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The

LOCAL AREA NETWORKS
PERSONAL COMPUTER IMPLEMENTATIONS

JPK
12/17/84

by
Aaron B. Balch

A thesis
Presented to the Graduate Committee
of Lehigh University
in Candidacy for the Degree of
Master of Science
in
Computer Science

Department of Computer Science and Electrical Engineering
Division of Computer Science
Lehigh University
November 1984

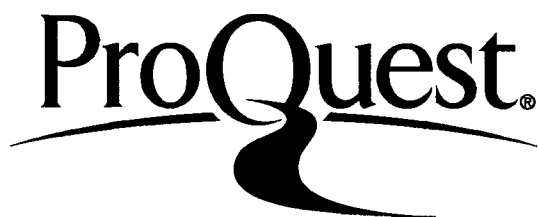
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This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science.

Dec. 14, 1984
Date

Professor in Charge

Head of the Division

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1. ABSTRACT

Local area networking is a form of computer communication that provides a reliable interconnection of different types of information processing equipment. Through the advances of both hardware and software technologies, the implementation of local area networking with personal computers has become possible. This paper examines these technologies as applied to the personal computer. Background in local area network architectures, such as network structure and topology, protocol, physical carrier, bandwidth, supported services, and the conformity to standards are presented in detail. It becomes apparent that the personal-computer local area networks are approaching their mainframe and mini-computer counterparts in capabilities and features. However, the personal computer network falls short in availability of network application software. This shortcoming can be overcome if the personal computer is exploited, through software, to take advantage of its networking potential.

2. INTRODUCTION

Local area networks (LANs) are usually described as a form of computer communications that offers reliable high-speed channels for interconnecting different types of information processing equipment within an organization. The equipment may be within an office, a group of offices, a building, or a closely spaced group of buildings.

However, local area networking implemented with personal computers (PCs) is still in its infancy. Generally speaking, personal computer LANs are not as fully developed as their mainframe and mini-computer counter parts in regard to available applications software.

In order to take a closer look at the use of personal computers in implementing local area networks, we must first define what is meant by a LAN. To this, we will look at what makes up a LAN in generic terms. In addition, this paper will examine the two prevalent LAN standards, the IEEE Standardization Project 802 and the International Standards Organizations (ISO) proposal, Open Systems Interconnection (OSI).

Finally, several personal computer LANs are examined in detail to identify the strong and weak areas in their respective implementations.

3. LOCAL AREA NETWORKING

The concept of local area networks has evolved through advances in both hardware and software technologies. LAN users are seeing advantages through the greater reliability in hardware and software, better supported facilities, flexibility in application programming, and faster response times. In addition, other advantages recognized are inter-networking capabilities, polyvalent message systems, and a wider variety of workstation selection.

By emphasizing complete systems rather than on a component-by-component basis, LANs can dramatically increase user productivity through the sharing of system-wide resources, such as common data, programs, and peripherals like printers. This helps to accommodate an organization's goals and structure. The LAN equipped with intelligent workstations such as personal computers, is leading to an integration of word processing (WP) and data processing (DP) functions.

The major problem confronting PC LANs is how to create useful processing, databasing, and communication tools within the cost constraints imposed by pricing today's computers and components. What this really means is we must take advantage of readily available off-the-shelf desktop units, floppy disks, hard disks, videos, and printers. Again it is very important that we note that the real power

of the use of the PC is not in the hardware but rather in the software.

To help differentiate LAN architectures we consider the following criteria:

- . Overall architecture, supported services, and the conformity to standards
- . The number of layers supported by the LAN
- . Gateways to other LANs
- . Network structure and topology (ring, ether, star, etc.)
- . Bits carried per second (broadband vs. baseband)
- . Protocol used (token, CD, slots, etc.)
- . Physical medium (twisted pair, flat wire, coaxial, etc.)
- . The way the information is transmitted on the carrier
- . Type and cost of the interface unit

In addition, there are five major components of a LAN:

- . The LAN architecture must be flexible, easy to implement and easy to maintain
- . Protocols must provide assurance of error detection, correction, and guaranteed message delivery
- . Bandwidth should be wide enough for the projected application
- . Service must meet the requirements in a cost effective way

- . The strategy should be to develop a LAN architecture which can promote parallelism and be open to future development

An inherent feature of any LAN is the concept of a network server. In general, a network server is a hardware and software package which is dedicated to the support of common resources. This package is made up of a file server, print server, and communications server. The file server manages the sharing of program and data resources, the print server manages the shared printer resources, and the communications server manages the LAN communications requirements in addition to providing a gateway or an internet function.

In its most elementary form, a LAN is two or more computers connected together by some type of medium, wire or cable, known as the carrier. This wire or carrier forms the data path between the two computers. The more common carriers available for use in LANs are the twisted-pair, flat wire cable, coaxial cable, and the optical fiber. The selection of a medium is generally dependent on the projected growth, interface cost, and the environment in which the network is being used.

LANs are generally classified according to three characteristics: bandwidth, protocol, and topology. Bandwidth is a network's data path capacity, i.e., a

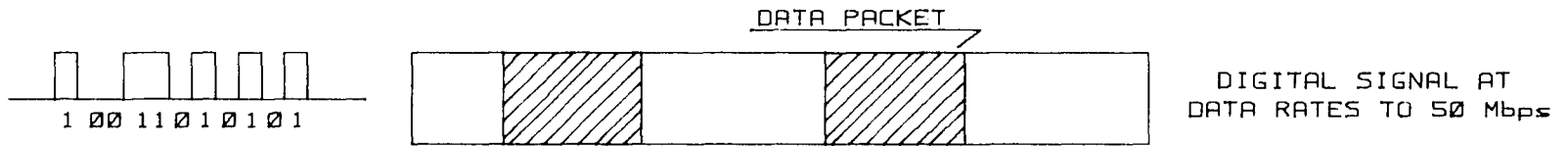
network's ability to move data. Protocol is a set of rules by which a network controls access by its devices. Topology is a network's physical structure.

In reference to bandwidth, there are two types of LAN systems: baseband systems and broadband systems, as shown in Figure 3-1.

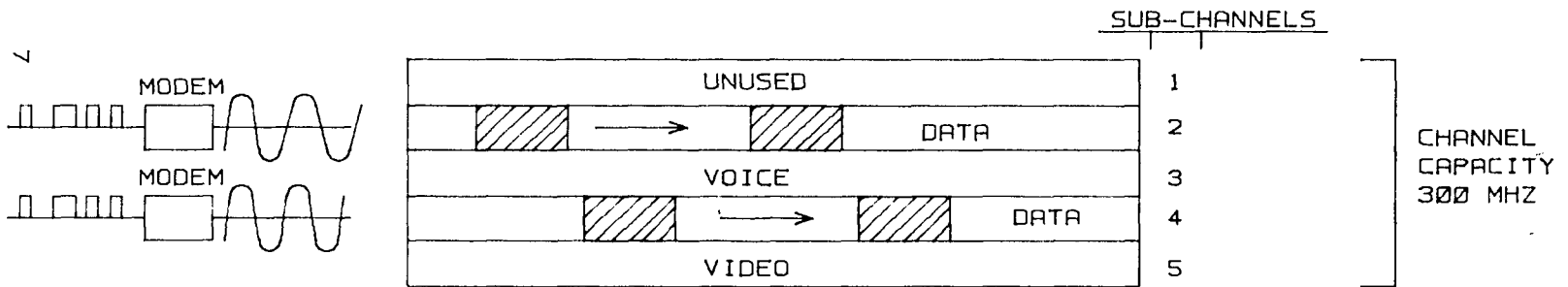
In a baseband system, a single digital signal - a serial stream of bits formed into a data packet - travels along the data path. These serial data packets are sent and received at a specific data rate, usually from zero to fifty megabits per second (Mbps). Baseband systems are the most popular due to their ease of installation and relatively low cost.

In a broadband system, data packets are transmitted as analog signals and therefore require modems which are devices for digital-to-analog conversion and vice versa. These data packets are sent along a high capacity media such as coaxial cable or CATV cable. This type of media has a bandwidth of 300 megahertz (MHz). With broadband systems, the bandwidth is usually partitioned into subchannels, each of which is assigned a specific function. Examples of functions would include high-speed data transmissions, low-speed data transmissions, video, and digitized voice. This technique of partitioning of the bandwidth is known as frequency division multiplexing, or FDM. FDM allows the

BASEBAND VS BROADBAND



(a) BASEBAND



(b) BROADBAND

FIGURE 3-1. BASEBAND AND BROADBAND TRANSMISSIONS.

organization using the network to select subchannel bandwidth according to the services desired on each channel.

Broadband systems, with their added capacity and diversity of services, add to the cost and complexity of implementing a LAN. A comparison of the baseband-broadband range in bits per second and of the LAN possibilities in either class are shown in Figure 3-2.

Baseband coaxial cable has a bit error rate of 10^{-6} , or one bit in one million. For twisted-pair wire, the figure is 10^{-5} , whereas broadband transmission has a bit error rate of less than 10^{-8} . A comparison of broadband and baseband LAN offerings are depicted in Table 3-1.

Protocol is simply the set of conventions that govern the format and control of information in transit through a communications network. It constitutes the "logical" connections to the "physical" lines of the carrier.

