LOCAL-AREA NETWORKS FOR THE IBM PC

BY J. SCOTT HAUGDAHL

Be sure of your networking goals and needs before you invest in expensive technology

THERE ARE 40 OEMs (original equipment manufacturers) of personal computer local networks in the industry; 18 (not including third-party OEMs) of these are basically only for the IBM PC. *None* of these systems is fully compatible with any of the others. Most were introduced in 1983, and many are from "me-too" vendors that have jumped on the IBM PC local-area-network (LAN) bandwagon. Table 1 indicates the wide variety of local networks available for the IBM PC.

Every vendor usually claims that it has the best technology, the best idea, the best implementation; clearly, this cannot be true for all of them. Manufacturers would like you to believe in the idea of the turnkey system, the kind of information source or utility that you simply plug your computer into and it works beautifully. No system is really as turnkey as we'd like it to be, mainly because the technology is so new. The oldest personal computer LAN vendors are three to four years old.

As everyone should be aware of by now, a revolution has taken place over the past 10 years in silicon and integrated circuit technology. The result is that the cost of a central processing unit is really a small fraction of the cost of a whole system. The real cost is in the electromechanical peripheral devices connected to a system—disk drives, printers, etc., and the necessary support circuitry it takes to drive them. Thus, with LANs you want to preserve the benefits of stand-alone microcomputers, namely, use of your favorite software and peripherals and having a machine all to yourself, as well as adding new benefits from networking. Besides sharing expensive peripherals, you can add electronic mail, multiuser databases, high-speed communications between personal computers, minicomputers, and mainframes, and a slew of multiuser applications such as accounting and inventory control.

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An interesting technological issue often ignored by manufacturers is the concept of open versus closed systems. Open systems are basically systems that are built to a published specification—either standardized or designed in a nonproprietary way. With open systems, all the design details of the implementation are published; closed systems are completely proprietary. Most systems that follow de facto standards, such as Ethernet or Arcnet, and those that follow "committee" standards, such as IEEE-802 or those of the National Bureau of Standards, tend to be open systems. Open systems that follow standards also typically allow the user to buy equipment that will work on a specific network from more than one vendor. Most of the microcomputer local networks, however, tend to be highly proprietary, leaving the end user at the mercy of the vendor.

Unfortunately, there are still some technical drawbacks to microcomputer LANs. The worst problem is the need LANs create for very complex and specialized software to handle

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the communication that will take place over the network. Also, when you are working with a complete system that is going to be spread out over thousands of feet, something may fail and it may be difficult to find out exactly what has failed and where. In the past, with the stand-alone personal computer, if you couldn't read a disk drive you had a pretty good idea that something was wrong with either the disk drive or the disk.

Unique expertise is usually needed in day-to-day operations to maintain and administer these systems. Also, the manufacturer should provide diagnostic tools to help you maintain the network. These are typically software programs that do a variety of tests, such as testing the network or the network interface in a particular computer. You should also be able to diagnose and repair problems concurrent with the normal operation of the network. For instance, if you have a computer that fails, you should be able to take the computer off the network and fix it and then put it back on without having to interrupt the normal use of the network.

The cost of the transmitting cable is probably one of the most deceiving things about LANs. Many vendors tout "low cost" when describing this item, whether it be coaxial cable or twisted-pair wire. The real cost is not the cable itself but how much it costs per foot to install it in a system. A number of companies have actually paid as much as $1000 per foot for installation.

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Table 1: A *survey of local-area networks that support the* IBM PC *and their features.*

VENDOR	NETWORK	MEDIUM	DATA RATE	ADDRESSABLE NODES *	LINK PROTOCOL	DISTANCE**	SERVER TYPES SUPPORTED	OS SUPPORT	OTHER PCs***
AST Research	PCnet II	T	800K	64K	CS	10	D,P	M	
Christain Rovsing	X-Net	T	1.8M	64K +	P	22	32	M	
Corvus	Omninet	T	1M	64	CS	10	D	M,P,C	Y
Davong	Multilink	C	2.5M	255	A	22	DP	M,P,C	
Fox Research	10-Net	T	1M	255	CS		F,P,32	M	
Great Lakes Computer	Great Net	C	5M	64	P			M	
Gateway Communications	G-Net	C	1.43M	256	CS	10	F,P,32,G	M	
IBM	Cluster	C	375K	64	CS	10	D	M	
IBM	PC Network	C	2M	64	CS	2	F,P,32,G	M	
3M	LAN/I	C	2.5M	255	A	22 +	G	M	
Nestar	PLAN 4000	C	2.5M	64K +	A	22	D,P,32,G	M,P	Y
NCR	DecisionNet	T	1M	64	CS	10	F	M,C	Y
Novell	NetWare/X	C	1.43M	256	CS	10	F,P	M	
Novell	NetWare/S	T	500K	24	P	2	F,P	M,C	Y
Orchid	PCnet	C	880K	64K	CS	10	D,P	M	
Percom Data	PerComNet	C	1M	256	TP	10	D	M,C	
Proteon	proNET	T,C,F	10M	256	TP	10	F,P	M	
Standard Data	STANDARDNET	C	3M	256	CS	2	D,F,P	M	
Tecmar	Elan	C	10M	64K +	E	10	D	M	
3Com Corporation	Ethernet	C,F	10M	64K +	E	10	D,P	M	
Ungermann-Bass	Net/One PC Baseband	C,F	10M	64K +	E	10	D,P,32,G	M	
Ungermann-Bass	Net/One PC Broadband	T	5M	64K +	CS	22 +	D,P,32,G	M	
VLSI Networks Inc.	1553-Net	C	3M	256	CS	2	D	M	Y
XCOMP	XNET	T	2.5M	256	CS	10	F,P	M	

