NAVAL POSTGRADUATE SCHOOL
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THESIS

K-12 LOCAL AREA NETWORK (LAN)
DESIGN GUIDE

by

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March, 1998

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This thesis is presented as a Local Area Network (LAN) design and planning guide for kindergarten through twelfth grade (K-12) educators preparing to design and implement LANs in K-12 schools and libraries. Data was collected during the implementation of LANs in K-12 schools of the Monterey Peninsula Uniform School District (MPUSD). Though the author recognizes that each school will have unique issues it is also reasonable to assume that other K-12 schools will have needs and face challenges similar to those of the MPUSD.

This document provides a person who is not a network professional with a LAN design guide based on network design practices, and lessons learned from the MPUSD LAN implementation. The information in this document is also relevant to Navy commands preparing to implement LANs in small and medium sized offices and training schools. Navy commands and schools will face many of the same challenges that the MPUSD schools faced when planning and implementing LANs.

The author focuses on areas that were most effective or most challenging during the MPUSD LAN implementation. Highlights of successful initiatives employed by educators during the MPUSD network installation process should prove valuable to other educators preparing to implement LANs in K-12 schools.

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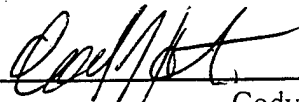Bachelor of University Studies, University of New Mexico, 1987

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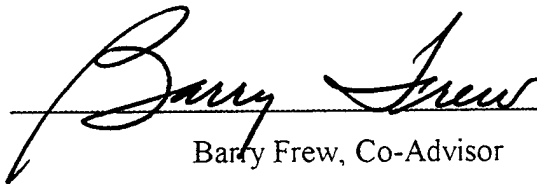
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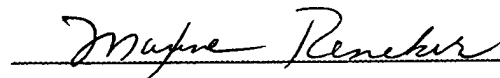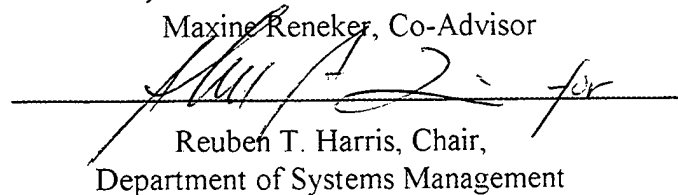# NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

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I.   INTRODUCTION

A.   PURPOSE

This thesis is presented as a Local Area Network (LAN) design and planning guide for kindergarten through twelfth grade (K-12) educators preparing to design and implement LANs in K-12 schools and libraries. Data was collected during the implementation of LANs in K-12 schools of the Monterey Peninsula Uniform School District (MPUSD). Though the author recognizes that each school will have unique issues it is also reasonable to assume that other K-12 schools will have needs and face challenges similar to those of the MPUSD.

Although computer technology changes very quickly, the information in this document remains useful because it provides a non-network professional with a LAN design guide based on network design practices and lessons learned from the MPUSD LAN implementation. The information in this document is also relevant to the Department of Defense (DOD) commands preparing to implement LANs in small and medium sized offices and schools. DOD commands and schools will face many of the same challenges that the MPUSD schools faced when planning and implementing LANs.

There are many LAN design and installation references that can provide additional technical information about the details of LAN design and installation. This document is different because it gives basic information on LAN design and implementation in a format that will allow educators or others with little background or knowledge in network design to ask the right questions and make educated decisions when planning a LAN. The author focuses on areas that were most effective or most challenging during the MPUSD LAN implementation. Highlights of successful initiatives employed by educators during the MPUSD network installation process should prove valuable to other educators preparing to implement LANs in K-12 schools.

B. BACKGROUND

Discussions with educators indicated that the two challenges of insufficient resources and limited technical expertise in the local area network arena plagued the MPUSD for years.   In spite of this, as early as 1987 the MPUSD began to research and implement network technology initiatives.

MPUSD formed the Education Technology Team in 1991 which worked with the Technology Goals Committee to form the Technology Steering Team which determines how technology resources and funding would be allocated. The efforts of this team resulted in MPUSD Technology Master Plan 1995-2000. One example of a LAN related goal outlined in the Technology Master Plan is:

> Plan, develop, and implement the installation, maintenance, support, and systematic upgrade of local and wide area networks to transmit and receive voice, video, and data in all schools and district work sites.

MPUSD worked diligently to accomplish this goal. Despite inadequate technical training, educators through trial and error, as well as on the-job-training (ojt) during LAN installations, gained knowledge of how to design LANS and install LAN components. Though many mistakes were made, the lessons learned and the experience gained enables MPUSD to continue to make significant progress in implementing LANs in Monterey County K-12 schools. MPUSD can also use this knowledge to improve existing LAN configurations and better design future LANs.

Although the MPUSD educators gained knowledge through trial, error and on the job training, a combined approach of formal LAN training with experience would increase the effectiveness of K-12 LAN installation. A balance of training and experience would enable educators to more easily and efficiently implement LANs. For example, as a result of, inexperienced personnel performing the installations, many of the early LAN systems were poorly designed and contained no planned layout of LAN components, which resulted in power cords and cables being installed in locations that posed safety hazards. Lack of documentation of installed cable and hardware combined with the failure to use a standardized layout scheme also created problems in the initial LAN installations.

Due to lack of funds, schools used existing and donated equipment. This resulted in file servers that were not adequate to support installed applications, and workstations without enough memory or hard

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drive space to meet expanding user needs. These sites initially planned to use 386 computers as servers and some were using 286 computers as workstations, but as new computer operating systems and software applications rapidly became available to the schools, these computers were becoming obsolete inadequate faster than expected. LAN planners had not expected such rapid changes in technology so their LAN implementations did not address future expansion. Other factors contributing to inadequate component selection were the lack of technical expertise and budget constraints.

Educators were not computer experts nor did they have the connections with industry that may have revealed that new applications and operating systems were being developed that required more powerful computers than those being installed in the MPUSD LANs. MPUSD did hire computer consultants to assist in the LAN design, but there was no MPUSD LAN expert qualified to evaluate and interpret the consultant's design of the district's LANs. MPUSD had already spent time and money implementing the consultant's recommendations before it realized that the consultant's recommendations would not meet the district's needs. This lesson underscores the need for having a trained network professional on the district's staff. Not having a resident expert to evaluate proposed LAN design made MPUSD more vulnerable to the risk of implementing a poorly designed LAN. Since that time one of the educators involved with the initial LAN installations has received formal training and has become a Certified Novell Engineer (CNE) serving as the MPUSD network engineer.

C. METHODOLOGY

A literature review of LAN implementation was conducted using published literature from computer periodicals and on-line information sources. Site visits to MPUSD K-12 school libraries with existing or proposed LANs were made, and informal discussions with educators, librarians, and LAN technology professionals were conducted. The information obtained from the informal discussions and site visits was useful in identifying which areas of LAN implementation were most difficult for MPUSD implementation efforts. This information was used by the author to better focus the information obtained through literature reviews and accepted LAN design practices, more specifically on problem areas identified during the interviews and site visits.

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II. NETWORK OVERVIEW

A. WHAT IS A NETWORK?

A network in its simplest form consists of two computers connected to each other by some media be it a physical cable or a wireless media. This media allows the computers to share and exchange data. All networks large and small get their roots from this simple system.

Networks are actually more complex than described above because they consist of various hardware and software components. These components enable computers and other network devices to communicate and share resources. Examples of network components include operating systems, file servers, applications servers. database servers. workstations. printers. hubs. routers. repeaters. bridges. and a variety of other components.

There are three sub-categories of networks, Local Area Networks (LAN), Wide Area Networks (WAN), and Metropolitan Area Networks (MAN) which span a smaller geographical area that the WAN, but for simplicity the MAN will be categorized as a WAN. A general definition of the WAN is included in this section, but further discussion of the WAN is outside the scope of this thesis.

B. WHAT IS A LOCAL AREA NETWORK (LAN)?

In its simplest form, a LAN is a communications network that provides users of workstations with a transmission medium and a path for sharing local and remote computer resources. A LAN is a computer network that operates within a limited geographic area. such as an office. a building, or a small cluster of buildings. A LAN consists of the network cable also called network media. protocols. network interface cards (nic). servers, workstations (clients). and other network devices. A more detailed discussion of each network component will be presented later in this document.

LANs are separated into two broad categories. peer-to-peer and server-based. The distinction between peer-to-peer and server-based networks is important because each category provides different capabilities.

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The type of network implemented will depend on several factors including [MS PRESS, 1996]:

* Organization size

* Security required

* Type of business

* Administrative support available

* Amount of network traffic

* Users needs

* Network budget

1. Peer-to-Peer Networks

Peer-to-peer networks are suitable for small organizations where the network will consist of 10 or fewer computers. A peer-to-peer network is workable in situations where network security is not important, and no centralized network administration is required. In a peer-to-peer network, all computers on the network can function as both clients and servers. In this type of network, each client can share resources with any computer on the network, and there is no centralized control over shared resources. The peer relationship means that no one computer has higher access priority or heightened responsibility to provide shared resources or network management. Peer-to-peer networks are not capable of handling high volumes of network traffic, but in networks of 10 or fewer they provide an easy means of sharing data and resources. Each computer in the peer network has the responsibility of administering its own user database, which means that the users must have a password and user account on every computer in the network. Peer-to-peer networks are less expensive and easier to install than server-based networks, but they also provide less functionality and are not very expandable.

While it may appear that peer-to-peer networks are unworthy of consideration because of their limitations, keep in mind that peer-to-peer networks offer some powerful inducements particularly to smaller organizations and networks. Peer-to-peer networks are the easiest and least expensive types of networks to install. Most peer-to peer networks require only an operating system, such as Windows 95 or

Windows for Workgroups. network interface cards. and a common network medium. Once the computers are connected, users can immediately begin sharing information and resources. [Tittel, Hudson, 1998]

2. Server-Base Networks

Server-based networks, also known as "client/server" networks. rely on special purpose computers called servers that provide centralized management and support to other computers. and resources on the network. In a server-based network, dedicated servers are installed for the purpose of providing network services such as: user logons, maintaining the authorized user accounts database. storing files, providing resources and shared applications to users, and providing network security.

There are a number of reasons to implement a server-based network, including centralized control over network resources through the use of network security control over the network using the server's configuration and setup. Server-based networks are scalable and allow for future network growth and expansion. These networks are robust and can support a large number of users depending on how the server is configured. Server-based networks can be tailored to meet the needs of small or large organizations, and they can handle high volumes of network traffic. Server-based networks are much more powerful than peer-to-peer networks. but they are also more expensive than peer-to-peer networks. Additionally, server-based networks require more administration. more training. and higher levels of technical expertise to implement than required in peer-to-peer networks.

