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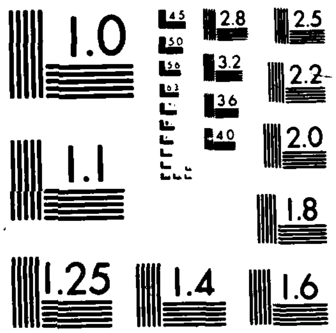
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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A METHODOLOGY FOR CHARACTERIZING
A GENERIC
LOCAL AREA COMPUTER NETWORK

by

Thomas L. Koontz

June 1986

Thesis Advisor: M.P. Spencer

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This thesis established a methodology for a manager of information systems to use when choosing a local area network (LAN) for an organization's computer communications. The methodology proposed describes the various decisions about a network that must be made, and the alternatives available. The outcome of the methodology will be a generic set of specifications for a basic communications LAN that the manager can use to find an adequate network.

This thesis is designed to introduce prospective LAN purchasers to LAN concepts and problems, and to give them a grasp of aspects of LAN technology that need to be considered before a LAN can be purchased. It is not a detailed guide to network engineering and implementation.

This thesis specifically addresses the major elements of the basic communications LAN. The higher level attributes of a LAN including applications, control and outside interfaces are not included.

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A Methodology For Characterizing
a Generic
Local Area Computer Network

by

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Lieutenant, United States Coast Guard
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ABSTRACT

This thesis establishes a methodology for a manager of information systems to use when choosing a local area network (LAN) for an organization's computer communications. The methodology proposed describes the various decisions about a network that must be made, and the alternatives available. The outcome of the methodology will be a generic set of specifications for a basic communications LAN that the manager can use to find an adequate network.

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I. INTRODUCTION

A. BACKGROUND

In the early sixties computer use was more or less limited to large batch processing jobs done on large data processing computers in centralized computer centers. Office automation consisted of an electric typewriter and an occasional dictaphone. Telecommunications was a voice telephone call, a telegram, or teletype message.

Today elementary school children are using computers to learn how to read, write, spell, add, and to program the computer itself. Some of the world's fastest computers are being used to examine worldwide weather and climate patterns and to solve engineering problems that could never have been solved ten years ago. Office automation now includes word processors, electronic mail systems, and micro-computers that sit on desks and provide a wide variety of decision support tools to users. Telecommunications may allow a user to send a file across a room over a pair of copper wires, or a letter across the world via a satellite link. The growth in these areas has been faster than any other technologies the world has ever seen. For a manager to stay current in almost any field he must become familiar with these technologies.

A manager concerned with information systems (IS) must be concerned with the management of data processing , tele-communications, office automation and the inter-relationships among the three. Today computer networks use all three technologies and can provide the link between them. A computer network is a collection of computers and related devices that can share information with each other. They may be used to link large computers to other large computers, small computers to large computers, small computers to each other, or any computers to related peripheral devices or computer controlled machinery. A network may stretch around the world or across a desk, and it may include three devices or three thousand.

There are numerous advantages to be gained through the use of computer networks. The work performed by central data processing computers can be distributed over a network to all appropriate users. This information can be delivered to the users' desks via their electronic mail or word processing equipment. Users at various locations can also provide data from their stations into terminals and over the network to the central data processing environment. The distributed office automation users and the central data processing users can use the network to gain access to other networks and services normally outside their own computer network by using various telecommunications links and services available to both their own network and to those that they wish to contact.

A local area computer network (LAN) is a high speed computer network limited to a small geographic area, such as a building, campus, or office complex. Since it is limited to small distances the network is able to attain higher data rates than a long haul network is able to. The limited distance usually allows the entire network to be bought, used and managed by one agency or division, in contrast to a wide area network where one of the major tasks may be the coordination of all the various organizations wishing to manage and use the network.

The reasons for needing a local area computer network are varied. An organization may find that the price reduction of available computing power has caused a proliferation of desk top computers and an insatiable demand for peripheral devices such as printers, modems, optical scanners, and mass memory storage devices. These devices can still be relatively expensive. A local area network allows sharing of these devices so that more users have access to them. These devices that may remain idle much of the time when dedicated to a single user can now be used much more efficiently when shared among many users.

A unit may find that as more small computers are being used it's information base is becoming fragmented. All the data exists and has been stored electronically, but the task of consolidating that information into a form that can be used has become monumental. A network will allow that information to be shared, compiled, and consolidated either automatically or at least remotely without a physical visit to each workstation.

The local area computer network makes decentralized computing with some centralized control and access possible. Every user can schedule his own computing resources and tasks and still have the access to central resources and information that he requires. The network can be controlled to regulate this access to information and resources so the conflicting goals of easy access and security can both be achieved with some reasonable balance between the two.

Local area network technology has evolved into a useful and viable information system management tool. A tool which can be used to manage an organization's information more effectively and efficiently than ever before. Before a manager can use this technology some tough decisions must be made.

B. THE PROBLEM

When a manager responsible for information systems in an organization determines that the organization has some need to link it's computing devices together, decisions must be made about how they can best be linked. For the purposes of this thesis it is assumed that the decision has already been made to use a LAN. Once this major decision has been made the selection process has just begun. All it takes is a glance at the advertisements in any computer or business magazine to realize that the variations of LANs are seemingly endless.

The manager has already eliminated many other possibilities to decide that a local area network is at least part of the solution to the organization's problem. The decision has been made that computers and related devices have to be interconnected in a limited geographic area. This indicates that long haul networks are not needed, at least not for this particular phase of the project. It has been decided that private branch exchanges, PBXs, are not right either because they are too slow, too vulnerable, or don't meet the organization's needs as well as a LAN. On request data transfers through dial up modems or simple floppy disk transfers are also not considered adequate solutions for the problem at hand. The manager has decided that a local area network will provide all or part of the computer communications needed by that organization. These other types of computer networks mentioned may also be needed in conjunction with one or more LANs and they should all be planned to interconnect, but that subject is beyond the scope of this thesis.

A requirements survey of an organization should provide a list of needs for a manager to work with. Using this list of requirements a manager must be able to choose the right local area network for that organization. In most cases where a local area network can be used it is not reasonable to assume that a manager will have the resources and time to have a local area network designed from it's basic components. Instead a network usually must be chosen from offered technologies. Choosing from among these offerings to come up with the best solution to meet the organization's needs is the real challenge for a manager.

Any manager who needs to choose a local area network will be overwhelmed by all the different possibilities offered by numerous vendors of hardware and software. There must be some way to choose which LAN is right. Once the manager has a set of general specifications for a network the various alternative networks matching those specifications can be explored. First the manager must know what kind of specifications are needed, and how to decide what those specifications are to be.

The manager wishing to buy a system has no clear guide to step through the various network attributes to arrive at a good general set of specifications based on the organization's needs. This thesis will provide a manager with a methodology to arrive at that set of specifications, while also providing some insight into the various components that make up a local area computer communications network.

Before the methodology recommended later in this thesis is used to help solve the problem of choosing hardware specifications for a physical computer network, the user must decide if there really is a problem in the context of that methodology. If the applications and functions to be performed over the network limit it to few nodes and slow speeds then almost any network will be able to do the job. Or if the user's needs are below the minimum capabilities of all LANs, the choice of LAN can be based on other factors than those addressed in the decision methodology. A network of a few microcomputers that all have the primary need to access the same central disk server may not even need all of the speed capability of the slowest LANs. If the bottleneck in the network is not the network itself, but some vital node on the network, the speed capability of the network becomes an irrelevant factor in the choice of network specifications. As a general rule a LAN with almost any set of generic specifications can handle up to eight nodes at speeds greater than 1.0 megabits per second (Mbps), over a range of up to two or three kilometers [Ref. 1: p. 61]. If the user's requirements are less than these minimums, and a LAN is still desired, the choosing of LAN specifications for the physical network is not a real problem. Almost any LAN can meet the user's requirements, and other factors, such as cost, or ease of installation can be the primary considerations when choosing the physical network.

The potential LAN user must know what limitations her applications place on the network before using the decision methodology of this thesis. The methodology presented here will not address any specifications for a LAN at the application level of the network. Instead it is designed to help a user choose specifications for a network which will pass data from one node to another in it's basic bit form. What is done with the data after it has been physically passed over the network is not addressed by these specifications. The application specifications of a network and it's software are a separate topic from that which is covered here. A potential LAN buyer should realize that these application specifications must also be chosen before a useable network can be obtained as a total LAN package of hardware and software.

The person choosing physical local area network specifications must have some knowledge of the different attributes available in a network. She must know about topologies available, transmission methods, media, access methods, and protocol requirements. She should know enough about what possibilities exist for each of these attributes so that she can choose among them, but not so much that she is drowned in a sea of numbers, diagrams, and details that do little to help decide on the relative merits of each alternative. This thesis will outline those possibilities and recommend a method for choosing among them.

After a set of generic specifications has been obtained those specifications must be matched against available products so that an actual physical LAN can be acquired and installed. Some of the additional considerations that must be made during this process will also be outlined in the thesis.

II. MAJOR ELEMENTS OF A LOCAL AREA NETWORK

A local area computer network is made up of nodes and links. The nodes may be small or large computers, printers, MODEMs, mass memory, remotely controlled tools, sensors, or a variety of other computer controlled or monitored devices. The nodes may or may not contain the control devices for the network. The links can be copper wire, coaxial cable, air, optical fiber or anything else capable of carrying electronic transmissions. The links may or may not include the interfaces to the nodes, the network control and the transmitting devices.

The way in which these nodes and links are put together and used will describe the LAN. The major elements that make up the LAN are:

- The topology of the network
- The medium used by the network
- The method of transmitting signals over the network
- The network access method
- Standard protocol requirements of the network

These major elements describe the communications network.

