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Selecting Local Network Facilities

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The Butler Cox Foundation

THE BUTLER COX FOUNDATION

REPORT SERIES NO. 38

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Abstract

In most organisations the spread of online terminals has been paralleled by an even more rapid spread of microcomputers. These microcomputers often exchange data with other computers, word processors and graphics systems and share expensive resources, such as large disc files and printers. All this increases the demands on local communication networks, so that many traditional networks are now becoming obviously inadequate.

The report aims to identify the significant developments and trends in local networks, and to assist Foundation members in selecting appropriate local networks to meet their needs.

We conclude that, although local network technology is advancing very rapidly, a logical and flexible selection exercise is possible, provided a strategic approach to system requirements is adopted.

Research

The report was researched and written by David Flint, a consultant specialising in telecommunications and office automation. He is a leading figure in the field of local networks and has contributed to several previous Foundation reports.

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THE BUTLER COX FOUNDATION

Butler Cox & Partners
Butler Cox is an independent management consultancy and research organisation, specialising in the application of information technology within commerce, government and industry. The company offers a wide range of services both to suppliers and users of this technology. The Butler Cox Foundation is a service operated by Butler Cox on behalf of subscribing members.

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THE BUTLER COX FOUNDATION

REPORT SERIES NO. 38

SELECTING LOCAL NETWORK FACILITIES

CONTENTS

SELECTING LOCAL NETWORK FACILITIES

REPORT SYNOPSIS

Behind familiar terms such as Ethernet, Cambridge Ring and micronet lies a complex range of options for managers seeking effective local communications. As online terminals and microcomputers have proliferated and interconnection has become increasingly important, the limitations of existing local communications have become evident. At the same time a host of novel network solutions have been offered, and more are on the way as the technology continues to advance. Effective planning of an organisation's local communications strategy demands a broad knowledge of today's networks and their respective merits; an appreciation of the changes that are likely over the coming years; and an awareness of the key issues that will affect success or failure.

The most innovative local networks fall into two main groups — local area networks (LANs) and integrated computerised branch exchanges (ICBXs). In a LAN, a wideband digital channel is carried around the site, and attached devices can use the whole capacity of the channel in turn. An ICBX is a PABX which has digital communications between the central switching units and the attached voice and data devices.

LANs all use packet switching techniques, but vary in transmission medium and in network configuration. Examples include optic fibre in a ring, coaxial cable in a star, and twisted pairs in a network bus. Speed of data transmission will vary according to the equipment supported by the network.

Voice-data ICBXs use twisted-pair cables laid in a star pattern, and employ telephony's traditional circuit-switching techniques to link local telephones and terminals to each other and to outside networks, notably the public telephone network. The central processor within an ICBX provides a variety of services.

The best-known LAN is the Xerox Ethernet, which uses special low-impedance cable laid in a tree configuration. Ethernet works well when traffic is light, but performance declines as the load increases. LANs based on a ring configuration include the Cambridge Ring, developed at Cambridge University, which uses twisted-pair, coaxial or optic fibre cables. Delays in accessing the ring are very short but the bandwidth is used relatively inefficiently.

LAN protocols are of three main types, using the techniques of polling, token passing, and contention respectively. IBM's support for token passing will have a major impact.

Micronets are local networks (usually LANs) that enable resources to be shared between microcomputers or other intelligent devices (such as word processors). A terminal suport network (TSN) is a LAN that supports unintelligent terminals and other simple digital devices such as facsimile transceivers.

ICBXs represent the second stage in the move from electromechanical PABXs to digital ones for data switching, which began with computerised branch exchanges (CBXs) based on large-scale integration (LSI) components. In ICBXs, digital transmission is used on the lines from the CBX to the telephone instrument; this gives faster, more reliable operation for terminal users. Hybrid CBX/LAN products are now appearing in the United States.

Future trends in local networks are being shaped by a combination of factors — developments in very large-scale integration (VLSI) technology, increased competitive pressure, a greater penetration of digital devices, and pressure from users who wish to interconnect systems from different suppliers. Local network products are already converging in technology and functions.

Against this background, a number of trends can be identified:

- —Standards are being established and used in products.
- —Interworking software is improving.
- —Communications media and services are becoming more integrated.
- —Networks are supporting a greater variety of interfaces.
- —Costs are falling rapidly.
- —Network hierarchies and new system architectures are emerging.

Implementations of both de facto and de jure standards in VLSI chip sets are proceeding in parallel with the definition of standards. As chip costs fall, Ethernet (and the token-passing ring standard) will be increasingly used in micronets. The emerging LAN standards will become general on microcomputers and workstations during 1984 and 1985, but this level of support will not provide interworking without compatibility at higher levels of the Open Systems Interconnecting (OSI) model. OSI higher-level standards will take some years to achieve; in the meantime, we expect a great increase in the available range of protocol convertors and inter-network gateways.

We believe that support for facsimile images on local networks will become commonplace, probably through the inclusion of facsimile images within electronic mail systems. The cost of most electronic components and products will fall at 30 per cent per annum over the next five years. For the period up to 1987, baseband interfaces will cost less than broadband ones and micronets will be cheaper than Ethernet.

For most large organisations, support for online terminals will be the first requirement for a local area network. But future requirements for fast file transfer and resource sharing may change this picture significantly. Any local area network strategy should be dependent on a technical systems strategy for data processing, factory and laboratory automation, personal computing and office systems. Otherwise, there are four local network policy options:

—Choose a main supplier, and wait for this supplier's solution.

—Install a local network that complies with emerging standards.

—Install a broadband network.

—Choose the best network currently available.

No single option will be right for all organisations, but we give three broad guidelines. Organisations that have to build multi-supplier systems (for technical or political reasons) should install Ethernet and move to OSI protocols at the higher levels. Those wanting the security of staying with the main supplier's architecture should wait until that supplier's local network is proven. Those wishing to retain flexibility should choose the most cost effective solution to their problems (but it would be wise to accept a small increase in total costs in order to use broadband if possible).

To determine the requirements and so identify the most appropriate network, six questions should be answered. What are the requirements for video communications? Is there a need for voice-data integration? Does the site need several incompatible networks? Is there a need to support fast file transfer and/or resource sharing between computers and workstations? How many host computers must be supported? How many terminals and other simple digital machines must be supported?

A detailed analysis of the conditions which point to specific network choices is included in the report. In general, the best choice will be determined by the need to offer particular services. Resource sharing between microcomputers will require a micronet (or a faster type of LAN); video communications will require a broadband network. Otherwise the requirement usually is for data circuits to connect terminals and other digital machines to host computers and wide area networks. Technically sound solutions include ICBXs, various types of LAN, and conventional data circuit switches.

Micronets are inexpensive and flexible, and can form an infrastructure through which a management services department can influence the use of microcomputers in the organisation. The more expensive LANs and ICBXs may be cost effective in particular circumstances, but are difficult to justify except on the basis of forecasts of future terminal populations and traffic patterns. Such forecasts depend on the strategies (if any) adopted for information systems. In the absence of a system strategy, the best course usually will be to choose the most cost effective system in the short term, but pay a modest premium for future flexibility.

PREFACE

The last three years have seen growing interest in local communication networks and the appearance of scores of novel, sometimes eccentric, products. There has been considerable debate on the role that local area networks (LANs) and digital telephone exchanges (PABXs) will play in local communications. Much of this debate has been conducted by suppliers and others with vested interests and, as a result, many of the key issues have not been clearly understood.

Purpose of this report and intended readership

The purpose of this report is to help management services managers understand the significance, though not the technical detail, of these new networks, so that they can choose appropriate local networks for their organisations.

Scope and structure of the report

Despite the novelty of many local network technologies, there is, we believe, enough experience to enable useful generalisations to be made and advice founded on experience to be offered. This report is built on such practical experience (we talked to representatives of 32 user organisations) and includes our predictions of developments in local networks.

Chapter 1 shows the problems large organisations face with their local communications and explains some of the terms we shall use.

Chapter 2 describes the development of the new technologies and outlines the experience of certain users.

Chapter 3 presents our view of the future development of local communications technology and products.

Chapter 4 explains the relationship between network strategy and the selection of a particular network. We discuss possible solutions to the problem of choosing a network during a period of rapid technical change.

Chapter 5 identifies the key issues, and their significance in selecting a local network.

The Conclusion summarises our views on local networks and gives the recommendations we consider to be most important to potential users.

We have provided a bibliography for those who wish to go more deeply into the subject, and a glossary to help the reader with the sometimes obscure terminology.

CHAPTER 1

INTRODUCTION

In recent years, computer users have increasingly recognised the limitations of their existing local communications networks. This realisation reflects both the rapid expansion in the use of online terminals and the marketing efforts of suppliers.

In most conventional systems, each terminal is connected to a computer, or to a central switch, by a dedicated line. As the number of terminals increases, so also does the number of lines. Where terminal penetration is high, the ducts (which were never intended to accommodate large quantities of coaxial cables) become overcrowded. New installations, location changes and maintenance all become difficult and expensive.

In many organisations the cost of installing new cables (sometimes as much as $1,000 per terminal) has become an embarrassment to the management services department. The disruption and delays caused by cable installation are often even more embarrassing.

Conventional local communication arrangements typically are limited in bandwidth and in switching capacity. The bandwidth constraint is important as terminals start to be used for speech and images, as well as for text and data. The lack of switching capacity becomes a problem when users start to access several computers.

In most organisations the spread of online terminals has been paralleled by an even more rapid spread of microcomputers. These microcomputers often exchange data with other computers, word processors and graphics systems and share expensive resources, such as large disc files and printers. All this increases the demands on local communication networks.

Most major computer suppliers offer solutions to some of these problems. A high-speed communications channel between a computer and a communications controller can provide greater bandwidth than usually is available between a computer and a cluster controller. Front-end processors can provide switching. Microcomputers can emulate terminals, or terminals may be upgraded to microcomputers. But these approaches are usually expensive and tend to restrict the user to a single supplier's products.

Advances have been made also in more conventional data communications products such as intelligent multiplexors and circuit switches. In Europe during 1983, computerised PABXs with inbuilt digital transmission facilities became available.