C. WHY BUILD A LAN?

LANs enable computer users to access and share several applications. communications and information sources from a single workstation. Today, LANs have a greater role in K-12 schools because advancements in technology have put the LAN and its conveyances in the hands of our children and their teachers. Installing a LAN is essential to improving an organization's ability to provide information and resources to large numbers of users who can use those resources simultaneously. LANs improve how we share data, by enhancing our ability to give more people access to the data. and allowing greater amounts and a greater variety of data formats to be shared through the LAN. LANs allow resources such as printers and applications to be shared among several users. eliminating the need to purchase the

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application or a printer for every user in the organization. Sharing resources ultimately saves money and allows the organization to redirect funding to improving other areas that can benefit from the money saved by not buying printers or numerous single user copies of applications.

D.   WHAT IS A WIDE AREA NETWORK (WAN)?

A WAN is a network of LANs extending beyond the local site, building, or region. WANs use common carrier lines to link LANs in remote buildings, other cities or around the world. The WAN can be thought of as a collection of LANs communicating with each other by telephone, satellite, or some other communications media. A LAN becomes a WAN when the physical and distance limitations are too great for adequate LAN connectivity. A WAN provides connectivity between more than one LAN, and most WANs are a combination of LANs and other types of communications components connected by communication links called WAN links [MS PRESS, 1996].

E.   NETWORK TOPOLOGY

A Network topology is the pattern created by the interconnection of cables and hardware devices in the network. It can be thought of as the schematic of how computers are physically connected to each other. The three basic topologies are the ring, bus, and star.

1.   Ring Topology

The ring topology connects computers on a single circle of cable. The signals travel around the ring in one direction and pass through each computer on the ring. In a ring topology, a signal is received, regenerated, and retransmitted by each consecutive station on the ring until it reaches its destination address. Because the signal on the ring passes through each computer, the failure of one computer can impact the entire network [MS Press, 1996]. Figure 1 below illustrates the basic structure of the Ring Topology.

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Figure 1. Ring Topology
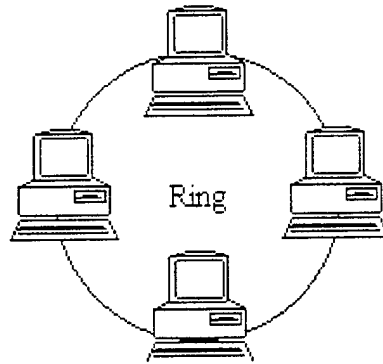
If the cable in a basic ring network breaks. the entire LAN goes down. With the ring topology, computer moves, additions. and removal require bringing the network down until all changes are complete. For this reason. modern ring oriented LANs implement a dual ring topology. Fiber distributed data interface (FDDI) is an example of an improved ring topology. FDDI avoids the problems inherent in a basic ring topology. FDDI uses a dual ring. which has a primary ring and backup ring. These two rings ensure that data can still be transmitted in the case of a failure on one of the rings. The basic ring topology has the following advantages and disadvantages:

Advantages	Disadvantages
- equal access for all computers	- 1 machine down, affects the entire network
-good performance despite many users	- problems are hard to isolate

Advantages and Disadvantages of Ring Topology

2.   Bus Topology

The bus topology is a common shared cable terminated on both ends. The bus topology, sometimes known as daisy chaining. is a method of wiring that connects each computer to the one next to it [Tittel, Robbins, 94]. The bus topology connects computers along the network cable in a linear fashion. The bus is frequently referred to as a broadcast medium. because transmissions are sent to all equipment attached on the cable. even if the transmission is addressed to only one station. Each station must process

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every transmission to determine whether message is addressed to it and accepts or ignores the transmission based on its destination address.

A broken connection between the bus backbone and a LAN user or an inactive station normally will not disrupt the rest of the network. The disadvantage of the bus topology is that any failure of the network cable brings down the entire LAN. Also. locating the source of the problem can be difficult. This is similar to trying to find the burned out light bulb in a string of tree lights where all the lights go out if one bulb burns out. Figure 2 below illustrates the basic structure of the Bus Topology.

Figure 2. Bus Topology
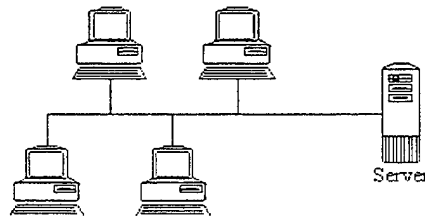
The bus is an easy topology to install. configure. and expand. The bus has the following advantages and disadvantages:

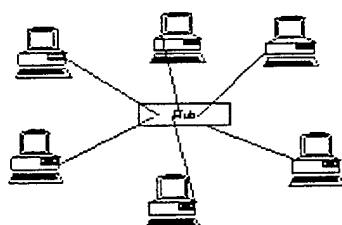| Advantages	Disadvantages
- less cable is required - simple, reliable - easy to expand	- slow with high network traffic - problems are hard to isolate - cable breaks can affect the network

Advantages and Disadvantages of Bus Topology

3.   **Star Topology**

The star topology is configured around a central wiring device called a hub which serves as crossroad for electrical signals traveling from each station on the network.   In star configuration, every

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computer connects directly to the network hub, which is why this is called a hub topology. A LAN

constructed in the star topology has built-in resistance to failure, downed stations and link failures.

Failure of a single computer has minimal effect on the overall operation of the network. This topology

allows for simple and economical computer moves, additions, and changes because removing one

computer from the network does not affect the others. The star topology is easy to maintain, monitor, and

manage because of the centralized aspect of the topology. The star topology is more robust than the bus

topology, but it also requires more network cable and additional equipment-namely the hub [Tittle,

Robbins 94].

Since the star topology routes all network traffic through a central point it has the potential for a

single point of failure. If the hub fails to function properly, the whole LAN could be affected. Figure 3

below illustrates the basic structure of the Star Topology.

Figure 3. Star Topology

The star topology offers the following advantages and disadvantages:

Advantages	Disadvantages
- easy to expand/modify - centralized monitoring & management - 1 machine fails doesn't affect network	- centralized point goes down, the whole network is down

Advantages and Disadvantages of Star Topology

Each network topology has a different physical layout and structure which must be considered

when designing a LAN. The best topology may not be any single topology, but may consist of a

combination of more than one topology. For example the combination of the Bus with the Ring would be called a Bus-Ring topology. Depending on an organization's LAN needs, the topology selected will vary. Based on the general LAN needs of K-12 schools, the recommendation for K-12 LAN topologies is a combination of the star and bus topologies. This topology called the star-bus, will combine robustness of the star topology with the simplicity and expandability of the bus topology. The star-bus facilitates computer moves, additions, changes and future expansion with minimal impact on the entire LAN. The star-bus topology allows the LAN to be designed so that each network segment has a star configuration, and each star is linked together in a bus topology as shown in Figure 4.

Figure 4. Star-Bus Topology
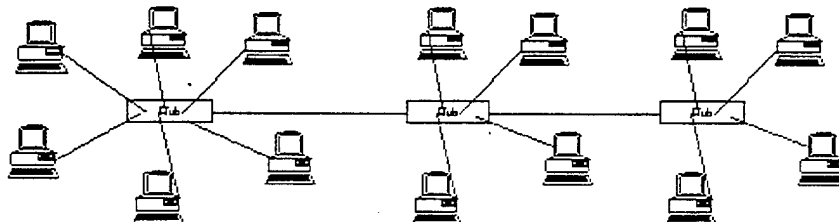
F.   TRANSMISSION MEDIA (NETWORK CABLE)

A major component of a LAN is the physical wire over which all network devices communicate. A properly designed LAN should be flexible enough to support current and future networking needs. While the cable itself is relatively inexpensive, the labor involved in installing cable or modifying existing cable runs can be labor intensive. Cable and hardware can quickly become the primary limiting factors in LAN implementation.

Network cable comes in various types and categories with different performance capabilities and limitations. It is important to select the cable that will meet the needs of each network based on the specific distance and network traffic requirements identified by the network designers. One factor to consider when selecting cable is bandwidth. Bandwidth refers to how much information can be sent over the cable at one time. Bandwidth is measured in Mega bits per second (Mbps) and can be thought of as

the "pipe" that network data travels through to get from one network device to the next. The bigger the "pipe" i.e. higher the bandwidth, the greater the amount of data that can travel across the network.

The three main types of networking cable are:

* Coaxial

* Twisted Pair

* Fiber-optic

1. Coaxial

Coaxial cable, often referred to as coax, was the first predominant medium for data transmission. There are four parts to coaxial cable: the inner conductor, the insulation around the solid inner conductor (the dielectric), a braided wire or metal foil outer conductor which serves as a shield against electro-magnetic interference/radio frequency interference (EMI/RFI), and an outer plastic jacket. The size of coaxial cable varies. The size and electrical characteristics of the cable are usually printed on the jacket of the cable for easy identification. Coaxial cable is further categorized as "thicknet" also know as 10Base5, and "thinnet" also known as 10Base2 or RG-58.

Coaxial cable is relatively immune to EMI/RFI and is able to carry signals distances of 185 meters (thinnet) and 500 meters (thicknet) with negligible impact from EMI before the signal must be regenerated and boosted by a repeater. Coax cable is often used in a bus topology. It is more difficult and more expensive to install than twisted pair because coax is more bulky, more complex, harder to work with than twisted pair cable. Coax is no longer the most commonly used medium for new LAN installations.

2. Twisted Pair

Twisted-pair cable is the type of cable used in houses and buildings for telephone connectivity to the telephone network. Twisted-pair cable consists of pairs of copper wire twisted together. The twisting allows the wires to carry more information than they could if the wires were left as separate straight strands [Levy 1995]. Additionally, the pairs are twisted so that the electrical field around one conductor will be as nearly canceled as possible by the equal but opposite (balanced) electrical field around the other

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conductor. This reduces the interference emitted by the pair and, reciprocally, reduces the interference by external fields.

There are two versions of the twisted-pair cable: unshielded twisted pair (UTP) and shielded twisted-pair (STP). STP has a metallic braid or foil wrapped around the twisted-pairs of wires to provide shielding from EMI/RFI, thus giving it a higher immunity to interference than UTP. STP is less susceptible to interference, but more expensive than UTP. UTP and STP both allow 10-100 Mbps transmission speeds, so if EMI is not an issue, UTP will work as well as STP.

Twisted-pair cable uses a small plastic RJ-45 connector. The RJ-45 connector connects the twisted pair cable to a network interface card or hub. The RJ-45 connector is similar to the RJ-11 connector used for telephones, but the RJ-45 connector has 8 pins and the RJ-11 connector only has 4 pins [MS Press, 1996].