Protocols have two basic functions. The first is the function of contact, which is responsible for the identification and synchronization and the creation of the connection over which data can flow (virtual circuit). The second function is transfer, which handles the acknowledgment of the delivered message, error detection and correction, and also synchronization. Another characteristic of protocols is its reliability. A protocol

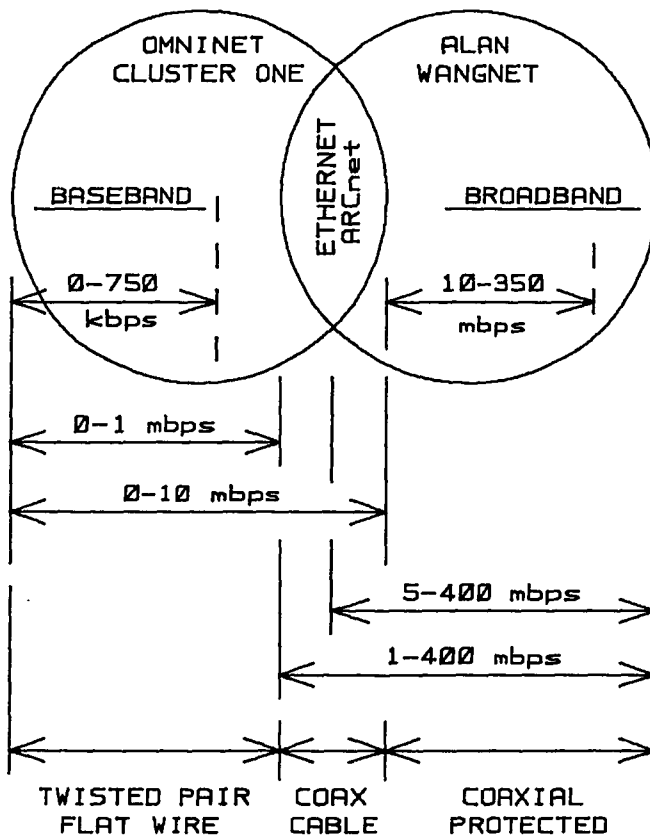


FIGURE 3-2. A COMPARISON OF THE BROADBAND - BASEBAND RANGE, IN BITS PER SECOND AND THE LAN POSSIBILITIES IN EITHER CLASS.

Vendor	LAN	Carrier	Data Rate
BROADBAND			
Network Systems	HYPERchannel	Coaxial	50 Mbps
Sytek	LocalNet	Coaxial	2.5 Mbps
Wang	Wangnet	Coaxial	340 MHz
3M/IS	Alan	Coaxial	300 MHz
BASEBAND			
Corvus	Omninet	Twisted-pair	1 Mbps
Datapoint	ARC	Coaxial	2.5 Mbps
Intel	Ethernet	Coaxial	10 Mbps
3COM	Ethernet	Coaxial	10 Mbps
Ungerman-Bass	Net/One	Coaxial	10 Mbps
Xerox	Ethernet	Coaxial	10 Mbps
Zilog	Z-Net	Coaxial	800 Kbps

Table 3-1. LAN offerings.

is reliable if it provides end-to-end accountability for the functions such as connection management, flow control, and delivery of messages. The reliability is only possible if the requirements such as packet structure, header, trailer, sequencing, channeling, and acceptance are met efficiently.

LAN protocols must support the following:

- . Cost effectiveness
- . Low contention
- . Modular design open to growth
- . Common text and database access
- . Shared resource principle
- . Basis for an integrated electronic office
- . Capacity to dynamically redefine and reconfigure the system

LAN capabilities are based on four criteria: the type of topology, volume of transmission, the transmission technology itself, and the access method. It is important to note that these criteria do have an impact on protocol choice.

It is important to distinguish between the two types of communication methods, asynchronous and synchronous.

Asynchronous communications allows for the transmission of characters with a random timing known as start-stop. The data bits of each character are introduced by a start-bit

and followed by a stop-bit, which separates a character. This type of transmission is inefficient and is generally used for low-speeds, 9.6 kilobits per second (Kbs) or less.

Synchronous communication requires a constant time interval between characters. Therefore, start-stop bits are not needed, leading to a more efficient communications. In synchronous communications, a group of characters are surrounded by a header and trailer for error detection and control purposes. Synchronous communications can be further broken down into character-oriented and bit-oriented. Character-oriented, also known as binary synchronous communications (BSC), the smallest recognizable entity is a character. In bit-oriented or packet switching, bits are organized into frames. An example of a data packet is shown in Figure 3-3.

LANs use the packet switching form of communication. Software in a LAN performs the packet assembly/disassembly, buffering, error detection, and flow control. These network dependent functions are separated from user devices by integrating protocols at the network interface unit level by a microprocessor based intelligent controller.

Protocols are important for data-basing and data communications. They allow multiple processes and users to benefit from multiple tasking, shared memory, and virtual memory implementation. Processes residing in the network

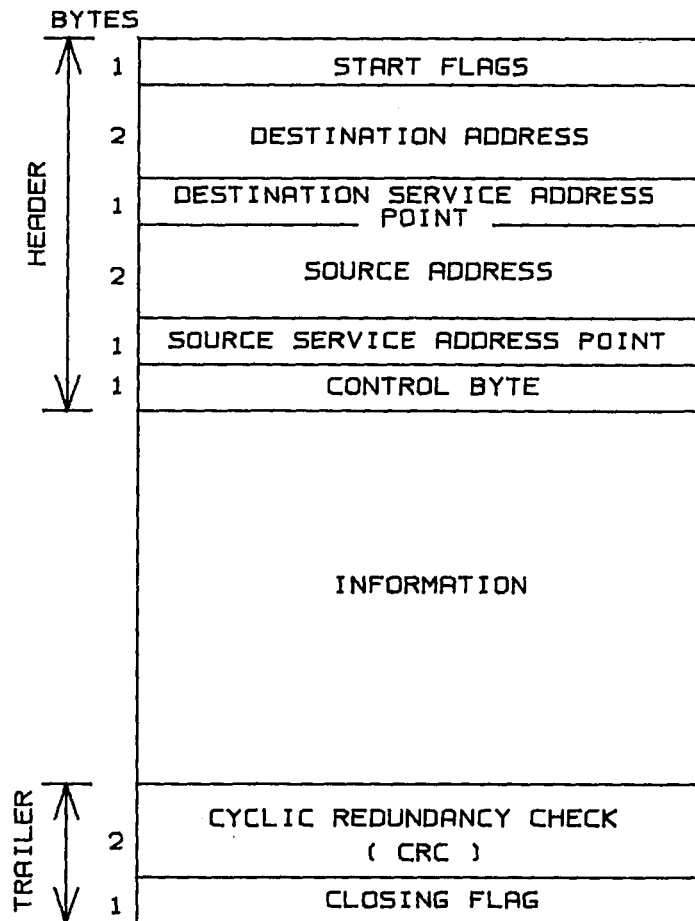


FIGURE 3-3. EXAMPLE OF A PACKET STRUCTURE.

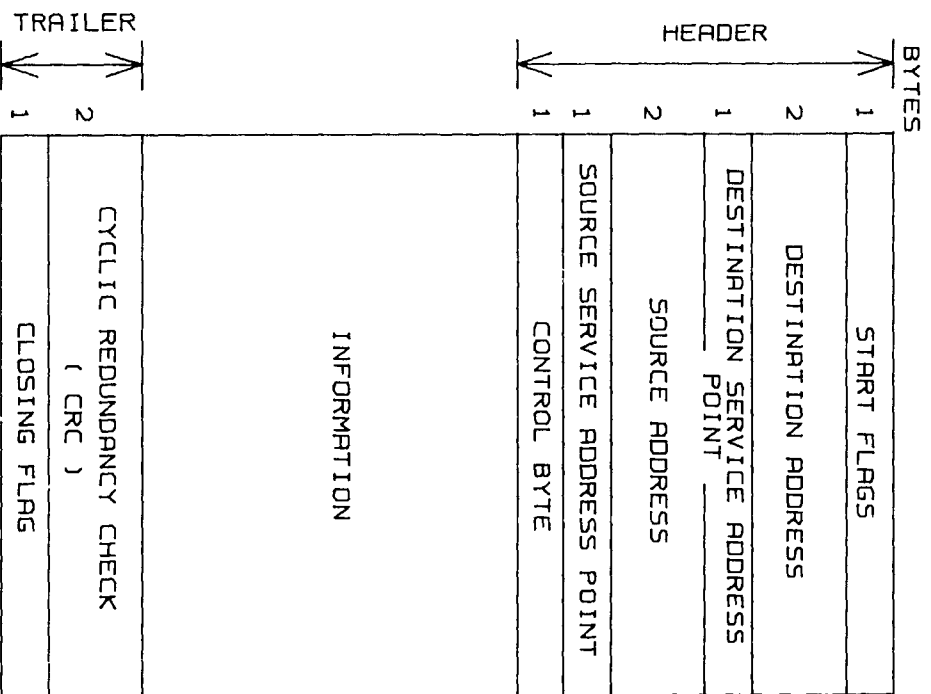


FIGURE 3-3. EXAMPLE OF A PACKET STRUCTURE.

