25. Both are considered "fast packet" technologies. ATM fixed length cells different from frame relay and X.25, which has varying cells. Fixed length cell buffers can be designed at a set length, thus facilitating hardware switching. Switching is done in hardware rather than software tables to help minimize latency. Latency is a critical matter for delay-sensitive video and voice traffic.

Why ATM is the choice for Stout network:

1. **Bandwidth:** Clearly, the 10BASE-T Ethernet and Token Ring LANs can no longer support the exponentially increasing traffic. Solutions other than ATM, LAN switches, and 100 Mbps Ethernet can provide bandwidth relief. They do not represent a comprehensive or a long term networking strategy. They are at best "patchwork fixes" implemented to exploit existing cabling infrastructures. ATM not only provides the bandwidth that utilize existing cabling usage, but it also generates benefits that save money while enhancing worker productivity
2. **Traffic Integration:** ATM can deliver data, video and voice simultaneously across the same medium. This is accomplished this by ascribing a Quality of Service marker to each cell transmitted.
3. **Network Integration:** ATM can integrate data, voice and video in a process that ultimately consolidates three separate networks into one. Efficiency, cost effectiveness, network management, and personnel requirements are therefore enormous.
4. **Scalability:** ATM spans the entire network throughout workgroups and campus, onto the enterprise backbone and across the carrier or private WAN. Each level can be used to meet current requirements and lay the foundation for growth.
5. **Unlimited Potential:** The capacity of fiber optic cable to transmit information is virtually limitless, and the technological ability to harness that power is increasing daily. Currently (2000) OC-12 (622 Mbps) is becoming a commonplace option among switch vendors for users requiring internet-work concentrations.

6. **Cost Effectiveness:** A large increase in the number of vendors offering ATM products has combined with technological advances to render ATM as a cost competitive solution, when compared to Fast Ethernet. In addition, the cost of implementing fiber optic cabling has dropped considerably over the past few years.

CHAPTER III

RESEARCH DESIGN

Introduction

This chapter describes the research method and processed used to review and analyze the existing body of knowledge in the UW-stout campus network field.

Research Design

The purpose of this research was to study and to understand the entire UW-Stout network hardware diagram, and to make suggestions for improving the network from the author's point of view.

Stout campus network has gradually upgraded from mainframe computers that existed in 1962, to the current Local Area Network. It was difficult to search for the entire collection of past campus network data. This data was not filed by the campus network faculty. As a result, this study would include the following: 1) Interviews with the Campus Chief Information Officer (CIO), Joe Brown and Associate Director of Telecom and Networking Service, Douglas Wahl. 2) Research from the Library Resource Center data. 3) Interviews with Stout network committee members. 4) Information provided from the current Stout network faculty.

The result of the thesis is an overall explanation of the network structure, from the earliest documents that could be found to the current structure. The content includes early mainframe computers, VAX system, and the LAN type network.

The recommendations include the opinions from the author, adviser, and CIO. Every attempt will be made to be constructive and feasible for improving the current campus network and its operations into the future.

CHPATER IV

RESULTS

Introduction

The earliest documents for the UW-Stout campus computer system and network that could be found were traced back to the 1960's. These documents were left by Gordon Jones; a member of the computer system purchasing committee, who retired in May 2000. Most of his documents are about mainframe computer systems and are not related to the campus network infrastructure.

In order to complete the campus network study, appointments were made with the Campus Chief Information Officers (CIO), Joe Brown and Associate Director of Telecom and Networking Service, Douglas Wahl.

Computer systems and the network history of UW-Stout

1960's

UW Stout's computer system has had a stable growth since the mid-1960's. This growth was similar to growth in other UW systems. During the earliest period, UW-Eau Claire, UW-River Falls, and UW-Stout shared the IBM 1620 batch-process computer for instructional and administrative purposes. The 1620 marked the beginning of the general use of computing for the Stout Community. This computer was moved between the three schools on a six-week rotation. The necessity of having a full-time computer used by UW-Stout students, faculty, and administrators, was in effect when the IBM 1401 replaced the IBM 1620 in 1967. Stout acquired IBM 1130 in 1968 because of rapid growth in academic batch-processing computer use. Programs such as Applied Mathematics that had a concentration in Computer Science used the computer extensively.

1970's

In the fall of 1972, UW-Stout had its first formal access to an interactive computing system, with the installation of a timesharing terminal connected to a dedicated port on the UW-La Cross computer. In that same year, Stout contracted with Digital Equipment Corporation for the lease/purchase of a PDP-11/40 computer (See Definition of Terms) and four terminals. The installation date occurred during the Fall of 1973. Three additional terminals were purchased by various academic departments.

In order to improve the Stout campus computer system and long-term network goals, the Academic Computing Advisory Committee was formed in the fall of 1977. There were representatives from each of the academic schools. Their tasks were to identify problems in academic computing and facility improvement, such as:

1. Storage space on time-share computer

Since 1977, the disk space on the PDP-11/40 had been 98% utilized. There were many users who did not have access or used the time-sharing system because of the disk space limitation.

2. Number of ports

One of the major advantages of time-sharing computing is that the main computer can link to terminals in different classrooms or laboratories. In July of 1977, there were only 16 ports for approximately 6,400 students. The UW System Long-Range Plan for Computing Services recommended that a minimum of 32 ports be required.

3. Job size

The maximum job size was 8K Word, which did not have enough memory to run multiple computer programs. This problem restricted both batch-processing and time-sharing computers.

4. Speed

The speed of peripheral equipment was a particular problem with batch-processing IBM 1130 computers. The printing time for jobs was increased in terms of involving statistical analysis of raw score, and item analysis from the test-scoring function. Students in the Introductory Computer Sciences were only allowed to print out two pages of per job to minimize process delay.

5. The language sophistication

Difficulty in tranferability languages for the IBM 1130 had been a problem for several years. For example, FORTRAN and COBOL had different codes, therefore they were incompatible and nontransferable.

6. Access to large-scale computing power

Current computer users tended to access large-scale computer systems with either remote access or from campus to campus for research and instructional purposes.

7. Reliability

With the increasing number of users and machine uses, the reliability of the computer system had lowered. The reliability of terminal performance had declined. Terminals were designed for maximum use of 4-6 hours per day, but were being used over 12 hours per day.

In November 1983, the University of Wisconsin System Purchasing contracted with Digital Corporation for the purchase of the time-sharing system (VAX/VMS) (See Definition of Terms) for the University of Wisconsin-Oshkosh and Stout. The agreement for VAX/VMS was that the current requirements of the school must be met. These requirements include:

1. Transportability of software

VAX\VMS had more software available than other computer systems in the market. The University of Wisconsin-System has approximately 35 VAX systems currently installed.

2. Communicating with existing ASCII terminals

VAX/VMS family can communicate to a variety of venders through proven software protocols as well as communicate with a full range of ASCII terminals.