Organisations today face a much greater range of alternatives in local data communications than ever before. Their choices are complicated further by the availability of workstations, microcomputers and office, laboratory and factory automation systems which are based on novel local networks such as Ethernet, XiNet and Teranet.

The aim of this report is to cut through some of this complexity and to clarify the significance of these new developments. We base the report on our understanding of local networks and on an analysis of user experience, to which we have added our predictions of likely developments in this field.

THE SCOPE OF THE REPORT

In this report, the words "local network" mean any network which provides switched digital communications on a single site. The site may be one office, or it may be a major office and manufacturing complex covering several square kilometres. (We do not discuss cable systems for use in the wider community of a town or metropolis, specialised local networks for use within computer rooms, or computer buses.)

We concentrate on two kinds of local network — local area networks and integrated computerised branch exchanges (ICBXs). We define these as follows:

—A local area network (LAN) is a local network in which a wideband digital channel is carried round a site, so that attached devices can use the full capacity of the channel in turn.

—An integrated computerised branch exchange (ICBX) is a PABX which has digital communications between the central switching units and the telephones and other attached devices (such as terminals, facsimile machines, etc.).

Local area networks

The common digital communications channels which make up a LAN may be provided by a variety of types of transmission medium laid in a variety of configurations; for instance, optic fibre configured as a ring, coaxial cable configured as a star and twisted-pairs configured as a bus. Data transmission speeds range from 50k bit/s, where only terminals are to be supported, to 20m bit/s to support links between minicomputers. (Even higher speeds are used in some specialised products.)

In each case this common communications channel is shared between attached devices. Data is transmitted in packets rather than over circuits so that each device uses the full capacity of the channel. The method used to share the channel (known as the medium access control protocol) is characteristic of the kind of LAN and determines many of its characteristics. There are three main kinds of protocol:

— Polling, which is used also in conventional multidrop lines. The overheads and delays increase with the number of attached devices and their need for rapid service.

— Token passing is a kind of distributed polling in which all attached devices act, in turn, as master. It has similar characteristics to polling except that it works particularly well on rings, and its distributed nature provides resilience.

— Contention is a medium access control method in which devices do not wait for a poll or token, but transmit when they find the channel clear. This reduces overheads and delays but can lead to collisions between transmissions. However, all contention systems have some means of resolving collisions when they do occur. This rather anarchic system works surprisingly well since most LANs are run at low levels of use, making collisions uncommon.

A wide variety of medium access control protocols have been developed in laboratories and some are used in commercial products. Details of these are given in references 1 and 3.

Each local network product can be categorised by its specific combination of medium, configuration, speed, signalling, medium access control protocol, services and interfaces.

Voice-data integrated PABXs

Voice-data integrated computerised branch exchanges (ICBXs) are the most recent results of the use of electronics in telephone switching systems. Usually, ICBXs are based on twisted-pair cables laid in a star configuration. Circuit switching techniques are used to connect telephones and terminals to each other and to wide area networks, notably the public telephone network. The central processor within an ICBX may provide a wide variety of services, and the exchanges vary in their internal structures and in the interfaces and services supported.

CHAPTER 2

THE HISTORY OF LOCAL NETWORKS

In this chapter we outline the historical development and use of different types of local network. First we describe developments in data transmission, concentrating on circuit-based networks and packet-switching networks. We go on to show how changing needs led to the development of LANs (and sophisticated systems based on LANs). Next we discuss the development of micronets (which are usually, but not always, LANs) to share resources between microcomputers. And we outline the development of networks to support terminals (terminal support networks). Finally, we describe advances in digital PABXs.

DEVELOPMENTS IN DATA TRANSMISSION

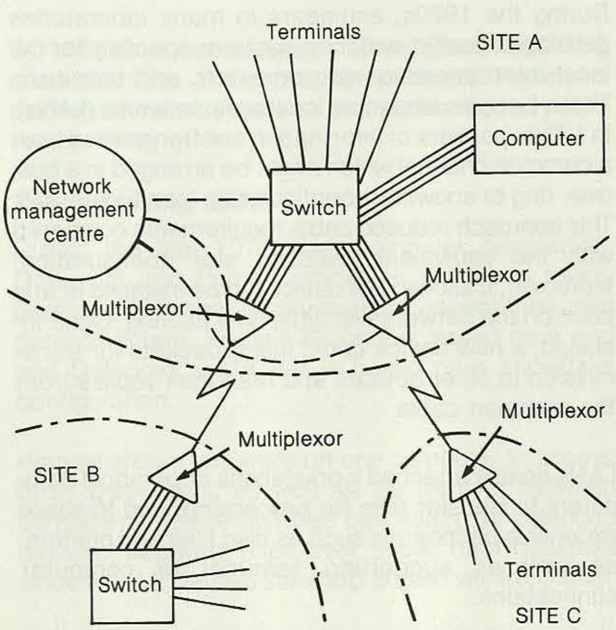
The first data communication networks were developed in the 1960s. At first a star-shaped network of cables was used to support local terminals attached to central computers. Later this was extended to longer distances through the use of modems and telephone lines, but the star configuration was retained.

In time, users became concerned about the cost of long-distance lines and high error rates. Suppliers responded by introducing cluster controllers, multiplexors, and synchronous working. Packet switching was developed for similar reasons (and to provide switching). In each case economies were possible because data could be transmitted much faster than it could be entered by an operator or printed out by a printer. Packet switching also allowed equipment operating at different speeds to exchange data.

During the 1970s, computer suppliers produced their own network architectures, defining how their terminals and computers could work together. But these architectures were adopted slowly and have evolved to reflect changing user requirements.

At the same time, specialist suppliers introduced vendor-independent networks. A typical example is the Gandalf range of products, where all the terminals on one site are connected to a central circuit switch. Switches on different sites are connected by leased lines using multiplexors (as shown in Figure 2.1).

Figure 2.1 Corporate circuit switched data network



In most products the emphasis remained on achieving economy while controlling networks which extended over hundreds or even thousands of kilometres.

Little attention was paid to local connections, the main exception being the development by a few suppliers of data networks based on cable TV (CATV) technology. In these networks, CATV coaxial cable was carried to all parts of the site. The available bandwidth (usually a little less than 300 MHz), was then divided into separate bands, each of which could be used independently for a particular purpose. These networks are now known as broadband networks.

In early broadband networks, the bands were used for security television and for data (which was transmitted by modulating a radio frequency carrier with the digital data). Switching was not usually provided.

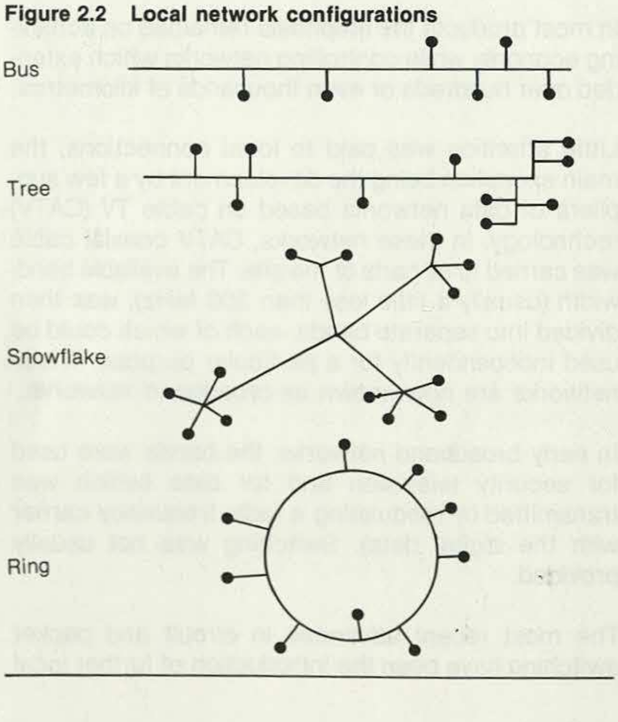
The most recent advances in circuit and packet switching have been the introduction of further local transmission options. IBM, for instance, now offers the Lee Data cable multiplexor as the IBM 3299 and Gandalf offers broadband cable as an alternative to V.24 cables and twisted pairs with line drivers. CASE was the first European company to exploit existing telephone wires for concurrent data transmission. In its Grapevine system, data is carried at frequencies outside the voice band at speeds up to 9.6k bit/s, and switching is provided centrally by a switching multiplexor.

THE DEVELOPMENT OF LOCAL AREA NETWORKS

During the 1970s, engineers in many laboratories developed packet switching systems specially for the local interconnection of computers and terminals. These became known as local area networks (LANs). In LANs, packets of information are transmitted over a common channel which might be arranged in a bus, tree, ring or snowflake configuration (see Figure 2.2). This approach reduced cable requirements compared with the equivalent switched star configuration. Moreover, it allows new devices to be installed at any point on the network with little new cabling. Once installed, a new device could insert packets for transmission to other devices and read their replies from the common cable.

LANs enable attached workstations or personal computers to transfer files for processing, and to share expensive peripherals such as disc files and printers, as well as supporting terminal to computer connections.

Figure 2.2 Local network configurations



LANs can be classified in various ways, though classification by configuration and communications technology is most common. However, we believe that the most useful classification is one made according to the most powerful machine that can be fully supported, as shown in Figure 2.3.

Figure 2.3 LAN classification

Device	*Network category*	*Internal speed (bit/s)*
Data terminal	Terminal support network	20k-300k
Microcomputer	Micronet	100k-1.5m
Minicomputer	Minicomputer network	2m-10m
Minicomputer and telephone	Integrated office network	2m-10m
Mainframe computer	Mainframe LAN	50m-500m

Ethernet

The best known LAN is Ethernet, which was developed at Xerox's Palo Alto Research Center in 1975. It was used at first to connect terminals to computers and also to support the Alto, a powerful personal computer which was the predecessor of the Xerox 8010 workstation. Using Ethernet, Alto workstations could communicate with shared devices called 'servers' that provided electronic mail, disc storage and printing facilities.