A. TOPOLOGY

The topology of the network is the way in which the network is physically layed out. It will determine which devices are directly connected with other devices and which are indirectly connected. The topology can provide for a more robust and secure network and it can determine where the network control resides. The topology used may limit the available choices of medium, access methods, and transmission methods. The primary topologies available today are ring, bus and star. In the United States ring and bus networks dominate the LAN market and star topologies are used more for private branch exchanges (PBX) or computer branch exchanges (CBX).

1. Ring

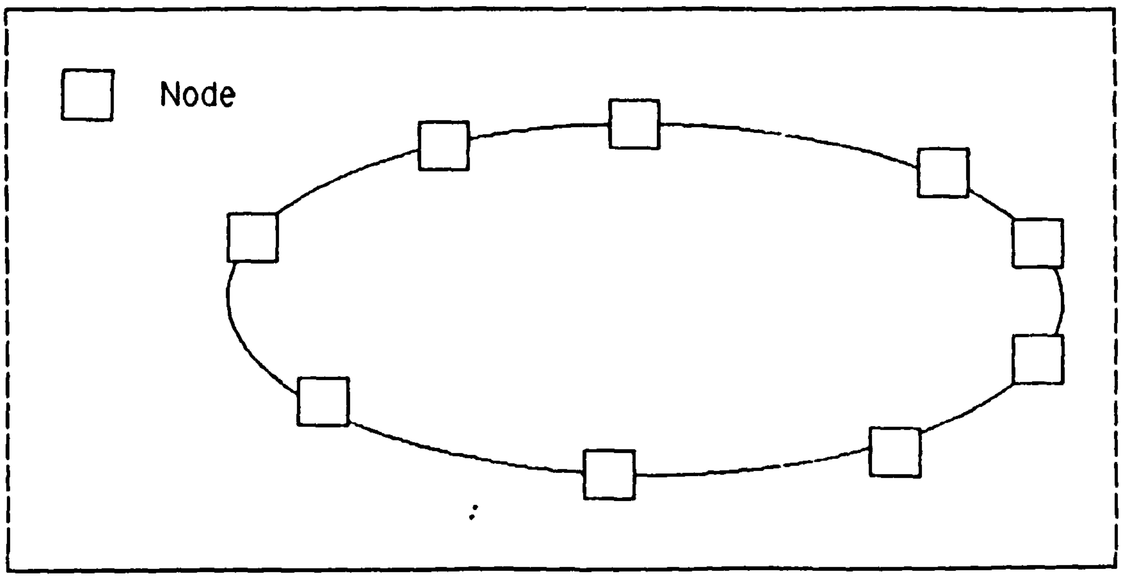

Figure 2.1 Ring Topology.

The ring topology is a chain of nodes and links attached together to form a continuous ring as shown in

Figure 2.1. In a ring each node acts as a repeater for the network. They time share the ring to get their information onto the network. At each node the block of data is received, processed for possible local use, and sent on to the next repeater or discarded as appropriate. This provides all nodes a chance to review all data, and regenerates fresh transmissions at each node, which helps to overcome compounded losses of data due to attenuation over the connecting links.

In a ring the links between the nodes are only transmission paths. The network control is not part of the links but instead is distributed among the nodes. It is possible for the network control to be performed in a separate node designed especially for control. A ring with this type of central control is said to have a loop topology [Ref. 2: p. 37].

Networks with a ring topology require small amounts of link medium for the entire network, can be relatively inexpensive, allow simple routing plans, and are easy to install. They are very susceptible to damage or failure at any of the nodes. If one link is broken, or one repeater fails the whole ring is disabled until that node or link can be repaired or physically bypassed. Redundancy can be built into the network but that redundancy will offset some of the advantages of the ring that it was chosen for. Since all the nodes of the ring time-share the whole network it is limited in the number of nodes it can accommodate.

2. Star

A star topology network consists of a central node connected over bi-directional links to outlying nodes as shown in Figure 2.2. This central node is the network controller and the switching hub for all the nodes of the network. The outlying nodes no longer have to be repeaters, they share the same link for incoming data addressed to them and outgoing data they send out. The control is now removed from the nodes, and resides in the central connector which can be considered as part of the links.

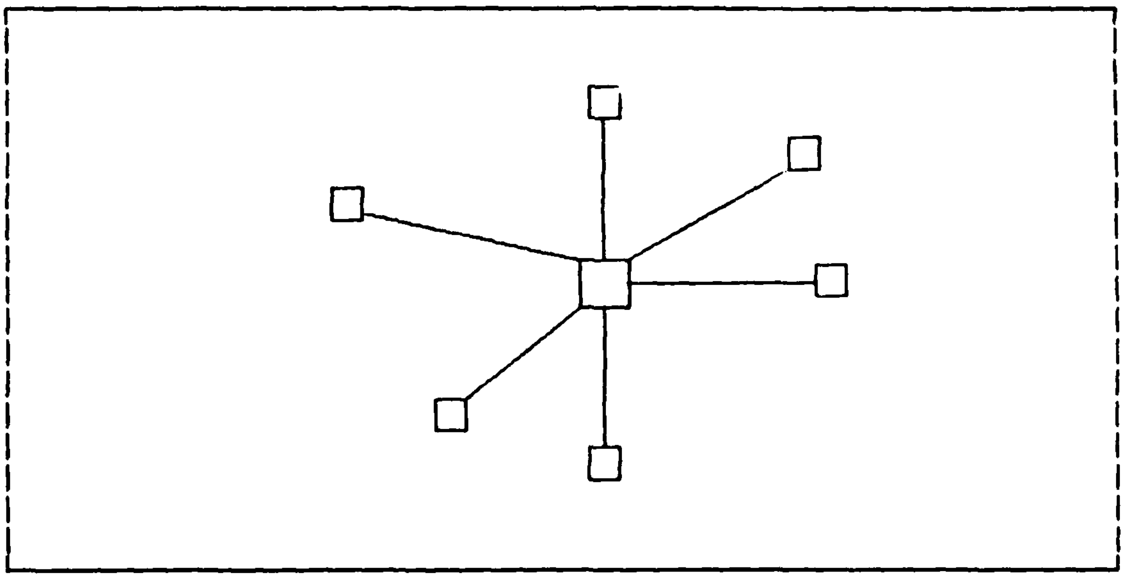

Figure 2.2 Star Topology.

If a node or it's links are damaged or inoperable the star will still function for all other nodes in the network. If the hub is capable of multi-tasking the nodes may all be able to use the network at the same time. Many existing business phone systems already have a type of star network for their internal system of phone lines. This phone system may have the capability to be expanded to carry data in addition to voice calls. For some users this solution to the network problem may be preferable to a LAN.

Making one central controller responsible for the operation of the entire network replaces the node by node vulnerability of a ring with a single point vulnerability. If the controller malfunctions the entire network is out of commission and no bypasses can be made. A redundant controller may be added to backup the first, but the expense of obtaining a spare for the single most complicated part of the network may be considerable. In some star networks, where the central node is a simple and inexpensive switching device, keeping a spare central node on hand may be an acceptable risk avoidance technique. Another added expense in a star network is the extra wire needed to connect all the nodes to the hub from where ever they are located.

3. Bus

A bus is an unclosed link with nodes attached along it's length. As shown in Figure 2.3 the nodes off the bus are not an integral part of the bus and do not need to act as repeaters of data for the data to flow through the network. The failure of a single node will therefore not impair the operation of the entire network. Information may move in either direction along the bus and will be sampled by all nodes on the bus so that they can determine if it is addressed to them.

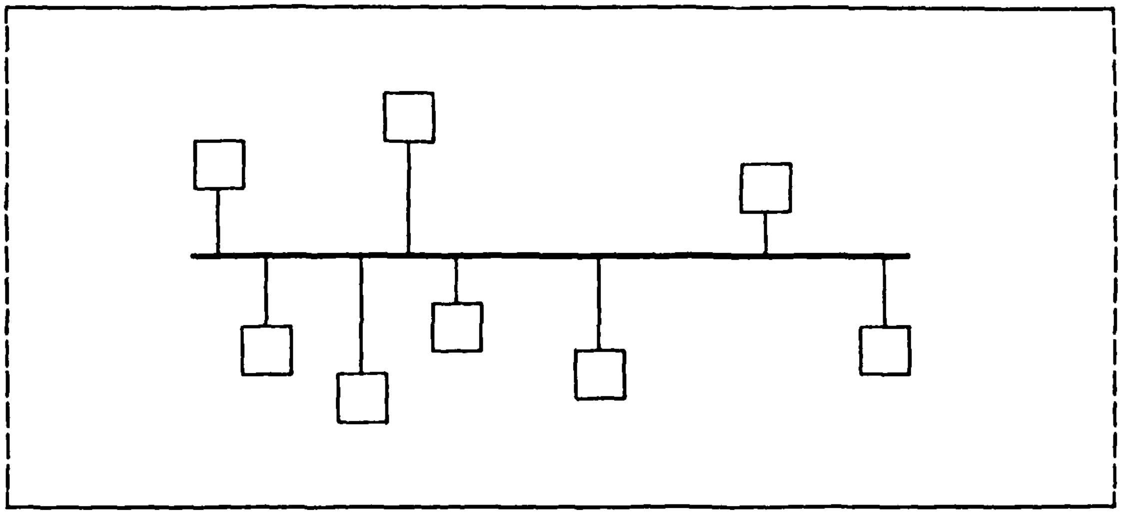

Figure 2.3 Bus Topology.

One node's data exclusively occupies the whole bus channel, so any access to the bus must be carefully controlled. Central polling, a logical ring setup, or a deterministic contention based access scheme may be used on a bus topology. Access methods will be outlined later in this thesis.