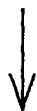
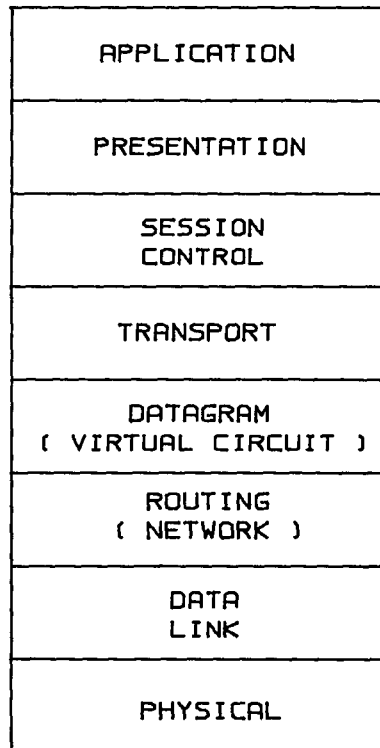
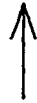
can hold the network and manipulate it because the protocols are available. Common data communication protocols make it feasible to work under a variety of operating systems residing in the attached workstations (PCs). These same protocols can be implemented in different LAN architectures.

A LAN interface is usually software-intensive. It involves different layers, each of which is assigned a specific function. This is what is known as the layered approach to network design. The layered concept is being emphasized by both the IEEE and the ISO in their LAN standardization efforts. An example of the layered approach is shown in Figure 3-4.

The five most often used LAN topologies are: centralized, bus or un-rooted tree, spider, loop, and virtual ring. These topologies are depicted in Figure 3-5.

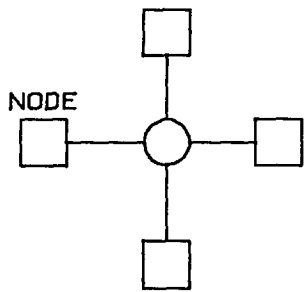
The centralized topology has two forms, star and hierarchical. Both are centralized, depend on an active resource (master), and in general the master is the one and only master. However, hierarchical offers in addition to a central master, nodes (intelligent concentrators) which as themselves act a star structures. This allows for sub-networking but is always based on the centralized principle. This approach is the oldest and least reliable topology. The central switch or master is usually a mini-computer and

TO TEXT AND DATA

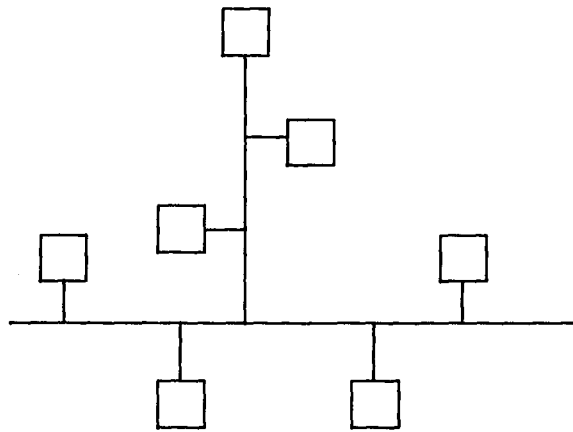


NETWORK CARRIER

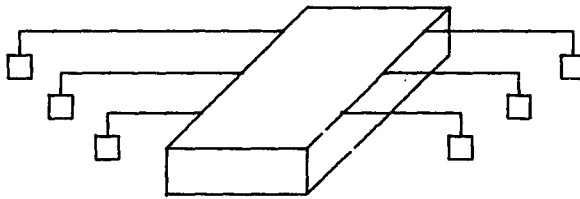
FIGURE 3-4. EXAMPLE OF LAYERED APPROACH TO NETWORK DESIGN.



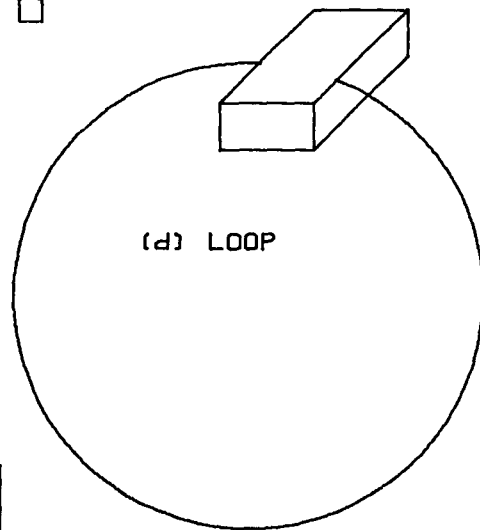
(a) CENTRALIZED



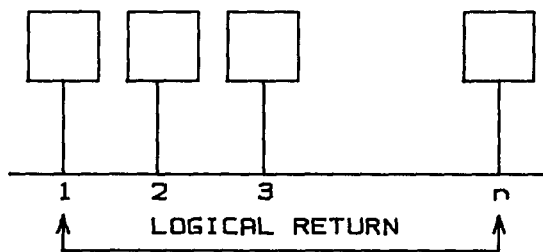
(b) BUS / UN-ROOTED TREE



(c) SPIDER



(d) LOOP



(e) VIRTUAL RING

FIGURE 3-5. TOPOLOGIES.

twisted-pair connections are commonly used.

In a bus or un-rooted tree, control is neither centralized nor a loop. Reconfigurability and distributed control capability are its strong points. Ethernet, of Xerox, Digital, and Intel, and LOCALNET of Sytek are based on this topology. Ethernet type LANs utilize a processor bus technology and is coaxial cable based. A typical LAN may have a maximum cable length of 5000 meters between any two workstations in the network. Within any 500 meter cable segment, up to 100 connections can be made. Up to Five segments can be linked together with repeaters. Each device on a segment must be a minimum of 2.5 meters apart. As can be seen, one of the disadvantages of this type of topology is that a considerable amount of planning is needed for its usage.

Unlike the centralized topologies, the spider interprocessor system defines an electronic pathway by means of a network of active and passive hubs. You link workstations together by connecting to the interprocessor bus. File and application processors are attached to this pathway which provides access to all resources. Datapoint's attached resource computer (ARC) is based on this topology.

In a loop structure, it presupposed a hub-polling protocol and a node-host attachment which acts as a central control (device). The host injects signals going in one

direction and then picks up signals as they return from the loop. To move from workstation to workstation requires the passing on of information (token). Various LAN architectures can be based on the loop and the medium can be coaxial cable, twisted-pair or flat wire.

The virtual ring, also known as round-robin, is based on token passing logically implemented on a bus. It is contrast to the loop which is a physical ring. Organized on a bus and software based, it supports priority handling through arithmetic implementation. An example is the Cambridge ring. It is a physical medium with logical capabilities, a loop structure subject to a form of frame division, in slots of 16, 32, or 64 bits. Each machine is assigned a slot and can only "speak" in its slot. This guarantees deterministic access, but is very rigid.

Each topology supports at least one type of cable access protocol, but most can support more than one. Basically there are four types but each can have dialects and/or hybrid possibilities. The four types are the slot approach, token passing, contention, and ordered access bus.

The Cambridge ring is an example of the slot approach and is based on a type of time division multiplexing (TDM). There is a constant number of fixed-length slots continuously circulating around the ring. A full/empty

indicator within the slot header signals the real state of the slot. Any workstation ready to transmit sets the indicator in the first empty slot to full, and places its data into the slot. The sender/receiver workstations share the ring bandwidth until they have completely transmitted their packets. When the sender receives the occupied slot it must change the indicator to empty which guarantees equal sharing of the bandwidth of all workstations.

Slots are short and therefore a message may have to be transmitted within several slots. Between two consecutive access possibilities of a particular workstation, the slot will travel exactly once around the ring in the empty state. All time periods of one cycle, in which the slot is empty, are grouped together in one continuous empty slot interval.

ARC and other round-robin topologies are based on token passing. A token is used for sending data, parameter reselection, terminating sessions and synchronization. Tokens have three states: assigned/not assigned to a workstation, assignable/not assignable, and available/not available.

When a token is assigned, the user gets the right to use the service. When not assigned, the user has no right to the service but may acquire the right without entering reselection. The not assignable state gives no rights to use the services and requires a reselection to change the

assigned/not assigned states. Finally, when the token is not available, the user has no rights to the service over the lifetime of the session connection.

At initialization, a designated workstation generates a free token. This free token passes around the ring until a workstation is ready to send, changing the token to busy and putting its packets onto the ring. The packets are of arbitrary length. Each workstation is responsible for removing its own packet (token) from the ring and passing a new free token to the next workstation to pass access permission.

The major advantages of token passing is that there is no control station, no master/slave relationships, and it is possible to build a priority mechanism so some workstations have priority over others.

The most common contention protocol is carrier sense multiple access with collision detection (CSMA/CD). It is used by Ethernet and other LANs. With CSMA/CD, every workstation wanting to transmit a packet must listen to the bus to see if any other transmission is in progress. If there is, the workstation defers its transmission until the end of the current transmission. If a collision is detected, transmission is aborted and the workstation reschedules its packet. This retransmission interval is

dynamically adjusted to the actual load on the bus. It is suitable for baseband systems and can be implemented with twisted-pair, flat wire, and coaxial cables. It is a non-centralized access control mechanism giving all workstations the same priority.

The carrier may be idle or busy. When allocated, the source station puts the destination address on the data line and after some delay the carrier line is activated. The destination address will trigger the software in the destination interface and cause it to start to receive a packet, which contains four fields: type, length, data, and check sum. Cable allocation occurs when a station puts its source address on the data line.

A major design criteria of any system using this method is the normalized propagation delay (NPD), which is the ratio of the time a packet takes to travel throughout the network to the time necessary to send a packet. The ratio should be as low as possible and less than one. Therefore, as the cable length increases, both the propagation delay and the NPD increase. And if the signaling rate increases, the packet transmission time decreases and the NPD increases. To conclude, as NPD increases, the effective throughput of the network decreases, that is to say, more time is taken up by collisions.