3. General purpose resource

VAX/VMS could be tuned and adapted to the needs of a specific installation and could be easily reconfigured for future needs.

4. State-of-the art design

VAX family systems allowed Digital the capability of adapting new technological advancements that reduced the purchase and operating costs.

5. Sophistication

VAX only required minimal operators and eliminated the need for punched cards and extensive paper output.

6. Interactive terminal orientation

There were large numbers of simultaneous timesharing users, along with interactive programs for the development and debugging strength of VMS.

7. Cost effectiveness

VAX was developed with new processors, peripherals, high level languages, software, and networking.

8. Networking Capabilities

DECnet is comprised of the networking software and hardware. This allows communication between machines running Digital Equipment Corporation (DEC) operating systems, as well as operating systems from other vendors. As with TCP/IP, each machine within the network is referred to as a "node" and is assigned a unique node name. Different computer systems can facilitate communications, share resources, and distribute computation with DECnet.

Digital Network Architecture (DNA) provided the common network architecture upon which all DECnet products were built. The architecture was designed to handle a wide range of application requirements. DNA also allowed nodes to perform the same functions as switches, front-ends, terminal concentrators, or hosts.

According to the Digital equipment corporation's document, the VAX system on DECnet could:

1. Provide an intercross communication facility that is highly transparent and easy to use.
2. Provide a higher-level language-programming interface.
3. Allow programs to access files within other systems.
4. Allow users and programs to access files within other systems.
5. Allow users to transmit command files to be executed on other systems.
6. Allow an operator to down-line load RSX-11s system images into other systems.
7. DECnet provides some key facilities for running a two or more NODE network.
8. Inter-process (Task-to-Task) Communication: programs executing on one system can exchange data with programs executing on other systems.
9. Intersystem Resource Sharing: programs executing on one system can access files and devices physically located or other systems. It is provided through the file system of the target node and is subjected to that node's file system restrictions.
10. Intersystem File Transfer: a program or user can transfer an entire data file from one system to another.
11. Network Command Terminal: a terminal on one VAX system can be connected to another VAX system within the network.

12. Down-Line System Loading: initial load images for RSX-11 systems (see Definition of Terms) in the network can be stored on the host VAX system, and be loaded into adjacent PDP-11 systems configured for the RSX-11 operating system.

    Down-Line Command File Loading: command language users can send command files to a remote node to be executed there. However, no status information or error messages are returned.
13. VAX/VMS also supports protocol emulators (Internets), which enable Digital systems to communicate with other vender's systems.

In 1978, PDP 11/40 was replaced by PDP 11/70 for academic needs and was sold to a used equipment vender in July of 1980. In addition, the IBM 1130 was sold in 1980 after twelve years of service to Stout (September 7, 1983).

1980's

In May of 1982, Stout established the underground Signal Duct Group with the responsibility to:

1. Completed a survey of all cable in the underground signal ducts and developed a continuous record keeping system.
2. Developed policies for duct and cable use.
3. Acted as the clearinghouse for all on or off campus requests for duct space or cable use.
4. Developed and maintain a signal duct system master plan.

5. Made recommendations for duct system expansion projects and assist in writing project requests.
6. Made recommendations for maximizing the use of existing proposed cables and duct space.

The group accomplished the following projects during 1983-84 (See Route Diagram in APPENDIX I):

1. Established the function of all non-identified cables in the underground duct system and remove the unnecessary cables to make rooms for new cables.
2. Planned and implemented a project to install cables between Bowman Hall and the Administration Building.
3. Added an underground duct bank into Froggatt Hall to serve the Commons, and the new Student Center.
4. Determined duct problems between HKMC and Johnson Fieldhouse, and either repaired the duct or added a small, parellel duct bank.
5. Provided a large capacity cable between Froggatt Hall and the Administration Building by way of Fryklund and Harvey Hall.

In January of 1983, UW-Stout installed a Honeywell central shared resource word processing system. In the same year, Stout had twenty-four workstations and eighteen letter quality printers.

In May of 1983, a document from the Chancellor’s staff presented a telecommunication Plan to integrate voice/video/data communications. According to the

Computing Planning and Coordinating Group (CCG), the definition of Telecommunication is:

> "Telecommunication is the transmission of data or information, be it voice, image, or data. It can include such currently discrete technologies as xerography, facsimile, typesetting, television, radio, telephone, computer printout, CRT screens, mail and a myriad of signal controls, (building energy monitoring and control devices, entrance security controls, parking lot gate controls, etc.)"

The purpose of telecommunication planning was to provide the telecommunication services that were needed by the University at a reasonable cost. The essential step was to identify the system requirements and resources available. The goal was to develop a system that reduced life-cycle cost for our current telecommunication services, or provide significant cost containment for needed expanded service.

The installation of the plan included telephone systems, closed circuit television systems, academic and administrative computer main frames with remote terminals, clock-signal systems, an energy monitoring system, a "credit card" student food service billing system, and a centralized word processing system.

During the Chancellor's staff meeting in September of 1983, a Six-Year Plan for Campus Telecommunication Interfacing System was discussed.

1. Stout would install its own telephone switching system (PBX) (See Definition of Terms) within 5 years, the system would allow most of the networks on campus to have interfacing connections to each other.

2. The number of terminals would be increased to 80. Approximately 60-70 microcomputers would be added by academic departments, and some would have network connections to the mainframe computer.
3. The cost of renting dedicated telephone lines for computing and word processing hook-up will continue to escalate over the next 6 years.
4. An increasing number of students will bring their computers to campus and access on the network with the academic computer main frame. Existing phone lines and modems or new lines would be connected to a campus PBX.
5. The centralized word processing system would expand to around 45 terminals in the Administration Building and Bowman Hall.
6. It would be desirable to establish a direct network access between the two centralized word processing systems in the Administration Building. Stand-alone word processors should be established in other areas, such as Graphic arts/duplicating center and the old student center.
7. The network wiring in Bowman Hall would be remodeled to incorporate coaxial cable and administrative computer terminals for student services and administrative activities.
8. New registration activities and professional conferences would access the mainframe computer in the new Student Center that would be built during 1983-85. New adequate cable and cable routes would be installed between the new Student Center and the Administration building.
9. The network cable would be established from the old Student Center to Fryklund Hall in order to be accessible to other buildings on campus.

10. An underground cable would be installed between North and South Campus in 1985-87. It would be possible to transfer the overhead cabling into the conduit if that proves to be desirable, or to add cabling while additional work is deemed as necessary.
11. Added an underground duct bank into Froggatt Hall to serve the Commons, housing Administration, and the new Student Center.
12. Repaired and added a small, parallel duct bank between HKMC Hall and the Johnson Fieldhouse.
13. Provided a large capacity cable between Froggatt Hall and the Administration building by way of Fryklund Hall and Harvey Hall.