3.   Fiber-optic

Fiber-optic cable is good for very high-speed, high-capacity data transmission because of the lack of attenuation (signal loss due to distance traveled) and the purity of the signal. Fiber-optic cable has an optical fiber core that is a thin strand of glass or plastic [MS Press, 1996]. Glass strands allow faster network transmission speeds over greater distances than do plastic strands. Communication in fiber optics is based upon encoded pulses of light. Each pulse of light is inserted at one end of the glass/plastic fiber by a light source (i.e., laser, light emitting diode (LED)). After traveling the length of the fiber, the light appearing at the opposite end is received by a light detector. The light source and detector are located within transceivers, each interfacing with an electrical medium. The core of the fiber is surrounded by glass cladding with an index of refraction less than that of the core to ensure total internal reflection of light.

The core and cladding are actually a single piece of glass; if the fiber is disassembled, the cladding cannot be separated from the core. The fiber core and cladding are covered by an absorbent material or coating to isolate the inner core from surrounding fibers. Fiber optic cables either have steel or composite stress members mixed with the fibers or a sheath of Kevlar to add tensile strength. This

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relieves the fibers of stress which results from pulling the cable during installation. (Note: Bending of the fiber attenuates light signals, may cause light to escape from the fiber, and can actually fracture the fiber, breaking the transmission path.) Finally, a jacket covers the entire cable. There is usually more than one fiber in a single cable. Often fibers are grouped with a number of twisted-pair copper wires in what is called a composite cable.

Fiber has a high bandwidth and low signal attenuation in comparison to coax and twisted-pair; it transfers information at a high data rate with little signal degradation. Because the signals are pulses of light, optical fiber is totally immune to EMI/RFI. Fiber is generally preferred for backbone connectivity between floors or buildings because of the advantages offered by the medium in performance, distance, reliability, and signal integrity.

4. Cable Considerations

Twisted-pair is frequently used for station connectivity to the backbone because it is inexpensive and easy to install compared to coaxial or fiber optic cable. Twisted-pair is flexible and easy to work with which allows it to be pulled around corners, where coax and fiber-optic cable cannot be installed without extra care during installation. Twisted-pair cable does not offer the bandwidth capacity of fiber-optic cable or the extended distances between stations offered by either coax or fiber optic cable, but it is inexpensive, and easy to install. Of the three types of cable (i.e. coax, twisted-pair, and fiber), twisted-pair is most susceptible to interference and should not be used in environments where substantial EMI/RFI exists.

Choosing an appropriate network cable depends on several factors including shielding requirements, security needs, transmission speed in Mega bits per second (Mbps), and attenuation. Another factor influencing cable selection is budget, and how much money an organization can spend on LAN cable.

As indicated by the table below, each cable type offers different capabilities in each of these areas. When determining what cable to use, the organization must clearly identify its networking needs. This will help when making the final decision on what media to use for the LAN.

The following is a comparison summary for the different network cable types:

	UTP	STP	Coaxial	Fiber-Optic
Cost	Lowest	Moderate	Moderate	Highest
Capacity	4-100 Mbps 10 Mbps (Typical)	4-100 Mbps 10 Mbps (Typical	10Mbps	2Gbps 100 Mbps (Typical
Attenuation Distance to Station	High 100 meters	High 100 meters	Lower 185-500 Meters	Lowest 2000 meters
Electromagnetic interference	Most sensitive to EMI	Less sensitive than UTP but still sensitive to EMI	Less sensitive than UTP but still sensitive to EMI	Not affected by EMI
Installation Ease	Very Easy	Very Easy	Easy	Difficult
Preferred Uses	Smaller sites or sites on tight Budget	Token Ring Networks. Networks on budget with EMI issues	Medium to large sits with high security needs	High speed data rates, highest security needs

Network Cable Comparisons

In organizations that have restricted budgets, limited technical expertise, the following sources can help determine what cable is suitable for use in your network:

* Assistance from professional cable installers

* Find network engineers who volunteer in the community

* Solicit local University network classes to help as class project

MPUSD schools were able to get a great deal of assistance from Pacific Bell and other volunteers determining which cable was best suited for its LAN use. The decision was based on relative cost of the cable and bandwidth requirements. The greatest costs in cable installation result from the labor and not the cost of the actual wire itself. MPUSD was able to reduce the labor costs of cable installation by obtaining volunteer help from local businesses and volunteer organizations in the community to install the cable.

MPUSD planners determined that K-12 LANs should be capable of at least 10 Megabits per second (Mbps) transmission rates with the potential for supporting up to 100 Mbps in the future to facilitate the high speed transfer of graphics and data, and to allow for future expansion. Based on these criteria, MPUSD planners decided that UTP category 5 (cat 5) would best suit the needs of its LAN installations.

G.   OPERATING SYSTEMS

Two essential software components are the network operating system (NOS), and the operating system (OS) for each computer on the network. The computer operating system coordinates all of the computer's functions and the network operating system manages all network requests and network functions. Both the NOS and the OS function like the conductor of a symphony, making sure that all the components work together [Levy, 1995].

The NOS will be installed on the network server computer. The NOS enables LAN client computers to share software applications resident on the server [Long, 93]. The NOS controls the activities of the network and provides the tools that the network administrator needs to manage the LAN.

In addition to the server NOS, each computer workstation on the LAN must have an operating system. Many IBM compatible PC computers will operate with MS-DOS 6.2, Microsoft Windows 95, or Microsoft Windows NT workstation, and Macintosh computers will run System 7.1 or higher. Without an operating system installed, the workstations would not be able to perform any local processing, or to run local applications. The operating system also enables the workstation to interact with the network operating system, by redirecting workstation requests to the network if they can't be processed locally.

Server-based networks, also called client server (c/s) networks, have network operating systems. Peer-to-peer networks can have either network operating systems or computer operating systems. The differences between networking operating systems used in c/s networks and those used in peer-to-peer networks become important when it comes to building robust networks, or building a simple, easy to install but less robust network.

Examples of network operating systems that fit into the c/s category are:

* Microsoft Windows NT Server

* IBM LAN Server

* Banyan VINES

* Novell NetWare 3.1x/4.x

* Microsoft LAN Manager

Examples of peer-to-peer network operating systems are:

* Microsoft Windows 95

* Macintosh AppleTalk

* Microsoft Windows for Workgroups

* Novell Personal NetWare

* Artisoft LANtastic

Two of the most used network operating systems are Microsoft Windows NT and Novell NetWare. Both Microsoft and Novell provide network operating systems that are industry standards. At one point in the 1990's Novell held approximately 80% of the NOS market [Microsoft TechNet, 1998]. Today Microsoft is capturing a larger portion of the NOS market share with the Windows NT network operating system.

With changes in operating system technology, it is becoming increasingly common for computer operating systems to have networking functionality built in. Rather than add a shell to provide networking intelligence, the operating system already understands networking and includes it as a member of the set of functions it provides. As networking becomes the norm, network support features will become standard components of the computer operating system as seen in Windows 95, Windows NT, UNIX, and Macintosh operating systems. This does not mean that all operating systems and network operating systems are equal. Some NOS and OS are more interoperable, user friendly, and robust than others.

MPUSD schools selected Novell NetWare as the NOS and a combination of Windows 95, Windows 3.11 and Macintosh as the OS in their K-12 LANs. To help other K-12 schools decide which NOS and OS are best, the following information is presented:

* Will applications and resources reside on the server and be shared, or they will reside on individual computers?

* Is security important?

* Is ease of use important?

* How well do the NOS and OS operate?

* What OS are currently installed?

Both Novell NetWare and Microsoft Windows NT NOS provide good application sharing capability, and operate well with many operating systems. Windows NT provides increased security over NetWare because it allows security restrictions to be placed on individual files as well as folders. Additionally, Windows NT is easier to administer once installed because of its graphical user interface. and its ability to allow a user access to many more resources with a single user id and password. If the results of the preceding questions indicate that good security, ease of use, and shared access to applications, printers and other resources, are important, then Novell NetWare or Windows NT are recommended as the NOS for K-12 schools. MPUSD K-12 schools selected Novell 4.1 as their NOS because it handles shared resources well and is compatible with popular stand-alone computer operating systems like Windows and Macintosh that are installed on many K-12 computers.

Based on the author's hands-on evaluation and use of NetWare, Windows NT Server, UNIX, and IBM LAN Server, the most robust and easy to use NOS was Windows NT. Additional evaluations of client operating systems revealed that Windows 95, Windows NT Workstation, and Macintosh were the most robust and easy to use. This evaluation revealed that the best combination of NOS and OS consisted of Microsoft Windows NT Server as the NOS, with Microsoft Windows 95, Windows NT workstations, or Macintosh as the OS. Novell NetWare was the next easiest NOS to use with Novell as the NOS, and Windows 95 or Macintosh as the OS. The ease of use, robustness and interoperability between Windows

95, Windows NT Workstation and Macintosh as the OS, and Windows NT Server or Novell as the NOS, make these systems ideal for use in K-12 LANs. These systems are relatively easy to install and maintain, plus there are already many network ready applications, and support tools available for these systems. As is evident by the number of software applications available off the shelf at computer stores, industry software developers have accepted Novell and Microsoft as leaders in the NOS industry. Consequently, there is a great deal of software support for these network operating systems.

After narrowing the choices down to Novell or Microsoft as the NOS, and either Macintosh, Windows 95 or Windows NT as the OS, each K-12 school must decide which combination of NOS and OS best serves the school's needs.

H.   PROTOCOLS

Protocols are rules and procedures for communicating. For example, diplomats from one country adhere to protocol to guide them in interacting with diplomats from other countries. The use of communication rules applies in the same way in the computer environment. When several computers are networked, the rules and technical procedures governing their communication and interaction are called protocols [MS Press, 1997]. Protocols perform functions that happen automatically without intervention by the computer user. Protocols break data into packets, and add addressing information to the packets so that the packets can travel from the sending computer to the destination computer. Protocols are essential in enabling communication on the network.

There are many protocols that can be used in computer communication, and each protocol has different capabilities and is used for a different purpose. The subject of protocols can get very technical, but for the purpose of this document, the protocol discussion will be limited to identifying a few of the most common protocols used in LANs. There is more in depth discussion of the Transport Control Protocol/Internet Control Protocol (TCP/IP) because of its importance to protocol standardization and increased interoperability. The most common protocols useful in K-12 LANs are:

* Transport Control Protocol/Internet Control Protocol (TCP/IP) – the standard internet protocol. (discussed in greater detail in the following section)

* NetBIOS extended user interface (NetBEUI) – a small fast LAN protocol used primarily in Microsoft networks.

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*   NWLink – Microsoft's version of IPX/SPX. used to allow Microsoft clients to communicate with Novell NOS.