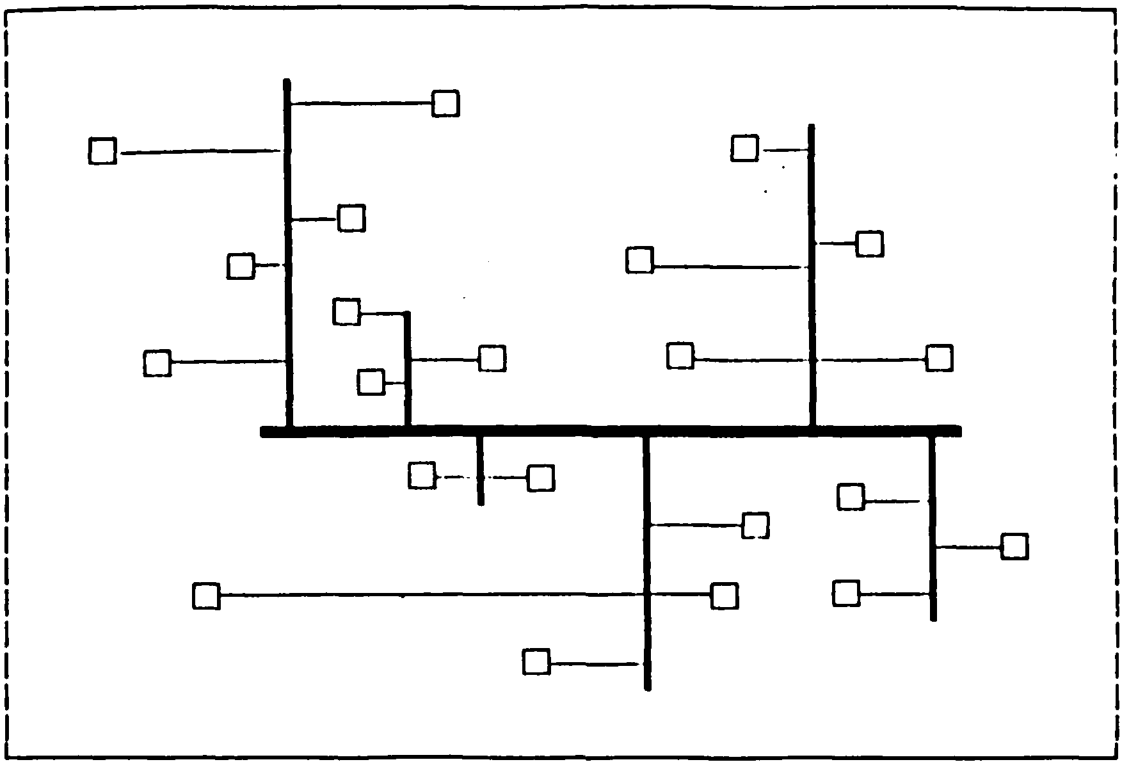

Figure 2.4 A tree topology is a modified bus topology.

A tree like the one drawn in Figure 2.4 is a special case of the bus, where several buses may branch off of the main backbone bus. Again the information put onto the tree is broadcasted throughout the entire network for all nodes to sample.

4. <u>Other Topologies</u>

Other possible topologies include combinations and variations of the above topologies as well as another type of topology called a mesh or matrix topology. A mesh or matrix topology is merely a set of direct node to node connections for any nodes that need to communicate with each other. As the mesh in Figure 2.5 shows, it can be quite a complicated network for more than a very few nodes. The complexity and expense of making all the permanent connections necessary for a matrix topology rules this one out for almost any application.

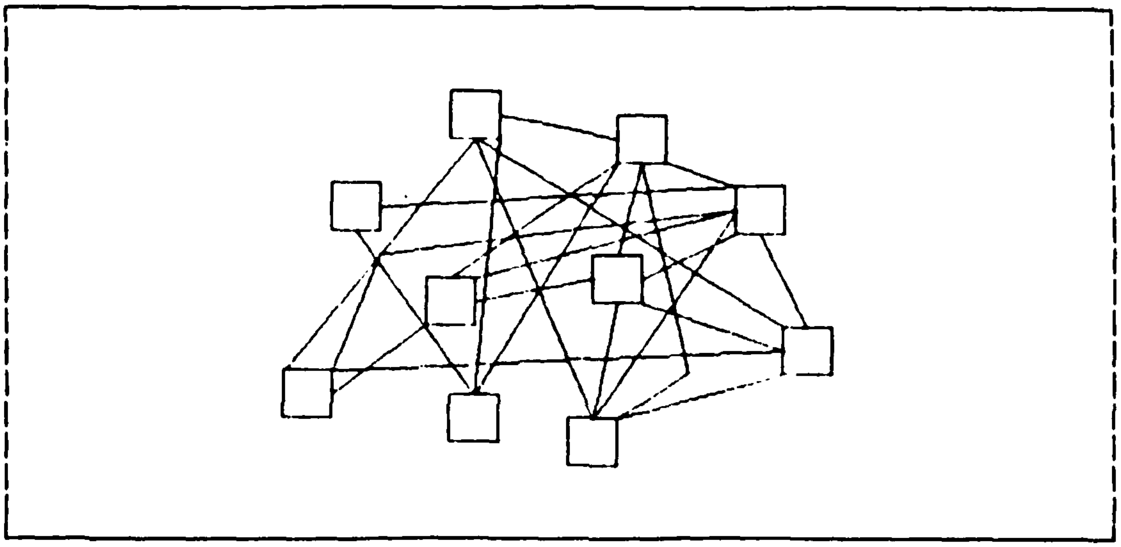

Figure 2.5 Mesh or Matrix Topology.

One possible combination of network topologies is a ring and star. The simple ring can have it's links drawn into a central switch which will monitor the connections and provide a bypass of any bad link so the network can continue to operate. This approach does not require a very complex central node and still does away with the vulnerability of a one-fail, all-fail ring. The central hub is no longer the complex switch which must connect one node to another dynamically, instead it just passes information from one node to the next in line, bypassing bad nodes.

B. MEDIA

The medium of the network is the physical conduit used to carry the signal representing information through the network. Although lengths of wire of one type or another are the primary media available there are other alternatives. The wire media most widely used is either coaxial cable or twisted pairs of copper wires. Some non-wire media are optical fibers carrying light pulses, and microwaves or infrared light waves travelling through the atmosphere.

1. Twisted Pair

A twisted pair of insulted copper wires is one of the most common mediums used for signal transmission. Most telephone connections for short and long distances are over twisted pair bundles. This medium has rather high attenuation and low available bandwidth. This limits both the speed and distance of transmission for point-to-point connections. To carry signals over longer distances the network must have repeaters for digital signals or amplifiers for analog signals.

2. Coaxial Cable

Coaxial cable is also a two-wire transmission medium. It has one of it's wires surrounded by the other with an insulation layer in between the two. Coaxial cable may also carry analog or digital signals. It can carry information faster than twisted pair and has a wider available bandwidth. Coaxial cable does not attenuate as much as twisted pair and can have repeaters or amplifiers spaced farther apart. Coaxial cable is more expensive than twisted pair but is also more versatile. It is a well known medium and is already a mature technology due to it's widespread use in cable television applications.

3. Optical Fiber

Optical fiber is a fairly new entry into the transmission medium market. An optical fiber is a thin piece of light refractive material that passes light rays down it's length. Optical fiber is very fast, is not disrupted by electro-mechanical interferences, and has low attenuation. It can transmit signals unboosted for much greater distances than any wire medium.

Optical fiber is still a relatively new technology and it is expensive. It is very hard to tap an optical fiber link, which makes it better suited to long point-to-point connections rather than multidrop connections. Although the problems are being worked out and the price is coming down, optical fiber is still not widely used for most LAN networks.

4. Other Media

Other media can be used in local area networks. Microwave systems can link networks in different buildings or towns together. Infrared transmitters may also link separate networks together although they are more susceptible to interference from weather or physical blocking. Infrared links are also used in open office environments where the transmission paths can be placed high enough so that they pass over the heads of employees', and above the partitions in the office. These methods may be easier to maintain and cheaper to install than other mediums, but they are generally special case solutions and not widely used as internal LAN links. They can however be good point-to-point inter-network connections between buildings and across open areas. [Ref. 1: pp. 66,67]

C. TRANSMISSION

According to William Stallings [Ref. 3: p. 29], "Transmission is the communication of data by the propagation and processing of signals." In this context there are two ways to transmit, analog or digital. With digital transmission discrete binary signal pulses that represent data are sent over the medium. Analog transmission sends a continuous stream of varying voltage amplitudes as the signal which cover a wide range of values rather than the discrete on-off pulses of a digital signal. The processing takes place at both ends of the transmission path. At the sending end the processing converts digital data to analog signals, and at the receiving end transmission signals are converted back into a form that the node can use.

A concept that is related to the type of transmission used deals with the sharing of the medium by different nodes. The basic premise behind computer networks is the sharing of resources. The network must be shared as a transmission path. This sharing is accomplished through multiplexing of some kind. The medium is either time shared by allowing different signals on the medium at different times, or frequency shared by dividing the entire bandwidth of the path into concurrently used channels of smaller bandwidths which can pass different blocks of information alongside each other. The former method is referred to as time division multiplexing, TDM, and the latter as frequency division multiplexing, FDM. An analog transmission signal can be used with TDM or FDM while a digital signals may only use TDM.

The terms baseband and broadband are frequently used when discussing LANs, usually with bus topology LANs. Baseband describes networks which only use one transmission channel on the medium. It is usually a digital signal although analog may also be sent. Since only one signal uses the path, FDM is not used in a baseband system, TDM may be and usually is. Baseband is simpler to use since modulators and demodulators at either end of the link do not need to work in multiple frequencies as they must with a system that transmits at various frequencies. A baseband signal propagates in both directions from the transmitting node.

A broadband transmission path carries a modulated analog signal. The data is converted to an analog signal before it is placed on the transmission path. This allows FDM on the medium, and TDM is possible on the individual paths created by the FDM. Complementary modulators and demodulators, *MODEMs*, must be at every node wishing to access the data. These MODEMs must be capable of handling the various frequencies used by the FDM. More channels can be allocated from the bandwidth as the need arises. This provides versatility for the medium, and adds to the complexity of the system. Each new channel added to the path reduces the capacity of the existing paths to carry data.