The Alto and Ethernet proved successful and were accepted by Xerox staff. By 1982, Xerox had installed about 1,500 workstations on over 60 Ethernets worldwide.

Ethernet operates at 10m bit/s. It requires special low-impedance cable that is laid in a tree configuration. The capacity is shared by a form of contention (described in chapter 1) known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD). LAN access methods are fully described in reference 3.

CSMA/CD is easy to implement and is robust. It works very well when traffic is light but performance declines rapidly as the load increases.

In September 1981 DEC, Intel and Xerox published a specification for Ethernet and committed themselves to develop products based on that specification. But the first products based on Ethernet were produced by independent companies like 3Com, Interlan and Ungermann-Bass. These products usually provided support for minicomputers and terminals rather than for workstations and servers.

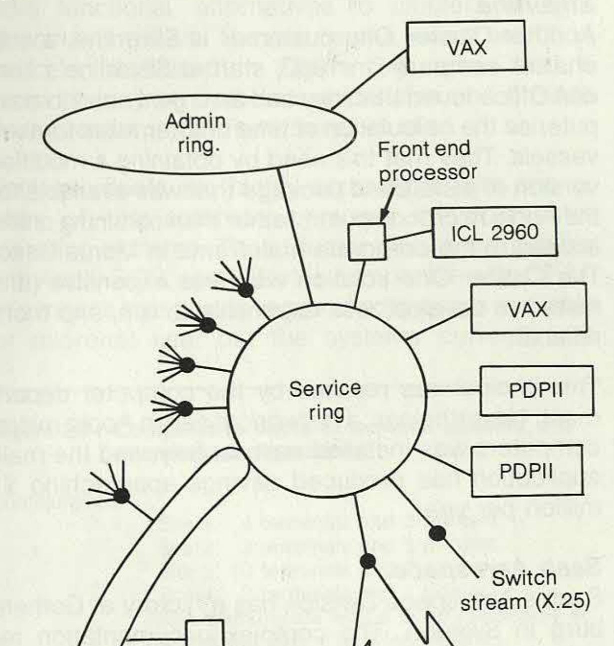
Xerox has since introduced the 8000 series office system in which intelligent workstations obtain access to shared servers over Ethernet. The 8000 series itself uses the Xerox Systems Integration Standards (XSIS). These standards have been published by Xerox to allow other suppliers to interwork with Xerox products.

The Cambridge Ring

LANs based on a ring configuration were developed by computer scientists in a number of different laboratories. Most widely publicised of these is the Cambridge Ring, developed at Cambridge University in the United Kingdom. The Cambridge Ring uses twisted-pair, coaxial or optic fibre cables to carry data at 10m bit/s. It provides very low delays in accessing the ring, at the price of low efficiency in using the bandwidth.

At Cambridge University the ring is used as the basis of a distributed operating system through which resources can be shared and systems can be developed locally. At the University of Kent in the United Kingdom, a Cambridge Ring connects terminals and microcomputers to several host computers. By 1983, this university was operating three such rings, providing more than 150 terminals with access to local DEC and ICL computers. In addition, a gateway provided access to CDC and ICL computers at other universities. This configuration is shown in Figure 2.4.

Figure 2.4 Cambridge rings at the University of Kent



Note: A fourth ring, used for development, has been omitted for clarity.
—>— = terminal multiplexors

Microcomputers attached to a Cambridge ring can act as terminals as well as accepting files and programs transferred from host computers using a file transfer protocol.

By 1983 six suppliers were offering Cambridge Ring products. One of the products, Racal's Planet, includes redundancy features that allows recovery from the breaking of the ring.

Token-passing LANs

During the late 1970s two computer companies, Datapoint and Prime Computers, produced token-passing LANs specifically to interconnect their own minicomputers. Prime's Ringnet is based on a ring and Datapoint's ARCNet is based on a snowflake configuration.

Ringnet allows terminals on one computer to access other computers, as well as file transfer between computers. These facilities can easily be extended between separate sites over public data networks since the X.25 level-3 standard is used within Ringnet.

ARCNet supports resource sharing in Datapoint's Attached Resource Computer Architecture. A number of computers are usually configured as file servers, and office systems and data processing applications are run on other computers located close to the users.

A token-passing ring similar to Ringnet forms the basis of the Apollo Domain computer network. In the Domain system, powerful single-user computers share resources through Apollo's Aegis operating system.

Standards

In the early 1980s IBM carried out work on token-passing rings, much of which now forms the basis of the relevant Institute of Electrical and Electronic Engineers (IEEE) standard. IBM currently charges $2,000 for a licence to use its patents. (IBM's support for the token-passing approach will certainly have a major impact on the use of this technology.)

IEEE has also developed a standard for a token-passing bus based on broadband technology. This technology is expected to prove attractive in process control applications.

Advocates of the token-passing approach, stress its good performance under heavy load and its consequential ability to carry interactive voice traffic. The token ring is the basis of Ztel's PNX telephone system which we describe on page 11.

MICRONETS

We use the term micronet to describe a local network (usually a LAN) that supports the sharing of resources between microcomputers, or between specialised devices such as programmable logic controllers and word processors. During the early 1980s the use of microcomputers in business grew dramatically. In small businesses, microcomputers provided a shared data processing facility on which payroll, general ledger and other conventional applications were run, usually in the form of packages. Microcomputers were used also in large organisations, supporting staff in both branch offices and centralised departments. Sometimes a number of microcomputers were installed in one office. From these experiences it became clear that the microcomputer was at its best when providing personal support to one individual, rather than being shared.

As the number of microcomputers installed in each office grew, users found that some resources could be shared, so reducing the costs of providing the necessary facilities. Most important of these shared resources was online storage (typically a Winchester disc) but printers and communications equipment also were shared to reduce costs. These incentives led to the development of micronets.

The first generation of micronets was developed by companies such as Corvus, a disc manufacturer, and Tandy, a microcomputer company. Both firms used special cables in a star configuration, with data transmission at rates below 100k bit/s. These products were widely adopted, especially by schools and colleges.

But these micronets had limited speed, range and flexibility, and second-generation products soon began to replace them. Most of the second-generation micronets are based on LANs operating at 500k to 1.5m bit/s over a common bus.

The most popular second-generation products have been Nestar's Cluster One, Corvus's Omninet and Digital Microsystems' HiNet. HiNet and Cluster One each support only one type of microcomputer, whilst Omninet (like the earlier Constellation) can support many types.

Cluster One, a typical example of a micronet, supports up to 64 Apple II computers, connected to a ribbon cable. The cable carries data at 240k bit/s and the capacity is shared by contention (described in chapter 1). Each network has a file server and may have a number of print servers.

Micronets in practice

The ways in which micronets have been used in recent years is illustrated by applications at Citibank, Silverline, Saab Aerospace and Fisons. The choice of micronet in these applications was based primarily on the software available, rather than on the network facilities.

Citibank

One of the most notable Cluster One installations is at Citibank's offices in London, where Apple IIs have been built into the desks used by foreign exchange dealers and are accessed using built-in graphics tablets.

Silverline

Another Cluster One customer is Silverline, a ship charter company. In 1982, staff at Silverline's London Office found that they had an urgent need to computerise the calculation of time charter rates for their vessels. They met this need by obtaining a modified version of a standard package that was available for the Apple microcomputer, rather than obtaining online access to the corporate mainframe in Monte Carlo. The Cluster One solution was less expensive (and faster) to develop, less expensive to run, and more reliable.

This choice was resisted by the computer department. Nevertheless, a network of seven Apple microcomputers was installed successfully, and the main application has produced savings approaching $1 million per year.

Saab Aerospace

Saab's Aerospace Division has a factory at Gothenburg in Sweden. The complex documentation required in the aerospace industry was a natural application for word processing. The factory also needed some local data processing, spreadsheet analysis and access to data on existing IBM, Xerox, Univac, DEC and DataSaab equipment. Saab decided to install a Compucorp Omeganet with 16 workstations and two file servers to meet these requirements. The network itself worked well from the start but there were problems with some of the microcomputers. Also, the database system originally supplied by Compucorp was not adequate and another had to be obtained from a different supplier. The system now works well.

Fisons

At present micronets are most appropriate in offices where users require computer support for different tasks, and where programming skills are available to construct bespoke multi-user applications. This has been the case at the Fisons group head office in Ipswich in the United Kingdom. During 1982, Fisons' staff identified requirements for accounting, database, word processing, mailing and spreadsheet facilities. Eventually, a need for up to 30 terminals was foreseen. The use of a minicomputer was rejected because of its high cost and the high costs of software packages.

Instead,Fisons wired their building for HiNet and installed ten workstations. By 1983 the network had been extended to 26 stations. The system meets the original needs and now also runs programs transferred from a PDP11 minicomputer, together with a personnel system developed by a manager with no previous computer experience.

Advantages and limitations of micronets

Micronets have been installed as lower cost, and more functional, alternatives to clusters of synchronous terminals. The results of a recent selection exercise, illustrated in Figure 2.5, show that a micronet may be both less expensive and provide more functions than a terminal cluster.

Most micronets are highly compatible with one or other of the common personal microcomputer operating systems. Thus Cluster One is compatible with Apple DOS, and HiNet is compatible with CP/M. This means that a wide range of software is available for micronet use, but the systems currently are restricted to the functions provided by single-user operating systems. The most significant limitations are:

—Maximum program size (often only 64k bytes).

—Maximum file size (8m bytes under CP/M).

—Lack of the file security and integrity features needed for concurrent access to data.

—Lack of application packages that can support multiple concurrent access to data.

—Lack of tools suitable for developing complex systems.

A comparison of time-sharing systems and micronets shows that neither approach is universally better. In particular:

—A time-shared computer is better for the development and execution of multi-user systems.

—A time-shared computer is necessary when users have large jobs that have to be performed quickly.

—A micronet is better when word processing and graphics are needed.

—A micronet is better where the user is performing a variety of loosely related tasks, especially if these include word processing and graphics.

To date, most micronets have been installed to support a single data processing system, with functions such as word processing being regarded as a bonus.