The protocol for the ordered access bus is known as

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The protocol for the ordered access bus is known as

multi-level multiple access (MLMA). MLMA is frame based and is implemented using variable length frames. The frame is made up of two parts, a request slot and an arbitrary number of packets, with each station attached to the bus owning one bit within the request slot. Each workstation sets its private bit indicating that it wants to transmit a packet within the frame. The transmission is assigned a priority which is known by all stations in the network.

The bus is molded as a single-server facility. Packets which have been newly generated and have not been scheduled are formed into a distribution queue, they must wait until a new frame starts. To make certain that all stations know of the entries made in the request slot, the scheduling time might need to be longer than the pure transmission time of the request slot.

The MLMA method is similar to the contention resolution method for computer interrupt systems. A basic assumption in its use, and a restrictive one at that, is that the distance between two stations transmitting in succession is uniformly distributed throughout the maximum bus length.

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4. STANDARDS

The continued advances in technology has brought about a move towards standardization of communication in regard to LANs. There are two predominate standards being formed: the IEEE Standardization Project 802 and ISO's Open Systems Interconnection (OSI).

The IEEE defines a LAN as:

"A LAN is a datacomm system allowing a number of independent devices to communicate directly with each other, within a moderately sized geographic area over a physical communication channel of moderate data rates."

The 802 group formed in February 1980 with the goal of standardizing a two layer transport mechanism for digital information interchange. It concentrated on media, access control, and higher-level interfaces. In addition to classical data processing it was to consider file transfer, database access, graphics, word processing, teletex, and digitized voice.

The devices considered for LAN attachment were computers of all types and sizes, terminals, printers, and plotters. The IEEE basically restricted itself with baseband, allowing for over 200 devices, in the 1-to-20 Mbps range, up to 2 Km in distance, and featuring code independence, single and multiple simultaneous users. It mainly addresses the office environment, with no mention of

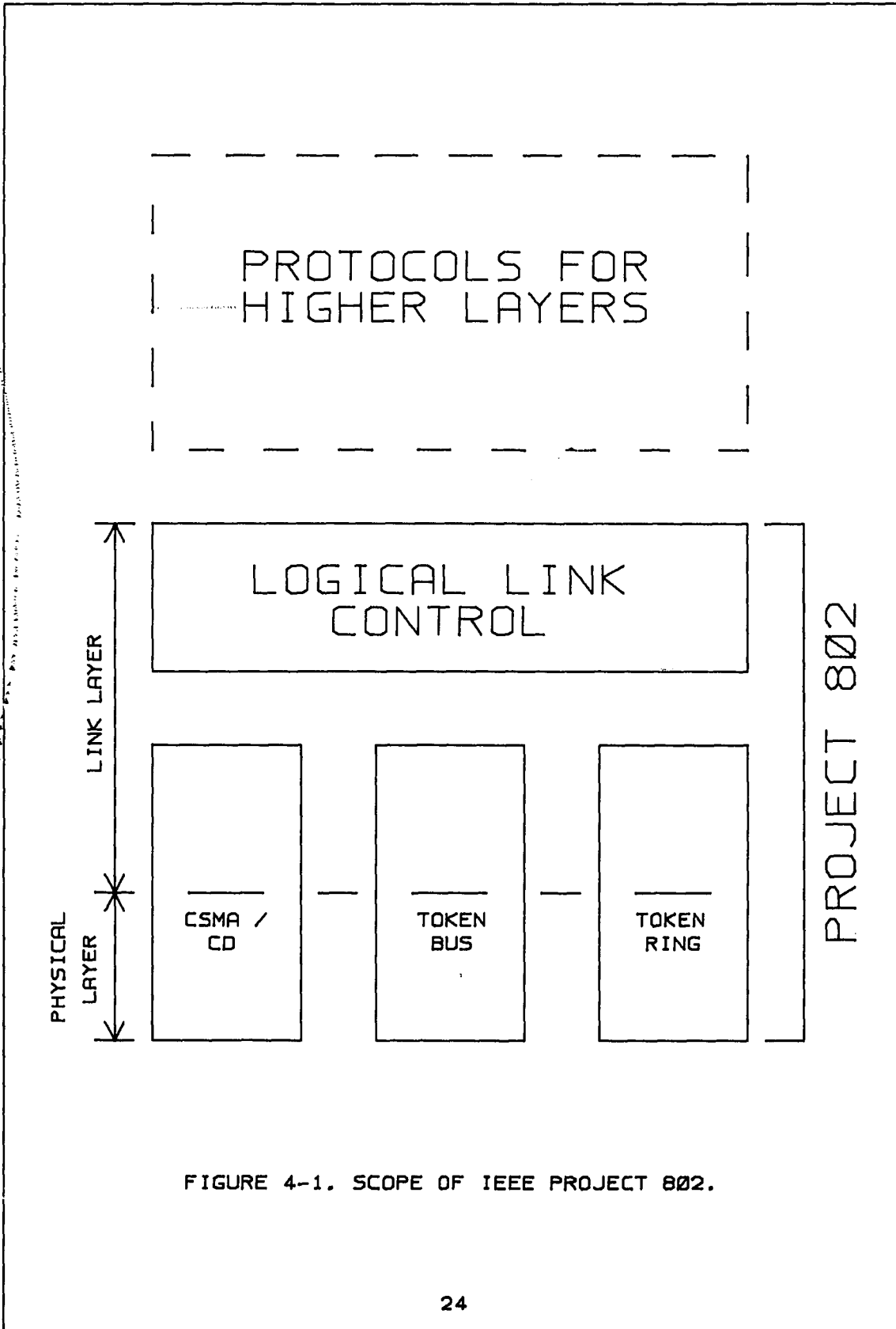


FIGURE 4-1. SCOPE OF IEEE PROJECT 802.

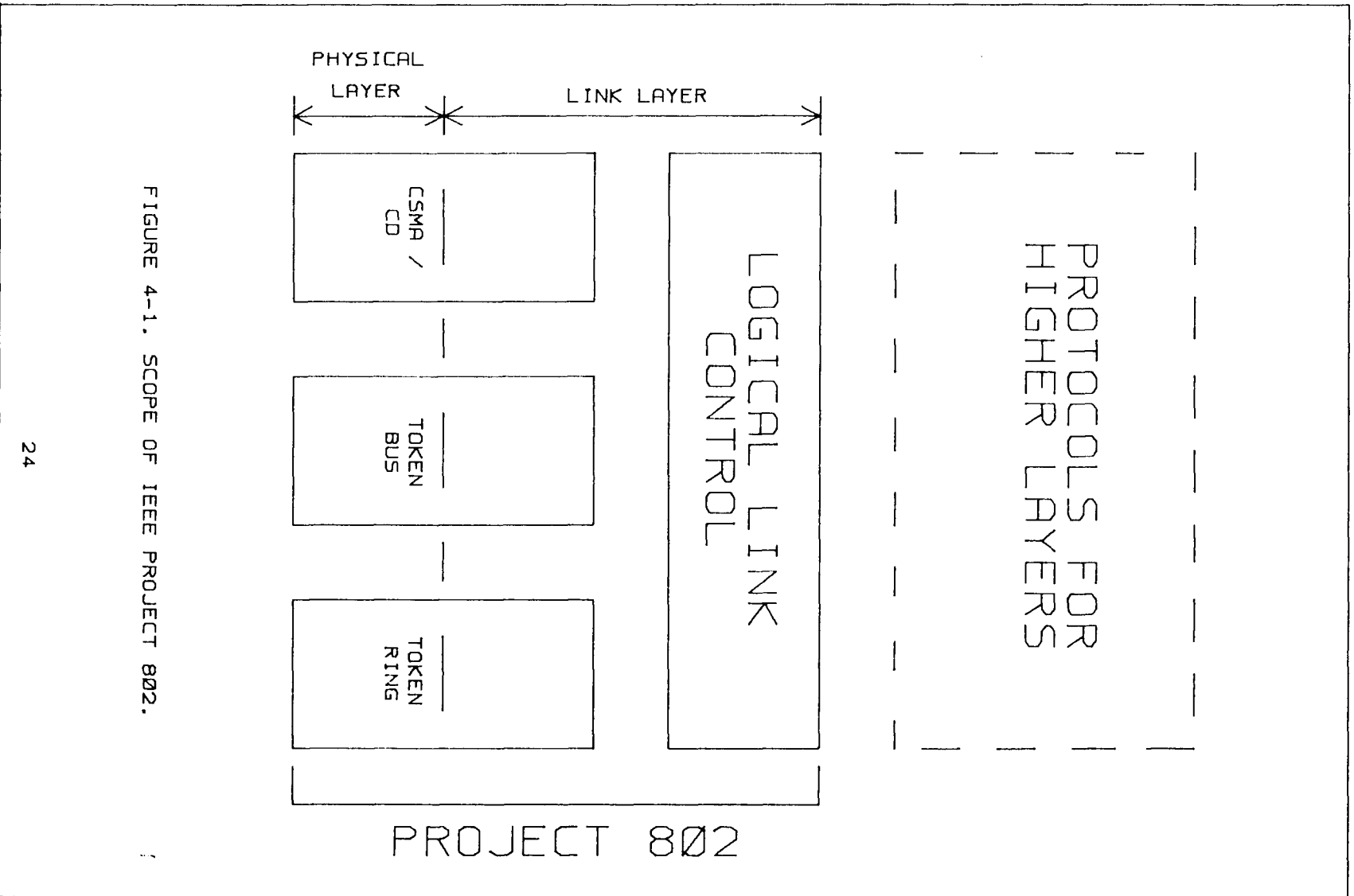


FIGURE 4-1. SCOPE OF IEEE PROJECT 802.

the factory environment. It should be noted that the 802 objective is only layers 1 and 2 of the ISO/OSI model.