D. ACCESS

The access method used on a network determines how information is placed on the network links from various nodes around the network. There are two broad classes of access methods, deterministic and probabilistic. Deterministic methods are those in which the availability of the network to any node can be determined in advance. Deterministic methods include polling, slots, register insertion, and token passing. [Ref. 4: p. 106] A probabilistic method is one where the access can not be determined in advance, only the probability of access, since there are not firm rules to ensure that all users will get access to the network within a period of time. Broadcast ALOHA and it's variations, carrier sense multiple access (CSMA), and CSMA with collision detection (CSMA/CD) are probabilistic access techniques. [Ref. 5: pp. 75-79]

1. Polling

Polling is a method where a central controlling node in the network polls each node of the network to see if it has any data to send over the network. Polling requires a complex central node which is capable of controlling the whole network. It is a simple scheme for the nodes, they don't speak unless spoken to.

Polling is inefficient if it is being used in a very busy network. The overhead needed for sending the poll out, and getting the reply back seriously cuts into the resources of the network that could be carrying data. The polled node is, by definition the only node which may transmit on the channel at one time. This also may waste the network resources if there is room for more data on the path than the polled node is sending.

2. Slots

This method has the network links divided into discrete slots of a fixed length of time. The time slots move through the network allowing nodes to place information in them. Each slot has some overhead associated with it so that it can be marked as available or full, and so it can have addresses and acknowledgements stored with it. As a slot passes by a node that wishes to transmit the node checks to see if the slot is available and seizes it if it is. The node then marks the slot as full and inserts it's data into the slot. The receiving node marks the slot with an acknowledgement, and as the slot again passes by the original sending node the sending node marks the slot as clear and passes it on so that the next node may have access to the slot. This rotation of slot access assures that all nodes will have access to the network if it is functioning properly.

This slotted access is generally used on rings, where the slots can rotate around the ring. It is a very simple method to employ. On a ring which is not used by very many nodes at once a lot of empty slots may be rotating past a node which has several slots of data to send. This node is restricted to only sending one slot at a time even though the others are available. The slots are of fixed size and the nodes must break their data up into the right size for the slots. These two factors can make a slotted ring network highly inefficient in some circumstances.

3. Register Insertion

Register or buffer insertion is primarily a ring access technique. Each node is a repeater which has a register as part of the ring structure. As data goes by a node it is shifted into one end of the register bit by bit. The node reads the data as it comes in and acts on it based on it's address and other overhead bits. The node either captures the data and passes it on, captures it and purges it from the network, or simply passes it through the register and back onto the ring bit by bit through the other end of the register.

If a node wishes to insert data onto the ring it waits until the register is empty and loads it's data into the ring register from a parallel register of the node. This new data is then shifted out of the register the same way any other data is. As more data comes in from the ring it can be processed and sent out behind the newly generated data. If no new data comes into the register the node may continue placing it's data into the register for output onto the ring.

Register insertion allows variable lengths of data to be placed on the ring, and also allows more than one section of data to be on the ring at a time. This allows good utilization of all the ring. Maximum lengths are set so that one node doesn't monopolize the ring by getting to it first. Proper addressing is extremely important so a node can purge the data at the proper time. A damaged address in the ring may allow a block of data to circle indefinitely, tying up the network. Some sort of external mechanism is needed to insure that damaged data blocks are removed from the ring.

4. Token Passing

Token passing, like polling, is a means by which the entire network is allocated for the use of one node at a time. A token, which is made up of a unique bit stream, moves through the network passing by each node. In a ring the token will circulate past each node in order as it travels around the ring. In a bus the token will be passed from node to node in a predetermined order. In both, priorities may be set to make some nodes more equal than others when gaining access to the token.

As this token passes by it acts as a signal to any node seeing it that the network is free. The node can then seize the token and send a variable amount of data out onto the network. Although the amount of data is variable it is limited by the size of the network. If the end of the transmission is interrupted by the beginning of the transmission coming back around on the network again there is too much data in the transmission. When the start of the data arrives back at the sending node, with or without the proper acknowledgements, the sending node replaces the token on the network for potential capture by the nodes downstream.

This token passing allows variable length message blocks on the network, but only one block of data from one node at a time. If a token gets lost, destroyed or scrambled there must be some scheme to get a new token generated on the network. There also must be a way to initially generate the token upon system start up, and a way to prevent two tokens from being on the network at the same time.

5. ALOHA

This method for access to a channel is a free-for-all technique. In it's roughest form ALOHA allows any node to transmit at any time it desires. If two or more nodes try to transmit at the same time a collision occurs and all messages are destroyed. The sending nodes wait for an acknowledgement from the destination (The acknowledgements are also subject to collisions) for a set period of time. If no acknowledgement is received the data is retransmitted. This method has obvious drawbacks. A node may be almost through sending it's block of data when another node starts transmitting and a collision occurs, invalidating both transmissions.

To overcome the problem of overlapping data collisions slotted ALOHA was developed. Slotted ALOHA divides time up into discrete transmitting slots where all transmissions must start at the beginning of the slot and end before the slot does. This forces the data blocks to either totally overlap or not collide at all. This doubles the chance of a node getting through the network, although with any moderate load there will still be many collisions [Ref. 3: p. 294]. Slotted ALOHA requires precise synchronization between all nodes to coordinate slot divisions of time. Slotted ALOHA is still a fairly simple access method although it is almost useless when any moderate to heavy load is offered to the network.

6. CSMA

Carrier sense multiple access, CSMA, is an improvement on ALOHA technology. CSMA allows a node to listen to the network before it transmits. If no other transmissions are sensed on the network the node can then transmit. This process eliminates some collisions, but two nodes can still start transmitting at the same time. The synchronization of slotted ALOHA is not necessary here, and the same advantages are gained. Distance between nodes has a great influence on the success of CSMA since a node's transmission will not be noticed for some time by another far away node. The sending node still waits for an acknowledgement from the destination, and re-transmits the data if none is received in a set period of time. That period of time may vary for different nodes so that the same collisions do not occur again.

If a collision occurs early in the transmission of a data frame the sending node still ties up the network by transmitting the rest of the message, even though it is now invalidated by the early collision. This tying up of network resources for an already useless message costs the network some valuable time which could have been used by other nodes and their transmissions. To overcome this problem a variation of CSMA was developed. CSMA with collision detection, CSMA/CD has a node send out it's data after listening for a clear spot, and then it continues to monitor the network while it is sending. If any collision is then detected on the network the sending nodes immediately cease transmission and try again later. This frees the network up for other signals right away. The time between collision detection and re-transmission still varies from node to node and has a degree of randomness so that the same data sets are not likely to collide with each other again. This method is more complex than other ALOHA variations but it is still relatively simple and a workable scheme for accessing the network under light to moderate loads. CSMA/CD is also dependant upon distances between nodes, and still performs poorly under heavy load requirements.

E. PROTOCOL STANDARDS

A protocol is the set of rules which tell the network how data is to be passed through it, and tell the nodes how they can use the network. There is a generally accepted hierarchy of protocols that has been adopted by the International Standards Organization (ISO). This is known as the Open Systems Interconnection (OSI) model. This model establishes a framework for protocol standards to be used for data communications. The OSI model does not define the standards, instead it outlines what the standards at various layers defined by the model should address. It requires all standards to be compatible with any standard above or below them. This is to insure that the standards at one layer can be developed and implemented independently of standards that may be used at other layers.

The ISO's model is divided into seven layers. At the lowest level is the physical layer. The physical layer includes specifications for the basic links, such as voltage levels, signal types, and connections used. Level two is the data-link level. It defines how the data is to go onto the network, including format and error handling at the level of the signal itself. For the physical LAN these first two layers are the primary concern for choosing the hardware of the network. [Ref. 6: p. 109]

The higher levels are concerned with routing of data packets, flow control, end-to-end message flow, session controls, displays, and applications. These higher levels are not concerned with the network as a communications path, but with the information being passed over it. Standards at the first two layers allow a data package to be passed from node A to node B. What happens to that data once it has been delivered is addressed in the higher levels of the hierarchy. These higher levels also address the interconnection of LANs to each other, and to other types of networks or systems. Consideration of these higher layer standards must be made when deciding how the machines attached to the network are going interact with each other. The consideration of these higher levels when choosing the network are beyond the scope of this thesis.

Although there are many vendors offering different protocols that allow the network to perform it's functions, there are some established standards consistent with the OSI model. At the physical layer there is the IEEE 802.3 standard for CSMA/CD networks; the IEEE 802.4 standard for token bus networks; and the IEEE 802.5 standard for token rings. A fairly successful commercial network standard is the Ethernet standard. The Ethernet and IEEE 802.3 standards are very similar and often are considered the same standard. The dominant standard at the link layer for LANs' is the

IEEE 802.2 standard. This standard is of course compatible with the layer one standards for LANs. [Ref. 7: pp. 245,246]

III. DECISION METHODOLOGY

When choosing a LAN a manager has many different priorities and requirements to consider. With the assumption that the requirements are already determined, those requirements must be matched to a series of choices and finally specifications. This chapter will suggest a framework for organizing those choices and comparisons, and outline some of the possibilities in each category of decision.

The manager looking for a LAN has a set of requirements that must be satisfied. Some of these requirements may be:

- System and node cost
- Node to node speed required
- Number of nodes to be allowed
- Distance between nodes, and total area covered by the network
- Type of nodes (open system or compatible nodes)
- Type of data (short and bursty, long and continuous, infrequent blocks,. . .)
- Intensity of use

Some of these requirements will need to be met by the higher layer protocol standards available to the hardware system. A potential network user must make sure that the hardware will support those needs at the lower protocol layers as described in Chapter 2. Several of the requirements directly influence the network choices at the lower two layers of the hierarchical OSI model.