* Theoretical maximum number (see text of article)

** Repeaters may be necessary to achieve the distance indicated

*** Other than the IBM PC

LEGEND

MEDIUM
- T = twisted-pair
- C = coax
- F = fiber

DATA RATE
- K = kilobits per second
- M = megabits per second

LINK PROTOCOL
- A = Arcnet
- E = Ethernet
- CS = CSMA
- TP = token passing
- P = proprietary

DISTANCE
- 2 = less than 2000 feet
- 10 = less than 10,000 feet
- 22 = less than 22,000 feet
- 22+ = 22,000 feet or more

SERVERS
- D = disk
- F = file
- P = print
- 32 = 3270
- G = gateway

OPERATING SYSTEM SUPPORT
- M = MS-DOS
- C = CP/M-86
- P = p-System

You probably won't see the transmitting cable cost in an IBM PC LAN cost estimate because these systems tend to be broadband types installed in metropolitan high rises with previously installed cable. On the other hand, cable cost can still be a cost factor in these IBM PC networks, especially if there are a lot of nodes on the system. They call for a lot of wire, and the environment may require union people or an electrical staff to install the system. All of these cost factors are important.

The way a vendor has designed the network interface board that connects the IBM PC to the network varies dramatically from vendor to vendor. Unfortunately, most end users don't really take a look at the hardware; they care more about the functionality at the application level.

This is unfortunate because the performance of these systems has to do with how intelligent the network interface board is. Does it use very-large-scale integration (VLSI) data-link controllers and/or dedicated central processors? Or does it use a lot of basic building blocks, such as small-scale integration (SSI)? Does it support direct memory access (DMA)? How about interrupts? Does it require a lot of processor time, for example, from the IBM PC's 8088 processor to service the card? Or can the IBM PC go off and do its own thing and be interrupted, for example, if a packet has been received? In some systems you can send a packet of data to the network-controller board and go away to perform another task. The controller will form the packet (add headers, addressing, checksums, etc.), sense when the network is free (or wait for a free token), and send the packet to the receiving node, all without any intervention from the IBM PC. On the other hand, some systems require constant attention from the host central processor, adding a tremendous amount of overhead to the system to support the network. In addition, intelligent controllers require less software to support the network—software that has to be designed, debugged, maintained, etc.—

which leaves more memory in the IBM PC for the individual user.

Most LAN data-link protocols in use today were derived from one of two general schemes known as carrier-sense multiple-access (CSMA) and token passing. The Xerox-developed Ethernet uses the best-known implementation of a carrier-sense multiple-access protocol; Ethernet assumes that its nodes will be connected in a bus-type layout and adds collision detection (so the protocol is called CSMA/CD). On the other hand, Datapoint Corporation used token passing over a bus layout in designing its popular Arcnet protocol. Several semiconductor houses are offering or will soon offer special chips for handling these and other protocols, but some local networks, such as Omninet from Corvus and Netware/X from Novell, rely on a dedicated microprocessor.

Servers

Let's take a look at servers, since they are key to supporting LANs. A server could be an IBM PC or a specialized "black box" that performs some function at the request of a client.

In general, how can you compare two or more servers? There are a few questions you might ask. What is the capacity of the server? In the case of a file server, how many megabytes of storage can it support? In the case of a print server, how many printers can it support? Can it print concurrently on more than one printer? Does it use virtual printing, spooled printing, or a combination of both? Can you have more than one of a certain type of server on the network?

Because all these servers support multiple users, you're going to need some sort of password protection scheme, as well as some means of protecting the data of one user from another. Also, because large amounts of disk storage are typically handled by a file server, it should support some form of backup, such as a streaming-tape drive. Some servers support other functions, such as a network-wide real-time clock/calendar, and synchronization of processes on

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the network by semaphores (flags that are typically implemented by subroutine calls to the network operating system) or lock tables.

Let's look at dedicated versus nondedicated file servers. Clearly, with a dedicated machine, you might hope to provide high performance through dedication. The server doesn't have to worry about anything except servicing requests and is probably more secure than the nondedicated machine; if nothing else, you can lock it up in a back room somewhere and make it physically secure. It is also more secure in the sense that a user program cannot interfere with the server and crash it (as can happen with a nondedicated server).

The disadvantage of dedicated file servers is cost, because they can no longer be used as workstations. However, costs can more than be recovered because response times will be better, thus saving people's time.

I am beginning to see more and more nondedicated servers, particularly in some of the "low-cost" networks that bill themselves as being "easy to afford and easy to install." Basically, this means that the user and server processor can coexist in a single machine, so users, for example, can have PC XTs and share their hard disks with other users on the network at the same time they are running a spreadsheet program. These nondedicated servers clearly have the cost advantage because you don't have to buy a dedicated machine.

They have some disadvantages, too. Nondedicated servers require a multiprocess operating system, which will generally degrade performance. An example of this degradation can be seen on the IBM PC. Every time you

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press a key on the keyboard, you generate a high-priority interrupt. If your nondedicated server machine is used by a typist, you may see the performance of the file server that happens to coexist in the same machine degrade to intolerable levels. Likewise, if suddenly 10 stations on the network try to share your disk, it may take a very long time to recalculate your spreadsheet program.