Sometimes, a micronet may be used to link existing machines of different kinds. Most micronets currently are unable to do this, being restricted to the supplier's own computers.

The majority of personal computing is within the scope of any current 8-bit microcomputer (though response may be rather slow in some cases). But microcomputers can be used also to support a working group rather than an individual, and this may involve both larger files and more complex processing. These needs generally require 16-bit microcomputers. The addressing range of a 16-bit machine may also be needed to run certain packages, especially sophisticated system development tools. (Caution is needed in this area since some 8-bit microcomputers are faster than some 16-bit microcomputers and can have their address range extended by a technical trick known as 'bank switching'.)

One common user requirement that has emerged is for access to data processing systems or minicomputers and mainframes. This is often vital to the success of the micronet. To do this, a micronet can emulate a cluster of interactive terminals over a

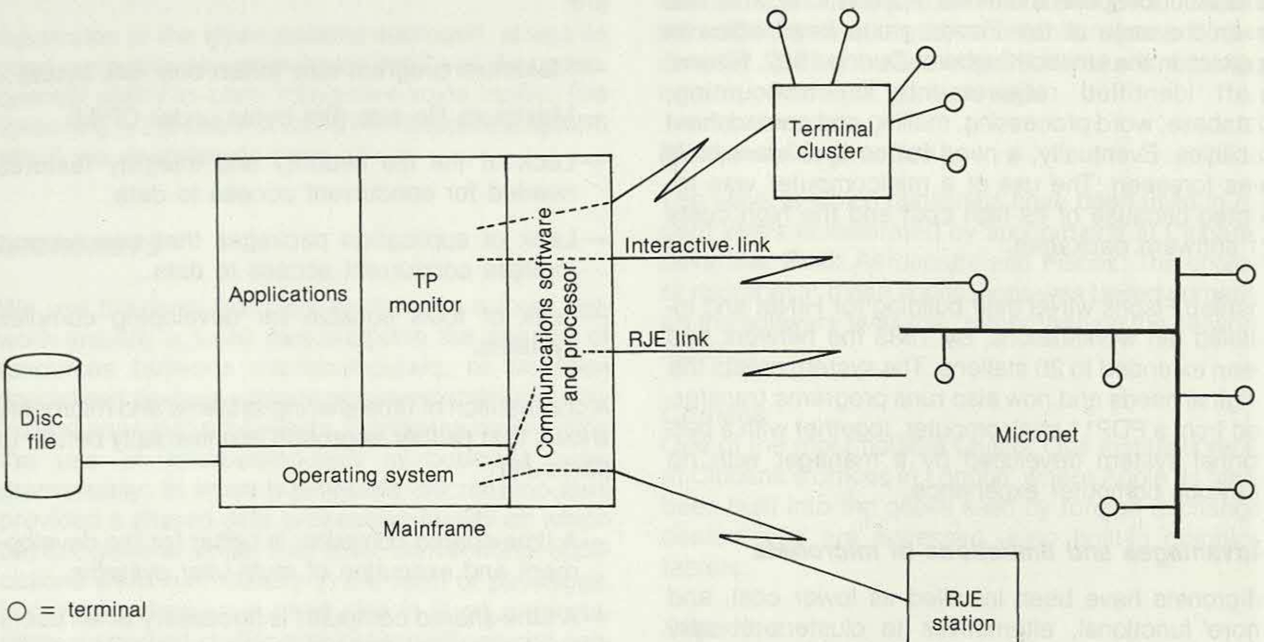
Figure 2.5 Comparative costs of terminal clusters and micronet configurations

Configuration:

Site 1: 4 terminals and 3 printers.
Site 2: 3 terminals and 3 printers.
Site 3: 10 terminals and 7 printers.
Site 4: 2 terminals and 1 printer.
All communicate with a large mainframe at a fifth site over 1 or 2 leased lines.

	Mainframe manufacturer proposal	*Micro software house proposal*
Sites 1 and 2	Unintelligent terminals and printers on cluster controller.	Micronets.
Sites 3 and 4	Intelligent terminals on multiplexors.	Micronets.
Shared storage	None.	52m bytes.
Cost	$230,000.	$140,000.
Personal computing	Available on sites 3 and 4 only at $5,000 per station.	Inherent capability of all workstations.

Figure 2.6 Mainframe-micronent communications



multiplex link, as shown in Figure 2.6. This gives access to the transaction processing facilities of the larger computer system so that the user can, for instance, prepare and validate a set of transactions on the microcomputer before submitting them to the mainframe system. Also, the user can extract data (sales figures, for example) for local processing.

Alternatively, access to time-sharing facilities may be used to extend the power available to the microcomputer user (for system development and file transfer). Micronets can emulate RJE stations, providing file transfer in both directions and local printing of mainframe files.

Many micronet users also need access to databases and other services on public networks. At present this will generally be achieved using ASCII communications, though videotex may be important in some cases. (In the future, X.21 and X.25 will become more important for this type of access.) Unfortunately there are currently no specific standards for micronets. Micronets based on Ethernet and the Datapoint ARCNet appeared during 1983 but neither type is ideal: Ethernet because of its high cost and the difficulties in pre-wiring buildings, and ARCNet because of its snowflake configuration.

Having started by adding a micronet to their microcomputer products, several suppliers are now developing microcomputer workstations for their networks. A workstation without peripheral ports or disc handling is cheaper to produce than a standard microcomputer, reinforcing the economy of the micronet.

Also, suppliers are introducing more powerful microcomputers based on 16-bit processors. The Corvus Concept, for instance, has been designed for use on Omninet. It is based on the Motorola 68000 processor, 256-512k bytes of main memory and a 15-inch 720 x 560 bit-mapped display. It can support a variety of peripherals including up to 20m bytes of hard disc and can run CP/M, PASCAL and FORTRAN programs. The operating system allows the screen to be divided into a number of distinct windows (connected to distinct processes) and specially written word processing and spreadsheet packages are available.

The limitations of micronets, then, are those of particular products at particular times. Because of the rapid pace of change, the limitations become significantly less important each year.

TERMINAL SUPPORT NETWORKS (TSNs)

In contrast to a micronet, which supports intelligent microcomputers and similar products, a terminal support network (TSN) is a LAN that supports unintelligent terminals and other simple digital devices such as facsimile transceivers. Terminal support may be provided on specially designed low-speed LANs, as one service on a high-speed LAN or on one or more bands of a broadband system.

Low-speed TSNs

The simplest LANs intended specifically for the support of data terminals operate at low speed, which keeps down costs. As we explained above, a LAN for terminals does not need the 10m bit/s of Ethernet, or the 500k bit/s of HiNet. The simplest terminal support LANs therefore operate at speeds between 30k bit/s and 500k bit/s. Examples include Clearway (56k bit/s and about $200 per port) and Multilink (300k bit/s and about $450 per port); both use coaxial cable rings.

These networks allow devices of different speeds to interwork and also tolerate various interpretations of the V.24 interface. Beyond this, they provide only a transparent circuit and have few facilities for error reporting, network management and call management. But, for just these reasons, they are easy to install and robust. The actual products are generally small boxes with a V.24 or other interface on one side and a ring connection on the other. It is usual to carry the ring to one outlet in each office so that equipment can easily be moved when necessary.

These low-speed terminal support networks compete directly with conventional data circuit switches, such as the Gandalf PACX, and often can pay for themselves in reduced cable and maintenance costs within a year or two. The cost advantage is increased where host computers can be connected over a multiplex interface such as X.25 instead of over a number of simple (often V.24) interfaces.

An illustration of the use of a terminal support network is provided by the research department of a leading British bank, in which a Clearway network has been installed to provide terminals with access to two local microcomputers (for APL) and to the internal time-sharing network (for access to a corporate computer). The network is installed in a suite of ten offices. It provides an alternative to direct cables, giving switching capability and greater flexibility when moving devices.

High-speed and broadband TSNs

Terminal support networks have been developed on the basis of both high-speed LANs and broadband cables. Ungermann-Bass's Net/One is based on Ethernet. As well as supporting asynchronous terminals, it provides support for some kinds of synchronous terminals, interfaces suitable for computers, network management, and facilities for locating resources on a set of linked Net/Ones that may be located on different sites.

The leading broadband terminal support network is Sytek's LocalNet. For terminal support, 120 frequencies (occupying 36MHz) are allocated to the LocalNet System 20. Many terminals and computer ports can share one frequency, the transmission capacity being shared by contention. To access ports on other frequencies, packets may be sent via a central unit known as a bridge, or the interface unit itself may shift in frequency. Sytek say that each LocalNet can support more than 20,000 terminals in this way.

During 1982 and 1983 many TSN products came on to the market but the announcement of HYPERbus by Network Systems Corporation (NSC) is particularly significant. NSC is the supplier of HYPERchannel, the leading LAN for mainframe interconnection. They also supply Netex software, which provides effective interworking between dissimilar computers over HYPERchannel. HYPERbus extends NSC's coverage out from the computer room and around the whole site. Unlike most terminal support networks, it supports individual IBM 3277 and 3278 terminals directly, providing switched access to 3274 cluster controllers. Also, HYPERbus supports Netex-compatible interworking between various micro, mini and mainframe computers.

During 1983 network suppliers began viewing software as the key feature of their networks. Thus Net/One became available on broadband and optical fibre networks while Contel announced a network (Contelnet) with a choice of two speeds, two medium access control disciplines and both baseband and broadband signalling.

The use of online terminals at the Swiss Federal Institute of Technology (ETH) illustrates the use of Net/One. In the early 1980s, terminal use grew rapidly. Modems were used over telephone lines but this proved expensive, restricted transmission speeds and led to large amounts of cabling. Between December 1981 and Spring 1982 ETH installed an eight-kilometre LocalNet. At this stage the network supported 580 terminals in 500 offices. By November 1982 it provided access to ten computers. Generally, the ETH network has proved reliable in spite of the absence of a network control centre and problems with call disconnection. Users welcomed the advantages of easy connection and increased transmission speeds — terminal users not yet on the network are pressing for connections.