The potential owner of a LAN must not only consider the choices outlined in the following chapter, he must also consider the broader information management applications that his network needs. The whole network will be a combination of the physical LAN, and the system that is being operated over that LAN.

The choices that a manager must make to choose the right local area computer communications network specifications are obviously closely related to the major elements of a physical LAN as described in Chapter 2 of this thesis. The choices must be made about topology, transmission method, access method, transmission medium, and standards to follow in order to arrive at a good set of specifications for a generic LAN. These specifications will not be for a specific LAN, but for a general LAN that may be offered in various forms by different vendors. Other choices will have to be made about the network's software that actually runs the higher level network applications of a network, but these other choices are outside the scope of this thesis.

In making the necessary choices a user will find that every decision made has an impact on future choices that are to be made. This cascading affect may have a negative impact on the decision process if the choices are not considered in the right order. Instead the decision process should form a logical tree of decisions, where each step narrows down the available decisions still to be made in a way which will get the user to the optimum set of specifications with a minimum number of steps and option comparisons [Ref. 8: p. 3].

The first decision to be made should be the one that impacts the most on the availability of the remaining choices. The topology will determine the access methods, mediums, and transmission methods that can be used on the network. Topology is the logical first choice to make in this process.

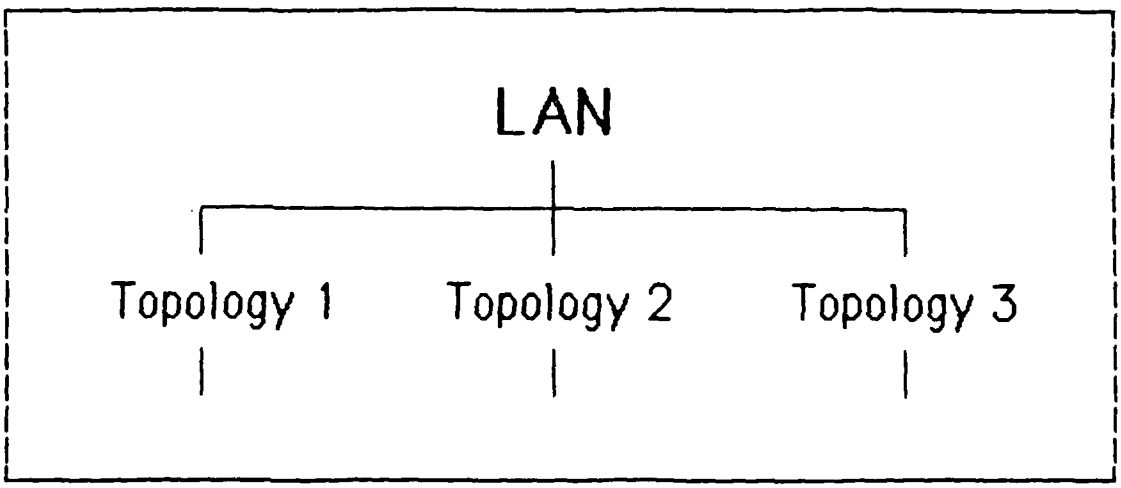

Figure 3.1 The decision tree, first decision.

Once a topology has been determined the other choices are limited. The choice of a medium will limit the available transmission options and impact on the factors affecting the choice of access method. The medium decision can clearly be followed by the choice of a transmission method to use in the network.

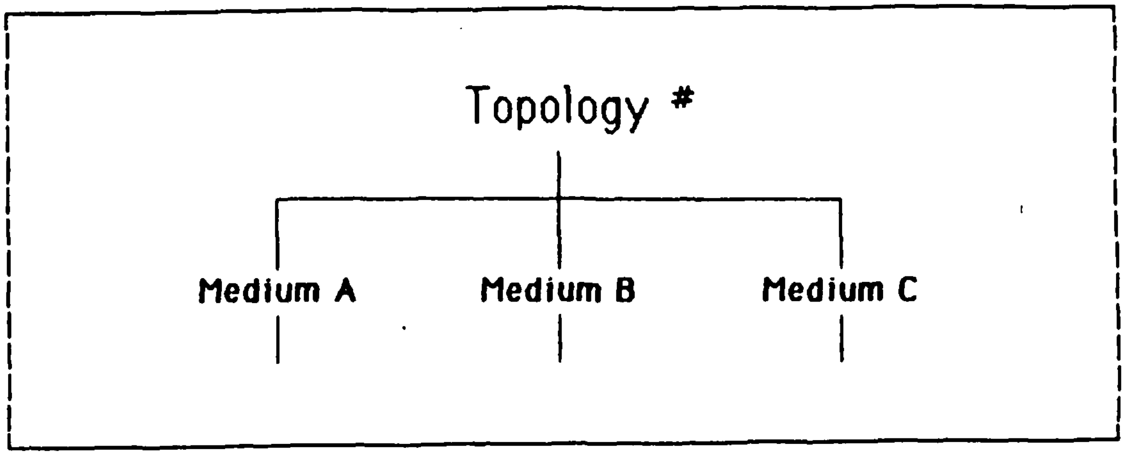

Figure 3.2 The decision tree, second decision.

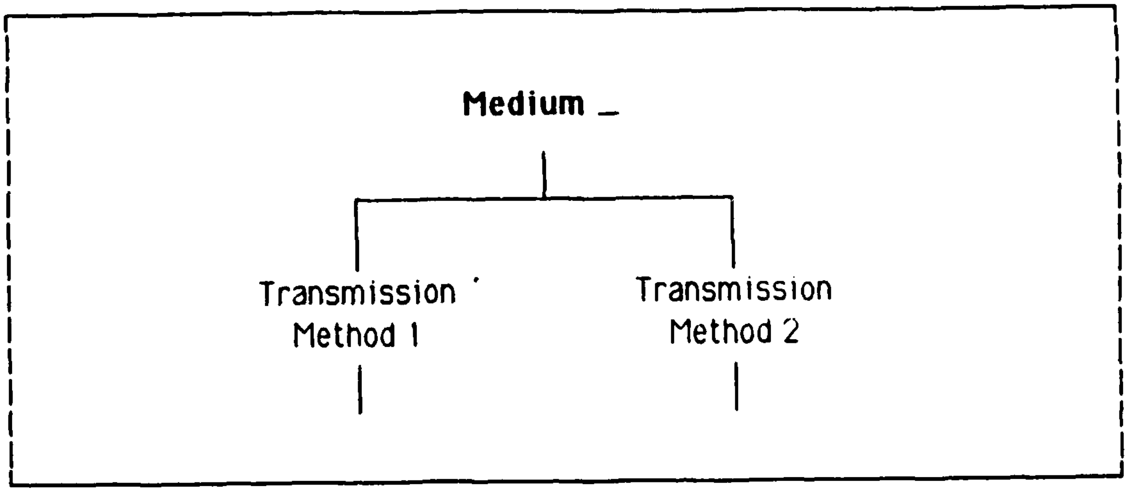

Figure 3.3 The decision tree, third decision.

The access method to be used can then be chosen after the other constraints of the network have been chosen. Rather than force the network hardware into a particular access method that was chosen in advance, this sequence of steps allows a manager to choose the access method that maximizes all of the network resources that have already been determined to be best for his requirements.

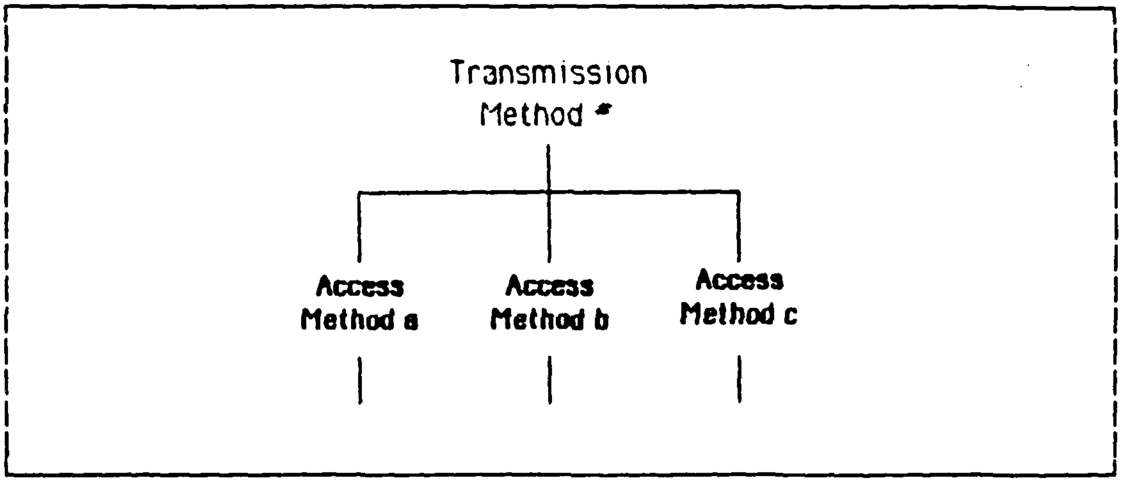

Figure 3.4 The decision tree, fourth decision.

One of the major elements of a LAN is the protocol standards adhered to. Once a manager chooses a topology, medium, transmission method, and access technique it becomes obvious that within the established standards available (as described in the previous chapter) there is no decision left to make. The physical layer standards all conform to a topology and an access method, and there is only one real link layer protocol available. The standard has already been chosen through elimination after an access method is chosen. The only thing to be considered then is whether or not to specify that the LAN desired must conform to one of the available standards.

The standards are written to overcome the incompatibility so prevalent in the computer and network fields today. Without some adherence to standards an open network, where all types of devices can communicate with each other, will never be possible. Some small applications with only one type of terminal tied to the network may be possible with a non-standard set of protocols running the network. This type of network will probably not be compatible with others and will have limited expandability. Adherence to standards is a worthy goal to try to achieve.

To fully develop the decision tree outlined in Figure 3.5 the generic labels at various layers must be replaced with available alternatives. The remainder of this chapter explores the various options to be considered at each decision point, and the alternative paths through the tree that will result.