*   Internetwork packet exchange/sequence packet exchange protocol (IPX/SPX) – A small, fast LAN protocol installed primarily on Novell networks.

*   AppleTalk protocol (ATP) – Apple Computer's proprietary protocol designed to enable Macintosh computers to share files and printers in a networked environment.

There are several protocols that K-12 schools could use. but TCP/IP is the Internet protocol of choice. There are many popular transport protocols from vendors. but industry and government are moving away from proprietary protocols and moving toward TCP/IP. TCP/IP is economical, provides flexibility, and is well established as an Internet protocol. TCP/IP is quickly becoming the nations leading protocol because of its ability to co-exist with other protocols and platforms. Since TCP/IP can co-exist successfully with other network protocols. offices and classrooms that already have networks installed can easily integrate TCP/IP with other protocols on the network.

Networks consisting of Apple Macintosh computers will probably use the AppleTalk protocol by default; PCs on a Novell NetWare LAN will probably use the IPX/SPX by default. and school districts with large LANs may be using IBM's System Network Architecture (SNA) protocol. None of these protocols provides broad connectivity and interoperability offered by TCP/IP.

The popularity of TCP/IP in government and industry is a major advantage to schools because there is already a broad-base of user applications and a variety of platforms that are TCP/IP compatible. Since leading industry software developers have accepted TCP/IP as a standard Internet protocol. many new applications and TCP/IP packages are appearing in the market place. Microsoft Corporation has adopted TCP/IP and bundles TCP/IP with Windows 95 and Windows NT. Indeed. it's Microsoft that's spurring many vendors to create applications that can take advantage of TCP/IP [Loshin, 1994].

TCP/IP supports many fundamental Network operations such as electronic mail. file transfer. interactive remote host access. database access. file sharing. and access to networked information resources. Additionally. TCP/IP is available on most. if not all. of the computing platforms likely to be

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used for instructional or administrative purposes. TCP/IP is available for the IBM compatible personal computers (PCs) running DOS or Windows and all versions of the Apple Macintosh. TCP/IP is standard on all UNIX-based systems and workstations produced by companies such as Sun Microsystems, Hewlett-Packard, Digital Equipment Corporation, and IBM. Mainframe computer manufacturers such as IBM and Unisys (Burroughs) now support TCP/IP as standard program product offerings for all of their traditional mainframe products. [CDE, 1994]

Since TCP/IP is non-proprietary, it can accommodate educational and administrative applications equally well so that one set of network cabling and one communications system may be used in both the classroom and the office [Russell, 1994].

In addition to being flexible, TCP/IP is simple enough to operate on low-end computing platforms such as the Apple Macintosh and PCs while still providing efficient support for large minicomputer and mainframe computing platforms. Since most schools own either Apple Macintosh or PCs, this protocol will definitely meet their needs.

TCP/IP benefits from over twenty years of refinement that has resulted in a large and technically sophisticated environment. TCP/IP supports local area network and wide area network services within the entire range of network data rates available today, from dial-up modem speeds to gigabit speed experimental networks. Communications can occur reliably among machines across this entire range of speeds. In addition to supporting standard data transport capabilities used by traditional data processing applications, TCP/IP can support voice and video necessary for teleconferencing and multimedia applications.

Many public and private college campuses with university-wide networks use TCP/IP for their primary communications services. Additionally, thousands of commercial and governmental organizations throughout the state and nation use these protocols. The MPUSD school district installed TCP/IP as the protocol of choice enables MPUSD K-12 schools to communicate network to network with the rest of the networked world.

I.   MEDIA ACCESS CONTROL (MAC)

Media Access Control (MAC) is the method used by the computer network card to allow computers on the network to communicate. Three common media access controls are Carrier Sense Multiple Access with Collision Detection (CSMA/CD), Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), and Token Passing. Each of these media access methods is associated with a specific type of network as follows:

*   CSMA/CD – Ethernet Networks

*   CSMA/CA – LocalTalk Networks

*   Token Passing – Token Ring Networks

CSMA/CD is the most relevant to the K-12 school LAN since most K-12 schools will install Ethernet Networks. In an Ethernet network, interface cards share the common cable by listening before they transmit and by transmitting only during a break in the traffic when the channel is quiet. The Media access method for Ethernet is Carrier-Sense Multiple Access with Collision Detection (CSMA/CD). CSMA/CD is a contention technique which allows devices to compete for medium access. The CSMA/CD function is performed by each device's Network Interface Card (NIC), commonly called an Ethernet card.

A good way to express the functionality of CSMA/CD is to blindfold a room full of people and have them converse with each other. Each person in the room gets to speak, but only if no one else is talking. In order to communicate a person they must listen for silence, and then start speaking when it is quiet. This describes the carrier-sense mode functionality. Multiple Access refers to the fact that every person can contend for transmission time. Occasionally two people begin to talk at the same time and realize that they must stop because someone is already talking. This is the collision detection mode. When a collision is sensed both guests will stop speaking, listen for silence for an independently random time, and resume talking.

CSMA/CD is used in bus type topologies on Ethernet networks. This access method is more desirable than CSMA/CA because it does not increase the amount of traffic on the network.

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AppleTalk is the name of the networking method used by Apple-Macintosh computers. The cable system for an AppleTalk network is called local talk. LocalTalk uses a media access method called CSMA/CA, which is similar to CSMA/CD. The major difference between the two methods is that in CSMA/CA, the computer sends a packet indicating that it is getting ready to send traffic. This method creates more network traffic because of the high number of computer broadcasts announcing that a computer is preparing to send traffic [Tittle, 1998].

Token Ring networks use a token passing method to provide equal access to the network for all computers. Computers cannot transmit data unless they have the token (a small data frame). Token passing keeps two computers from transmitting on the network wire at the same time, which eliminates collisions. The token is passed from one computer to the next, and once that computer finishes transmitting, the token is passed to the next computer in line. [Tittle, 1998]

The nature of the media access method will cause network problems if nodes on the network are located too far apart. When selecting a media (cable) ensure that distance between the stations is considered. If the distance between workstations on the network exceeds the rated cable distances, the media access method will not work properly, in this case, it is possible that network interface cards will issue a carrier sense signal, listen, hear nothing, and send their messages-only to have the data collide. These collisions degrade network performance and reduce network reliability in transmitting information from one network device to another. This reduces a user's ability to share resources and the end result is a loss in productivity.

J.   NETWORK COMPONENTS

The configuration of a K-12 school's LAN will be determined on a case by case basis depending on the network needs of the school. This section provides an overview of the most common components that installed on a LAN. The information in this section provides information to guide K-12 educators in identifying the most common network components.

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1. Printers

Various types of printers can be used on a LAN. Laser printers are fast. high capacity printing devices that print high quality documents. They lend themselves to LAN environments because of speed and versatility. Sharing printers on the LAN allows many users to print to the same printer. This reduces the cost of having to purchase a separate printer for each user. Dot matrix printers are excellent for preprinted forms, multipart forms, and address labels. Ink jet printers provide higher quality printouts than dot matrix printers, but are slower and produce slightly lower quality output than laser printers. Network printers can be attached to print servers. i.e. computers on the LAN that allow other computers to access the printer, or they can be connected directly to the LAN using network cards designed for network ready printers.

2. Workstations

A workstation is a computer on the network that allows users to access network resources. Workstations. commonly called clients. are fully functional computer systems that can have a number of configurations. Most workstations have a monitor. central processing unit (CPU). CD-ROM. keyboard, hard drive, floppy drive, random access memory (RAM). and an operating system. Some workstations will have additional specialized equipment like tape drives. sound cards or other devices. Today's typical workstation configuration would be a Pentium 400 Mega Hertz (MHZ) CPU. with a Windows 95 operating system. a 8 GigaByte (GB) hard drive. 3.5" floppy drive. 128 Mega Bytes (MB) of RAM, a 24 speed CD-ROM. and a network interface card (NIC). The workstation is considered a node on the network that allows users to perform routine tasks such as running software applications. accessing E-mail, and interacting with other nodes.

3. Network Adapter

Each peripheral device on the network requires a piece of hardware called a network adapter card also known as a network interface card (NIC). NICs are the cards that are installed inside network devices that enable the device to communicate on the LAN. The network adapter connects the network device to the network cable. The connector on a NIC is designed to be connected to a specific cable type,

i.e. Twisted-pair, Thinnet, Thicknet, or Fiber. NICs that are designed to connect to more than one type of cable are called "Combo" cards. "Combo" cards make it easier to switch from one cable type to another without replacing the NIC.

The NIC contains the hardware or MAC address usually stamped on the card, preset by the manufacturer and cannot be changed. Manufacturers are issued blocks of MAC addresses to ensure that these preset addresses are unique and will not be duplicated. Network adapters provide the interface to drive the signal onto the network media and receive the signal from the network by providing the encoding and decoding of the signal. Additionally, the NIC initiates the media access control on the LAN.

4. Hubs

One major trend in the network industry has been the popular acceptance of the wiring hub as the predominant method of cabling a LAN. The hub, also called a concentrator, provides a central point for connecting network wiring. A hub makes it easier to track and manage which computers are connected to the LAN. One job of the hub is to regenerate an incoming signal from any node (network device) on the LAN and rebroadcast it to all other nodes. A major advantage of a hub is that it allows the network manager to make changes to the LAN without rewiring the network. Hubs can also detect malfunctioning network interface cards and reroute network data to prevent other computers on the network from being impacted by a malfunctioning computer.

5. Repeaters

A repeater is a network device that regenerates (boosts) the network signal. As the signals travel down the cable, they degrade and become weaker. A repeater boosts the signal and increases the distance a signal can travel on the network. For example, on a network that uses 10baseT cable, the distance a signal can travel is 100 meters without the use of a repeater. If a repeater is used, the signal can travel the 100 meters plus an additional 100 meters after the repeater regenerates the signal. Repeaters extend the distance of the LAN and join different LAN segments.

6. Bridges

Similar to a repeater, a bridge joins LAN segments, and regenerates network signals. Bridges provide all of the functionality of repeaters, and they also enable network traffic isolation. When a LAN has too many computers installed on a segment, bridges can divide the LAN into additional segments i.e. sections. By segmenting the LAN, traffic on individual segments is reduced and network performance improves. The bridge maintains a table of what computers are located on its segment, and routes traffic from one computer to another based on this routing table. Bridges use a single path to route data from one network node to another.

7. Routers

In networks that have multiple protocols and many LAN segments, bridges may not be adequate for providing fast communication among all of the segments. A router has all of the functionality of a bridge, and can determine what path is best for sending data and filtering broadcast traffic from one LAN segment to another. The router is capable of using multiple paths to route data, and provides improved traffic isolation. Routers are more sophisticated than bridges or repeaters and they provide the functionality to communicate with other networks outside of the LAN. Smart routers are advanced routers that enable the router to determine which path is best to send data from one node to the destination node.