DIGITAL PABXs

Historically, there have been a number of problems with the use of electromechanical PABXs for data switching. The long holding times characteristic of data calls occupy expensive switching capacity. Also, the economies of packet switching and multiplexing are not available for inter-site traffic, and transmissions are often slow and error-prone.

Computerised branch exchanges (CBXs)

The use of large scale integration (LSI) components for switching has overcome the first problem by making non-blocking, computerised PABXs economic. These exchanges (called computerised branch exchanges) are capable of switching all lines at the same time. For example, the Ericsson MD110 is fully non-blocking up to its maximum size of 384 lines and can allow a terminal and telephone to be in concurrent use on every line. For very large configurations it is still unusual to install non-blocking CBXs, because blocking is rare in the normal use of these systems.

Computer control enables the CBX to provide features like call redirection for data and voice calls. Also it allows a number of terminals to contend for the use of a limited pool of modems or to share the use of an X.25 or other multiplex interface to a wide area network. This type of interface allows the terminal user to obtain economical use of circuits between sites. Also, inter-site traffic is protected from the transmission errors found on trunk lines by a data link protocol. Suppliers such as AT&T, CIT-Alcatel, Ericsson, Northern Telecom, Plessey, and Rolm introduced support for low-speed data traffic in the early 1980s but this facility has not been widely used. According to a survey of 260 CBX users in North America (conducted by Arthur D. Little in 1983) the data support facility was used only where moves were frequent, usage was low or flexible off-site access was needed.

To provide terminals with reliable transmission speeds above 19.2k bit/s means changing to digital transmission on the lines from the CBX to the telephone instrument. This transition produced the voice-data integrated computerised branch exchange (ICBX).

Integrated computerised branch exchanges (ICBXs)

The first ICBX to appear on the market was the Intecom IBX (which, at the time of writing, was still not available in Europe). The configuration of the IBX is shown in Figure 2.7. All telephones are digital instruments and are connected, by twisted-pair cables carrying 144k bit/s, to local switching partitions. A range of telephone instruments is available which can accept digital data at speeds up to 56k bit/s. The switchng partitions are connected to the master control unit over optic fibre cables. The master control unit provides interfaces to a wide area telephone service, and to data networks via an X.25 gateway, as well as providing modem pooling and protocol conversion. (The IBX protocol convertors can provide interworking between ASCII and 3270 devices.)

In 1983 Intecom went further by adding Ethernet support to their product. This is more than just an external interface. The IBX accepts data at the full 10m bit/s speed and transmits it through the IBX network at 1m bit/s. Delays due to buffering mean that the effective speed is rather less than 1m bit/s. Though much slower than Ethernet, this speed is sufficient for many practical purposes.

Hybrid CBX and LAN products

In Europe all currently available CBXs are based firmly on the telephone switching tradition (circuit-switched calls carried on twisted pairs). In the United

Figure 2.7 The Intecom IBX

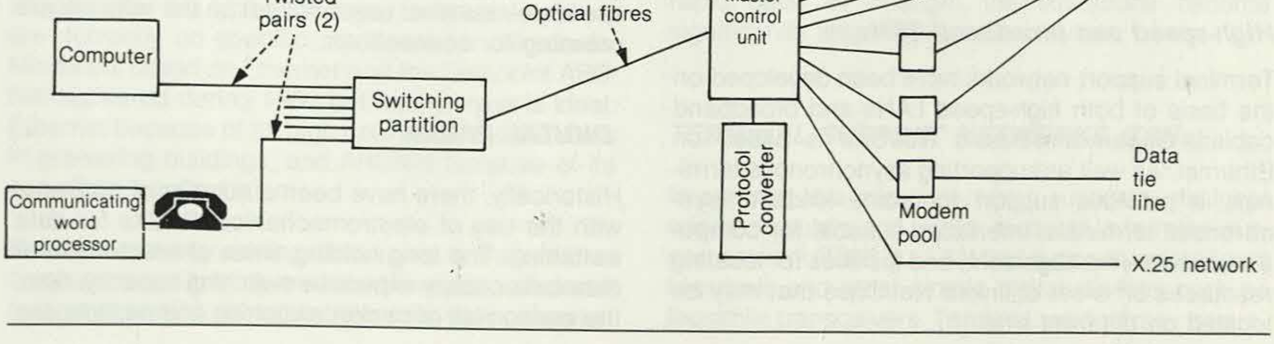
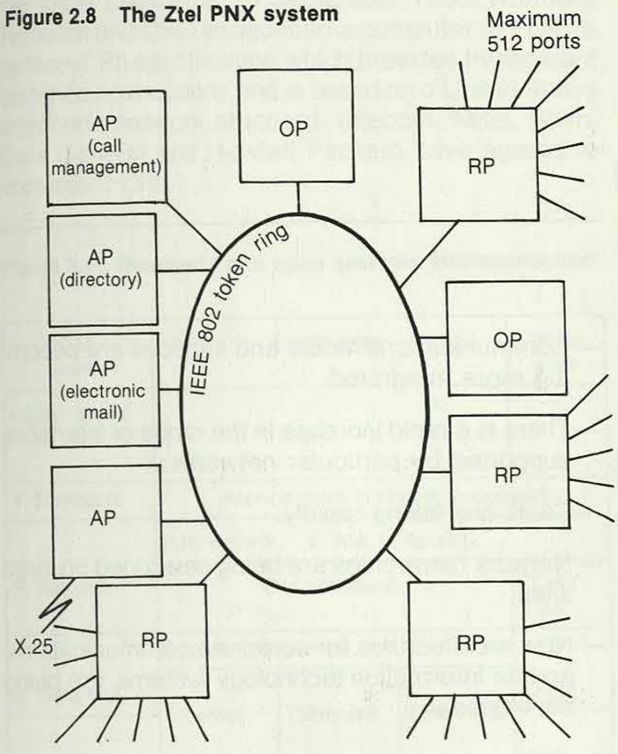


Figure 2.8 The Ztel PNX system



RP — Ring Processor
AP — Application Processor
OP — Other processor (non-Ztel)

States, three suppliers (CXC, Prolink and Ztel) had, by mid-1983, announced CBXs based on LAN technology.

The Ztel PNX system is a particularly interesting product (see the configuration shown in Figure 2.8). It may be seen as either a LAN with voice support or as a distributed ICBX in which the components are linked by a LAN. Ztel has used the IEEE standard for the token-passing ring. Other equipment can be attached to the ring and this may be particularly interesting to IBM users who will thus have the option of replacing both telephone and data communications equipment with a single integrated network.

CBX-based office systems

In the last few years, CBX suppliers have announced sophisticated telephone instruments to complement their switches. These range from multi-button featurephones through the Northern Telecom Displayphone to, in future, personal computers. We discussed these developments in Foundation Report No. 35 — Multifunction Equipment.

Suppliers are also adding further central facilities, such as electronic mail and store-and-forward voice messaging. But so far no supplier has gone beyond the provision of separate services by offering a fully integrated office system.

CHAPTER 3

TRENDS IN LOCAL NETWORKING

The technology of local networks is changing very rapidly and this is likely to continue for the rest of the decade. In this chapter we examine some of the main trends in local networks.

The changes influencing local networks are similar to those affecting all information technology markets. They are caused by developments in very large scale integration technology, increased competitive pressure, a greater penetration of digital devices, and user pressure for interworking between systems from different suppliers.

One immediate consequence is that, at the low-cost end of the local networks market, there is already considerable overlap between micronets and the specialised low-speed terminal support networks (TSNs). This distinction is now becoming blurred as micronets are given the ability to support terminals and TSNs are given microcomputer interfaces. For instance, the Multilink TSN originally had only V.24 interfaces but now it has Multibus and Apple interfaces also.

Terminal support was the key service offered by most of the early minicomputer LAN-based products like Polynet and Net/One. Now networks are acquiring microcomputer interfaces as well; Ethernet, in particular, is being used as the basis of micronets under names like Applenet and E-LAN.

A similar pattern is found when CBXs are considered. Low-speed data communication to V.24 interfaces for terminals is being supplemented by specialised interfaces for microcomputer-based workstations, thus providing a direct competitor to conventional and LAN-based micronets. One CBX, the Intecom IBX, even provides plug compatibility with Ethernet (as mentioned in chapter 2 on page 10).

As local network products converge in technology and functions, the following trends are emerging:

—Standards are being established.

—These standards are used more and more in commercial products.

—Interworking software is becoming more sophisticated.

—Communications media and services are becoming more integrated.

—There is a rapid increase in the range of interfaces supported by particular networks.

—Costs are falling rapidly.

—Network hierarchies are being developed on large sites.

—New architectures for corporate communications, and for information technology systems, are being developed.

We now discuss each of these trends in turn.

THE ESTABLISHMENT OF STANDARDS

In the past, trying to produce standards in computing and communications has been a very protracted process. In general, standards have lagged behind the widespread use of the technology. In the case of local networks, however, the position is quite different. When the IEEE tried to standardise LANs, there were only a few thousand working LANs in the world. Most of these were micronets. Now the IEEE project 802 has produced draft standards for Ethernet (802.3) and for a 1m bit/s token-passing bus (802.4). A standard for a 4m bit/s token-passing ring (802.5) is expected during 1984. There is also a standard (802.2 — Logical Link Control) for the services that all LANs should provide for the network and for higher Open Systems Interconnection (OSI) layers of the devices that use them. The relationship between these standards and the OSI model is shown in Figure 3.1.

In contrast to LANs, the position on ICBX standards is less encouraging. Current ICBXs such as the SL/1, Plessey IDX and Ericsson MD110 all use proprietary interfaces to digital telephone instruments. Several suppliers have promised to conform with ISDN standards when they become available, but this probably means waiting at least until 1985 for local digital distribution (between the ICBX and the telephone).

Several collaborative ventures have been arranged between computer suppliers and ICBX suppliers to produce interface specifications which may pre-empt the ISDN standards. In September 1983, Northern Telecom and DEC announced a computer to PBX interface (CPI) specification which provides transparent switched connections and is based on a United States telephone network standard. Intecom, Mitel, Rolm, Data General and Hewlett Packard have agreed to implement CPI.