There is also the issue of security: a programmer may be able to make direct calls to the BIOS (basic input/output system) and circumvent the server's security mechanism, gaining access to files and passwords.

Another trade-off is centralized versus decentralized file service. A centralized file service means there is one file server on the network, controlling the resources and simplifying management, so that you don't have the problem of multiple file copies existing in widely distributed places (as with decentralized file services). You may be able to take advantage of the economies of scale here; instead of buying 10 IBM PCs with 10 small hard disks, you might be able to buy one centralized file server with a large hard disk that can be shared.

However, the server is a potential bottleneck, particularly if you don't go with a high-performance processor. A lot of users on the network can try to access the file server simultaneously. Clearly, if that server should ever fail, all the disks that are on the network are going to be down. The server then becomes a central point of failure.

Most of these centralized networks use off-the-shelf IBM PC XTs as servers. Often, PC XTs that were purchased before networking was considered can be used. If something goes wrong with the PC XT, another one can often be swapped in. On the other hand, high-performance servers, such as Nestar's PLAN 4000 server (based on multibus architecture and using a 68000 processor from Motorola), can offer substantially better network disk-sharing performance.

Finally, there is a real difference between file and disk servers. The terms are often used interchangeably, but most vendors' "file" servers are really disk servers.

Disk servers service users' requests for disk I/O (input/ouput) at a low level. This requires a low-level modification of the users' workstations to intercept BIOS requests for reading and writing disk sectors. Thus the server is really a disk "volume" server, and file I/O is handled directly by the operating system in the PC.

File servers service users' requests for disk I/O at a higher level. This high-level modification to users' workstations is performed at a level that intercepts DOS requests for file operations, such as opening, reading, and

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closing. The server then has control over files and can enforce automatic file locking to prevent a file from being written to by two or more users simultaneously. Another advantage of file servers is that disk space for individual users does not have to be preallocated. A user's storage space can grow dynamically as space is needed.

IBM PC Local Networks

Note that while the systems in table 1 are designed for the IBM PC, some may work as well with compatibles. Since more than 30 microcomputers are reasonably compatible with the IBM PC, there are more than 500 combinations of PC-compatibles and LAN systems. It is often up to the user to find out what works together and what doesn't. You should also note that all of the vendors listed plan to support the PC AT as well.

3Com EtherSeries

3Com, a privately held company that went public this spring, has a number of Ethernet products, one of which is the EtherSeries line for the IBM PC. 3Com got its start designing and selling Ethernet components, transceivers, cables, and some board-level products. In December 1982 it introduced the first Ethernet board for the IBM PC, based on the VLSI data-link controller from Seeq Technology. At that time, the board was really just a hardware product with some crude software, but now with the EtherSeries, 3Com has a systems-level product. To no one's surprise, the EtherSeries product is beginning to dominate 3Com's sales and now accounts for about 50 percent of the company's revenue.

EtherSeries is a complete Ethernet system for the IBM PC. The file server (actually a disk server) can be either a PC XT, an IBM PC made to look like a PC XT, or a 3Com machine. IBM PCs require the 3Com EtherShare software package and one EtherLink interface card. Alternatively, you can buy the higher-performance 3Com server that is based on the Altos 586 workstation, which uses a high-speed 8086 processor. The IBM PC version does not require dedication. Both versions can download the disk operating system (DOS) to diskless IBM PCs (which contain an optional boot ROM [read-only memory] on the network interface card).

EtherShare manages virtual disks at the volume level. Passwords are required to "log on," and optional passwords can be placed on volumes. Volumes can be made private for individual use only, public for use by several users in a read-only fashion, and shared for multiple read/write access. However, there is nothing implied in EtherShare that protects multiple writers from corrupting each other's data by writing to the same disk area at the same time. The application software must take advantage of semaphores and locks that are provided by EtherShare.

EtherShare can provide other server functions such as spooled virtual printing (EtherPrint) and electronic mail (EtherMail). An interesting feature of the print server is that you can have multiple users spooling data simultaneously without interfering with each other. The server maintains buffer spool files on the disk, and the first file to "close" (or time out while waiting for more print data from the network) starts printing. EtherMail runs on top of EtherShare, as does EtherPrint, so that you can have EtherMail, EtherShare, and EtherPrint all running on the same machine. EtherMail provides electronic mail for all the users on the system, sets up mailboxes for them on the file server, and can find other users mailboxes on other EtherShares in the network. So EtherShare really becomes a multipurpose server.

IBM Cluster Control Program

IBM gave its "stamp of approval" to IBM PC local networks on March 1, 1984, at the same time it announced the IBM Portable PC.

IBM's Cluster Control Program is designed to be a low-cost, entry-level system, as you will see when you look at the technical specs. (The Cluster Control Program name is somewhat deceiving; "program" refers to the entire system, not to a piece of software.) Compared to other more sophisticated, more mature networks that are available today, I see this system as primitive at best. IBM wanted to design a simple system that could be used by the "average" end user. The company didn't call it a LAN because it didn't want it compared with high-performance LANs.