Hubs, repeaters, bridges and routers all provide a means of centralizing the networks wiring and amplifying the signal to and from different network devices. LAN planners should review additional information on each of these devices to gain a clear understanding of when to use each device. Additional information can be found in books like "Networking Essentials" training kit from Microsoft Press, or Novell's, "NetWare Construction Kit" from Wiley.

8. Servers

In smaller networks, several server functions are generally located on a single machine. As a network increases in size, the distribution of server software across the network increases. Normally, a

computer used for server purposes contains only the server software and is not used as a workstation because of the large RAM requirement by the server process.

A server is a computer containing a software process or group of processes working together to provide resources and complete network requests. Servers are generally high performance workstations or minicomputers that use high-speed processors like the Intel Pentium processor, Motorola processors, UNIX based minicomputers, and Digital Equipment Corporation (DEC) MicroVAX. A typical server might have a Pentium 400MHZ CPU, Windows NT Server, several 8 GB hard drives, 3.5 inch floppy drive, 128 MB RAM, 32 speed CD-ROM, and a NIC.

There are different types of servers: file, print, application, database, fax, communication, and e-mail servers. A file server performs functions such as open, close, read, and write for file resources stored on a departmental LAN hard disk. Print servers provide spooling and centralized print queue management. A print server allows LAN users to quickly transfer print jobs and continue their work without having to wait for free time on the printer. There are printers currently on the market with their own network adapters which eliminate the need for a dedicated print server. Application and database servers store programs and data on a centralized computer that can be shared by many users. They also run the programs for users with workstations too small or slow to efficiently run the programs. Remote access servers allow users to dial in and connect to the LAN from remote locations to access network resources. Fax servers enable users to send and receive faxes over the LAN without the need of have individual fax machines or modems for every user. An E-mail server handles mail storage and transfer on the LAN.

9.   Applications

Applications are software programs used by computer users to produce documents, prepare reports, create presentations, store data and a variety of other activities. Examples of applications are word processors, database management systems, spreadsheets, and presentation graphics. These applications can be installed as stand-alone (single computer) applications, or they can be installed as

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shared network applications (on the server). Stand-alone applications require that a separate copy of the application be purchased for every computer that will install the application.

Network applications allow software to be purchased and installed on the servers so that all network users have access to the application. Network applications are less costly than stand-alone applications if several users require access to the application because a license (allowing multiple computers to use the software) can be purchased for less than the cost of buying individual copies of the software for every computer. There are different types of application licenses that may be purchased. The most cost effective is a concurrent license which allows a predetermined number of users to use an application at any one time, and eliminates the problem of paying for excess licenses that are not being used. For example, a concurrent license that allows 25 users to use a word processor will only allow 25 people to use the program at one time. If 26 people attempt to use the word processor, access will be denied for the 26th user. Some applications may be used by every person in the organization, and require a site license may be required to allow all users access to the application. Application licenses purchased from the manufactures of software applications come in a variety of user or client access capacities i.e. 10, 25, 30, 100+ users licenses. In order to decide which application licenses to purchase, an organization must carefully determine which applications will be used, and how many users will need access to the applications. Another type of licensing is the server license. A server license is different from an application license because the server license determines how many computers will be allowed to connect to the server simultaneously. The server license is specific to the server and network operating system, not the applications running on the server. Selecting a good licensing approach can save an organization a great deal of money because licenses eliminate the need to purchase individual copies of applications for each computer on the LAN.

One disadvantage of networked applications is that they cause an increase in the amount of information that must be processed over the network and increase the network traffic. Network applications require more bandwidth than stand-alone applications. Applications that require high bandwidth are graphics programs, and specialized multi-media programs. Word processors and databases

require lower bandwidth and are more suitable as network applications than intensive graphics programs. For example, computer graphics and drawing programs, educational multi-media software, and video conferencing require much more bandwidth than word processing and spreadsheet applications. Additionally, video conferencing using the internet and the world wide web (WWW) require increased network bandwidth, and should be evaluated when deciding which applications to install on the network. The internet and WWW are more widely used for distributed education. The expanded use of the WWW in K-12 schools is a topic for further research, and is not discussed in this document. Planners should consider purchasing stand-alone copies of these high bandwidth applications rather than attempting to share these programs over the network. When deciding which applications will be shared network applications and which will be stand-alone applications, it is important to remember that there is a trade off between network performance and the cost of buying stand-alone applications.

K. NETWORK PROTECTION DEVICES

Power failures, brownouts, and alternating current (ac) power surges can create problems on computers, LAN systems, and file servers. Unexpected power changes can damage computers and erase or corrupt data on the computers. The American National Standards Institute (ANSI) lists 111/193 volts as the minimum permissible service voltage on a 120/208 volt service. In most cases, measuring voltage at the wall socket would show that the voltage is already near or at either extreme of the voltage range; therefore, any fluctuation will exceed the manufacturer's design limitation. The following paragraphs discuss power protection sources.

1. Surge Suppression

Surge suppression devices are normally used to protect printers and user workstations. These devices provide noise filtering and surge suppression, generally in the form of a power strip. The surge suppression does not provide for brownouts, voltage sags beyond the nominal limit, or complete loss of power.

2. Uninterruptible Power Supply (UPS)

An uninterruptible power supply (UPS) is the safest form of protection for the most critical equipment (i.e., servers and hubs). The UPS is like the battery backup in an alarm clock allowing the clock to keep work for a specified amount of time. Most UPS manufacturers provide the ability to monitor the power supply of the server/hub. In the event that power transfers to the UPS, the network can be notified via a separate software monitoring program loaded in the server. The UPS comes in two basic types: standby UPS and on-line UPS. The standby UPS provides power in the event of loss of commercial power. Under normal conditions, it performs no filtering of power other than surge protection for the equipment. The duration of power availability is determined by the equipment load and battery rating.

The on-line UPS provides continuous power filtering and regulation to protect against all forms of power fluctuations. In addition, it provides battery backup capabilities. The duration of power availability is determined by the equipment load and battery rating. It is preferable to have an on-line UPS to provide protection from power failures.

3. Backup Devices

Backup devices provide a means of storing important information and data for future retrieval. There are several different types of back up devices available for use in the LAN. Quarter-inch cartridge (QIC) tape backup systems are popular, inexpensive and reliable. Another device that is available as a tool for backup is the 8mm digital audio tape (dat) cartridge drive. Tape backup devices will support a variety of storage capacities . Common tape storage capacities currently include 4 GB and 8 GB and it continues to increase. When determining what tape capacity to use it is important to make the decision based on the needs identified for protecting data on the LAN. Planners should ask, "How often are backups conducted, and what data is to be stored on the tapes?"

III. LAN DESIGN FUNDAMENTALS

The LAN design process is divided into several steps. Each step in the design process requires key decisions to assign resources or select material and components to use in the LAN. Making these decisions can be difficult for a person who does not have a clear understanding of LAN technology. In addition to the technical issues, it is important to identify what the LAN will be used for. LAN planners need a clear understanding of the planned uses for the LAN because the network must provide value to the organization or it may not get approved for installation. This chapter will help a non-technical person make informed decisions in the LAN design process. This section provides an introduction and step-by-step LAN design template that gives a K-12 educator a starting point to addresses the main steps in K-12 LAN design. The major categories in the LAN design process are:

* Appoint a Planning and Design Team

* Conduct a Needs Analysis

* Conduct a Site Assessment

* Design the LAN

* Select the Equipment

* Gain Buy-in and Support

* Implement the LAN

* Management the LAN

A. DESIGN TEAM

Prior to beginning the design process. it is important to assemble a planning and design team consisting of end-user representatives. vendors. consultants, and network design experts. The team should have representatives from all of the entities involved in the LAN design so that there is good coordination between the various players providing equipment. services and the knowledge required to design and implement a LAN. The planning and design team should also include at least one top-level management person. In order for the LAN to be approved and successful. it must have support from the upper level

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managers and decision-makers. If managers are involved in the planning. there will be greater support for the project. For the best chance of success. the project should include a wide range of people from different departments. different backgrounds. and a variety of organizational functions. Planners must ensure that a good cross section of people in the organization is represented. For example. customer service, sales, faculty, students, management and information services are just of a few of the groups that will need to provide input to planners. Without the support of these groups, a LAN implementation could fail because users refuse to use the LAN. To avoid this, the design team must ensure that the LAN meets user needs, accommodates the equipment to be installed. meets the sites wiring requirements, and addresses future LAN expansion.

The resources and personnel available to serve on this team may vary for each organization. If an organization, such as a school. does not have the technical expertise on staff. there may be resources available in the community with the necessary expertise to help. Organizations can request assistance from businesses and volunteers with LAN expertise. For instance. MPUSD was able to elicit the expertise of the Initiative for Information Infrastructure and Linkage Applications (I3LA) network design team, which was involved in the design and implementation of LANs connecting kindergarten through twelfth grade (K-12) students, educators and research institutions throughout Monterey and Santa Cruz counties.

Schools that do not have network design professionals on staff should seek qualified volunteers, businesses, and local universities as potential partners to assist with the school's LAN design and implementation. Ultimately the school district will select the LAN design team, and with the help of professionals, who volunteer as advisors. the team can be assembled based on the recommendations of industry experts.

MPUSD partners were very helpful in the district's LAN implementation initiative. Many of the partners worked closely with key members of the MPUSD staff. In the partnership with the Naval Postgraduate School (NPS). MPUSD teachers and librarians used NPS students and faculty as a source of knowledge for network technologies research and LAN design expertise. In return. NPS students were able to use MPUSD LAN initiatives and topics for thesis research and hands on experience with LAN

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design, cable installation. and network configuration. The partnership with Pacific Bell enabled MPUSD schools to receive telecommunications services and training.

Numerous other partnerships with businesses and other organizations provided free labor, equipment, and promoted MPUSD network technology initiatives throughout the community. A major benefit of partnerships like these is increased public awareness and enthusiasm to provide assistance and support for K-12 networking initiatives.

After selecting the team. it is important to define what each member's responsibilities are, before the LAN design process begins. This ensures that each member of the team has a function and clearly understands that the rest of the team is depending on that member to complete a required task. Additionally, this allows the team to have a point of contact for specific functions and saves time. K-12 educators must ensure that the LAN design team is composed of members with a variety of skills. The team should have members with the skills to:

* Conduct the needs analysis

* Perform the site survey

* Design the network

* Evaluate and recommend vendor selections for hardware and software

* Install the LAN components

* Management the network

The members conducting the needs analysis should be good communicators who have network design experience, and the skills to formulate questions that allow them to discover what users need. It is not enough to ask a potential LAN user. "What do you need on the LAN?" because the user probably does not know what is needed. An experienced LAN designer can help the user determine what functionality is required on the LAN by asking the right questions. A list of potential questions is listed later in the design section of this document. The members conducting the site survey should include LAN technicians and cable installers with experience in LAN installation. The design team should also include system administrators and members with systems analysis. network design and engineering experience. A

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network manager should be appointed, and that person will be responsible for directing the overall design team, and approving vendor selections.