The statement that Joe Brown presented to the University Management Information Systems Advisory Group Minutes of March 6, 1989 stated: " There were four areas that use computer services: Residence Hall labs, Food Service-commons, Student Center and Residence Hall Administration. They were currently running a VAX 3600 and Micro VAX II ".

According to the University of Wisconsin-Stout memorandum on June 22, 1989, there were:

1. 42 workstations and 22 printers under Honeywell DPS-6 system located in the Administrative Computer Center.
2. 20 workstations and 4 printers under Wang VS System located in the Continuing Education office and the Vice Chancellor's Office.
3. 11 workstations and 4 printers under Wang OIS System located in the Graduate Admissions Office.

4. 42 workstations and 7 printers under Micro-VAX All-In-One System located in Auxiliary Services Office.
5. 41 workstation and under ITOS Word Processing software running on DEC equipment in Technical Computing Center.

1990's

The following is a summary from "Networking at UW-Stout: A White Paper in 1993". In 1993, Stout operated a campus-wide data network based on voice and video. The network was based on a 10MBPS fiber backbone, 2 diagonal links that cross the Communications Center and the Library Learning Center. The backbone used Plexcom hubs and bridges that was managed by PlexView's signaling network management protocol (SNMP) (See Definition of Terms). Pathworks and Netware were scattered around the campus. Most were on the same side of the bridge reflecting the majority of the population they served.

The data network, IEEE 802.3 Ethernet-based on inter-building fiber and intra-building 10 BaseT was an unshielded twisted pair cable in the Administration and Academic area. The 10Base2 coaxial thinnet was in most of the Auxiliary areas. The Ethernet network had an asynchronous 9.6 kbps connection available. All of the intra-building wirings were completely installed by November 1993, from each building switch to all of the workstations. The network was controlled and monitored by an SNMP-based management system. Each building network was separated from the CORE CAMPUS NETWORK (CCN) by Bridges and Routers. The CCN supported most of the computer systems, such as the IBM ES9000 mainframe, Digital 6410 VAX, Cisco WiscNet route, and inter-building bridging.

Digital 6400010 computers were for all services. The IBM ES-9000 computers provided authorization and network security.

Administrative and Academic buildings had Star-based wiring to a central building concentrator. An Ethernet base-repeater provided in/out connection to each station with full remote management. The concentrator was connected with fiber optics to the central fiber optics hub located in the Communications Center. The entire network was managed by Computing & Telecommunications. In non-fiber buildings, 9.6 kbps terminal connectivity was provided over copper pairs from a centrally located terminal server in the Administration building. Approximately 250 9.6 KBPS terminals still connect with a Micom data switch.

The Auxiliary areas were generally provided by an Ethernet connection with Thinnet coax in North Hall, Price Commons, and the Memorial Student Center. The computer system supporting these operations was located in North Hall. A fiber interconnection from the main campus network provided connectivity to the Auxiliary network via a host computer (Mickey). The residence halls were linked to North Hall via the campus copper pair-based cable system with asynchronous connectivity. Centralized network management was presently not a part of this network segment.

Documentations can be divided into 2 segments, such as intra-building and inter-building network structure, according to the University of Wisconsin-Stout Information Technology Strategic Plan 1995-1997 (Issued on April 14 and 19,1995).

Intra-building network structure

1. Planned to install a pilot ATM switching backbone in 1996-99 to interconnect Ethernet switches. This would provide a platform to increase network performance. After the installation, the campus network would become an intergraded system of data, voice, and video to support multimedia on desktop computers.
2. Upgraded electronics and mechanical control hardware for both satellite-received systems to include C-Ku and half transponder capability with digital decoding would be completed by the summer of 1996. After the installation, the campus network would receive digital programming and improve the reliability of downloading.
3. Modified and Upgraded Datability terminal servers would provide better dial-in access to support SLIP/PPP/IPX (See Definition of Terms) and increase the number of available phone lines for access. Students and staff could access the campus network with dial-in access, WiscNet and the Internet.
4. Established connectivity and server enhancements would provide remote LAN access for administrative users. Faculty and staff would be able to access office LAN servers from remote locations through telephone modems.
5. A new router and associated T-1 service would be installed in September of 1995, to increase network speed 24 times. The WiscNet connection between the Stoutcampus and Eau Claire campus increased from 56Kbs to T1.

6. Developed and implemented a campus-wide disaster recovery plan to protect critical data sources, services, processes, and utilities from disasters of various types and magnitudes.

Inter-building network structure

1. Planned to install a pilot wireless data-networking project in 2-3 campus labs to test the wireless environment used by laptop computers.
2. Upgraded thirty terminals in the Library used by students at desktop workstations. Students were available to access FTP (See Definition of Terms) download information from full-text digitized databases.
3. The Nakatani Center had been created and began operation in the fall of 1995. The center had 12 student workstations (6 PC, 6 Mac/Pc), an instructor workstation (PC, Mac, videotape, videodisc, video/data display), CD-ROM writer, printer, scanner, and desktop video with access to remote servers.
4. Upgraded library staff workstations that had the capability of accessing the Internet.

In Dec 1996, Dr. Raymond K. Neff was invited by Stout as a network consultant to examine the entire campus network infrastructure. He participated and organized meetings with faculty, students, and the head of each department. After the overall examination on the infrastructure, his recommendations were as follows: 1) Organizational Structure for Information Technology 2) Reducing the Support Burden for Microcomputers 3) upgrading the Campus Network.

1. Organizational Structure for Information Technology:

Stout network structure needed a new department entitled Information Technology Service (ITS) and divided the network functions into branches. Chief Information Office (CIO) needed to be created and had the responsibility to report to the Provost. ITS should be configured as an auxiliary service to support and charge the network services that each campus department wanted. In addition, ITS was also responsible for the campus's administrative applications software. Dr. Neff also predicted ITS and LLC would have several functions that would overlap in the next five years. He recommended that ITS and LLC be merged as a network unit.

2. Reducing the Support Burden for Microcomputers:

The recommendation is to reduce the support burden for microcomputers that would prevent problems to the greatest extent possible. First, ITS should set a hardware replacement policy to replace fast-changing hardware components every three years, and every six years for slow-changing hardware components. Hardware components should have a three-year warranty for part replacement and labor services. The campus should avoid keeping components with long service times, so faculty and students could have a superior hardware environment.

3. Upgrading the Campus Network:

Much of the Stout network depended on the VAX computer, so Dr. Neff suggested transfer the domain name server function from VAX to an independent server, such as UNIX or a Windows NT server system. Two server systems were needed. One would be the primary server system, and the other be ready as a redundancy-server system. To increase the data transmission rate, edge switches in each campus building should be upgraded to new ten-megabit-second Ethernet Switches, each with two 155 megabit-per-second (OC-3) ATM uplinks to the backbone. A Category 5 twisted pair cable would be the standard for all workstations' wiring. The older PLEXCOM concentrator hubs used by the college of Technology, Engineering, and Management would be upgraded to 100 megabit-per-second Ethernet using Cabletron or 3COM switches, and all the existing DECNET network equipments would be retired from the service in 1997.