Project 802 defines three types of LAN technologies:

- . Contention using CSMA/CD
- . A token bus
- . A token ring

Lets examine the three media access control methods which have been chosen, starting with CSMA/CD. Using CSMA/CD, the channel can be in any one of the three states: (1) idle, (2) contention, or (3) transmission. In the idle state, the channel carries no signal. In the contention state, the signal results from packets in collision or jamming. In the transmission state, the channel carries signals from a packet. Therefore, in a typical CSMA/CD bus solution every workstation transmits and receives from and to every other workstation. This mechanism is reliable, but CSMA tends to fall apart over 25 Km because of energy problems.

In conclusion, with CSMA/CD, transceivers may only transmit when the channel is idle. If a collision is detected, the transmission is aborted. Therefore, the more collisions, the greater the bus saturation and idle time is wasted. This design is projected to work better under a light load. The major advantages are that control is distributed, immediate access is possible, and the time to

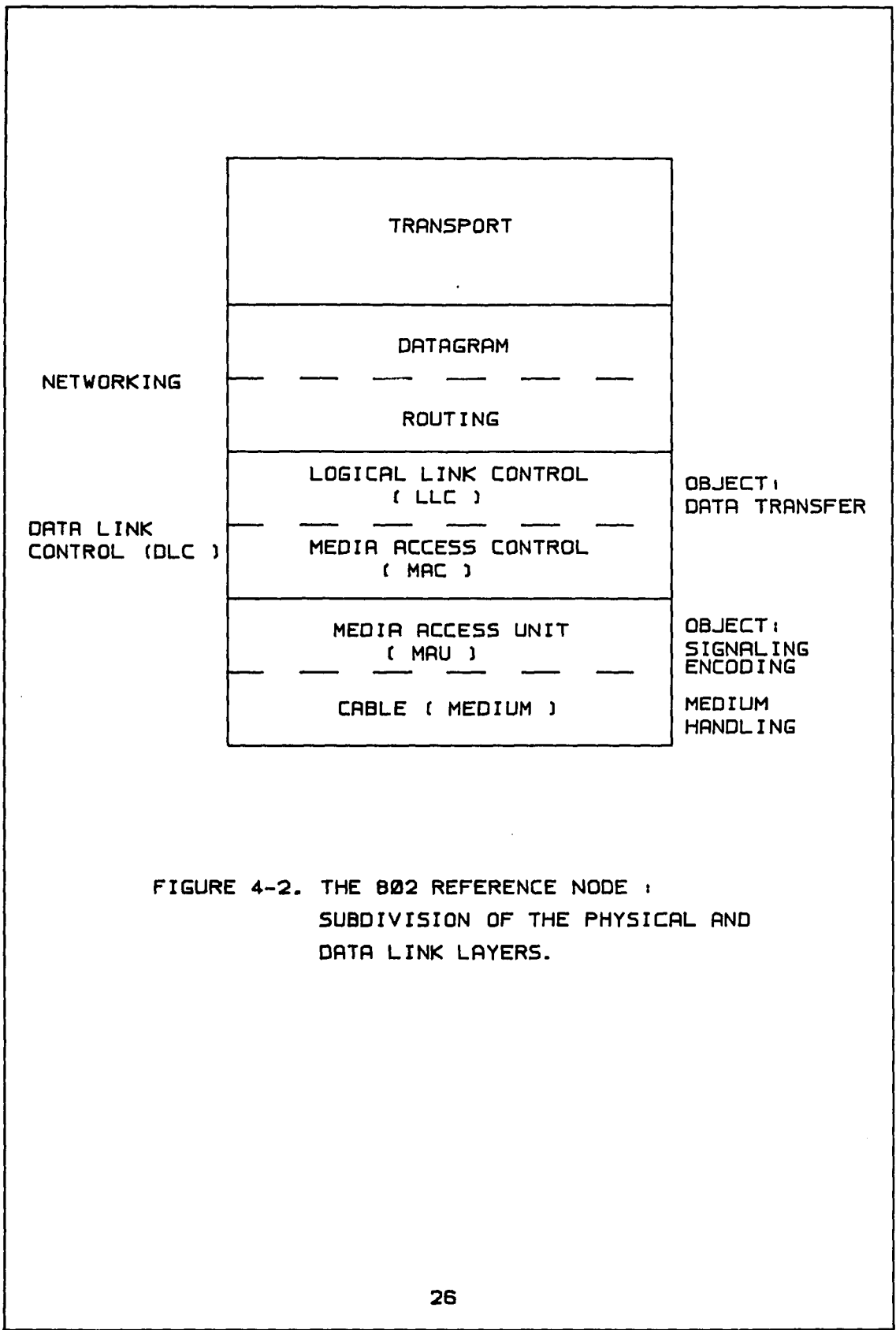


FIGURE 4-2. THE 802 REFERENCE NODE :
 SUBDIVISION OF THE PHYSICAL AND
 DATA LINK LAYERS.

resolve conflicts is unbounded.

A basic model of the token standard is shown in Figure 4-3. A physical or logical hub connects all nodes and workstations. Only one of them is working and it has the token. When it is done transmitting, it passes control (token), to another work station either serially or in accordance with a priority table.

In a ring topology with the token passing discipline, every workstation transmits and receives from just one other workstation and control is either decentralized and passed from station to station or centralized where one station determines the workstation that will get the token. There is a polling arbitration which requires a given amount of time to handle passing control and the message transmission. Polling is a form of priority arbitration that passes control from workstation to workstation around the network. Whatever station possesses the token has the highest priority. A variation is the notion of a "passive hub." It plays no direct control role, but rather it simply connects the workstations so that polling can be thought of as moving around a wheel.

As noted previously, network traffic can go in a loop or bus fashion. The token is deterministic, but its major problem is how to enter and exit the bus. Some of the advantages of the passive hub are that there is central

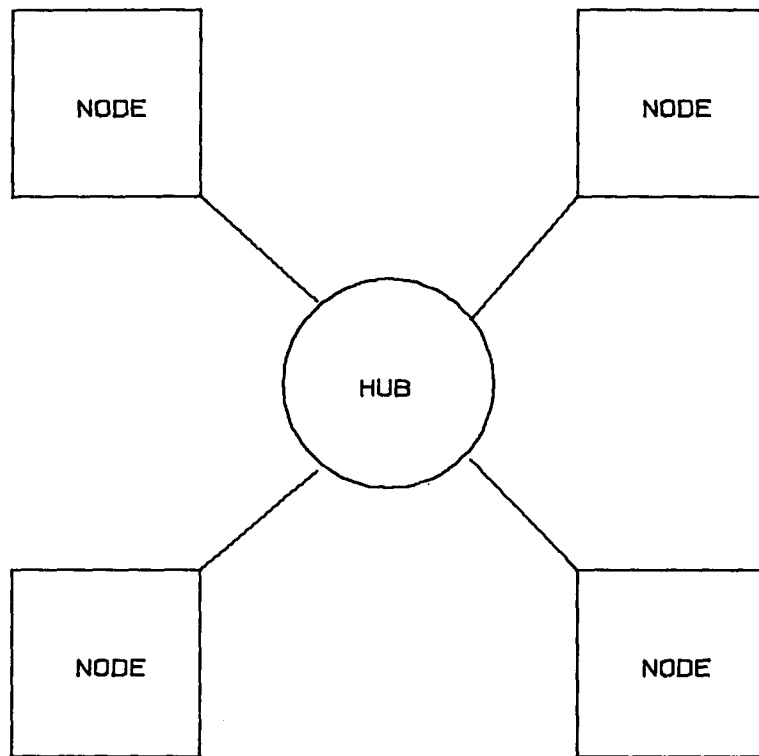


FIGURE 4-3. TOKEN PASSING .

control, no collisions occur, overhead is a linear function of the number of transceivers, throughput is good under a heavy load, a linear waiting time is achievable, and load balancing is possible

The International Standards Organization (ISO) recognized the need for universality in exchanging information between and within networks and across geographical boundaries.

In 1978, the ISO issued a recommendation to move towards greater conformity in the design of communications networks and the control of distributed processing. The recommendation is in the form of a seven layer model for network architecture known as Open Systems Interconnection (OSI). The ISO/OSI model is shown in Figure 4-4.

The power of the layered approach is that a change in one of the layers does not upset the design and/or work of the other layers, even the adjoining ones. Successive layers are connected through interfaces. An interface is a set of rules defining the relationship among different functions within the same node. Entities in the same layer communicate with each other using a peer protocol. A single entity must be both sender and receiver making it possible to define the total interaction that makes up the peer protocol by specifying the actions of the single entity. A major advantage of this approach is that a network's

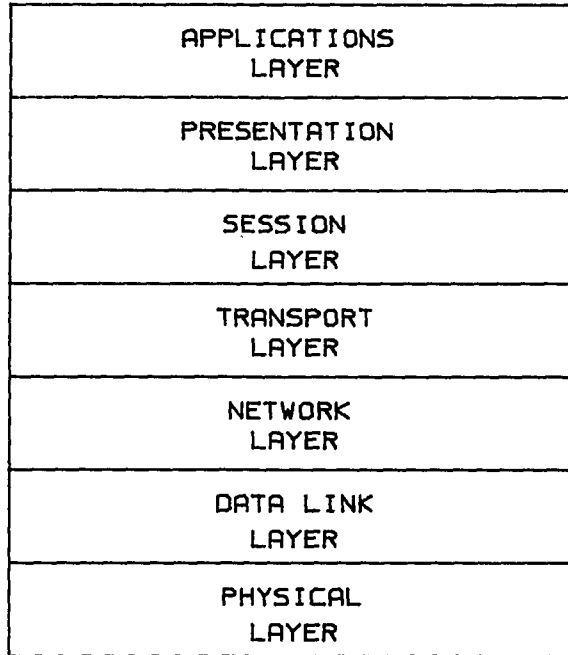


FIGURE 4-4. SEVEN LAYER ISO/OSI STANDARD.