The Cluster runs at a modest 375K bps (bits per second) and uses a carrier-sense multiple-access protocol with collision avoidance (CSMA/CA). It uses 75-Ω (ohm) CATV-type coaxial cable. You can run the main bus connection as far as 1000 meters instead of the typical 1000 feet, partly because of the modest data rate. The addressing structure allows as many as 64 users per cluster. In practice that number would be far less, depending on the applications and the kind of things you do.

The Cluster supports the IBM PC, PC XT, PC Portable, and the PCjr. There are two different versions of the adapter, one for the PCjr and one for all the other machines. The PCjr adapter plugs into the side of the machine, which, at least in the initial shipments, contains a power supply that is inadequate to power more than the PCjr and the adapter. In order to have the Cluster adapter and a disk drive, printer adapter card, or internal modem plugged in, you must have the power-expansion adapter, which was announced this summer.

The network software requires DOS 2.1 and supports station-to-station communication; you can send files or messages back and forth between users. The package also has some diagnostics to help identify problems (for example, the network card) and it includes disk-server capabilities for the PC XT.

The disk server, like the hardware itself, also supports the IBM microcomputers previously mentioned. It requires a PC XT or a PC made to work like an XT. As an option, the IPL (initial program load) allows you to

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download the DOS 2.1 operating system from the PC XT right into your workstation; in fact, the PCjr is supported in this way because it does not have a disk drive when it is on the network.

The disk server supports sharing at the volume level and supports only two volumes at one time per user. You can mount only two virtual disk volumes at one time, one of which can be a public volume shared by all users on the system (read only), and the other a user's private volume. However, you'll start seeing more and more sophisticated software to support the system as third-party software vendors jump on the bandwagon.

IBM PC Network

In mid-August of this year, IBM announced its first "real LAN," the IBM PC Network. The PC Network is based on broadband technology developed by Sytek Inc. Sytek supplies the PC Network Adapter Card and the Network Translator Unit, or head end, to IBM. The Network Translator comes with a connector assembly for attaching as many as 8 IBM PCs within a radius of 200 feet. A cabling component, consisting of cable segments, a network-base expander, and various network distance kits, is used to increase the number of networked IBM PCs from 8 to 72. In addition, IBM is an OEM of Sytek for LocalNet/IBM PC protocols, modified Sytek LocalNet 20 protocols that are used in the Adapter Card for higher-level protocol implementation.

The IBM PC Network operates at 2 megabytes per second on one channel of a midsplit broadband system for distances up to 1000 feet. With the components that are available from IBM, the maximum number of IBM PCs supported on the network is 72. These limitations, however, appear to be due to IBM marketing decisions and are not inherent in the design.

The PC Network is designed for the IBM PC, PC XT, Portable PC, and the new PC AT. Unlike the Cluster, it will not support the PCjr. It is being promoted as offering highly reliable, maintenance-free operation and has extensive self-test and diagnostic capabilities.

The Adapter Card for the PC Network uses an Intel 82586 Ethernet data-link controller chip to provide access control. An Intel 80188 microprocessor running at 6 MHz and 16K by 8 RAM (random-access read/write memory) data buffers are used for protocol processing, packet assembly/disassembly, and other control functions. A custom VLSI chip, jointly developed by IBM and Sytek, is used to implement protocols up to Level 5, the session level. Up to 16 active aliases and 32 active sessions are allowed per IBM PC. Release 3.1 of DOS will be required to support PCs on the network.

IBM representatives have stated that the PC Network Adapter Card will work on third-party installed networks. Certainly Sytek will help anyone who wants to install IBM PCs on its LocalNet 20, anyone who wants to install more than 72 nodes, or anyone who wants to develop large integrated local networks. IBM appears to be targeting small businesses, the mass market, and large non-IBM accounts with this product. The Network Adapter Card is currently available, but the network software (DOS 3.1) will not be available until early next year.

IBM has also stated its intention to interconnect the PC Network to its token-ring network (announced, but not commercially deliverable for another two years), and that all PC Network software will also run on IBM PCs directly attached to the token ring. Thus, software developed for the PC Network will not become obsolete when IBM begins to implement its token-passing ring network. However, it is not clear how the Cluster fits into IBM's overall LAN strategy, if at all. One nice application for the broadband IBM PC network would be to support several "subnetworks" of Cluster systems.

Orchid Technology's PCnet

Orchid Technology's PCnet is available from a number of different vendors in addition to Orchid. AST's PCnet, Santa Clara Systems' PCnet, and IDEAssociates' IDEAnet are all basically the same system.

PCnet is a CSMA-type system that

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uses coaxial cable as a transport medium. It also supports collision detection and is software-intensive. The network board has no VLSI or central processor. It requires constant attention from the PC's processor to support all the data-link functions to form the packet, ship it, watch for collisions, etc. Benchmarks for PCnet are beginning to run slower than other systems, due in part to overhead to support the networking function, as well as Orchid's proprietary multiprocess operating system. Again, the network board provides only a physical interface between the IBM PC and the network. It also turns out that PCnet really runs at the raw data rate of 880K bps—not 1 megabit per second, as stated in Orchid's brochures.

PCnet uses 75-Ω CATV-type coaxial cable. It can run as long as 3000 or 7000 feet, depending on the cable type.

PCnet is available with a number of options. You can get a multifunction memory board, some ports, and a diskless board that allows you to boot from the network, eliminating the need for floppy-disk drives at the workstation.