Dr. Neff also recommended that "the campus network should be based on the" hub and spoke" model. Each building should be equipped with electronics to operate as a self-contained unit as far as transmission over the inter-building backbone is concerned". As a result, if the backbone is out of service, the building network can still function with its internal devices. For backbone redundancy, he also stated that the network's backbone cable should consist of at least 24 strands of multimode fable and 12 strands of single mode fiber.

The entire UW-Stout campus network in 1998 had been changed to be based on the ATM switch network after Dr. Neff's recommendations. The network also provided point-to-point support for IP, IPX, and DecNet Ethernet to nearly 1,500 nodes made up of more than 20 segments through 18 buildings (Shown in APPENDIX II). The Internet access via WiscNet provided a T-1 (1.544 Mbps) private line, and the dial-in remote access provided 28.8 Kbs to campus network support PPP. Mr. Wahl pointed out "the dial-in access was supported by Switch C2828 linked to Backbone Switch LS1010 located in the Communications Center. The backbone network theoretically is cross-wired between the Communication Center and the Library Learning Center. This connection is linked by four LS1010 switches. The four Backbone Switches are linked with a four corner connection via OC12 optical fibers." Each campus building had its own switch that was either the switch C2822 or switch C5500. They are restricted by their own Virtual Local Area Network (VLAN). Most data servers were centered in the Communications Center for easy network management. Brown states "a Switch C5500 in the Library Learning center functions as a back up server linked to the Backbone Switch LS1010. In the event of one of the switches in the Communications Center had shut down, the entire campus network could be still operate using the Switch C5500 in Library Learning Center." To simplify the system, the campus network would be broke down into three segments, including the residence halls, the Communications Center, and Library Learning Center. Each segment had its own distinguishable switch and bandwidth connection.

The campus network diagram is shown in APPENDIX II. Switches in the residence halls, Hovlid, Fleming, Antrim/Frogget, CKTO, South, HKMC, Wigen, and JTC, incorporate Switch C2822 via an OC3 connection to North Hall. North Hall, it is linked to the Switch LS101 in the Communications Center with OC3 connection.

Switch C5500 in North Hall, Harvey Hall, University Service, Merle Price Commons, General Services, Louis Smith Tainter, Memorial Student Center, Vocational Rehabilitation, Communication Technology, Administration Building, and Switch C2822 in Heating Plant is connected to the Communication Center with an OC3 connection.

The remaining campus switches, incorporate C5500, C2822, and C5000, (See Definition of Terms) were linked to Library Learning Center with multiple OC3 connections. Switch C5500 located in the Memorial Student Center, Student Health Center, Bowman Hall, Education and Human Services, Johnson Fieldhouse, Applied

Arts, Fryklund Hall, Home Economics, Jarvis Science Hall, Jarvis Tech Wing, and, Michael's Hall are all connected to the Library Learning Center. The Switch C2822 located in Fryklund Hall and the Child and Family Study Center is connected to the Library Learning center. Finally, Switch C5500 connected the Library Learning Center to Michael's Inter-media Distribution Facility.

The current network diagram (2000) is still based on the same switches. The only difference from 1998 are the Switches and connections in the residence halls and Louis Smith Tainter. They have been upgraded to Switch 3548. The backbone wirings have been upgraded from OC12 to OC24. Future upgrades will increase to an OC48 connection.

Within the Residence Hall segment, the North Hall main Switch C5500 still remains the same, but the connection to the Backbone Switch LS1010 has been upgraded to OC12 with a 1 G bps connection. The rest of the switches in each hall were upgraded from Switch 2822 to Switch 3548. The module slots on each hall's switch are replaced by 1G Bps with 10/100 bandwidths for each end-workstation. Louis Smith Tainter also has upgraded with the same structure as the residence halls. The Switch C2828 located in Communications Center is no longer in use for dial-in access. This access has been incorporated with Switch C5500, with bandwidth increasing to 56 K Bps.

CHAPTER V

Conclusion, Suggestions, and Recommendations

The purpose of this study was to recommend criteria for the development of the future Stout wireless campus network.

Study objectives

The objective of the study are to:

1. Describe the UW-Stout campus network overview.
2. Describe campus building connectivity to the backbone
3. Determine the future needs and recommendations.

Conclusion

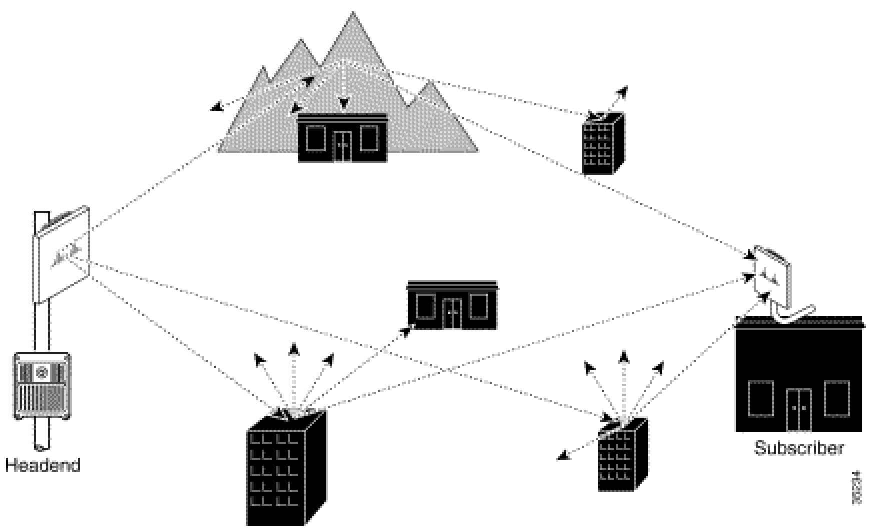
Stout’s network has developed from mainframe computers to the current ATM base network with data, video, and voice services. Many department stand-alone networks have also been incorporated into the main campus network with core, distribution, and access structures. The core layer is located in the Communication Center with a larger server farm via backbone link to back-up servers, located in Library Learning Center. The distribution layer is between switches in each major school building and the backbone, between Communication Center and Library Learning Center.

Suggestions and Recommendations for a Wireless Network

Stout is planning to upgrade its ATM network into the futuristic wireless campus network. It is imperative that it complies with IEE802.11b (See Definition of Terms). Several large companies including 3Com, Lucent, and Cisco, have set the standard for wireless communication networks and have tested products from various manufacturers to ensure compatibility with the WI-FI standard. Before the WI-FI standard, companies created their own wireless networking protocols for use with their own equipment. This forced users to stick with the same company’s equipment. The IEEE802.11b standard can transmit data via spread spectrum radio waves at 11 megabits per second, up to 100 feet from the terminal. The wireless LAN can be connected to the existing wired LAN as an extension. Wireless client devices are available as PCI (Peripheral Component Interconnect) cards, ISA (Industry Standard Architecture) cards, and PCMCIA (Personal Computer Memory Card International Association) cards for laptops. In choosing wireless networking equipment, it is a good idea to go with some of the established wireless vendors such as 3Com, Lucent, Cisco, and Nokia for a long term services and support.