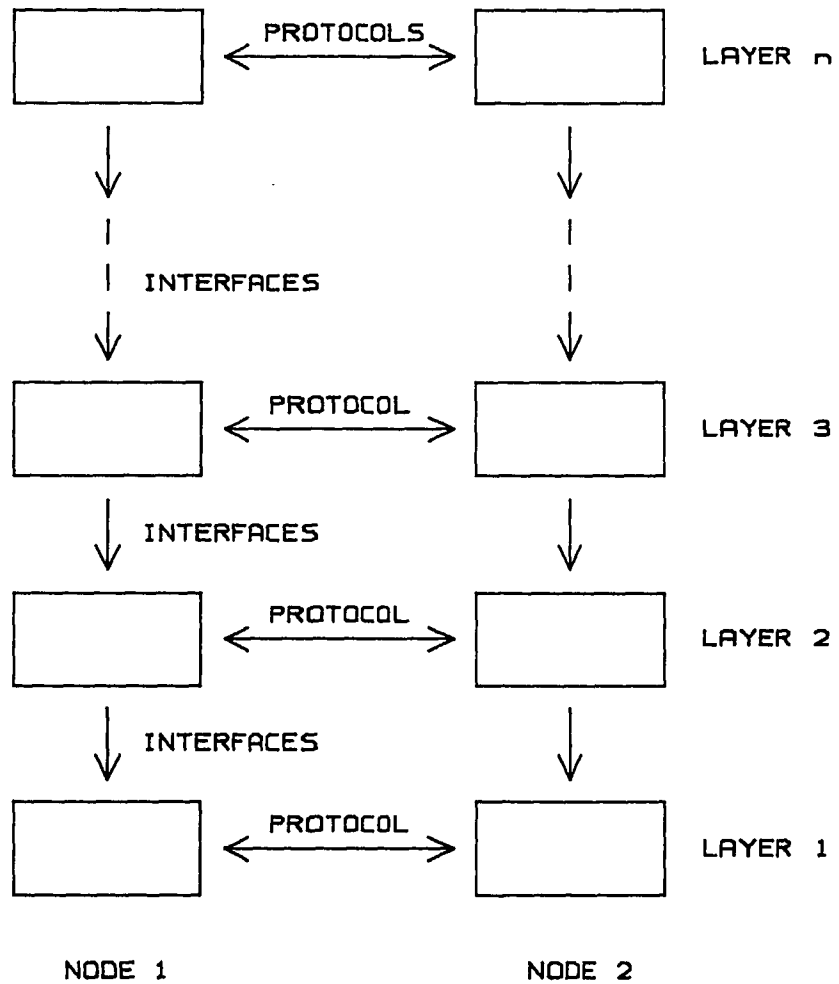


FIGURE 4-5. PROTOCOLS AND INTERFACES.

transmission format could be changed from parallel to serial without effecting any but the lowest layers.

The physical link layer defines the electrical and mechanical aspects to interfacing to a physical medium for transmitting data. In addition it defines setup, maintenance, and disconnect of the physical links. When implemented, this layer includes a software device driver for each communications device and the hardware itself: interface devices, modems, communication lines.

The establishment of an error-free communications path between network nodes over the physical channel, framing of messages for transmission, integrity checks of received messages, management of access to and use of the channel, and ensuring proper sequence of data transmitted are the functions of the data link layer.

The network control layer addresses messages, sets up the path between communicating nodes, routes messages across intervening nodes to their destination, and controls the flow of messages between nodes.

The transport layer provides end-to-end control of a communication session once the path has been established. This allows processes to exchange data reliably and sequentially, independent of which systems are communicating or their location in the network.

The session control layer establishes and controls the system-dependent aspects of communications sessions between specific nodes in the network. Also it bridges the gap between the services provided by the transport layer and the logical functions running under the operating system in a participating node.

The translation and conversion of encoded data, that has been transmitted, into formats which enable video screens and printers is the function of the presentation and control layer.

The applications/user layer provides services that directly support user and application tasks and overall system management. Examples of the services at this level include resource sharing, file transfers, remote file access, data base management, and network management.

A layered design is also important in terms of computer hardware and firmware technology. Functions performed in the software modules of the network architecture will, over time, be transferable to hardware and firmware - most notably through LSI and VLSI - particularly as a result of the standardization of more communications functions. These components will be produced in quantity, lowering unit costs, and increasing functionality.

5. PERSONAL COMPUTER IMPLEMENTATIONS

Personal computer LANs provide three major benefits: sharing of peripherals, sharing of information, and personal communications. Peripheral sharing enables networked PCs to share printers and high-capacity/high-performance disks. This allows the high cost of these peripherals to be distributed among the entire PC network. In addition, the workstations are smaller and quieter.

Another benefit, sharing of common information, impacts user productivity through the ease and speed of access. Also, data residing in one place, with multiple access, is not prone to errors of transcription and media conversion.

The third benefit of personal communication is realized through electronic mail. To be cost justified, electronic mail needs to be actively and widely used. It provides the dispensing of information directly, quickly, and reliably.

This paper will examine three LAN technologies as implemented on the IBM Personal Computer (IBM PC). They include:

- . EtherSeries by 3COM Corporation (Ethernet)
- . PC Network by IBM (Ethernet-like)
- . MultiLink by Davong Systems, Inc. (ARC)

Ethernet is a high performance, baseband, bus-oriented LAN, using the CSMA/CD access protocol, designed by Xerox

Corporation in the early 1970's. Later, it became a standard through a joint effort of Xerox, Digital Equipment Corporation (DEC), and Intel Corporation. It was also adopted as a standard by the IEEE.

Ethernet is a hardware standard solving the fundamental problems of equipment interconnection. It allows efficient communication among a variety of computer equipment, mainframes, minicomputers, and personal computers.

Coaxial cable is used as the bus part of Ethernet (Figure 5-1). Workstations may be attached anywhere along this cable by an Ethernet transceiver and a multi-wire drop cable. This drop cable is then attached to an Ethernet controller which plugs into the computer.

The coaxial cable is strung throughout a building based on needs. Each coaxial segment is limited to a length of 500 meters. However, with the use of repeaters, workstations may be up to 2.5 kilometers apart. The number of stations is limited to 100 per cable segment and to 1000 per network.

The most notable feature of Ethernet is its transmission of 10 Mbps (mega-bits per second). This speed makes networks with a very large number of stations feasible.