A. TOPOLOGY

The three major topologies described in Chapter 2 are ring, bus, and star. Each should be considered for different applications.

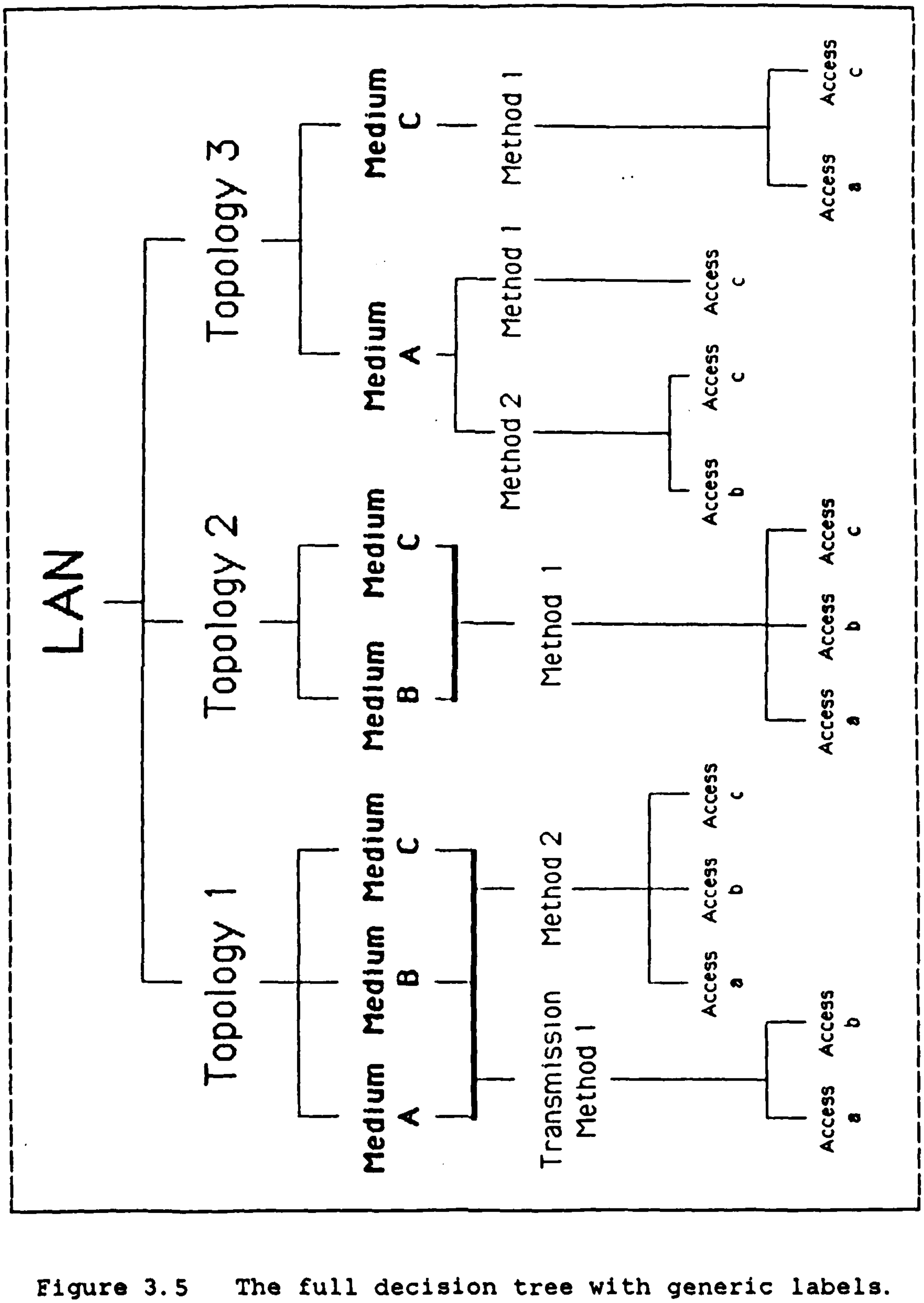

Figure 3.5 The full decision tree with generic labels.

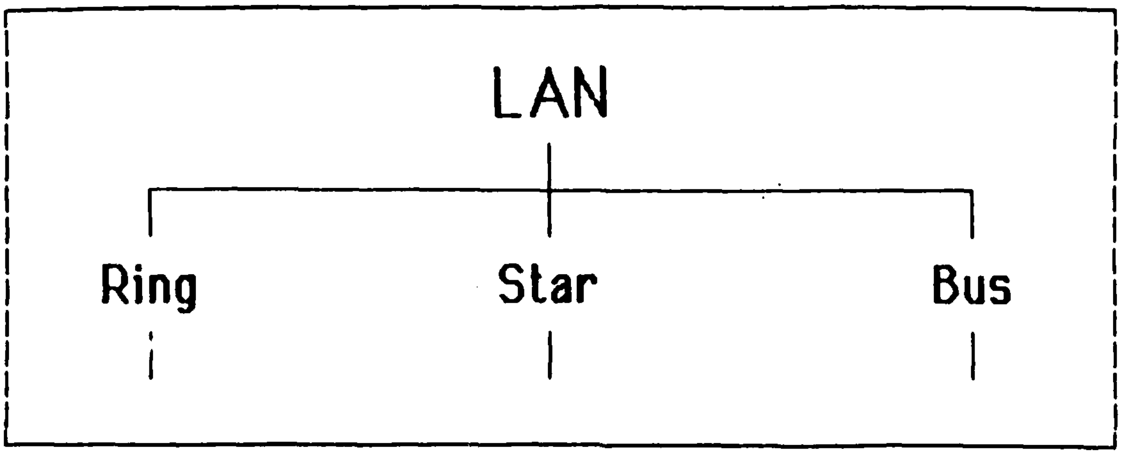

Figure 3.6 The decision tree with labels for topologies.

The star network is fairly simple and can be inexpensive. New nodes may be added without a major readjustment and the central controller can take care of the functioning of the network. The failure of one outlying node will not cause the entire network to fail.

When one node needs to communicate with another outlying node the central switch needs to handle the connection relays. With more than a few connections the central controller can be overwhelmed. With all the switching being done at the central node it becomes a bottleneck that seriously limits the speed and capacity of the star network. With only one node in charge the system is very vulnerable to the failure of that node. In networks where the outlying nodes need to do most of their communications with the central node anyway a star will probably prove to be adequate since the ability of the central node to process the various demands on it is probably the limiting factor for speed and capacity anyway.

The ring network is a series of point-to-point links. It too can be fairly inexpensive and easy to set up. A ring enables more nodes to be on the network than a star. As with any LAN, when a great number of active nodes are trying to use the network there is a great slow down in the network. A ring is also fairly susceptible to failure due to the weak link nature of the connections. If one node or link is disabled the whole network goes down.

Each node requires some network control capability to act as a repeater. A central control node can be added to negate this need, and then the ring is turned into a loop. The ring as a loop then has the same vulnerability as a star with the vulnerable central controller, and it has the weak link problems. A ring is not easy to reconfigure or expand once it is installed. Any new node must be added between two existing nodes, this may be physically difficult if there are not two nodes already located nearby. A ring should be used where most nodes must communicate with a variety of other nodes around the ring, and there is little demand for future reconfiguration. The access methods available to a ring topology network do allow fairest access to the network.

A bus network features distributed network control in an easily reconfigureable physical layout. Most buses are not susceptible to either a central control failure or repeater failure in a node. If the backbone bus is damaged the whole network will be disabled. The bus will probably require less wire than a star or ring since only one wire runs by all the nodes. An additional tap onto the line by a new node only requires a wire from that new node to the bus and the tap hardware itself, making reconfigurations fairly easy. There is a length restriction on the wire between the node and the bus, and the bus may not be able to be tapped at the bus's closest point, in that case the bus can have an extension added onto it's end and the new part of the bus can be led by the new node.

A bus may not be able to achieve the speeds of a point-to-point network, or give as fair access to the network, but it can provide a simple wiring solution to a good number of nodes. A bus network can be used in situations where different nodes talk to various other nodes, and there may be some need for future reconfiguration. The layout of the nodes may also preclude the installation of a ring of wire through all the nodes and back to the first node in a complete circle, in which case a bus may be the better topology.

Of the three topologies, bus and ring show the most promise for open local area networks today. Star networks are being used for small groups of nodes in low demand situations. Other networks besides those with bus, star, and ring topologies may be hard to find if a user still wishes to use standard protocols. Many specialized systems may use any number of different topologies and non-standard specifications for other network elements.

B. MEDIUM

Once a topology is chosen our other choices have more constraints on them. In the choice of a medium Chapter 2 described three major mediums available for LAN use: Twisted pair, optical fiber, and coaxial cable. As was mentioned the other non-connection media are used mostly for inter-network connections.

A ring network can use any of the three mediums efficiently. Bus networks generally use twisted pair or coaxial cable links. A star network can efficiently use twisted pair for it's point-to-point links, but the switches available can not usually handle the speed of coaxial cable or optical fiber, and the added cost of using these media would be wasted [Ref. 1: p. 68]. If the star's hub merely makes circuit connections between outlying nodes for the duration of a communications session the higher speed mediums may be preferred to twisted pair.

Twisted pair is much cheaper than the other media, and also slower and less reliable. It cannot carry as many transmission paths as coaxial or optical fiber. The signal losses are greater in twisted pair, limiting the speed and distance attainable. Today the primary use of twisted pair is to carry analog voice signals on the public telephone system.

Coaxial cable is the most versatile medium available. It is widely used in the cable television industry and is a mature technology. It can be tapped for multidrop systems such as in a bus, or it can be used as the link for point-to-point connections between nodes. It can carry more channels of information than twisted pair and is capable of carrying various kinds of information simultaneously (TV, voice, data).