A Client who wants to change a hard-wired network to wireless should not adapt an entire wireless network. Users who need the mobility offered by a wireless network should have no trouble adding wireless capabilities to their LAN using the devices from established manufacturers that support the IEEE802.11 standard. The WI-FI logo or that it is labeled 802.11 compliant label is important when verifying client equipment.

To set up a wireless campus network, the broadband fixed wireless point-to-multipoint subscribers should be placed around the campus geographical edge with an effective transmission range. It is designed to receive radio frequency (RF) signals from the Headend that also transmits a return signal. (See Figure 1) This return signal is a point-to-point signal; a properly installed subscriber antenna must be oriented with the Headend antenna to which it is transmitting.



(Figure 1)

Problem -Unauthorized users

Most wireless networks have been susceptible to intruders. According to MCSE TCP/IP for Dummines, p158, " A DHCP server can't detect which addresses are already being used on a network. If a host has a manually configured IP address that falls within a DHCP scope (an IP address pool), there is a chance that the DHCP will assign a duplicate of that address to another host." As a result, a network invader can find out the possible address range of Stout network gateway, subnet, IP, and DNS from any school computer that can be checked with the IP configuration. He or she can configure their computer network and gain access to Stout network with his or her wireless network card if they are in a valid wireless range.

Suggestions and Recommendations

The following Suggestions and Recommendations explain why a wireless network is more adequate for Stout future needs:

1. Mobility and Convenience

Many students find mobility and convenience to be an essential part of today's busy lifestyle. An article in Philadelphia Inquirer, June 10, 2000, by President Constantine Papadakis of Drexel University was quoted as saying "A Cyber Campus will improve our students' overall college experience by giving them greater freedom and mobility. With Internet access from anywhere on campus - dining halls, outside on campus benches, or in classrooms - there will also be greater collaboration among students."

As a result, students will be able to research assignments online, download schoolwork, check e-mail and access the campus-computing network unencumbered by Ethernet cables and connectors. They can study and connect to the network from most obscure areas such as libraries, study lounges, and outdoors.

2. Less Cost

When the wireless campus network begins, incoming freshmen will lease laptops from UW-Stout. As a result, the number of computers in the computer labs will decrease because students can operate their own computers anywhere on campus.

"We are very pleased to be able to bring this leading-edge technology to our campus. It will enable all our students, faculty and staff to have access to e-mail and the Internet quickly and far less expensively than traditional methods," said William A. Shields, Ph.D., Rockford College president.

In addition, fewer computer technicians would be needed because of the decreasing number of desktops.

3. Practicality for students

Students are denied access to required services, such as CD-ROM, file management on C drive, and control panel in computer labs, classrooms, and in the Library. Students are unable to learn adequate computer operations management from these public computers. Students could teach themselves functionality of new software and its operation if they own their own computers. When problems arise, students would try to fix a problem themselves, or get help from peers. A positive computer-learning environment would be created by peer motivation.

Solution for Unauthorized users

UW-Stout's network should be guarded from intruders. This can be done by incorporating WEP into the network and other inscription protocols. John Pescatore, an analyst at Stamford, who worked for both the National Security Agency and the U.S. Secret Service, said, "Wireless LAN users must ensure that the built-in Wireless Equivalent Privacy (WEP) 40-bit encryption protocol is turned on after installation." WEP is an optional IEEE 802.11 feature used to provide data encryption of wireless data packets.

Pescatore estimates that only 20% of users turn on the WEP feature. He also states; without using WEP you are vulnerable to anyone who is motivated to overhear your traffic.

"Each user is issued a key that has to be configured on the wireless access point as well as the client in order to gain entry to the network," he says.

Brad Mercer, a Cisco Customer service representative in Wisconsin, also responded to me via e-mail with a similar solution, " Our wireless products have something called (WEP), which is a 128-bit encryption for wireless networks, and only allows people on the network that you give access to."

DEFINITION OF TERMS

To clarify the use of technical terms that will be used throughout this study, the following definitions are provided.

Asynchronous Transfer Mode (ATM)

ATM is a layered architecture allowing multiple services like voice, data and video, to be mixed over the network. Three lower level layers have been defined to implement the features of ATM. The Adaptation layer assures the appropriate service characteristics and divides all types of data into the 48 byte payload that will make up the ATM cell. The ATM layer takes the data to be sent and adds the 5 byte header information that assures the cell is sent on the right connection. The Physical layer defines the electrical characteristics and network interfaces. This layer "puts the bits on the wire." ATM is not tied to a specific type of physical transport. (Newton, 1998)

Ethernet

Ethernet is a LAN technology that transmits information between computers at 10 million bits per second (10Mbps). New Ethernet standards are currently under development that will provide for data rates of 100Mbps. There are several LAN technologies in use today, but Ethernet is by far the most popular technology for departmental networks. (Newton, 1998)

File Transfer Protocol (FTP)

FTP is used for file sharing between computers that use TCP/IP to communicate. FTP allows users to log on to a remote computer on a network and see what files are on the computer. It allows users to also upload and download files between the two connections. FTP is a widely used Application layer protocol because an FTP service exists for almost every operating system.

IBM 1130

The IBM 1130 was a third generation machine aimed at the low-end scientific market. It used 360-era technology and had a 16 bit binary architecture, not very different from minicomputers like the PDP-11 or Nova.

The address space was 15 bits, so you could only get 32K words of core memory. The 1130 used a nice 1442 card reader/punch from the IBM 1440 series. Since it had a column serial punch other bit.

IBM 1401

The IBM 1401 came onto the market in the early 1960's. It was called the Model T of the computer business. The basic 1401 was about 5 feet high and 3 feet across. It came with 4,096 characters of memory. The memory was 6-bit (plus 1 parity bit) CORE memory, made out of little metal donuts strung on a wire mesh by workers (mostly women) at IBM factories. The has a Storage Expansion Unit which expanded the core storage to an amazing 16K.

IBM 1620

The 1620 were IBM's first transistorized low-end scientific machine. It was a decimal machine, but it did not have a fixed word length. Each digit was individually addressable and was six bits wide: four numeric bits, a "field mark" bit and a parity check bit.

The basic 1620 came with 20,000 digits, but all memory was core storage. I/O was by punch card and a console typewriter, options included paper tape and, later, a disk drive from the 1401 series.

The most remarkable thing about the 1620 was that it did arithmetic digit-by-digit using table look-up. Addition and multiplication tables had to be stored at fixed positions in low memory. Division was by subroutine, though optional divide instructions could be purchased to speed things up.