Like most of the other systems, PCnet does not require a dedicated disk server. You can have two different types of workstations: user PCs and shared PCs. User PCs cannot share their peripherals (with the exception of a printer) with other users on the network. On the other hand, you can make your peripherals, such as a hard disk on a PC XT, available to other users.

PCnet supports a distributed semaphore system. The semaphore table is maintained at each and every machine in the system. This also adds overhead to the system because tables at all PCs must be updated when they change. One of the more interesting features on the system is the remote execution command, which allows you, for example, to compile a Pascal program on a remote machine in the network.

You must be careful when sharing peripherals in PCnet. It is possible to mix output on a printer being shared by more than one person because there is no implied semaphore locking: either you have to build a network print utility that uses the distributed semaphore system or you have to have everyone who wants to use a shared printer use a procedure that says, "Try to lock the printer by entering a semaphore lock command from the keyboard before you try to print. If it's in use, try later. Unlock the semaphore when done."

AST now has a lower-cost version of PCnet available called PCnet II, which runs at 800 bps, uses a collision-avoidance scheme, and is software-compatible with PCnet. AST has also developed its own more efficient software for PCnet II.

Ungermann-Bass Net/One Personal Connection

Ungermann-Bass has built a reputation with its Ethernet products, which make up the Net/One product line. These products are basically intelligent boxes that enable you to connect any computer, mainframe, or personal computer to Ethernet. The first products supported terminals in mainframe environments connected via Ethernet, which allowed users to establish virtual terminal connections with a host.

The newest Net/One product is the Net/One Personal Connection for the IBM PC, introduced at the end of last year. This product puts Ungermann-Bass head to head with 3Com; it is aggressively priced as well. It is a true Ethernet system and employs the high-level Xerox Network Systems (XNS) protocols. It is also the first true LAN for PCs to offer a broadband option.

Like most of the other systems based on the IBM PC, the servers are all designed around the PC XT. They are available as a file server, a print server, and an SNA (Systems Network Architecture) Gateway. Multiple servers of the same or a different type are allowed on the same network and do not have to be dedicated.

The network-interface card is called the Network Interface Unit (NIU), a

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board that contains an on-board, high-performance VLSI Ethernet data-link controller from Intel. It also has an on-board, high-performance Intel 80186 microprocessor, 8K bytes of ROM, and 128K bytes of RAM. It requires an external Ethernet transceiver (3Com offers a built-in transceiver). The network interface card is a complete microcomputer on a board, dedicated to handling the XNS protocols and the data-link function. It turns out that this card is more powerful than the IBM PC itself! A less-powerful, less-expensive version is available; it lacks the 80186 and its support RAM and ROM.

A broadband version of the Net/One Personal Connection is totally software-compatible with the baseband Net/One and can also run on existing CATV installations. It runs at 5 megabytes per second and consists of an RF (radio frequency) modem board that plugs into a slot on the IBM PC with a jumper to the baseband board.

Ungermann-Bass entered into an agreement with Davong, through which Ungermann-Bass acquired sorely needed network software to make its system work. Davong has developed a stable networking product called Multilink (also for the IBM PC), which has excellent software to go with it. This will also enable the Net/One Personal Connection to support CP/M-86 and the UCSD p-System, as well as MS-DOS.

Mixing IBM PCs with Other Machines

Let's take a look at two systems that support not only more than one type of personal computer but also more than one type of operating system. So far, all of the systems we've looked at work only with the IBM PC (and some compatibles) and only support the MS-DOS operating system (with the exception of Net/One).

Corvus

Corvus started by selling the first 5¼-inch add-on Winchester drives for personal computers. The first networking product from Corvus was called the Multiplexer, but it was not a true LAN. It was simply a device that allowed you to share a hard disk by partitions. Along came Omninet, a true LAN. Omninet uses CSMA with positive acknowledgment (often called CSMA/PA); hence, Omninet can ensure reliable packet transmission and reception by waiting a brief instant for an acknowledgment from a receiving node after sending a packet. This improves network performance substantially.

Omninet supports more kinds of personal computers than any other network; it has versions for the IBM PC, Apple II, Corvus Concept, TI Professional, DEC Rainbow, and S-100 systems. In addition, a number of other manufacturers are offering it as an option with their personal computers.

The Omninet's address limitation is 63 nodes; once again, the number would be less in actual practice, depending on the applications. And it runs at 1 megabit per second over twisted-pair wire. The total cable cannot exceed 1000 feet without repeaters (an active junction box); up to 4000 feet is possible with repeaters.

The network interface board, called a transporter, contains an on-board 6801 microprocessor to handle the network communication details. It supports DMA as well as interrupts.

Omninet uses a disk server that is actually a single-board Z80-based microcomputer with a built-in network interface. The server is available as a stand-alone box that connects to an external Corvus drive or is built into a 5¼-inch Winchester disk assembly. Corvus is actually the first vendor to integrate a network controller into a disk drive. As many as eight drives with the built-in Omninet interface can be attached to the network.

The software to support networking is called Constellation. The early version was called Constellation I and supported only the Apple II. Constellation II is for IBM and for all the other types of microcomputers. It supports not only different types of PCs but different operating systems as well. On the Apple, you can run Apple Pascal, DOS 3.3, and CP/M; on the IBM PC, you can run DOS 1.1, 2.0, CP/M-86, or the UCSD p-System.