The network manager is the point of contact who is responsible for the overall network implementation and management. If the district does not have a person on staff with network experience or skills, it should hire someone, or identify a person on the staff who is interested in being the network manager. This person should be trained as a network manager and be involved in the design, implementation and hands on training associated with implementing the district's LANs. The network manager will help develop the LAN specifications including cable types, cable layout, network configuration, and what network components will be installed on the LAN.

The network manager should be part of the design team and be an expert in LAN design and management. As the LAN grows and becomes more complex, the network manager should provide direction for appropriate infrastructure changes that will meet the increasing requirements of a growing network. Without a knowledgeable individual who is interested and involved, a growing LAN could place educators in the hands of high priced or incompetent consultants who are only interested in making a fast buck. A proactive approach to identifying a single point of contact who understands how the infrastructure is integrated can allow designers to better connect the components of the LAN and produce less costly LAN implementation by reducing or eliminating consulting fees.

The design team will also need equipment and tools to do the job correctly. For example, the team might need computers, software, internet access, spreadsheets, database applications, word processors, project management software, printers and any other tools they require to complete the design. Having the right tools is essential to the design process.

B.   NEEDS ANALYSIS

A LAN can offer an organization the opportunity to improve its current operations, and processes. A key factor in the success of the LAN is to ensure that it is designed with the organization's goals and the end-user's needs in mind. LAN planners should identify who the end user is and ask some important questions such as: What will this network be used for? Who will use it? What information is

better shared using a LAN? The needs analysis will help planners determine whether a LAN is needed, and what needs the LAN will fill. Since a LAN provides a mechanism for sharing information, it will work well for people who already share information with others in the organization. During the needs assessment, a commonly asked question is: what is the best design for my LAN? The best network configuration is one that will meet end user needs today and in the future. It is essential to build a LAN based on clearly defined current user requirements and anticipated future requirements. Another key point is to insure that the LAN is based on a systems design that allows for expandability and interoperability with a variety of hardware and software products. As users begin to understand that the LAN provides options previously unavailable on their stand-alone computers, user needs may expand so the design teams must plan for requirements to increase over time.

During the need analysis, problems with current processes and methods of operation might be identified, and should be analyzed and evaluated to determine whether or not a LAN would improve the process. The needs analysis provides factual information that will be used to support spending money for the LAN. The needs analysis will help prioritize tasks in order to maximize the benefits from a LAN implementation. The first step in the needs analysis is to identify and document the organizations current activities. Include technical processes, shared processes, computerized processes and non-computerized processes. For example, if a request is manually prepared and distributed, it should be included as a candidate for being computerized. While documenting current processes and potential new processes, list staff skills and functions, and review staff capabilities using existing applications and technologies. Identify opportunities to enhance current staff capabilities given additional software and hardware. Identify and list potential application upgrades that could improve existing services, processes for internal and external communication.

The information required for the needs analysis might already be compiled as the result of some other activity or document that the organization has previously produced. For instance, in the MPUSD effort, the design team collected some of the end-user requirements from needs assessments used in providing the supporting documentation for grants obtained to implement previous networking

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technologies initiatives [Matray, 94]. Needs data is also collected through interviews with users, reviewing currently used forms, and having users complete questionnaires. Once the data has been collected, there are different formats that could be used to document information obtained during the needs assessment. Planners could document the data in paragraph style reports or use a table format as shown in sample needs analysis which follows. Site survey forms containing information about the physical requirements of the LAN site should be prepared, and the LAN requester should be interviewed to help define the requirements of the LAN.

Since LANs in many K-12 schools will have similar end user requirements, districts that plan to implement LANs in several schools could create a K-12 needs analysis template for K-12 schools located in the same school district. Districts might want to conduct a district wide needs assessment, and use the information collected during that assessment as a guide or master plan for conducting needs assessments at individual K-12 LAN sites. Individual LAN sites will still need to perform a needs assessment that is specific to that school's needs, but the template help get the process started.

Successful network planners anticipate growth and address potential growth requirements during the needs analysis because user requirements for enhanced capability on the LAN will increase. LAN growth is caused by several factors, ranging from increased student population and users, to increased demand for network services that don't result from an increase in the number of people using the LAN. Other factors to consider in the needs analysis are technology changes, such as, changes in industry trends, increased availability of network applications, and user demands for higher bandwidth on the network due to changes in data volume, data formats, or types of applications being used on the LAN. For instance, users may initially use only text formats which require very little bandwidth, but over time they will use graphics, video, and video teleconferencing which require much more bandwidth and more powerful computer systems. Whatever the cause for growth, it is better to be prepared for changes by planning for future requirement increases during the needs analysis.

Planners can take the following actions to better design LANs that are more easily upgraded and expanded:

* Buy hubs which can be linked together

* Select networking software that allows upgrades to accommodate at least 25 more users than the number licensed at the initial LAN installation

* Ensure that wiring plans allow adding more cable, workstations and network drops per room in the future by installing additional cable and leaving the extra cable coiled in the ceiling for future expansion

* Select and use automated network monitoring tools that provide statistical information about network performance

* Select network management software that allows remote network management and permits remote installations and upgrades of software

* Train network personnel

The goal is to develop a needs analysis that meets the current, as well as, future LAN requirements. A good needs analysis will allow the network to expand in the future without having to tear everything apart and starting over from the beginning. The network can be viewed as a "living" entity that will grow as it matures and develops increased capability.

The following is an example of a simple needs analysis in a table format:

Item	Description of need or requirement
1	All students and staff need access to a high output quality printer. The school does not have the budget to purchase a printer for every student or staff member.
2	New academic software programs come on compact disk (CD), but not all computers have CD-ROMs. Students need access to these titles, but there is no money to purchase CD-ROMS for every computer, or to purchase single user copies of all the software titles for every student.
3	We need to control access to computers based on the users requirements for certain information. We need a way to customize access levels.
4	Computer classes currently have 30 students, but that will increase to 45 in 6 months. We need to share graphics files and applications in the classes.

Sample: Needs Analysis

C. SITE ANALYSIS

A major consideration in LAN design is to determine the physical considerations of the LAN site. Planners can assume that the LAN will evolve to eventually cover the entire organization. Since many LANs are initially designed for a few offices or departments, the first step is to decide what areas the LAN will cover initially. Will it encompass several departments, a single building, a single classroom

or multiple buildings [Schatt, 93]? The physical layout and location of LAN components are factors to consider when planning the LAN.

A site diagram including the existing or planned cable paths and the buildings that will house the LAN components is required. This diagram will be a valuable and useful tool throughout the LAN design and implementation. The diagram can be used to create a network for use during the installation. The network map should show building floor plans, rooms, hardware locations, and it should be a comprehensive guide which displays all other aspects of the site that could impact the LAN. The network map should show the locations of ducts, elevators, conduits, equipment rooms, fire exits, water sources, etc. The map should show details of the network and include the locations of workstations, servers, cables, hubs, printers and other LAN components. The network map is one of the first and most important tools used to design and plan a LAN. If there is a pre-existing LAN, it should be mapped at the beginning of the design process and included as part of the network map.

The network map is essential to having a good plan and will serve the designer well from start to finish. It will also provide an effective means of tracking network progress and expansion as the LAN evolves over time. The site analysis allows the LAN designer to determine where existing resources and services can be used and where new resources are required e.g. electrical outlets, water sources, lights, closets, wall construction, ceiling construction, conduits etc.

If details of a site are not available on the premises, the designer may need to contact the city planer's office to get the blue prints or to become familiar with city wiring and building codes.

D.   LAN DESIGN

Designers must remember that the general purpose of the LAN is to share resources. In order to be justified and useful, the new LAN must be closely linked to an organization's functions. To do this, planners should use the data collected during the needs analysis to emphasize what the LAN will do and how it will save time, money, or improve the quality of the organizations products and services. In addition, K-12 school, planners would also emphasize how a LAN will improve the learning environment,

enhance students ability to access resources that promote the learning process, and share information that facilitates increased comprehension and knowledge.

Discussions about the organization's functions will help identify the generic functions that a LAN can provide. The most common generic functions of a LAN provide access to spreadsheets, word processors, database management systems. electronic mail. shared files and directories, and printers.

The design team will plan the LAN based on information from the needs analysis and site analysis. The LAN design should provide solutions to the issues identified, and potential and future uses identified during the needs assessment and site analysis. LAN designers will write several revisions before a final design is approved. To reduce the time required to design a LAN, planners can use templates when creating the initial LAN design. This approach allows planners to narrow the list of possible LAN configurations. Rather than research every possible component which might be appropriate for the network, LAN professionals start with a predetermined "good for most situations" network plan which they modify and customize to fit the LAN being designed. It is much easier to build a LAN using this approach than it is to choose every component from scratch [MS Press, 1996].

The following presents a generic LAN configuration for a network with 75 or fewer users:

Network Component/Service	Item Used
Topology	Star Bus
Network Cable	Cat 5 Unshielded Twisted Pair (UTP)
Network Interface Card (NIC)	Ethernet 10BaseT
Hubs	Multi-Port Ethernet 10BaseT
Shared Resources, files. directories. CD-ROMS	˙ Operating systems like Windows 95, and Windows NT that enable peer-to-peer resource sharing in addition to server-based resource control
Network Component/Service	Item Used
Shared Printers	Printers with network cards. LAN computers acting as print servers
Special Purpose Servers/Services	Email servers. fax servers. network modems. Remote Access Servers

LAN Configuration

This configuration provides a starting point for many LANs, but is not the answer to all LAN designs, and should only be used as a starting point. The user needs and requirements will drive the LAN

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configuration even in cases where this preplanned LAN configuration might appear to a good final LAN solution.

Even though planners use a template approach, it is important to remember that LANs are not designed in a "one size fits all" manner. Planners must resist the temptation of pre-maturely selecting specific brands of hardware and software when outlining LAN specifications. Before deciding which manufacturer to use, planners must have a good understanding of what functions the LAN will provide and what specifications must be met. The initial LAN design recommendations should be general in scope, and specific in context. The initial design recommendations give the LAN designer an opportunity to interject personal opinion and speculation as to the potential uses of the LAN. The designer should use previously collected information to support any ideas, and opinions presented in the initial design. The initial design will identify the general LAN configuration as identified below:

Hardware Design	Software Design
Topology	Network (Server) Operating System
Network Cable	Workstation (Client) Operating System
File Server	Special Application Software
Workstations	LAN Management Software
Fault Tolerance	General Function Software

Initial Design Considerations

This initial design is more of an overview of how the network will be configured. As discussed earlier in this thesis each item listed in the table has a specific function and is suitable under different circumstances. In order to determine which network configuration is appropriate for a network, planners must refer back to the user and organizational requirements.