Optical fiber is one of the newest transmission media offered. Light waves are modulated over the thin piece of optical fiber. It is faster, less susceptible to signal loss, and can carry more data paths than twisted pair or coaxial cable. Optical fiber is presently best suited to point-to-point links and does not easily allow taps like those needed in a bus network. It is the most expensive of the three media but it's cost is coming down as the technology advances and it's use increases. It is best suited for high speed point-to-point applications.

C. TRANSMISSION METHOD

The method of transmission is only a real choice at this stage for bus networks. Ring networks with their structure of nodes regenerating each bit they receive, and at the same time checking them for relevance to their own needs indicates a need for digital signals. For a ring to use any FDM analog signals each node would need to have the ability to receive, translate, and transmit at multiple frequencies quickly, an expensive and complicated scheme. Digital signals are the obvious choice for rings although analog signals are possible. An optical fiber ring requires a device to convert the light to electrical impulses that can be read by the nodes, and a device to create the light from pulses. These devices add expense to the network besides the cost of the fiber itself. The type of transmission over optical fibers is a special type of analog signalling done in conjunction with the modulation of the signal onto the light waves.

A star network will have at it's central node the switch. This switch must either be for circuit switching, or for some kind of packet or message switching. If the need for the network is to establish occasional point-to-point links between the outer nodes a circuit switch will continuously connect the two nodes for the duration of the need. This is similar to making a phone call, where the two users are connected until they hang up. This connection can be made for analog or digital transmissions.

If more dynamic connections are necessary a packet switch is in order. A packet switch will take a small group of bits (called a packet) in to the switch, holding them in a queue if necessary, and at the proper time pass them through to the right destination. The destination is then responsible for putting all the packets together in the proper order for delivery to the node, even if the packets came from different sources. A packet switch will only process digital signals. The complexity of a packet switch will generally overcome the primary reason for choosing a star network, simplicity. A digital transmission over a circuit switch with some means to assure multiple access would seem to be the simplest configuration for transmission in a star.

A bus network using twisted pair may use analog or digital transmission although digital is more common. Again the simplicity of digital transmission is best suited to the common simplicity of twisted pair. Analog transmission is possible with MODEMs, but that adds some complexity. If that added complexity is acceptable then generally a wider bandwidth medium should also be acceptable.

When coaxial cable is the medium chosen the bus networks introduce baseband and broadband. Usually baseband is thought of as 50 ohm coaxial cable carrying digital transmissions. Broadband is then 75 ohm coaxial cable carrying FDM analog signals. Digital twisted pair is sometimes called baseband also. Analog twisted pair is not referred to as broadband because of it's bandwidth limitations.

A digital baseband system is simpler and cheaper than a broadband one. There is a single path per wire, and the distance covered can not be very large. An analog broadband network is more complex, requires MODEMs, and is harder to install. All three of these factors add to it's expense. A broadband network allows higher capacity, longer distances, and different types of information. A variation of broadband is single channel broadband which dedicates the whole link to one transmission path (no FDM). This is fast and fairly simple. It needs MODEMs but they need not be able to handle various frequencies as they must with broadband. It's advantage over baseband is the potential speed achieveable. The disadvantage is that fewer nodes are possible.

D. ACCESS

Access to the network is the next issue to be addressed. Generally the bus networks use ALOHA or CSMA access methods and the rings use slots, token passing, or register insertion, although buses now also use token passing in a token passing bus. The token passing bus networks have a solid place in the LAN market and they are growing in popularity.

A star network is accessed through it's switch. The packet switch actually accepts input from all nodes at almost any time and queues them until they can be passed onto the proper nodes. This means that no nodes are denied access, but delays may become intolerable if the queues are large. The central node may also use polling to provide access to itself. The poller asks each node in turn if it has any data to send, if it does a circuit is set up and the data is sent to the proper node or nodes. There can be time limits or interrupt capabilities installed to insure that all nodes get fair access to the network. Polling requires less memory in the switch, and doesn't restrict the transmissions to digital signals, but it can add inefficiencies to the network. Even if only one node wishes to transmit it must still wait for all the other nodes to be polled.

Networks with ring topologies may use slots, token passing, or register insertion. A slotted ring is simple, allows multiple users on the ring and requires little maintenance. The slotted ring does not allow variable frame sizes of data to be placed on the ring. A token ring network allows all nodes an equal chance at the ring, but only one at a time. The frame size is variable in a token ring. The maintenance of tokens can cause major problems for the network. Register insertion effectively uses the entire ring, allowing multiple users and variable frame sizes. As with token rings the maintenance of the ring can be a problem since a damaged frame must be removed from the register insertion ring by some outside interference.

A lightly used network may be able to use slots effectively. A network where few nodes need longer access to the ring may be better off with a token passing method. If the organization can afford the complexity, expense, and maintenance of a register insertion network it can provide the most versatile access to the network for the most users.

Bus networks may use variations of ALOHA and CSMA. All analog buses may use ALOHA and CSMA, while digital buses have other options available to them in addition to those probabilistic access methods. ALOHA is simple and cheap but not very practical for a LAN. For the most part if a network can use ALOHA it probably could survive as a simple dial-up network rather than as a LAN. Even slotted ALOHA can't provide the minimal access that makes a LAN an attractive option when compared to temporary connections such as dial-ups.

CSMA is better than ALOHA, but as mentioned in the last chapter collisions still cause major interference problems. CSMA/CD is simple enough to implement easily and provides fair access to the network under most conditions. Under moderate demands CSMA/CD provides good access to the bus, but when heavier loads are placed on the network the access gets exponentially worse. There is a requirement for a minimum size of data frame, and another for the distance between nodes to insure that the nodes can hear the collisions in time to do anything about them.

A token bus is based on the token ring network. Although it is possible to use it on an analog system the modulation and demodulation of the analog signal into digital form, and vice-versa, adds delay and expense to the network. The analog signal must be in digital form for the node to check it's bit patterns for the addressing bits. The token bus sends the token to various nodes arranged in a logical ring. Priorities may be set and a precedence order may be established and modified. The token travels from node to node in the order prescribed, not in the physical order of the nodes. Token bus is newer than CSMA/CD and requires much more maintenance and is more complex. It allows excellent and fair access to the bus, and although it is slower than CSMA/CD under light to moderate loads, it performs much better under heavier demands on the network.

A completed tree with all it's branches labelled is presented in Figure 3.7. This tree outlines the decision process described above. After following a path through the tree the potential LAN user can arrive at several sets of specifications. Some of those sets should be considered as grounds for a re-evaluation of the problem.

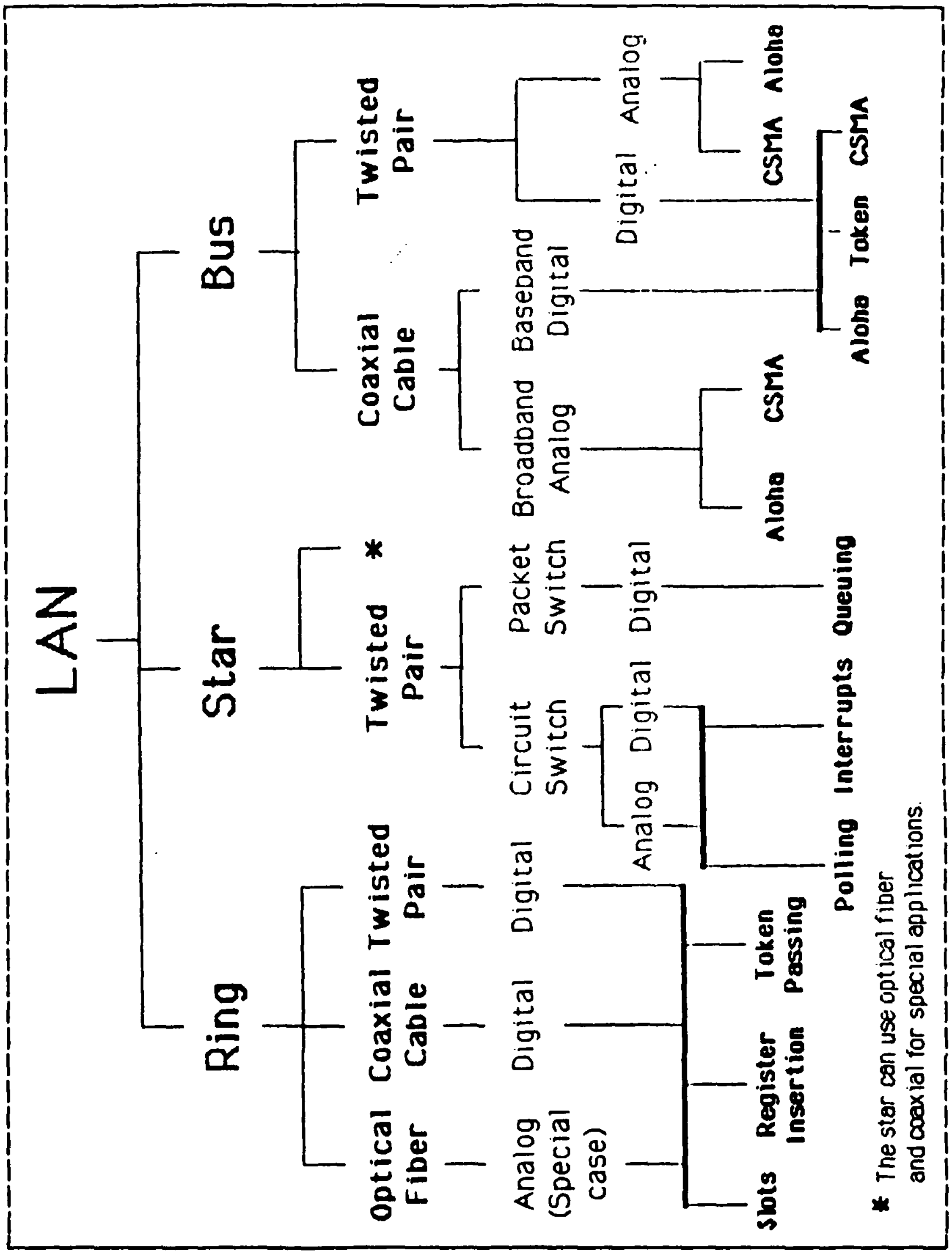

Figure 3.7 The full labeled decision tree.