Security on Omninet is minimal. A user name and password are required to boot up a personal computer on the network. Once users are on the network, they must also have access to the volumes they want to use (a "system manager" decides who can access what volumes).

Corvus supplies a Spool utility that enables you to spool files to printers as well as other (compatible or noncompatible) personal computers. Users with the same personal computers can, of course, share the same volumes directly. Again, nothing prevents users from writing to the same file at the same time and corrupting data, but semaphores are available for users or programmers.

Corvus was one of the first companies in the microcomputer network business to recognize a need to back up data. Two years ago it introduced a product called Mirror, which lets you dump a mirror image of a Corvus hard disk to a standard videotape recorder. Corvus also has a product called The Bank, a high-capacity (200-megabyte) tape-cartridge drive that interfaces directly to Omninet. The Bank can be used as a backup to the disk server and can also be directly accessed by workstations in the manner of a slow disk server.

One of the more interesting Omninet products is the SNA Gateway. The Gateway allows workstations to run terminal-emulation software and establish a virtual connection with a remote host. More than one user can use the Gateway at the same time. It supports 3270 terminal protocols as well as SNA/SDLC (synchronous data-link control) communications protocols to the host.

Nestar

Nestar was the first third-party vendor to produce a true personal computer LAN. It was called the Cluster/One Model A for Apple computers, and it made its debut in 1980. The Cluster/One is not being sold anymore, now that Nestar is pushing its PLAN 4000

system. PLAN 4000 is based on the Arcnet token-passing protocol with XNS protocols at a higher level; it is about four to five times faster than the Cluster/One in end-to-end throughput. In addition, it now supports the IBM PC.

As for the Datapoint Arcnet specifications, the PLAN 4000 network communicates at the raw data rate of 2.5 megabits per second over RG-62 (3270-type) coaxial cable. A VLSI data-link controller (from Standard Microsystems) handles this low-level communication. IBM PCs in this system can be up to 22,000 feet (approximately 4 miles) apart. Active repeaters (equivalent to the Datapoint HUBs), which also connect the workstations to the network, are required every 2000 feet. Each PLAN 4000 can support as many as 254 workstations, but again, a more practical number is lower.

Nestar has preserved a lot of application and server software developed for the Cluster/One and transported it to the PLAN 4000. Because of its early development, Nestar has more servers than any other vendor. These servers include file (actually a disk server), print, 3270, 3278, SNA, telex, file transfer, and gateway (between PLAN systems).

The file server is a high-performance server machine that uses the Motorola 68000 processor and is based on a multibus design. It has a built-in streaming-tape drive for backup, disk capacity of more then 500 megabytes, and a built-in modem port for remote diagnostics. Passwords are supported at the directory and volume levels (the file server supports a tree-like hierarchy of directories and volumes). PC-DOS 2.0 and the UCSD p-System operating systems are supported. With Apple IIs or IIIs, Apple Pascal, DOS 3.3, and CP/M are supported.

Unfortunately, this "Mercedes" of file servers is rather expensive: $20,000 for 60 megabytes of hard-disk memory. A lower-cost version, the PLAN 3000, supports only one disk of up to 60 megabytes. The PLAN 2000 is for OEMs and is essentially a board-level product that includes software for a disk server based on the PC XT.

The gateway server is currently unique to Nestar among the personal computer network vendors. It allows real-time communication between two PLAN 4000 networks. For example, they might be on two different floors. You can actually transfer data at 2.5 megabits per second between systems; in fact, if you had two PLAN 4000 systems with a gateway server, you could establish virtual connections with disks on other network file servers and use them as if they were local. Nestar overcomes the addressing limitation by assigning each network interface card that ships out of the factory a unique Ethernet address (Ethernet has a 48-bit address space, so each manufacturer can have its own portion of it). This address is used by the gateway. So you can actually have two stations on two different networks with the same Arcnet address, differentiated by their Ethernet address. The gateway does support the connection of more than two systems.

Software

Personal computer LANs have some interesting capabilities that tend to not make software manufacturers happy. If you take your application and load it onto a hard disk or a shared disk, everybody on the network can run it. Manufacturers, at least until now, have licensed their software to run on a single central processor.

As LANs become more prevalent you will begin to see software manufacturers offering network-wide licensing strategies. Rather than charging the price of 10 copies of VisiCalc to

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use it on a 10-node network, the company can charge you for two or three copies and give you a network-wide license. 3Com, for example, already offers network licenses of VisiCalc and VisiFile. Application vendors are also coming up with schemes (sometimes in concert with vendors of LANs) to control the number of copies of one program running at one time.

Operating Systems

A number of software houses are beginning to offer network-operating systems that will operate on a number of different personal computer local networks. These vendors include Softech (Liaison), Novell (NetWare/OS), Digital Research (DR Net), Applied Intelligence (PC/NOS), and Phoenix Software (PAXNET).

Let's take a closer look at Digital Research's DR Net and Novell's NetWare/OS.

Digital Research DR Net

DR Net (available by the time this article is published) is going to preserve compatibility, at least at some level, with all the CP/M operating systems. The various operating systems are going to have different roles to play in the DR Net system. As with the other network-operating-system vendors, Digital Research would like to see an operating system for a wide variety of networks with a user interface that remains unchanged, so users don't really care which network they are on.

Because Digital Research preserved compatibility among all versions of CP/M, 8- and 16-bit systems can in fact share the same files on the same network.