In early 1982, 3COM Corp. began the investigation and

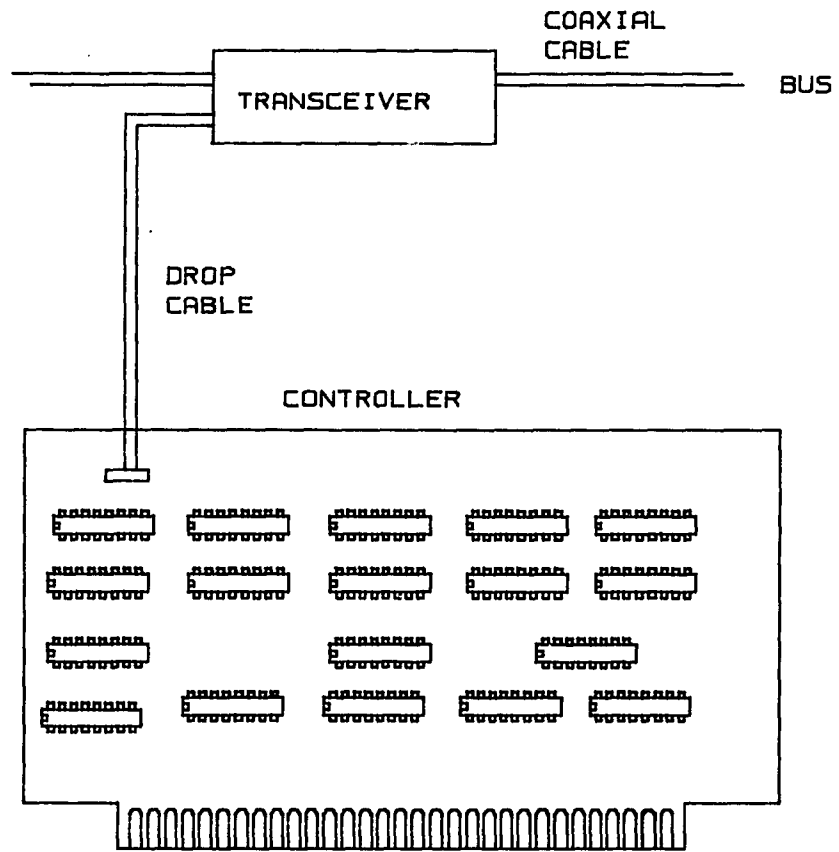


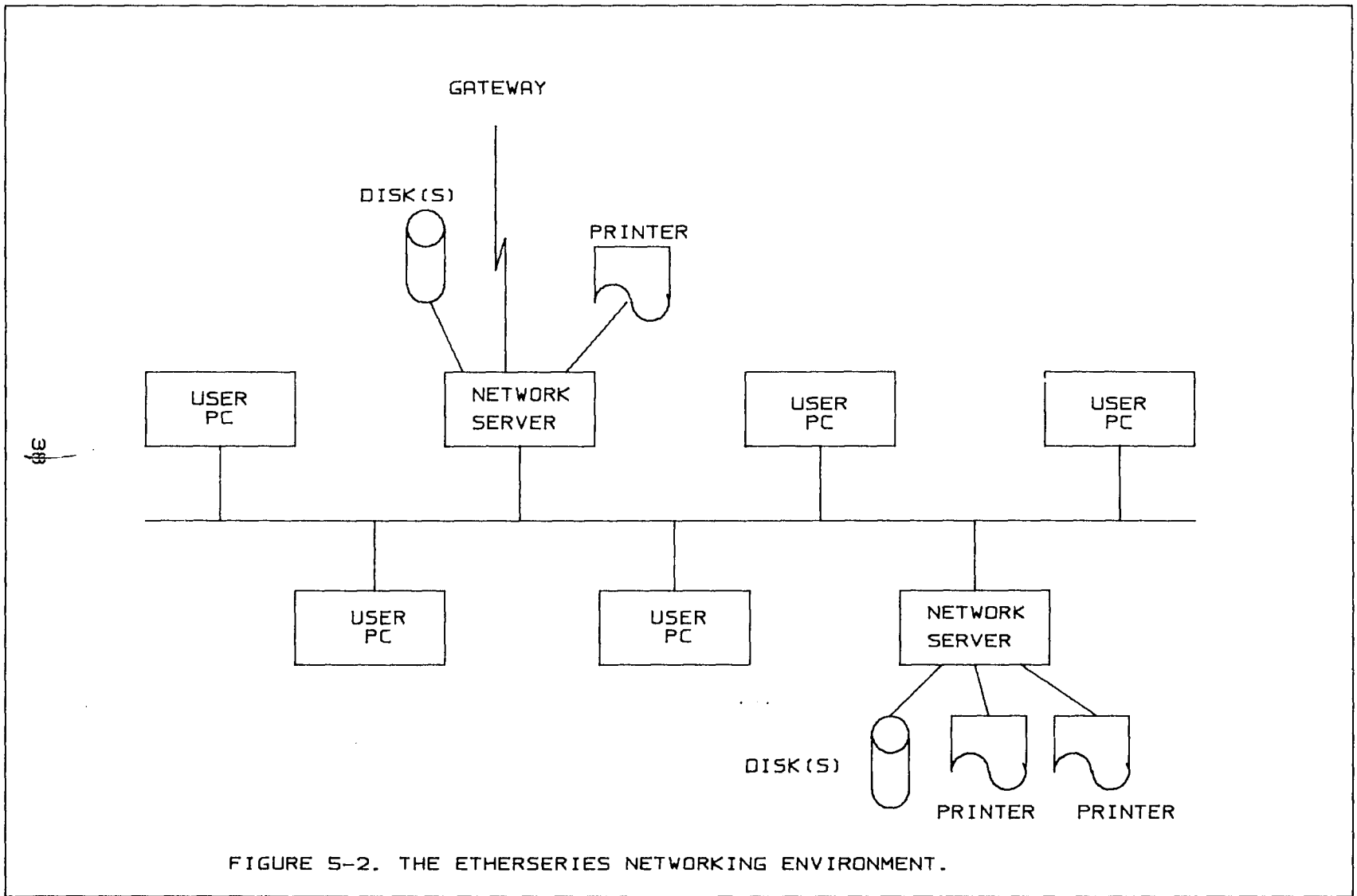
FIGURE 5-1. TYPICAL ETHERNET CONNECTION.

design of an Ethernet network based on the IBM PC. The architecture for providing network services is based on user PCs and servers as shown in Figure 5-2. User PCs are the workstations attached to the LAN. Servers are computers attached to the shared disks, printers, and other shared resources, such as electronic mail.

Three server types are available: PC, AP, and VAX. All three servers provide virtually identical services and are indistinguishable to user PCs. At the low end, the PC Network Server consists of a standard IBM PC, IBM PC XT, or IBM PC compatible, with a 3COM Ethernet interface and software. The AP Network Server, a medium-range system, is a separate 3COM box containing a high-speed processor and a 30-megabyte disk. At the high end, the server is a standard DEC VAX minicomputer running the Unix operating system, combined with a 3COM Ethernet interface and software. This paper will concentrate on the PC Network Server.

The 3COM EtherSeries Local Network Communication for Personal Computers is the integration of hardware and software networking products for the IBM PC and compatibles. It is based on the industry standard Ethernet local network.

EtherSeries products provide a local network connection and access to shared disks, shared printers, and electronic mail services. In addition, the use of PC DOS commands,



application programs, and data files function in the same manner as a standalone PC, except that your capabilities and resources are increased.

In a typical network, one PC has a hard disk and a printer physically attached and is designated the Network Server. Other PCs configured in the network request disk and printing services from the Network Server and thereby can be configured without disk or printer peripherals.

Four distinct products make up EtherSeries: EtherLink, EtherShare, EtherPrint, and EtherMail.

EtherLink is a printed circuit board that plugs into an expansion slot in each PC in the LAN, including the Network Server. It contains an on-board transceiver which maintains all critical Ethernet parameters, but simplifies cabling. It sends and receives information across the LAN and conforms to the Ethernet specifications. It is fully compatible with other Ethernet equipment.

Thin Ethernet cable is used to connect all computers included in the LAN. It can also connect to the standard Ethernet cable through the use of an external transceiver cable. The Thin Ethernet is 2/10th of an inch in diameter, compared to 4/10th of an inch for the standard Ethernet cable. The lighter weight, greater pliability, and smaller size simplify cable routing and installation.

EtherShare is software residing on the Network Server and allows many PCs and/or compatibles on an Ethernet LAN to share a single or multiple hard disks.

The physical disk is divided into volumes which are treated like diskettes. EtherShare volumes can be made public, private, or shared. Public volumes usually contain common program and information files for use by everyone on the LAN (read only). Private volumes can be used only by their owner (read/write). Shared volumes can be accessed by one or more users simultaneously but are controlled by the specific application programs.

EtherPrint is software that allows many users to print program, data, and text files on a shared printer. The EtherPrint software is installed with the Network Server, functioning as a print server. It can control two parallel printers per server.

EtherMail is an electronic mail service. Users can compose, forward, and reply to messages and read, file, and print messages received. Users can send messages to a single individual or to an entire group via a distribution list.

The Ethermail software is also installed on the Network Server.

The EtherShare, EtherPrint, and EtherMail services are

provided by installing these programs on a Network Server. The LAN can have multiple servers operation together to provide disk sharing, printer sharing, and electronic mail on the same EtherSeries network.

In addition to the four EtherSeries products, an Administration program runs on each server to manage such functions as starting up and shutting down the server, checking network status, installing network applications, and modifying passwords.

The PC Network Server provides two modes of operation: Standard Mode and Dedicated Mode. Users can switch between modes if necessary, but only one mode can be used at any one time and all users must be logged out before modes can be changed.

Standard Mode allows a single PC to be used as a Network Server and a regular PC workstation. This means that the PC's disk and printer(s) can serve the needs of all network users while at the same time, functioning as a regular PC workstation, although with some restrictions to normal operation.

The Standard Mode server software lets users log into the server from this PC and use its shared facilities as if it were a separate computer. The needs of other network users must be considered before starting or turning off this

PC.

A server running in Standard Mode supports only one shared physical disk and does not support EtherMail. Also, users cannot access volumes on other servers in the network.

When the PC Network Server is in Dedicated Mode, it is dedicated to serving the needs of the LAN. This means that the server can not be used as a regular PC workstation.

Dedicated Mode is required when the LAN contains more than one Network Server, in networks that need EtherMail and in networks that require multiple disks for network storage.

A PC server running in Dedicated Mode supports one to fifteen physical disks and all EtherSeries applications.

All EtherSeries software that provides access to shared resources over the LAN consists of two parts: server software and user software. The server software runs on the Network Server and manages the shared resources. The user software runs on the PCs that use the shared resources.

An EtherLink card may be equipped with the EtherStart option allowing a PC in the LAN to operate without expensive floppy diskette drives. When the PC is turned on, EtherStart automatically loads the operating system (PC DOS) from a network server disk.

MODE:	STANDARD	DEDICATED
EtherShare	Complete Service	Complete Service
EtherPrint	Two Printers	Two printers
- view print spool queue	No	Yes
- delete print files from queue	No	Yes
EtherMail	Not Available	Complete Service
Use simultaneously as a regular PC	Yes	No
Number of disk drives for network storage	One (32Mb max)	Up to 15 (15 x 32Mb max)
Network Control and Status and Admin functions	No -- switch to Dedicated Mode	Yes

Table 5-1. Comparison of EtherSeries Network Server Standard and Dedicated Modes.

IBM announced PC Network, but it will not be available until January 1985. It is the result of a joint effort between IBM and Sytek, Inc., who specializes in broadband networks. PC Network will be available across the entire IBM line of PCs. The architecture does not require a dedicated server. Therefore, PCs designated as servers can be used as a user workstation while sharing resources with other PCs in the network.