If the specifications arrived at call for an analog star network the decision to use a LAN should be re-examined. If a user has chosen this path an error was probably made when a LAN was chosen in the first place. A CBX or PBX might better meet this user's requirements. Other star choices should also be examined to see if a CBX might make a better solution. The vendor offerings for the PBX family of networks are much broader than for star LANs.

A decision to use ALOHA or simple CSMA on a bus should also be reconsidered. If that amount of access and reliability is all that is needed a simple dial-up system or a manual switched system may be more efficient. If very high speeds are the driving requirement for a network high speed local networks, HSLNs should be researched and compared to the specifications found for a LAN.

A manager wishing to purchase a LAN from a vendor should be able to use this tree to get a better idea of what kind of decisions must be made to get a good general set of specifications for a local area computer communications network. He may find that as he works through the tree from top to bottom that he has to backtrack and follow another path through the tree. In the end he should come up with a better idea of what specifications he needs for his local area computer communications network.

IV. OTHER CONSIDERATIONS AND RECOMMENDATIONS

A. OTHER CONSIDERATIONS FOR POTENTIAL LAN BUYERS

After a manager gets a set of specifications for the communications LAN he must determine which offered networks meeting those specifications best fit his needs. He has to sort through all of the claims and promises of the various manufacturers and vendors, and find out if their networks are right for his organization.

The claims of the network peddlers must be reviewed with some care, if not skepticism. Figures and numbers can be presented in a less than open manner by someone trying to sell a product. Performance figures claimed for a network must be checked and clarified. Even though a network may perform at a certain speed with a set number of nodes under perfect conditions, it may not perform that way all of the time. The user must consider the effect of his particular applications on the system. He should also recognize that maximum data rates claimed for a network are usually point-to-point rates between two nodes. The end-to-end speed for a LAN has been estimated to be as low as ten percent of the maximum node-to-node rate [Ref. 9: pp. 51, 52]. This is due to resource sharing, repeater delays, and other delays inherent in a network. The performance will be different for various applications, number of nodes, and other factors. The changing performances resulting from a change in these factors must be explored by the potential buyer.

Some managers may have other priorities than performance. The major factor for them may be getting the data from one node to another totally intact. If this is their major concern they may look for products with extensive error handling routines and overhead. Although these networks will be slower, a lot of users need the added security at the expense of efficiency and are willing to make this tradeoff.

Potential buyers need to look at the standards adhered to by the various network designers. A user with different types of incompatible machines that need to interact with each other over the network must have a network design that adheres to standards. This network must be able to pass the translated material between the machines in some common form. A manager with incompatible devices may also wish to explore the subject of network interfaces in-depth. For an organization with a set of compatible machines and operating systems the standards are less important, unless the network needs to communicate with non-compatible outside networks. A manager with a compatible environment of computer devices may wish to focus his attention on the evaluation of networks built specifically for his type of machines.

If the LAN is part of a larger information resource architecture the possible interfaces to the rest of the architecture will have to be researched. Again standards are very important for this network. The available bridges to other LANs, gateways to other networks, and various other possible interfaces will have to be analyzed and compared.

As mentioned before, higher layer protocol considerations should also be taken into account by the network purchaser. The applications that will be performed over the network must be taken into consideration when comparing networks to insure that the networks' software can handle them. How invisible does the network have to be for the users at various nodes? The simplicity of using the network must be matched to the experience level of the users. If they don't match, then either the experience level of the users, or the simplicity of the network will have to be adjusted.

The actual management of the network is another subject which should be considered by the buyer. The network management package may include monitoring, backup, control services, and testing. The user must decide how much of this service should be built-in, and how much should be done by the person managing the system. He must also decide who the person managing the system is to be, and what her tasks will be. How will the system be kept up to date, and who will control expansions and further development of the network?

If a command language is needed for the LAN the manager must decide what an acceptable command language includes. How the user gets on and off the network, network service selection procedures, security, error message generation, and other network commands may be included in the command language. The desire for these features must be countered against the need for invisibility and simplicity of the LAN. This consideration and other higher level software considerations must be made before a network can be chosen and installed. [Ref. 10: pp. 118-120]

The vendors must also be evaluated to see if they provide more than just software and hardware. Is it a major company with a proven track record? Will it be around a year from now? The potential buyer must compare the extent of, and quality of documentation and user training offered by the various vendors. He should try and seek some verification of performance and operational claims made by vendors. He must ascertain the quality of the hardware, software, and maintenance provided by the vendors.

Once the specifications for the communications network have been chosen the research and work involved in choosing the right network has just begun. As with any other business decision made by a manager the alternatives and risks involved must be weighed against each other before a conclusion can be reached. Only after these careful considerations can the right local area network be chosen for any organization.

B. FOLLOW ON WORK

The following are recommendations for further work in this area. Some improvements to the basic methodology presented in Chapter 3 are outlined first. They are followed by what can be done in related areas to compliment the work done in this thesis.

1. Decision Methodology Improvement

There are several approaches that can be taken to improve on the basic decision methodology presented in the last chapter:

- The tree can be expanded into a more complex matrix.
- Weights can be assigned to the various factors so a quantitative analysis can be made.
- Specific vendor offerings can be matched with various specification sets so that prospective buyers have a shopping list of LANs to choose from.

When using the decision tree of Figure 3.7 a user makes a choice and moves down to the next decision node of the branch. One of the disadvantages of this is that the tree structure forces the user into making his choices in a specified order. The order of the tree was established for the general case, some users may have other priorities that would make another order of decisions more logical. Once a higher branch node is selected that node's subsets are all the choices left to the user unless he backs up the branch and changes his decision at a higher level in the tree.

A multi-dimensional array of decisions would allow a user to enter the methodology at any decision point, or at several at once. This would allow him to prioritize his own decisions about the network specifications. A menu-driven computer program could even be written to allow a person to enter the matrix at any point, and guide him through the decisions and variations that are still available after each sub-branch is selected.

By using a methodology which includes quantitative analysis a user of the methodology may be able to get a better grasp of the tradeoffs available. Various network choices in the tree impact differently on different need criteria. The different decisions at each level can be assigned values corresponding to their impact on different criteria such as: Speed, cost, vulnerability, robustness, security, maintainability, and simplicity.

As the prospective LAN buyer prepares to use the tree he can assign relative weights to the criteria established by his requirements analysis. As he follows the decision tree down he can compare alternative choices according to their impact on the weighted criteria. The weights can then be multiplied by the assigned impact values for that choice and they can be totalled with other products at the other levels of the tree. If several alternative routes through the tree are explored there is a total weighted figure for each one, and the optimum route may be chosen. This method could also be implemented into a decision aid computer program. [Ref. 8: pp. 3-7, 25]

Another possible improvement to the decision methodology is a match up of various vendors' offerings to the possible network specification lists that have been generated by stepping through the tree. Extensive research into present LAN offerings would need to be done so that an acceptable list could be compiled. This list would need to be updated regularly to stay current with the changing technology and marketplace. Here again some computer work could help. A data base of attributes, configurations and vendors could be established, and modified periodically by it's users.

2. Related Areas

There is a substantial amount of work that can be performed in other areas that would complement this thesis. Even a topic narrowed down as far as this was, choosing a LAN, is too broad for one thesis to cover adequately.

As mentioned in the introductory chapter of this thesis, the assumption was made that a LAN was already chosen as the best solution for the manager wishing to use the methodology of this thesis. In order to arrive at this conclusion the manager had to carefully match his requirements to the different types of networks available.

The requirements analysis for a unit wishing computer communications is a major undertaking. The potential buyer must get data about the environment inside and outside the organization including the desires of the operators and managers, the cost constraints placed on the project, and hundreds of other details. All of these various factors must be sorted and compiled into a good set of requirements and criteria for a particular organization's needs. An organizational tool that would help guide a manager through all the details of requirements analysis, and let him derive a good set of criteria for choosing computer communications aids would be invaluable. The development of such a guide would be a substantial project.

After he has the requirements for his network the manager must decide what type of computer communications network would best fit those requirements. A methodology similar to the one developed in this thesis could be developed to help a manager make the proper decisions at that level.

As discussed in the first section of this chapter, a manager is far from done when he has a good set of specifications for a communications LAN. Another project of related work would be to develop a guide to take a manager through the higher level choices of a LAN. Such a guide would also be of benefit to potential LAN purchasers.

LIST OF REFERENCES

1. Stallings, W., Local Networks, an Introduction, Macmillan Publishing Company, New York, 1984.

2. Digital Equipment Corporation, Introduction to Local Area Networks, Digital Equipment Corporation, Bedford, Massachusetts, 1982.

3. Stallings, W., Data and Computer Communications, Macmillan Publishing Company, New York, 1985.

4. Gee, K.C.E., Introduction to Local Area Computer Networks, John Wiley & Sons, New York, 1983.

5. Tropper, C., Local Computer Network Technologies, Academic Press, Inc., New York, 1981.

6. Rosner, R.D., Packet Switching, Lifetime Learning Publications, Belmont, California, 1982.

7. Graube, M. and Mulder, M., "Local Area Networks," Computer, October, 1984.

8. Naval Postgraduate School Technical Report NPS52-80-007, Desirable Properties of a Network Taxonomy, by E.E. McCoy and B.J. Carey, May, 1980.

9. Hirsch, P., "Local-Area Networks and Beyond," Computerworld, January, 1983.

10. Bingham, J.E. and Davies, G.W.P., Planning for Data Communications, John Wiley & Sons, New York, 1977.

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