The basic idea of DR Net is illustrated in figure 1. The NDOS, a cap on top of the operating system, performs as a true file server rather than a disk server. NDOS takes a look at each DOS request that comes through. If it's for a local peripheral, the request is passed down to the local operating sytem and through the local I/O system. When it's a request for a virtual peripheral, it's shipped over to the network I/O system and straight out to the network hardware. From there it goes out to a server, comes back to the requester, and passes back to the application. As many as 16 users can be supported at a server simultaneously. And because it's a file server, users are able to put password protection on individual files.

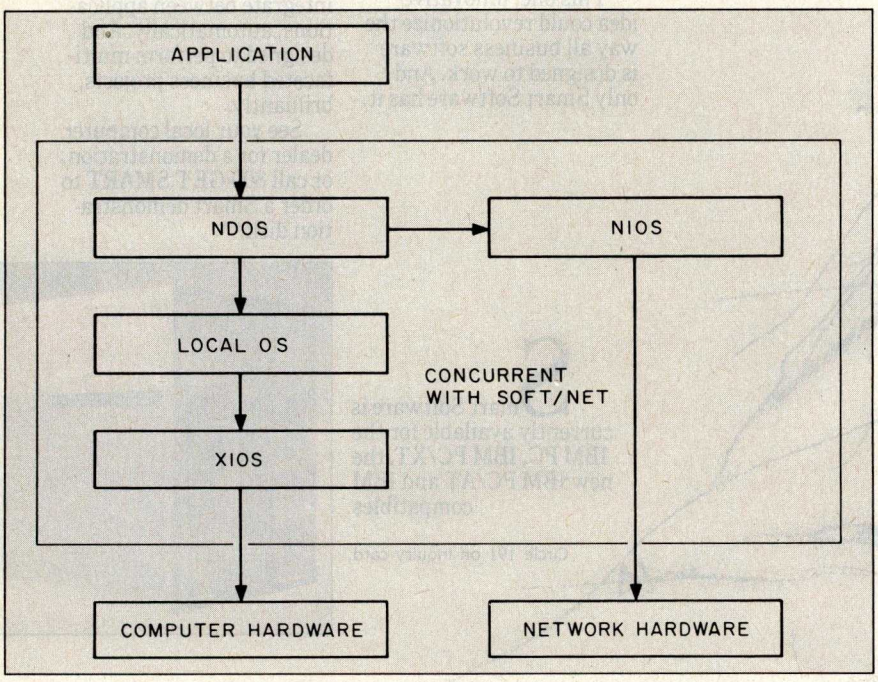

Figure 1: *The structure of* DR Net, *in which* NDOS *is a true file server.*

Digital Research did, in fact, put record-locking facilities into some of its earlier operating systems, particularly MP/M. And it has included those on the CP/M-86 and Concurrent CP/M-86 products. So you can have multiuser file sharing with record locking. And because this is built into the operating system, the application programs don't necessarily have to use a semaphore scheme to support a multiuser application.

Some of the operating systems, particularly the more primitive ones, can only be requesters. For instance, CP/M-80 and CP/M-86 are basically only requester operating systems; MP/M, on the other hand, whether 8-bit or 16-bit, actually was designed to provide file sharing to CP/M systems.

Novell NetWare/OS

Novell NetWare/OS software is portable across a number of different networks. Novell currently has eight different versions of NetWare, applying to different network hardware. The versions are NetWare/D for Davong's Multilink, NetWare/E for 3Com's EtherLink board, NetWare/G for Gateway's G-NET (also referred to as the Novell NetWare/X system), NetWare/N for Nestar's PLAN 2000, NetWare/O for the Omninet transporter, NetWare/P for Proteon's proNET token-ring system, NetWare/PC for Orchid's PCnet, and NetWare/S for Novell's NetWare/S system. All of these systems use the PC XT (with the exception of NetWare/S, which uses a 68000-based file server) as a (true) file server.

One thing to keep in mind is that you cannot mix and match NetWare with the other vendors' server products and have them communicate with each other. Although one of the nicest file servers around, NetWare is a highly proprietary, closed system. The search for a system that integrates everyone's networking hardware and software goes on.

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Let's take a look at some of the capabilities of the NetWare/OS file server. NetWare puts a cap on top of DOS, much like DR Net. NetWare implements a number of functions in the server to increase its performance. For instance, it dedicates a large portion of memory as a disk cache and performs elevator-seeking on the hard disk. You can queue up requests, and as they process, they will move the heads on the hard disk like an elevator so that the heads won't be thrashing back and forth. The heads move by processing pending requests in an order that minimizes disk-head movement. Currently, only one server is supported per network, but it can be used in a dedicated or nondedicated mode.

On the PC XT server Novell put in its own multiprocess operating system, as illustrated in figure 2. A lot of processes are taking place at one time. For instance, server processes are provided so that six pending requests are possible. NetWare/OS has a disk read/write process that manages the cache. It also writes out blocks that have been modified and are sitting in the cache. Print spooling is a background task that can support as many as three printers at the server (PC XT). NetWare/OS also has a console-handling process that supports a wide variety of commands that you can enter from the console at the server itself. All these processes interact to form the NetWare/OS file (and print) server.

Because NetWare/OS is a true file server, a file can be automatically locked while it's open so that the server won't let somebody else open the same file. Another interesting feature is a broadcast command that can be entered at the console or user's personal computer. This lets a user send a one-line message to the other active stations on the network; it will appear on the twenty-fifth line of the personal computer's display.