Internet Protocol (IP)

IP is a connectionless protocol that operates at the Network layer of the OSI model. When data packets are sent over the network, IP is responsible for addressing the packets and routing them through the network. Attached to each packet is an IP header that contains the sending address and the receiving address. If data is transmitted across networks that do not have the same packet size, the packets may be split up during transmission. If this happens, a new IP header is added to each part of the split packet. When the packets reach their final destination, the IP puts all the packets together again in the correct order.

IPX

Internet Packet exchange (IPX) is Novell Netware's native LAN communications protocol, used to move data between server and workstation programs running on different network nodes.

LAN

A LAN or Local Area Network is a computer network (or data communications network) that is confined to a room, a building, or a group of adjacent buildings. A similar network on a large scale is sometimes referred to as WAN (Wide Area Network), or in some cases more specifically, a MAN (Metropolitan Area Network) if it is confined to a single metropolitan area. The term LAN is most often used to refer to network created out of a certain class of networking equipment which is tailored to communication over a short distance. LAN equipments design takes advantage of the short distance to supply a high transmission-rate at a relatively low cost.

A typical use of a LAN is to tie together personal computer in an office in such a way that they can use a single printer and a file server (briefly a file server is a computer set up so that other computers can access its hard disk as if their own). LANs are also used to transmit e-mail between personal computers in an office, or to attach all the personal computers in the office to a WAN or to the Internet.

- Technologies: LAN Technologies are Token Ring, FDDI, and Fast Ethernet. Ethernet is the most common type in use today.
- LAN topologies are:
    1. Bus
        - All devices are connected to a central cable, called the bus or backbone
        - Bus networks are relatively inexpensive and easy to install for small networks.
        - Ethernet systems use a bus topology.
    2. Ring

- All devices are connected to one another in the shape of a closed loop, so that each device is connected directly to two other devices, one on either side of it.
- Ring topologies are relatively expensive and difficult to install, but they offer high bandwidth and can span distance.

3. Star

- All devices are connected to a central hub.
- Star networks are relatively easy to install and manage, but bottlenecks can occur because all data must pass through the hub. (Aschermann, 1998)

Logical Components

- A Network Operating System (NOS) is required.
- Server software is necessary to manage the network, prioritize the applications' requests for network resources, and provide network security by controlling access to files.
- Client Software is used on individual workstations. The client software is responsible for making the connection between the workstation and the server.

MPC

A protocol entity implements the client side of the MPOA architecture. An MPOA client implements the Next Hop Client (NHC) functionality of the Next Hop Resolution Protocol (NHRP).

OSI Model

In 1978, the international Standards Organization (ISO) released a set of specifications for connecting devices on a network. In 1984, the ISO updated these specifications and called it the Open System Interconnection (OSI) model. This model has become an international standard for networking. It divides the process into seven groups, called layers. Into these layers are fitted the protocol standards developed by the ISO and other standards bodies, including the Institute of Electrical and Electronic Engineers (IEEE), American National Standards Institute (ANSI), and the International Telecommunications Union (ITU), formerly known as the CCITT (International Consulting for Telephone and Telegraph).

The OSI model is not a single definition of how data communications actually takes place in the real world. Numerous protocols may exist at each layer. The OSI model states how the process should be divided and what protocols should be used at each layer. If a network vendor implements one of the protocols at each layer, its network components should work with other vendors' offerings.

The OSI model is modular. Each successive layer of the OSI model works with the one above and below it. At least in theory, you may substitute one protocol for another at the same layer without affecting the operation of layers above or below.

MYRIAD PROTOCOL STACKS

Layer	**ISO**	**TCP/IP**	**IBM**
7. Application	**FTAM X.400** **JTAM X.500** **VT** **CASE**	**SMTP** **FTP** **NFS** **Telnet** **SNMP**	
6. Presentation	**8923**		
5. Session	**8327**		**NetBIOS** **APPC**
4. Transport	**8073 (TPO)** **8602 (CONS)**	**UDP** **TCP**	**NetBEUI** **APPC**
3. Network	**8208 (X.25)** **8473 (CLNS)** **9542 (ES-IS)** **8348 (CONS)**	**IP**	**APPC**
2. Data-Link	**8802.2 LLC** **8802.3/4/5**	**LLC** **Ethernet**	**LLC** **HDLC** **SDLC** **MAC**

1. Physical	**8802.3 Ethernet** **8802.4 Token Bus** **8802.5 Token Ring**	**Ethernet** **FDDI** **Token Ring**	**Token Ring** **Ethernet** **FDDI**

The OSI model is not a single definition of how data communications takes place. It states how the processes should be divided and offers several options. In addition to the OSI protocols, as defined by ISO, networks can use the TCP/IP protocol suite, the IBM Systems Network Architecture (SNA) suite, and others. TCP/IP and SNA roughly follow the OSI structure.

The seven layers can be grouped into two distinct categories. The first four layers—physical, data link, network, and transport—provide the end-to-end services necessary for the transfer of data between two systems. These layers provide the protocols associated with the communications network used to link two computers together.

The top three layers—the application, presentation, and session layers— provide the application services required for the exchange of information. That is, they allow two applications, each running on a different node of the network, to interact with each other through the services provided by their respective operating systems.

The following is a description of what each layer does.

1. **The Physical layer**- provides the electrical and mechanical interface to the network medium (the cable). This layer gives the data-link layer (layer 2) its ability to transport a stream of serial data bits between two communicating systems; it conveys the bits that move along the cable. It is responsible for making

sure that the raw bits get from one place to another, no matter what shape they are in, and deals with the mechanical and electrical characteristics of the cable.

2. **The Data-Link layer-** handles the physical transfer, framing (the assembly of data into a single unit or block), flow control and error-control functions (and retransmission in the event of an error) over a single transmission link; it is responsible for getting the data packaged and onto the network cable. The data link layer provides the network layer (layer 3) reliable information-transfer capabilities. The data-link layer is often subdivided into two parts—Logical Link Control (LLC) and Medium Access Control (MAC)—depending on the implementation.

3. **The Network layer-** establishes, maintains, and terminates logical and/or physical connections. The network layer is responsible for translating logical addresses, or names, into physical addresses. It provides network routing and flow-control functions across the computer-network interface.

4. **The Transport layer-** ensures data is successfully sent and received between the two computers. If data is sent incorrectly, this layer has the responsibility to ask for retransmission of the data. Specifically, it pro-vides a network-independent, reliable message-independent, reliable message-interchange service to the top three application-oriented layers. This layer acts as an interface between the bottom and top three layers. By providing the session layer (layer 5) with a reliable message-transfer service, it hides the detailed operation of the underlying network from the session layer.

5. **The Session layer-** decides when to turn communication on and off between two computers—it provides the mechanisms that control the data-exchange process and coordinates the interaction between them. It sets up and clears communication channels between two communicating components. Unlike the network layer (layer 3), it deals with the programs running in each machine to establish conversations between them.