After completing and presenting the initial design, planners must prepare a more detailed LAN design. The detailed design will specify the hardware, software, NOS, OS, and all of the components that will be configured on the LAN. When preparing the specifications for the detailed design, planners will

collect a great deal of information. The following questions provide a template of questions that planners should answer in the LAN design:

* What type of network will be designed. Peer–to–Peer or Server-Based?

* How important is security on the LAN?

* How many users will need access to the LAN?

* How will user access be assigned?

* How many client and server computers will be installed?

* Where will servers be located?

* What network topology will be used?

* What transmission speed is required? 10Mbps or 100Mbps?

* How far apart will network devices be?

* Is electromagnetic Interference a concern?

* What network cable will be used?

* What network interface card will be used?

* What network operating system will be use?

* What client operating system(s) will be used?

* Which network protocols will be implemented?

* What special services will be required?

* Will e-mail be connected outside of the organization?

* What users require access to printers?

* How many printers will be installed?

* Will applications be shared over the network or reside on each workstation?

* How will data be protected from loss or damage?

* How will virus protection be implemented?

* How will servers be protected from power failures?

* What hardware will be used?

What happens if planners neglect to develop a clear plan and fail to address the types of questions that facilitate good LAN design? The following LAN example highlights a few of the most common pitfalls that planners should be aware of when designing a LAN. The data presented in the following illustration was collected in a mini case study of an actual company network. For this example the company name is not disclosed, and a fictitious company name is used.

The ABC Company LAN uses 10base2 (Thin Ethernet) in a star-bus topology. There are 32 personal computers, 3 printers, a scanner and a tape backup attached to 9 LAN segments connected by repeaters. The server uses a Windows NT Network Operating System, and Windows 95 as the workstation Operating System. The server, workstations and Network Operating System are adequate for the LAN's current needs. However, there are many problems with the current system in terms of safety, security and reliability.

Cable locations and placement are the cause of major safety problems. A poorly planned cable layout poses tripping hazards. Cables routed between workstations and bundles of tangled wires left on the floor are in the way of pedestrian traffic. An unused tangle of cable is on the floor in front of a file cabinet, creating a tripping hazard and an unprofessional appearance. Some segments on the LAN are approaching the 185 meter distance limit for 10base2 Ethernet cable. It is difficult to determine the segment length because the cable has many coils and tangles. The cables installed in the ceiling and along the walls is disorganized and twisted. The cable is in danger of being caught in doors or being stepped on, and there are several cable splices on the LAN that are not shown on the network diagram.

In addition to safety problems, the ABC Company LAN is plagued with security problems ranging from copyright violations, to excess user access privileges. ABC Company is guilty of software license violations because the Microsoft Office Suite is shared on the sever, and accessed by all of the workstations. Sharing the application on the network is not the issue, but there is no license metering software installed as required by Microsoft. Furthermore, ABC Company claims to have purchased 35 software licenses, but they could not provide any documentation or proof of purchase for the licenses.

ABC Company has several security problems that network planners should avoid. The server is not in a locked room or controlled access location, and it can be physically accessed by unauthorized personnel. Planners must ensure that servers are installed in an area with restricted access so that only authorized personnel have access to the server. This will reduce the chances that someone could damage the server either accidentally or intentionally. Additionally, the following security problems were identified:

* Guest accounts - The Guest account was given full access to all of the network printers and no password was required. The Guest account had unlimited concurrent logins and access to many resources on the server for no apparent reason.

* Unused accounts - There were several user accounts that had been entered on the server but had never been used and had no password.

* Excess Rights for the "EVERYONE" group - The group "EVERYONE" contained access rights to network resources that were not appropriate for non-staff users of the LAN.

Network reliability is decreased for several reasons:

* Inadequate training - The LAN administrator is not adequately trained.

* Network users are not trained to use the LAN.

* Inadequate procedures and documentation - The procedures and documentation needed for maintaining the server, repeaters and other LAN equipment do not exist.

* No LAN management tools - There are no software or hardware tools to help manage the LAN. Common LAN management tools include protocol analyzers, and inventory/configuration control databases.

* Repeater power supply - The repeaters are located downstairs in a room used by other staff and are powered by the same strip as a user's personal computer.

* No UPS - There is no UPS or other power protection device. If the power is interrupted the LAN will be inaccessible until power is restored and the server is restarted. Without an UPS there is greater chance that a power failure will damage computer equipment.

There are several equipment items that need to be replaced or purchased. The items listed below will help LAN managers increase network reliability:

* Tape Backup - The tape backup (4GB) currently used does not have the capacity to back up the server on a single tape. Tapes are changed manually, which means that the system cannot perform unattended (without human intervention) backups, consequently, someone must come in during off work hours to change the tapes and conduct backups. An upgraded

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tape backup would save time. improve the backup capacity. and eliminate the need for attended backups.

* Cable Tester - There is no equipment to test the cables for reliability or length. Since many LAN performance issues are cable problems. a cable tester could save a great deal of troubleshooting time by helping the administrator identify cable problems quickly.

* Workstation Hard Disks - There are several workstations that do not have enough disk space to install the required operating systems or applications. These workstations are running most of their applications from the server. which creates excessive traffic and network delays. Larger hard drives will allow applications to be run on the local workstations.

* Workstation Memory - Most of the workstations have 8 MB of RAM and this is not enough to run multiple MS Office programs. To run these applications. Workstations should be configured with at least 32 MB of RAM.

* LAN Printers - The LAN based printers are set up as shared printers on user computers. There is no separate print server or printer connection device. If a user is using the computer. print jobs will interrupt the user's work and the user can cause problems with jobs that are printing. Separate print servers will improve printing performance and reduce the chance of a print job being lost.

This example is presented to help planners visualize what can go wrong without proper network planning. The problems identified in this illustration are common LAN issues. that can be avoided with proper planning.

What could the LAN manager of ABC Company do to correct these network problems? Some problems are more severe than others. so how does a LAN manager determine which problems have higher priority. Determining the relative priority of LAN problems will be determined by each organization on a case by case basis. The following list is the author's preference for prioritizing LAN problems:

* Safety problems

* Copyright violations

* Network management. training and security problems

* Network performance problems

* Individual workstation problems

* Network expansion problems

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ABC Company could correct their LAN problems in three phases, immediate, short term, and future expansion. The immediate solution would be to eliminate the safety problems by rerouting cables away from areas that currently cause tripping hazards. Additionally, some workstations can be moved to different LAN segments to reduce the length of cable required and eliminate the need for excess cable on some of the longer runs.

Another part of the immediate solution is to correct the copyright violations with Microsoft Office. As a "quick fix", ABC Company could purchase a copy of Microsoft Office for each user and install it on every workstation or to purchase the required licenses and continue to run Office from the server. This situation requires LAN managers to make an important decision and weigh the consequences of the decision. If they purchase site licenses and continue to run Office from the server as a shared application, they solve the license problem and continue with business as usual, but network performance will not improve. If they purchase individual copies of Office for each workstation, users can run the application from their local workstations, which reduces network traffic and solves the license violations. This option requires that some workstations be upgraded before Office can be installed, so the decision to install additional software will force the need for workstation upgrades to be moved to a higher priority. Whatever decision the LAN managers make should be thought out and planned. Every configuration change can impact some other aspect of the LAN. It is important that LAN managers stay focused on the reason behind the decision, so that the details influencing the final decision do not cause them to lose sight of why the decision is being made.

Short-term solutions to ABC's LAN problems include:

* Provide training for the LAN administrators and LAN users.

* Improve procedures and documentation and establish an area to store hardware and software documentation.

* Improve and document procedures for LAN support and maintenance.

* Remove all user accounts that have no password.

* If an account cannot be password protected, restrict workstation access and limit the number of concurrent logins.

* Restructure group rights to allow proper access for both staff and volunteer accounts.

* Provide a disaster recovery plan to restore operations in the event of a catastrophic LAN failure.

* Install an upgraded tape backup system on the server to allow unattended backups and reduce network traffic. The backup system should be able to store at least 8 GB of data on a single tape and allow scheduled unattended backups.

* Provide LAN management hardware and software that assists LAN managers in solving problems before they occur or to quickly restore service when there is a problem. LAN management tools may include: LANDesk or Equivalent Management System, Cable Testers, Protocol Analyzers.

* Replace shared power strips with a UPS.

* Update workstations as soon as possible to a minimum configuration with enough disk space for local software as discussed previously.

* Use dedicated print servers instead of sharing individual user's computers as print servers.

After identifying the immediate and short-term solutions that will improve the ABC Company LAN, network managers and planners should identify LAN improvements that will facilitate future LAN expansion and long term network solutions. ABC Company should consider the following future LAN improvements:

* Develop an Intranet

* Install LAN-based databases.

* Improve infrastructure by replacing 10base2 cable to 10baseT to improve reliability.

* Move servers and repeaters to a locked room for improved security.

* Upgrade workstation operating system software to Windows '95 or NT to provide for future growth.

The problems discussed in the ABC Company LAN example are common in many LAN implementations, but these kinds of problems can be avoided if LAN planners take the time to assess LAN requirements and develop a clear design plan. Successful LAN design requires time, effort, expertise, and experience. The information contained in this section was presented to provide the reader with a good set of questions and examples of potential LAN design issues. This information will help non-network

professionals formulate additional questions and identify situations related to LAN design that contribute to their LAN design efforts.

E.   IDENTIFY AND SELECT COMPONENTS

After creating the initial LAN design. and identifying the LAN's functions. one of the first implementation decisions that must be made is component selection for use on the LAN. For organizations that have pre-existing cable. network hardware in place. or corporate standard to meet, the choice may be constrained by the need to be compatible with existing equipment. For completely new installations, the choice of network components will depend on several factors. including cost, performance, and compatibility [Gibbs. 1995]. The component selection process is very important because it directly impacts how well the LAN will function and how easy it will be to expand the LAN in the future. When selecting network components. planners must select components based on the outcome of the user analysis and needs. Components should provide opportunity for future expansion and LAN growth. While cost is a factor, planners must be careful not to allow cost to force the purchase of inadequate components that do not meet user needs and requirements. The following questions will help guide planners when identifying LAN components:

* What kind of server will be used?

* What is an appropriate network operating system?