The PC Network protocol is about as close as it can get to Ethernet and not be Ethernet. It uses the CSMA/CD access method, but on broadband medium. This allows other data services like voice and video to share the cable without causing any electrical interference between the different signals.

The PC Network is made up of two parts: the Network Adapter Card and the PC Network Program.

The Network Adapter Card is a printed circuit board that plugs into an expansion slot in each PC in the LAN. It contains a high performance processor and custom circuitry dedicated to network functions. In addition, it is equipped with DMA (direct memory access), allowing the adapter to "talk" to the network while the host PC runs applications.

The network adapter is also equipped with 32 Kbytes of on-board ROM (read-only memory) programs which include

powerful high-level network commands. These programs directly correspond to the first five layers of the ISO/OSI standard: physical, data link, network, transport, and session. The adapter card also supports up to 32 concurrent sessions on one card. It allocates its 16 Kbytes of on-board RAM (random access memory) to assemble and transmit the largest possible data packets for maximum speed. It will dynamically divide the RAM among multiple users when they are present and reallocate it as users log out.

The Network Program runs under IBM PC DOS 3.1. Therefore, it is software residing on every PC in the network. It implements the file sharing and read-only protection of files. It also supports the use of passwords for control of specific disks, files, and print servers.

Each print server can share up to three PC DOS print devices. Each print device is queued, requiring a hard disk to spool the print jobs. The printing itself is done in background and does not interfere with normal PC operations. The print queue for each print device will handle up to 100 files.

The Network Program is a simple, logical extension of regular PC DOS commands. In addition, it supports an operating mode with menus.

Another feature of the PC Network is that every PC

(node) in the LAN is assigned a name, such as "Aaron's PC" or "Server1". These names are used to move data, print files, and messages through the network. The ability to send messages to other users is a rudimentary form of electronic mail.

The Network Program is modular and reconfigurable in design. In its basic mode, a user can redirect file I/O requests and print requests to a server PC. This remote resource is then treated as if it was directly attached to the local PC.

A user PC can "listen" to the network and receive messages, routing them to the console, a file, or a local printer. This "receiver" function receives messages at the same time the PC is running local programs.

A third level adds a full-screen editor to the above two functions, allowing a user to forward messages to multiple users.

A "server" is at the top level. At this level a PC can share its disk and printer resources with other users in the LAN, concurrent with local applications.

IBM PCs are connected to the LAN via broadband coaxial cable. The PC Network supports up to 72 PCs in a 1,000 foot radius. However, with commercially available broadband amplifiers and equipment available from cable TV

vendors, the system can interconnect up to 1,000 PCs and extend over several miles. The system supports a transmission speed of 2 Mbps.

The system uses two 6 MHz channels (the same bandwidth as a TV channel), one to receive data and one to transmit data. The adapter card has an RF modem, an actual transmitter, and a receiver pretuned to these channels. This requires the use of a translator (transmitter). Its function is to take everything it "hears" on the receive frequency and resend it on the transmit frequency. This ensures that every PC in the LAN gets a strong signal.

A standard TV cable can easily carry 50 TV-like channels. Therefore, PC Network still has 48 unused channels. These spare frequencies (channels) leave the door open for the addition of voice and video (teleconferencing) applications.

MultiLink by Davong Systems, Inc., is based on Datapoint's ARCNET technology. It allows up to 255 IBM PCs and PC-compatibles to communicate and share resources over a LAN.

The MultiLink hardware uses a VLSI implementation of the network controller providing a low-cost and effective PC implementation. The hardware controls access to the LAN bus via token passing. Its transmission rate is 2.5 Mbps and up

to 20,000 feet between any two workstations is supported.

The network uses coaxial cable and network "hubs" to connect workstations in the LAN. Two types of hubs are supported: a low-cost, passive, 4-connector hub and an active 8-connector hub. The network has an arbitrary topology, therefore allowing hubs to be connected to other hubs or workstations. However, there are three restrictions: no two workstations can be more than 20,000 feet apart, a passive hub cannot connect to another passive hub, and no loops are allowed.

Passive hubs employ resistors to split the signal into each of the four connections. Active hubs have both a power supply and logic to regenerate the signal, echoing it to the seven other connections. The cable attached to an active hub is restricted to a maximum length of 2,000 feet. On a passive hub the maximum is 100 feet.

The hardware works by passing a token from station to station. After receiving the token, a workstation can transmit one message, then must pass the token to the next station. This guarantees equal access to all stations in the LAN and provides an efficient utilization of the LAN data bus.

The MultiLink network user is provided with shared disk resources, printer spooling, and electronic mail

facilities. Any PC connected to the LAN can be used as a workstation, network file server, and print spooler all at the same time. LAN control is decentralized, with resources located by name, and access controlled by passwords.

Every resource in the LAN has a name. These resources can be shared hard disks, printer, or user defined facilities. Whenever a resource name is used it will automatically be located over the LAN.

Hard disks are divided into volumes by a hierarchical directory structure. This allows volumes with common attributes to be grouped together. Volumes are contiguous to provide maximum performance.

Passwords are used to restrict access to each hard disk and/or volume. Two passwords may be defined for each volume: a group password and a private password. In addition to passwords, each volume has three types of access: public, group, and private. Public access is granted to everyone who uses a volume without a password. Access rights may be none, read only, or read/write. None means no access rights to the volume. Read only access allows everything but modifying the volume. Read/write access allows any operation on the volume.

Printer spooling allows any printer connected to a LAN PC to be used as a shared printer. Each PC can support

up to two printers.

The electronic mail option provides all the facilities to send memos, notes, letters, and data files over the network. The ability to send mail over a phone line to another network or user is also provided.

MultiLink's network software implementation contains four major components: multi-tasking kernel, disk cache, pipelined network activity, and pacing.

The multi-tasking kernel is the basic scheduler and control mechanism for the system. It uses a message-switching type architecture, providing a powerful multi-tasking environment with very low overhead.

The entire system design is based on a high performance disk cache. A disk cache is a large set of disk data blocks kept in the PCs memory, providing an intelligent buffering of data transfers between memory and a hard disk. All I/O activities use the central disk cache manager.

The disk cache is managed using the least recently used (LRU) algorithm. When a new cache block is required, the oldest block in the cache is released and reallocated.

The disk cache solves a great many performance problems usually associated with a hard disk.

The network hardware interface contains buffers for

four network messages to support double buffering of both network input and output. This means that while the current input message is being processed, the next one can be received over the network. The network I/O software extends this double buffering to process three or more messages in parallel. This is often called "pipelined" processing. By overlapping network activities, throughput is much higher than if requests were processed one at a time.

The pacing parameter reduces the amount of available network processing time, guaranteeing that local applications can run effectively. Without pacing, LAN requests may flood a workstation, preventing any local use of the workstation.

The MultiLink network uses a subset of the Xerox Network Standard (XNS) to allow future compatibility with gateways to other networks.

	EtherSeries (Baseband)	PC Network (Broadband)	MultiLink (Baseband)
Date Rate	10 Mbps	2 Mbps	2.5 Mbps
Maximum Number of nodes	100 per segment 1000 per network (using repeaters)	72	255
Access Method	CSMA/CD	CSMA/CD	Token Passing
Error Detection	CRC	CRC	CRC
Maximum length of network	1000 ft. (Thin) 3280 ft. (Thick)	2,000 ft.	20,000 ft.
Packet size	512-12,144 bits	Dynamic	n/a

Table 5-2. Comparison of PC implementations.

6. CONCLUSIONS

The three LANs examined in this paper have demonstrated that personal computers are a viable means for implementing local area networking systems. Each has taken proven network architectures and transported them for use on industry standard (off-the-shelf) personal computers. This was accomplished through VLSI technology. In addition, these PC LANs were developed without compromise to standards set forth by the IEEE and ISO.

Each PC LAN has presented the user with a simple interface, usually as an extension to the PC operating system. By making the network interface transparent to the user, little training is required before the user can take advantage of the additional facilities provided by a LAN.

The major problem facing the PC LAN developers is the unavailability of true multi-user application software. Although each PC LAN supports shared file access (concurrent access of the same file by multiple users), off-the-shelf software is strictly single-user. What this means is that applications must be designed or rewritten specifically for a LAN environment.

This problem is predominantly caused by application software developers. Most popular PC application packages, like 1-2-3 by Lotus Development Corporation, require at

least one floppy diskette drive to implement their copy protection schemes, thereby limiting the effectiveness of a LAN. Therefore, as long as the PC user is willing to pay \$500.00 or more for each copy of a package, the software vendor has no real incentive to move their products to a networking environment.

Like all substantial hardware advances, such as local area networking on PCs, the available application software lags behind. However, some application developers are designing their products to run in multiple environments. Once this happens throughout the entire industry, LANs and PCs will become a fact of life.

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8. VITA

The author was born to Mr. and Mrs. Leonard L. Balch, Jr. on June 27, 1956 in Port Jervis, New York. He earned his A.A.S. degree in Business Data Processing from Orange County Community College in 1976 and his B.S. in Computer Science from East Stroudsburg State College in 1978. In the fall of 1979, he began graduate study in Computer Science at Lehigh University. He has been with the Computer Engineering Division of Pentamation Enterprises, Inc. in Bethlehem since 1978. His primary responsibilities has been in programming and integration of microprocessor based systems with emphasis on communication and local area networks.