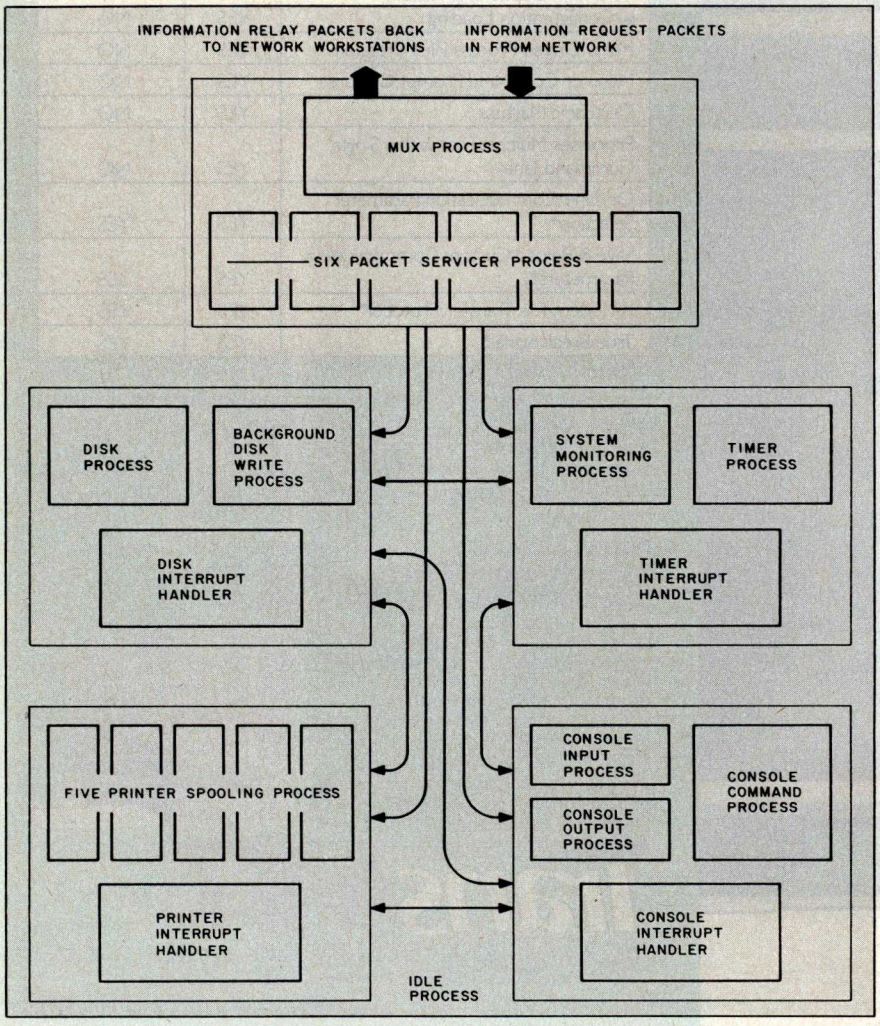

Figure 2: *Novell's own multiprocess operating system in* NetWare/OS.

Conclusions

It's unfortunate that all of the IBM PC LANs are incompatible with each other and that many use highly proprietary software. Eventually, there is going to be a shakeout, and survival for some vendors may mean revamping their product lines or building gateways to the more "accepted" personal computer LANs. It's also unfortunate that so many vendors have a lot of hype in their advertising and marketing. And users may find that, in the long run, inexpensive systems actually cost more in terms of lost productivity due to poor response times when several personal computers are involved.

There are still several missing pieces to IBM PC local networks (which can be found in mainframe systems), such as system accounting functions, performance monitoring, and management tools. And standards are lacking at all levels, although more and more vendors are implementing de facto standards.

I'd like to conclude with six cautions. First, be leery of vendors' performance claims. Raw data rates of the network can be deceiving if the system has poor hardware and complex

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software to support it.

Second, beware of the "low" cost: $500 to $800 per connection may not be the dominant cost when you consider that every networking system will have at least one shared hard disk, which is typically a $6000 PC XT. And recall that installation of the cable typically costs far more than the cable itself.

Third, watch out for software integrity. Some networks introduced a year or so ago still have bugs. Also, the more "distributed" types of systems (sharing any personal computer's resources anywhere on the network) tend to be shaky because of the complexity of the multitasking networking software. And these systems typically require 64K to 128K more bytes of RAM for every personal computer than the "nondistributed" types.

Fourth, don't be surprised if your favorite stand-alone software package doesn't run on a local network. These packages are designed for stand-alone personal computers, are often copy-protected, often make assumptions about the local environment, and are clearly not designed for multiuser environments. However, most software that uses standard BIOS calls works satisfactorily when used in a network, provided that users aren't manipulating the same files.

Fifth, watch out for conflicts between the network board and other add-on boards. There are only a few DMA and interrupt channels in the IBM PC, and many third-party vendors use them. So don't be surprised if you have to remove your favorite hardware board as well!

Finally, no system available today is truly turnkey. For example, the vendors don't tell you about the hidden costs in a system such as personnel costs. Somebody has to install that network. People have to be trained. Someone has to maintain and manage the system. ■

This article is based on the upcoming Architecture Technology "Personal Computer Local Networks Report," which will be available at the time of this printing.