* How much RAM will the server and workstations need?

* What type of hard drives do the server and workstations have?

* What type of video cards will the server and workstations have?

* What types of workstations are needed?

* What is an appropriate operating system for the workstations?

* What is the best cabling?

* What hubs will be used?

* What network adapter cards will be used?

* What printers will be installed?

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*   What types of backup equipment will be used?

*   What type of UPS will be used?

When selecting network components, planners should spend time researching how well components operate in a network environment and identify problems with specific network operating systems and certain hardware components. Vendors should provide a list of the components that inter-operate together in a given network configuration. Planners must ensure that component vendors test and ensure that components work in the network environment, and get a written agreement that the vendor will support the components after they are installed on the LAN.

When attempting to determine which components to use, planners should contact the operating system, network operating system, and vendors to obtain information on specific network components, and how well they work in specific network environments. Network component manufactures produce compatibility information for many of the products that they produce. This information can save network planners time and money by helping them make informed component purchase decisions.

F.   GETTING FINANCIAL BUY-IN

There is more to implementing a LAN than just walking up one day and saying. "Wouldn't it be nice to have a LAN?" In some cases a LAN may not be needed to accomplish the organization's goals. When seeking financial buy-in, it is essential that the LAN proposal be linked to making or saving money. As with any proposal requiring money to be spent and resources to be allocated. LAN implementation requires that a good business case be made in order to get the project approved. The five steps prior to this one enabled planners to identify problems, needs, equipment and design solutions that support a case for or against implementing a LAN. Now the point has been reached where the viability of the plan will almost certainly be based on the financial argument, "does the plan make financial sense for the organization?" [Gibbs, 1995]

Although each organization will take a different approach to providing cost justification for its LAN, there is a common set of rules to follow when presenting the financial case. The following six rules should be used as guidance when seeking financial approval and buy-in for LAN projects:

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* Avoid issues that do not have quantifiable benefits. Just saying that a network will make business more efficient doesn't provide a basis for a yes-or-no decision. The alternative is to say that, for example, turn around on jobs will be 50% faster and job profitability will increase by 25%. This kind of argument will be very easy to agree to, provided the figures are verifiable.

* Avoid technical discussions. Very few people are interested in, or can understand, the technical issues of networking. Keep the proposal grounded in business issues.

* Make sure that time periods are realistic-preferably pessimistic. Don't present an implementation schedule that will be difficult to achieve. Err on the side of caution. (Remember Murphy's Law of Contingent Failure-"If something can go wrong, it will.")

* Keep it relevant. Adding features or facilities that aren't relevant to business not only is of no interest to those who can sign off on the proposal, but it may detract from the perceived value of the system.

* Address reliability and security. Most decision-makers will look for problems that are implicit in a proposal. The possibility and consequences of network failure or unauthorized access need to be considered and covered adequately. For smaller less critical networks, this probably won't be a big issue, but it's still worth addressing in order to ensure that there is a plan for dealing with problems.

* Assess risks. Again, decision-makers are usually not keen on taking risks if they'll ultimately have to take responsibility. As the LAN plans develop identify areas of risk. For example, if a major obstacle occurs during installation, what will the consequences be? How will the project recover from problems? These issues are easily handled if they are planned for and addressed in the proposal.

When presenting the financial case, remember that there are intangible benefits that support LAN implementation e.g. increased morale, competitive advantage, and increased customer and user satisfaction, but it is difficult to estimate the impact of these intangible benefits unless quantitative values can be associated with the benefit. The most effective business argument for a network is one based on money to be saved or profits to be made. Gibb's Golden Rule of Information Technology states "If it don't make money and it don't save money, it ain't it." [Gibbs, 1996]

G.   NETWORK MANAGEMENT

Assuming the network is approved and installed, the next major area of concern is network management. Since the network that will run itself has not been invented, Network Managers must ensure that the following areas of network management are supported:

* User administration- Creating and maintaining user accounts and appropriate security access to resources, as well as conducting user training.

* Resource management- The implementation and support of network resources.

* Configuration management- Planning the original configuration, expanding it, and maintaining the configuration information and documentation. Ensuring that hardware and software standards are set and maintained to ensure network interoperability and ease of management.

* Performance management- Monitoring and tracking network activity to maintain and enhance the systems performance. Tuning the network to achieve maximum performance by eliminating malfunctioning components or upgrading inadequate components.

* Maintenance- Preventing, detecting, and solving network problems.

Daily network management requires that the network administrator perform a variety of activities. Administrators must create user accounts, enforce network security, train users and support user needs. Additionally, the network administrator will update existing software, install new software, and add computers and network devices to the LAN [MS PRESS, 1996]. Protecting data is another area of responsibility for the network administrator. The network administrator must perform back-ups, manage virus software, and other fault tolerance equipment, e.g. UPS, RAID servers.

Network managers must implement policies and take action to ensure the security of both the data and the equipment on the network. Network management requires that the administrator do the "dirty job" of policing the LAN to protect network resources. A poorly managed LAN will quickly become plagued with problems.

IV. CONCLUSION

The Local Area Network (LAN) has become a tool that the K-12 community uses extensively, and educators are working to leverage LAN technologies by implementing LANs in K-12 schools. The K-12 LAN implementation initiative will continue to gain momentum as educators become more technically aware. The MPUSD educators involved in the LAN implementation process gained a great deal of knowledge and understanding of LAN technologies. MPUSD educator's increased level of knowledge is directly related to their participation in the LAN design and implementation initiatives. The progress made in the MPUSD LAN implementation can guide other schools in their LAN implementation efforts.

To be successful with LAN implementation initiatives, educators must gain a greater understanding of LAN design basics. These basics include: hardware configurations, operating system selection, software options, site considerations, and network management. K-12 educators will be key players in on-going K-12 LAN design and planning and will need a good understanding of the basic steps related to network planning in order to design and implement cost effective and useful K-12 LANs.

On the job training alone will not give educators the best chance for success. The results of this research reveal that a combined approach of formal training and on the job experience is the best method for educators to gain a good understanding of how to design and implement K-12 LANs. In order to design LANs that best meet the needs of the users, educators must also be involved in the technical aspects of designing and installing their school LANs.

A valuable lesson learned in the MPUSD effort is that it is less time consuming and less expensive to provide educators with formal training, on the job experience, and adequate resources to enable correct LAN design and implementation, than it is to redesign and reconfigure the LAN.

It is important for network planners to remember that network technologies are constantly evolving, and today's LAN solutions may quickly become obsolete as new technologies are developed. To reduce the chance of designing a system that will be totally obsolete by the time it is implemented, planners should make every effort to identify current and projected future user's needs prior to designing

the LAN. Planners should remain flexible when designing a network, and stay current with technology and industry trends because today's LAN solution can become tomorrow's problem.

While this thesis only addresses a small portion of the information required to bridge the gap between network theory and the actual design and implementation of LANs in K-12 schools, it provides a tool that allows the non-technical person to ask the right questions when planning a LAN. LAN planners must understand that designing a LAN requires more than simply buying a few computers and some network components to implement a LAN. The LAN design process is a time consuming effort which takes a great deal of thought and communication with potential users, managers and network professionals.

LAN design consists of different phases that require important decisions to be made. These decisions determine what resources, material and components will be used on the LAN. These decisions can be difficult for a person who does not have a clear understanding of LAN technology. Technology related issues are important, and equally, if not more important, are the reasons to build or not to build the LAN. What will the LAN be used for, and how will those functions contribute to the overall success of the organization? LAN planners need a clear understanding of the planned uses for the LAN because the network must provide value to the organization, or it will fail to be approved.

This thesis has provided an introduction and step-by-step LAN design template that gives a K-12 educator a starting point to address the main steps in LAN design. LAN planners should follow the steps to appoint a planning and design team, conduct a needs analysis, design the LAN, select the equipment, gain buy-in and support, implement the LAN, and manage the LAN. There are many resources, tools and experts available to help with LAN design and implementation. None of these sources of help will be useful if the organization desiring the LAN cannot communicate what the LAN should be able to do. This guide gives the LAN novice a better chance of being able to communicate with design experts and allows the non-technical person to take an active role in designing a LAN that meets its users' needs.

APPENDIX

ASCII: American Standard Code for Information Interchange
ANSI: American National Standards Institute
BIOS: Basic Input Output System
BPS: Bits Per Second
CD-ROM: Compact Disc-Read Only Memory
CGA: Color Graphics Adaptor
CMOS: Complementary Metal Oxide Semiconductor
CPS: Characters Per Second
CPU: Central Processing Unit
CRT: Cathode Ray Tube
CRC: Cyclic Redundancy Check
CSU/DSU: Control Sending Unit/Digital Sending Unit
DAT: Digital Audio Tape
DIP (switch): Dual-In-line Package
DLL: Dynamic Loaded Libraries
DMA: Direct Memory Access
DOS: Disk Operating System
DRAM: Dynamic Random Access Memory
EGA: Extended Graphics Adaptor
EISA: Extended Industry Standard Architecture
EMI: ElectroMagnetic Interference
EPROM: Erasable Programmable Read Only Memory
ESD: Electro-Static Discharge
FAT: File Allocation Table
FDD: Floppy Disk Drive
FDDI: Fiber Distributed Data Interface
GB: GigaByte
GUI: Graphical User Interface
HDD or HD: Hard Disk Drive
HTML: HyperText Markup Language
I/O: Input/Output
IC: Integrated Circuit
IPX: Internet Packet eXchange
ISA: Industry Standard Architecture
KB: KiloByte
LAN: Local Area Network
MAN: Metropolitan Area Network
MB: MegaByte
Mbps: Mega bits per second
MHz: Megahertz
MODEM: MOdulator DEModulator
NOS: Network Operating System
OSI: Open Systems Interconnection
PCI: Peripheral Component Interface
POST: Power-On Self Test
PPP: Point-to-Point Protocol
PROM: Programmable Read Only Memory
QIC: Quarter Inch Cartridge
RAID: Redundant Array of Inexpensive Disks

RAM: Random Access Memory
RFI: Radio Frequency Interference
ROM: Read Only Memory
SCSI: Small Computer Systems Interface
SIMM: Single Inline Memory Module
SLIP: Serial Line Internet Protocol
SRAM: Static Random Access Memory
TB: TeraByte
TCP/IP: Transfer Control Protocol/Internet Protocol
UART: Universal Asynchronous Receiver/Transmitter
UMB: Upper Memory Block
UPS: Uninterruptable Power Supply
URL: Uniform Resource Locator
VESA: Video Enhanced Standards Association
VGA: Video Gate Array
VLB: VESA Local Bus
VRAM: Video Random Access Memory
WAN: Wide Area Network
WWW: World Wide Web
ZIF: Zero Insertion Force

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