Figure 3.1 Standards and open systems interconnection

OSI level	*Local area*			*Wide area*
Higher levels				
4: Transport	Inter-network sublayer (proposed)			
3: Network	Inter-networ	ECMA 72 (draft)		
		(No standard)		CCITT X.25
2: Data link	Logical link control			LAPB
2: Data link / 1: Physical	Ethernet	Token bus	Token ring	
1: Physical				V.24
(Medium)	50 ohm coaxial cable tree	CATV cable tree	Cable ring	

THE INCREASING USE OF STANDARDS

Implementations of both de facto and de jure standards in VLSI chip sets are proceeding in parallel with the definition of standards. The first Ethernet controller chips were designed by Ungermann-Bass and produced by Fujitsu in 1982. They began to appear in products in Europe during 1983. By then several other suppliers also had produced controller chips in commercial quantities.

As chip costs fall (the Intel chip set cost less than $90 in 1983), we believe that Ethernet (and the token-passing ring standard) will be used increasingly in micronets. Ethernet interfaces are available already for the Apple II, IBM PC and other popular microcomputers. More than 30 suppliers had announced support for Ethernet at the time of writing this report. From 1985, we expect that new chip-based local network systems will be based mostly on standard LANs.

Chips for the Datapoint ARCNet controller and for Zilog's Z-Net have been announced and IBM and Texas Instruments have made an arrangement to produce token ring controller chips. Several suppliers have also begun to ship products based on other suppliers' LAN technology. These include the Nestar Plan 4000 (based on ARC), a NEC micronet (based on the Q1 micronet), Torchnet (based on Econet) and Research Machines Chain (based on Z-Net).

We expect that support for the emerging LAN standards, and especially for Logical Link Control, will become general on microcomputers and workstations during 1984 and 1985. But this level of support will not provide interworking without compatibility at higher levels of the OSI model — a subject we discuss in the next section.

THE AVAILABILITY OF INTERWORKING SOFTWARE

If equipment from several suppliers is to interwork effectively, it is necessary (but not sufficient) that packets of information should be exchanged using a common data link layer. In particular:

—If more than one network is to be connected, then a network layer must provide routeing.

—A transport layer must provide secure connections between processes in the attached computers.

—A session layer must regulate the flow of messages.

—A presentation layer must specify coding and formats.

Not only is OSI standardisation less advanced at these higher levels of the architecture, but it has been overtaken by a large number of proprietary network architectures such as SNA, DCA, IPA, DECNET and XSIS. Some suppliers, ICL and Univac for instance, have promised to align their proprietary architectures with OSI standards when those are ratified. Though welcome, this process will take a number of years.

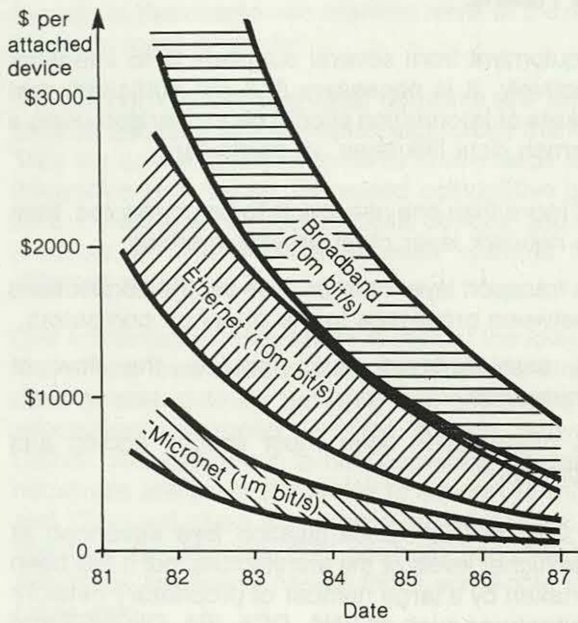
In the meantime, we expect to see a great increase in the available range of protocol convertors and inter-network gateways. Most of these will provide only the simpler and commoner functions, such as support for interactive terminals and file transfer. Other gateways will attempt to make a comprehensive translation between the architectures so that, for instance, an IBM computer running SNA can appear as a node in a DECNET network.

THE INTEGRATION OF COMMUNICATIONS MEDIA

At present, LANs can support resource sharing and the communication of data and text between attached devices. Where the attached devices support computer graphics, the supporting data structures can be transferred over the LAN. The capability to carry facsimile images also exists, though very few LANs have the necessary external interfaces to provide more than a low-speed facsimile circuit.

In the future, we believe that support for facsimile images on local networks will become commonplace. This will probably come through the inclusion of facsimile images within electronic mail systems. The local network will provide rapid local distribution of messages that have been received from other sites and filed. This configuration is shown in Figure 3.2.

Figure 3.3 LAN interface cost trends



The two requirements of interactive voice communications and local resource sharing on a network are sharply opposed. On the one hand, voice communication requires consistent low delays and is tolerant of errors. On the other hand, resource sharing requires low average delay for 'bursty' transmission at high speeds without residual errors. Because of this distinction, most currently available LANs can only provide stored speech, and most current ICBXs cannot provide effective local resource sharing. The Hasler SILK, Ztel PNX and Intecom IBX are partial exceptions to these generalisations, but as yet there is insufficient practical experience to determine their success in meeting the two distinct requirements. In our view transmission rates in excess of 10m bit/s will be needed to complete the integration of voice and data. Systems based on signalling at 100m bit/s are under development in a number of laboratories. At these speeds contention becomes very inefficient and rings show considerable advantages, especially for speech. We therefore expect that packet switching on high-speed rings will be used for the most advanced systems during the latter part of the 1980s.

A variety of integrated networks will become available in some European countries during the next few years (especially in the United Kingdom, encouraged by the liberalisation of the telecommunications environment and by the revision of the PABX standards to make them suitable for LANs).

Broadband LANs can carry video but cannot provide integrated services. Although very high-speed LANs that could provide such services are under development, we believe that they will not find application (except in atypical environments such as broadcasting studios) before 1990 at the earliest.

THE INCREASING RANGE OF INTERFACES

The range of external interfaces available on local networks is being increased rapidly by all the main suppliers. The first terminal support networks that were released supported only the V.24 (RS232) interface. Now many provide V.35 (RS422), X.21, X.25 and various proprietary synchronous interfaces (most notably IBM 2780 and 3270).

High-speed interfaces also are being provided for the more common minicomputers and microcomputers. To exploit these interfaces fully in host computers means that the computer software should treat the LAN as a multiplex channel to its terminals. By 1983 suitable software was available for only a small number of computers and operating systems.

The range of interfaces for the main utility networks will continue to increase during the 1980s. This will allow devices of many types (and from many suppliers) to be attached. However, interworking between otherwise incompatible devices will not necessarily be provided.

We expect suppliers to add interfaces to the more common types of leased lines and wide area networks. At first these interfaces will provide only the most basic kinds of service-bridges between similar local networks and support for asynchronous terminal traffic. In time, further services — file transfer, remote job entry, electronic mail, and file access, for instance — will be added. Whatever the particular services, gateways to public networks will need to provide accounting, monitoring and security functions, like those of the modern CBX but considerably more complex.

THE RAPID FALL IN COSTS

Local network costs vary considerably. Interfaces to the lowest-cost micronets are less than $200 (and those to the lowest-cost terminal support networks are less than $250) whilst interfaces for the most sophisticated terminal support networks cost up to $1,200. High-speed interfaces to some minicomputer

LANs cost even more ($6,000 in one case). For the European market, the following LAN interface prices were representative in 1983:

—Micronet ($200-$600).

—Ethernet ($1,000-$2,000).

—Low-cost TSN ($450).

—High-cost TSN ($750).

—ICBX data circuit ($650).

These costs exclude cables, installation, network management, and broadband head-end equipment which will add between ten per cent and 150 per cent to the total cost of a particular network.

The cost of electronic components will fall rapidly during the coming years. Over the next five years we expect to see prices falling at a compound rate of at least 30 per cent per annum, except for the lowest-cost products. In many cases the costs of controllers will be included in the prices of terminals and computers. Ethernet and IBM token ring interfaces may become as common as IEEE 488 is now — that is to say, widely available but not universal.

Figure 3.3 shows our forecasts of the falling costs of LAN interfaces. The range of the forecasts reflects not only the uncertainties of prediction but also the different pricing policies of various suppliers. The most significant implications of our forecasts are that, for the period up to 1987:

—Baseband interfaces will cost less than broadband interfaces operating at the same speed.

—Micronets will be cheaper than Ethernet.

The cost of network systems will fall more slowly, because of the increasing proportion of the staff and software costs.

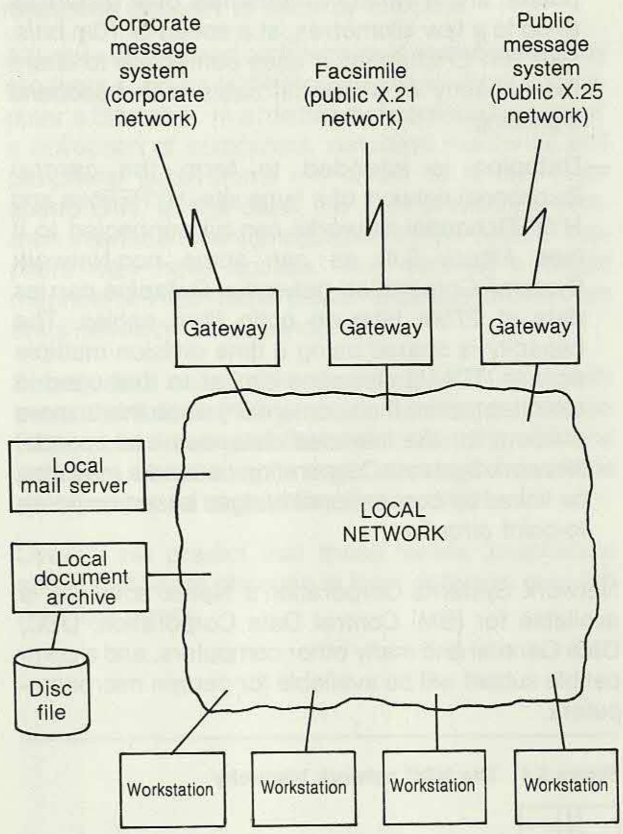
Having discussed briefly the subject of future cost trends, we return to the question of costs in chapters 4 and 5.