6. **The Presentation layer-** performs code conversion and data reformatting (syntax translation). It is the translator of the network, making sure the data is in the correct form for the receiving application. Of course, both the sending and receiving applications must be able to use data sub-scribing to one of the available abstract data syntax forms.

7. **The Application layer-** provides the user interface between the software running in the computer and the network. It provides functions to the user's software, including file transfer access and management (FTAM) and electronic mail (Aschermann, 1998).

PDP-11

The PDP-11 architecture, introduced in 1970, was designed to cover a wide range of price/functionality ratios. The PDP-11/40 (1973) is the direct descendant (in the equal-cost/increasing-functionality line) of the PDP-11/20, the root of the PDP-11 family tree. It has 8k 16-bit words of core memory and is equipped with a fast paper tape reader/punch, a cartridge disk unit, a DECtape unit and a pair of 8" single-sided floppy drives. The console is a DECwriter matrix printer, replacing the original Teletype unit.

Physical Components

- The Network Server is the heart of the system. It is a computer that contains the network operating system, NOS.

- The Workstations are the individual computers that connect independently to the server. A Network Interface Card (NIC) and sufficient RAM are needed for the computers having network connection.

- Peripherals are detachable parts that connect to a computer. These include printers, modems, and scanners. Networked computers can share all these devices.

- There are four types of cabling; Unshielded Twisted Pair Wire (UTP), Shielded Twisted Pair Wire (STP), Coaxial cable, and Fiber optic cable.

Point to Point Protocol (PPP)

It is a method of providing a direct connection to the Internet over a telephone line with a modem. In fact, when you are using a PPP connection, your computer becomes a node on the Internet. With PPP, your computer can make use of the Internet just as a computer connected to the campus Ethernet does, only at a slower speed. PPP enables you to do the following over a dial-up connection:

- Send and receive files via FTP

- Use a World Wide Web browser, such as Netscape Navigator

- Use other programs that require a "live" Internet connection

- Any combination of the above simultaneously (Newton, 1998)

Remote Access Service

It is a service that provides remote networking for telecommuters, mobile workers, and system administrators who monitor and mange servers at multiple branch offices. Users with RAS on a Windows NT-based computer can dial in to remotely access their networks for services such as file and printer sharing, electronic mail, scheduling, and SQL database access. (Aschermann, 1998)

RSX-11s system

RSX-11S is a memory-based, real-time operating system with minimum of 16K bytes of memory. It is designed to run on a PDP-11 or Micro/PDP-11 processor and compatible with the RSX-11M disk-based operating system. However, RSX-11S is designed for the run-time execution of memory-resident application programs and requires the support of a disk-based host system for system generation and program development.

RSX-11S has most of the features and capabilities of the RSX-11M system. RSX-11S supports all of the peripheral devices that are supported under RSX-11M, plus CPU options such as floating point processors, parity memory, and memory management.

Signaling network management protocol (SNMP)

SNMP is the most common method by which network management applications can query a management agent using a supported MIB (management information Base). SNMP operates at the OSI Application layer. The IP-based SNMP is the basis of most network management software, to the extent that today the phrase ”managed device” implies SNMP compliance. Although SNMP was designed as the TCP’s stack network management protocol, it can now mange virtually any network type and has been extended to include non-TCP device such as 802.1 Ethernet bridges, and not limited to TCP/IP.

Simple Mail Transfer Protocol (SMTP)

SMTP makes sure that e-mail is delivered from the sender’s server to the intended recipient’s e-mail server. It does not handle the delivery to the final e-mail desktop location. SMTP is an Application layer protocol.

SLIP

Serial Line Internet Protocol (SLIP) is an Internet protocol. It is used to run IP over serial lines such as telephone circuits.

Switch C2822

The Switch has 25 10BaseT switched Ethernet ports (including the AUI switch port on the back panel). Each port provides users or groups of users dedicated 10-Mbps bandwidth to resources within the network. The switches also have two expansion slots for the optional Catalyst 2820 100BaseT, FDDI, and ATM modules for delivering maximum performance to high-speed servers and to backbone switches and routers.

Switch C3548

Catalyst 3548 XL—A single-rack-unit (RU), stackable 10/100 and Gigabit Ethernet switch with 48 10BaseT/100BaseTX ports and two GBIC-based Gigabit Ethernet ports. The Catalyst 3548 XL is ideal for delivering dedicated 10- or 100-Mbps to individual users and servers in high-density workgroups from a stack, cluster, or standalone configuration. Built-in dual GBIC-based Gigabit Ethernet ports provide users with a flexible and scalable solution for Gigabit Ethernet uplinks and Gig Stack GBIC stacking.

Switch C5000

The Catalyst 5000 Family, based upon a high-speed crossbar frame switching fabric, uses an input/output (I/O) queuing model. This cost-effective architecture gives the most efficient switching fabric for unicast and multicast/multimedia applications. Multiple 1.2-Gbps input buses into the 3.6-Gbps-crossbar fabric ensure backward compatibility to existing Catalyst 5000 interface modules. This benefit is key for customers with existing Catalyst 5000 interface modules in the network.

The Catalyst 5000 Family architecture maintains two additional buses, the management and index/control buses. The management bus is a serial bus that carries configuration information to each module and statistical information from each module to the Supervisor Engine. The index/control bus carries port-select information from the central encoded address recognition logic to the ports. This information determines which ports forward the packet and which flush it from the buffer. This architecture supports store and forward and uses fair arbitration and address recognition logic for all modules. Each frame that traverses the frame switching bus may be destined to a single port or to multiple ports, allowing for high-speed multicast forwarding without the need for frame copies.

<u>Switch C5500</u>

The Catalyst 5500 LAN is a 13-slot switch. Slot 1 is reserved for the supervisor engine module, which provides switching, local and remote management, and dual Fast Ethernet uplinks. Slot 2 is available for a second, redundant supervisor engine, or any of the other supported modules. Slots 3-12 support any of the supported modules. Slot 13 can be populated only with a LightStream 1010 ATM Switch Processor (ASP). If an ASP is present in slot 13, slots 9-12 support any of the standard LightStream 1010 ATM switch port adapter modules (PAMs).

The Catalyst 5500 has a 3.6-Gbps media-independent switch fabric and a 5-Gbps cell-switch fabric. The back plane provides the connection between power supplies, supervisor engine, interface modules, and backbone module. The 3.6-Gbps media-independent fabric supports Ethernet, Fast Ethernet, FDDI/CDDI, ATM LAN Emulation, and RSM modules. The 5-Gbps cell-based fabric supports a LightStream 1010 ASP module and ATM PAMs.

<u>Switch LS1010</u>

The lightStream 1010 is the first member of ATM switch of Cisco products. The transfer rate can be spanned from 5 to 40 Gbps with OC-48 media, providing services for both cell-based and packet-based applications.

The LightStream 1010 is common use in the foundation for many large campus ATM network backbone today. The switch processor and port modules can be used with the Catalyst switch 5500, providing many options for deployment in addition to investment protection.