THE DEVELOPMENT OF NETWORK HIERARCHIES

Traditional telephone equipment uses a single type of signalling on one type of cable, the twisted pair (though a number of pairs may be packed together in a single jacket, this does not alter the principle).

In contrast, early work on LANs assumed that a single LAN would be able to serve every device on one site. Current LANs often violate this principle to keep costs down. In Net/One, for instance, the high cost of the Ethernet interface is shared among a number of low-cost terminals by multiplexing. There are several reasons for having more than one kind of LAN on one site:

Figure 3.2 Electronic mail and the local network



—Microcomputers may be served by a low-cost micronet which will have a limited range and choice of interfaces.

—On a large site, for example a factory or university campus, computers may need to communicate at high speed over long distances, justifying a dedicated high-speed LAN.

—Terminals in a small area may be connected over a low-cost terminal support network.

Already several suppliers have announced different levels (hierarchies) of products to match a variety of needs. One of the most sophisticated of these is offered by Network Systems Corporation. The Network Systems Corporation hierarchy (see Figure 3.4) contains three elements:

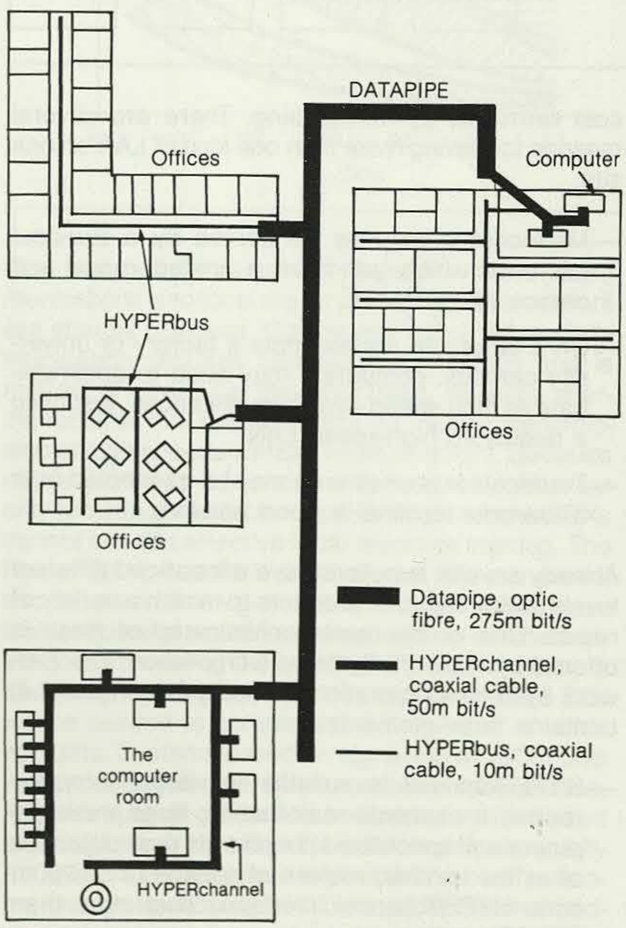
—HYPERchannel is suitable for large computer rooms. It connects mainframes, large minicomputers and specialised peripherals over distances of a few hundred metres at speeds of 50-200m bit/s. HYPERchannel interfaces cost more than $40,000 each.

—HYPERbus is intended for offices and light industrial plants. It connects microcomputers, minicomputers, and a variety of terminals over distances of up to a few kilometres, at a speed of 10m bit/s. Like HYPERchannel, it uses contention to share the capacity of a coaxial cable with baseband signalling.

—Datapipe is intended to form the central (backbone) network of a large site. HYPERbus and HYPERchannel networks can be connected to it (see Figure 3.4) as can some non-Network Systems Corporation networks. Datapipe carries data at 275m bit/s on optic fibre cables. The capacity is shared using a time division multiple access (TDMA) discipline similar to that used in satellites (rather than contention) since this is more efficient for the intended distances and speeds. Network Systems Corporation networks may also be linked by conventional bridges based on point-to-point circuits.

Network Systems Corporation's Netex software is available for IBM, Control Data Corporation, DEC, Data General and many other computers, and a compatible subset will be available for certain microcomputers.

Figure 3.4 The NSC network hierarchy



Network hierarchies are available also from:

—Wang, whose baseband micronet complements broadband support for terminals and inter-computer communication.

—Sytek, whose low and medium-speed services operate at different frequencies on the same broadband cables.

—Corvus, who are developing a multi-channel broadband network to connect up to 16 Omninet micronets.

IBM spokesmen have discussed a hierarchy of rings based on similar general principles. Hierarchies are found also in advanced CBXs such as the Intecom IBX and Rolm CBX; high-speed links connect distributed switching or multiplexing units while telephones are connected to those units by twisted pairs. We expect the trend towards network hierarchies to be an important factor over the next few years.

THE DEVELOPMENT OF NEW ARCHITECTURES

LANs have their most distinctive advantages in interconnecting computers and allowing the computers to share resources such as discs, printers and gateways. In practice, economies in disc storage provide the single largest reason for the development and installation of micronets (the commonest type of LAN).

Many existing micronets allow only a small number of microcomputers to share the resources of a single 'master station'. Future advanced workstation networks, operating at 10m bit/s or higher speeds, will often be based on standard LANs, and will support hundreds or even thousands of microcomputers. In the future, each workstation will be able to make concurrent accesses to a number of servers. The servers are likely to include:

—File servers which substitute for individual floppy discs.

—Database servers.

—Print servers.

—Processing servers, which provide more powerful processors when the user station does not have enough local intelligence or storage.

—Mail servers.

—Communications gateways to public and private networks and to local data processing, word processing and computer aided design systems.

—Applications servers, providing access to specialised databases and systems for accounting, planning, costing and other key business functions.

We also believe that in future a range of user workstations will appear. These will include word processors for typists, low-power data access units for managers, and powerful workstations for professionals. To allow workstations and servers to be developed separately, sometimes by different suppliers, their interactions will be formalised as a set of protocols collected in a workstation architecture. The Xerox systems interconnection standards (XSIS) architecture is the first such example.

These architectures can be implemented on machines ranging from 64k microcomputers costing $3,000 to 1m bytes computer-aided design stations costing $15,000 or more. It is difficult to develop networks to handle workstations that differ greatly in processing power, so most workstation networks will be based on workstations of similar power and cost. Usually, however, there will be several compatible options within each type. An advanced architecture has been developed by Apollo Computers for their Domain network, in which every computer is able to act concurrently as both 'user' and 'server'. The specially developed network operating system gives all processors access to files, programs, and other resources (subject to security checks).

A further LAN-based architecture is foreshadowed by products such as HYPERchannel and Stratus Computer's Stratalink. In a 'distributed computer complex' a collection of computers, database machines and peripheral subsystems are linked by a very high-speed LAN. In this case, the LAN provides a common interface to which equipment from several suppliers may have access, thus allowing a single machine of 'mainframe' power to be assembled from units developed independently.

Some useful units for this architecture have already become available. They include the Masstor and the Britton-Lee Intelligent Database Machine. Several suppliers are working on major developments of this architecture for announcement in 1984.

Overall, we predict that these trends foreshadow some significant changes in local networks over the next few years.

CHAPTER 4

CHOOSING A COMMUNICATIONS STRATEGY

In this chapter we explain why organisations need a communications strategy. We then describe the relationship between communications and system strategies, offer a perspective on future system developments, and outline the different communication policy options that are available. Finally we discuss the strategic significance of micronets.

THE NEED FOR A LOCAL COMMUNICATIONS STRATEGY

It is generally possible to find the local network that best meets a given set of requirements. In most cases the decision depends on a small number of issues, most commonly whether to support video, voice-data integration, fast file transfer and local resource sharing. The quantity and distribution of equipment and the particular interfaces needed are also important in some cases. We discuss the significance of these key issues in the next two chapters.

In practice, however, the issues are considerably more complex than this general overview suggests. Usually a local network is seen as a long-term investment. Like the choice of a mainframe, it not only meets existing needs, but also determines the requirements that can and cannot be met in the future.

An over-estimate of demand involves wasted capacity which can be expensive. An under-estimate, or the appearance of new kinds of communications traffic, may necessitate special engineering or even the premature replacement of a network. Therefore, it is vital to identify significant future requirements before choosing a local communications network.

Many communications managers create sophisticated plans through which users identify their future needs. They then aggregate the demand and adjust it according to historical trends, corporate policy, cash limits and other practical guidelines.

Such exercises are often unsatisfactory for two reasons. First, it is rare for users to see their future business systems needs clearly. Second, suppliers continually develop new ways to meet given needs.

Reactive planning may work in the short term when systems development is centralised. It is likely to fail in the longer term, however, especially when systems development and procurement are decentralised. Reactive planning also is unlikely to foresee needs associated with genuinely novel developments.

An example, admittedly extreme, may serve to illustrate this point. A large American computer company has systems development staff based on a number of sites under local management. During the 1970s the company installed a store-and-forward file transfer network, mainly for remote job entry and the distribution of new software releases.

Gradually, systems staff began to use this network for text as well as data. An informal electronic mail system grew up, linking staff in the various locations and allowing them to exchange ideas. After some years it became clear that this had affected not only the flow of information but control of the systems development process. Local management was no longer in control.

Recently, many organisations have experienced similar problems with the use of personal computers. These problems will become even more noticeable as sophisticated office systems come into use. Reactive planning will work even less well in future, when systems development responsibilities move out to local sites and to the users themselves.