Telephone switching system (PBX)

A private branch exchange (PBX) is like a private telephone network. If there is only a small percentage of users are on the phone at a given time, PBX has the ability to replace several individual phone lines with a smaller number of shared lines offers. As a result, cost savings would be the potential for significance. A PBX is a system that allows organizations to implement such line sharing.

A PBX is comprised of numerous components that maintain internal lines and handles connections to outside lines. As a natural outgrowth of this roll, PBXs have come to provide many features. These features are supported by the PBXs components, such as a telephone trunk, a computer and related software, a network of phone lines and an interface for a human operator. A telephone trunk is the set of phone lines that connect the PBX to the outside world. The computer switchboard maintain and operators the internal lines and provides an interface between the PBX and the public telephone network. This computer also handles any features the PBX provides. The PBX includes a network of interconnected lines, which connect the various users within the organization. A PBX also usually has a console or switchboard to interface with the operator. This could be a software program the computer runs.

Telnet

Telnet enables a user to log on to a computer remotely and run applications. All processing occurs on the remote computer. The user's computer is nothing but a dumb terminal used for display. Telnet is available for most operating system and is included with Windows 98 and Windows NT. Telnet is an Application layer protocol (Newton, 1998).

Transmission Control Protocol (TCP)

TCP is a connection-oriented protocol that functions on the Transport layer of the OSI model. When two computers on a network need to communicate, TCP opens a connection between the computers. When the data packet is ready to be sent, TCP adds to the packet header information that contains flow control and error checking.

VAX/VMS

VAX/VMS is the standard VAX operating system and it is like DOS the most common operating system for Personal Computers. VMS uses a dos-like commands and utilities that allow you to control your computing environment and perform computer related tasks. These commands are part of the Digital Command Language or DCL.

VAX commands are not case sensitive. Commands may be entered in uppercase, lowercase or a combination of both character sets. All commands are converted by the system to uppercase automatically.

Wired Equivalency Privacy (WEP)

WEP is an optional IEEE 802.11 feature used to provide data encryption of wireless data packets. As specified in the standard, WEP uses the RC4 algorithm with a 40-bit and 128-bit encryption. When WEP is enabled, each station (clients and Access Points) has a set of keys. The keys are used to encrypt the data before it is transmitted through the airwaves. If a station receives a packet that is encrypted, it can only correctly decrypt the packet if it has the correct key.

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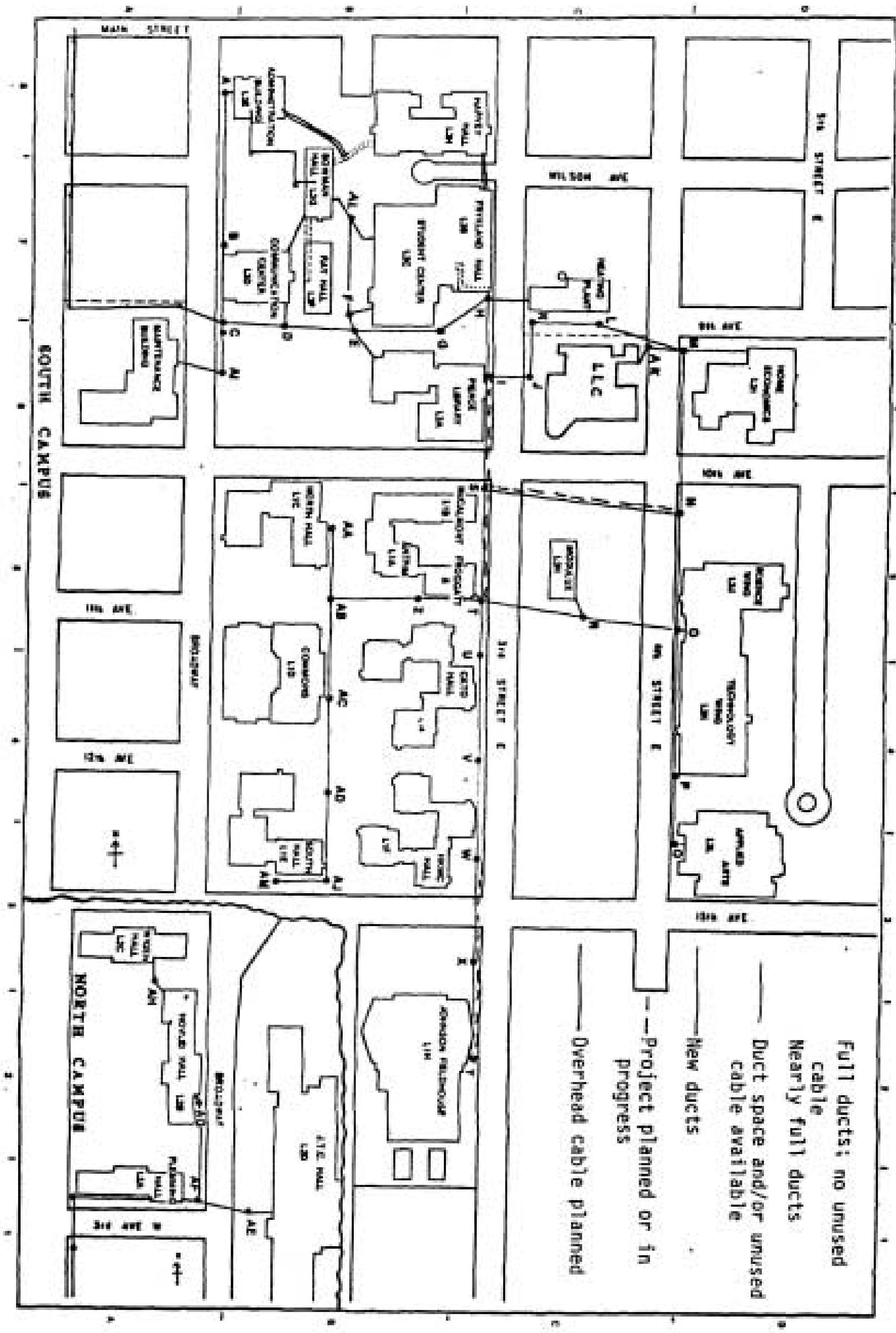
APPENDIX I


Full ducts: no unused cable
Nearly full ducts
Duct space and/or unused cable available
New ducts
Project planned or in progress
Overhead cable planned
SOUTH CAMPUS
NORTH CAMPUS
MAIN STREET
WILSON AVE
9th AVE
10th AVE
11th AVE
12th AVE
13th AVE
3rd STREET E
4th STREET E
5th STREET E
BROADWAY
LLC
HEATING PLANT
STUDENT CENTER
ADMINISTRATION BUILDING
COMMUNICATION CENTER
MAINTENANCE BUILDING
HOME ECONOMICS
NORTH HALL
COMMONS
SOUTH HALL
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APPENDIX II