One way that a local network can constrain applications may be seen by considering the use of full-motion video. A broadband network will encourage the use of video for information, training, remote inspection and other functions. It allows video conferences to be carried to every part of a building, which will encourage user acceptance. But a broadband system will commit the organisation to analogue video technology, thus making the eventual introduction of digital video more difficult. Communications managers must therefore compare the short to medium-term benefits (and high initial costs) of a broadband network with the greater long-term benefits to be expected from digital video.

THE RELATIONSHIP BETWEEN COMMUNICATIONS AND SYSTEMS STRATEGIES

Most large organisations have installed substantial numbers of online terminals and this trend is continuing. Support for these terminals will therefore be the first requirement for a local network. This requirement may be met by ICBXs, LANs and other technologies and the most cost effective network will depend upon the penetration, distribution and use of terminals, and on the existence of ducts and cables.

Future requirements for fast file transfer and for resource sharing may change this picture significantly. Fast file transfer to a microcomputer requires transfer rates of at least 50k bit/s (sufficient to copy a 1m byte floppy disc in three minutes). To download a large file to a minicomputer much higher speeds are desirable. Resource sharing between computers, especially the sharing of disc storage, also requires higher speeds. To provide acceptable response times, a speed of 300k bit/s is needed for microcomputers, and a speed of at least 2m bit/s is needed for minicomputers.

The need for these facilities depends both on user requirements and on the architecture used. Fast file transfer is essential for certain styles of distributed computing. But if each minicomputer controls its own files, this need will not arise. Alternatively, if file transfer requirements are not urgent, tape transfer could be used. Very similar considerations apply to resource sharing. User requirements for data sharing and processing power may be met either by terminals on a minicomputer or by a micronet. The network implications in these two cases are very different.

It follows from these arguments that a local network strategy is dependent on a technical systems strategy for data processing, factory and laboratory automation, personal computing and office systems. Such a strategy should show both the nature of future systems and utilities and the architecture that will be used to support them. The architecture would imply a local communications strategy, which could then be adopted.

Few organisations have such a strategy. We therefore now describe the main trends in the structure and use of information systems, and indicate how these affect communications requirements. We follow this by discussing the main options for a network policy.

THE FUTURE SYSTEMS ENVIRONMENT

Clearly no two organisations will experience exactly the same pattern of change. Nevertheless, there will be five common trends that will affect the systems environment:

—A continued growth in computer use.

—A rapid increase in network use, particularly between organisations.

—A shift from centralised to distributed and personal computing.

—A modest growth in videoconferencing and a rapid, but very patchy, growth in other video services from a very small base (for example, training programmes).

—Slow progress on the integration of digital data, text, image and speech.

These trends have many implications, the most significant of which are:

—Computing will extend to many more business sites in the shape of point-of-sale systems, teletex, word processors and microcomputers. Most sites will have some computing.

—Routine business communications between organisations (such as invoice and order information) will be carried more and more on networks, rather than on paper.

—Increasing numbers of staff at all levels will make routine use of computers.

These trends have implications for wide area as well as local networks. We now discuss these two topics in turn.

The impact on wide area networks

The implications for wide area networks are:

—The use of public data networks for inter-organisation communication will grow.

—Standards will become much more important, especially for file transfer, electronic mail and data definition.

—The use of electronic mail will increase, starting within organisations and then linking more widely as standards and gateways become available.

—Local processing will reduce the relative importance of communications from the periphery to central machines. Batch transfer will become more important relative to interactive working. Machine reliability will become increasingly important.

—Inter-site full-motion video will remain unimportant, except for the TV industry, until at least 1988. Slow-scan and freeze-frame video between sites may increase in importance.

—Speech and data will not be functionally integrated in inter-site communications.

The impact on local networks (short-term)

For local communications, the following trends will be important in the short term:

—The use of word processors and personal computers will grow (as shown in Figure 4.1). They will require intermittent file transfer and some interactive communications (via terminal emulation). The case for resource sharing will remain strong but it will only be possible where some discipline has been used in equipment procurement.

—Resource sharing networks, mainly micronets, will remain largely distinct from data circuit networks. Data circuit networks will provide terminals with access to both local and central computers.

—Systems for automating factories, laboratories and offices will remain largely distinct though they will communicate with each other more and more.

—Although the volume of voice traffic will continue to exceed the volume of data traffic, most data networks will remain independent of voice networks.

—The biggest use of local video will be for site security, at least in Europe.

The impact on local networks (longer-term)

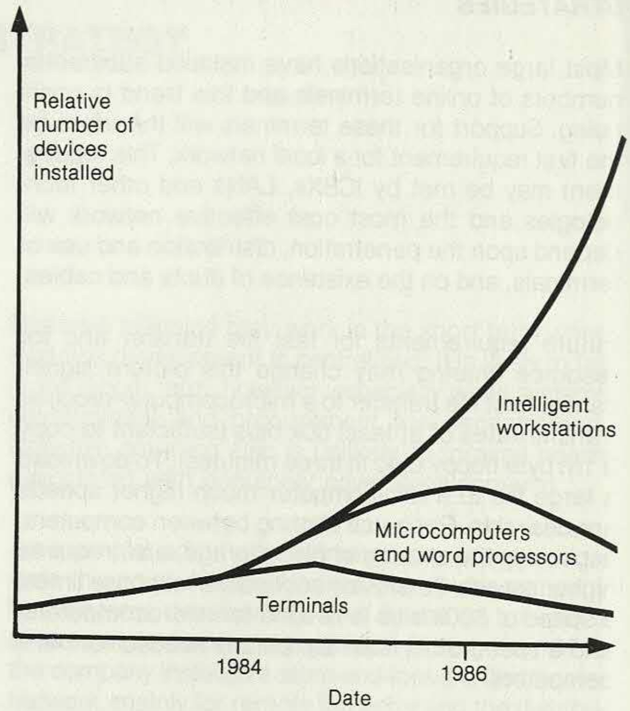
In the longer term a rather different pattern will emerge:

—Intelligent workstations will replace traditional terminals and microcomputers (as shown in Figure 4.1). Eventually, these workstations will provide the majority of the processing power available within most organisations.

—Although some workstations will have their own hard discs, economies of scale, operational convenience and the need to share information within working groups will ensure the continuing importance of shared storage. Two other factors will encourage the use of shared storage. First, the general trend for users' storage requirements to grow as their understanding of computers increases, as machine power and software sophistication increase, and as graphics and electronic mail come into wider use. Second, the development of specialised data management servers such as database machines and associative search engines. (Indeed both these developments have already been introduced: The database machine by Britton Lee and Intel, and the associative store by ICL and Datafusion.) Products like these are likely to find an increasing place in office computing as both the volumes of data and the ambitions of users grow.

—Resource sharing networks, mainly LANs, will progressively be extended to larger areas within organisations, and data circuit networks will no longer be installed.

Figure 4.1 The evolution of workstations



—Image and stored voice capability will be added to workstation communications.

—As workstations become commonplace, users will demand a very high level of reliability. Initially 99 per cent availability may be enough (contrast computers, where this is often not achieved) but 99.95 per cent may well be needed in five years. Some situations, such as medical applications and process control, may demand even higher reliability.

—The systems supporting separate business functions and areas will come together to form integrated business systems.

—Many individual departments and sites will install powerful computers to meet local needs. As a result, the relative importance of corporate computers will decline.

—Off-site communication facilities (such as telex, teletex, PSTN and corporate networks) will be adopted almost universally. On large sites, gateway access to older systems will be a key issue — this access often will include fast file transfer.

—During the period 1984-1989, we expect that most local communication systems will conform either to the terminal-host model or the workstation-server model. But some systems will follow the Apollo Domain in providing services to users through the co-operation of several networked computers, each of which may itself include several specialised processors. These systems will rely on distributed operating systems and distributed database systems, through which the user will be able to access personal, local and corporate data. (After 1989, these systems will become much more important.)

—Interactive voice communications will remain a dominant requirement.

LOCAL COMMUNICATION POLICY OPTIONS

In most cases a technical systems strategy will imply a local network policy. Indeed, network considerations will be important in determining such a strategy. But these strategies are difficult to formulate, and senior management support for them is not common, especially when technology is advancing very quickly. We believe that most organisations will not be able to establish the necessary strategies.

In the absence of a technical systems strategy, there are four alternative local communication policy options:

—Choose one main supplier, wait for this supplier to solve the communications problems, and then apply the solution.

—Install a local network that complies with emerging standards.

—Install a broadband network.

—Choose the best available network to meet existing and foreseen needs.

The 'main supplier' option

The option of following one main supplier will be preferred by many organisations. It is an easy option and, if a major supplier is chosen, probably a safe one. And it is very likely that the network will fit well with the supplier's other products. But this approach has three main disadvantages:

—It tends to create a closed system, in which other suppliers' products cannot readily be used.

—It often leads to the use of unnecessarily expensive components.

—It delays benefits until the chosen supplier has developed the necessary products.

This approach makes the choice of the main supplier a crucial one. At present, the choice will lie between a full-range computer company, most commonly IBM, and a company with strength in the area of greatest interest. The former approach may confine the user to an obsolete architecture. The latter approach will require the integration of other suppliers' products into the main supplier's architecture.

The 'follow standards' option

The option of installing a local network that conforms to emerging standards has been advocated by a number of commentators. Until 1983 this meant, in practice, Ethernet. IBM's intention of adopting the IEEE token-passing ring will encourage this approach, although operational experience of this technology is limited. For factory sites some organisations may also wish to consider the IEEE token bus.

Experience to date indicates that Ethernet will prove an expensive choice. For a variety of technical reasons, notably the high signalling speed, Ethernet electronics and cables are expensive. Also, it is impractical to install outlets in every office at the time the network is installed. The IEEE token-passing ring will lend itself to lower-cost cabling plans; but not if the highly resilient approaches favoured by IBM are used. Cabling for the IEEE token bus should be low-cost and convenient. Regrettably, few suppliers currently support it.

We therefore recommend the adoption of a standard network as a strategic choice only to those organisations that are obliged to plan for multi-supplier sites.

The broadband option

The broadband option can support existing equipment on low-speed services, with the option of moving to faster services in the future. This will be more expensive than the use of low-speed baseband networks and there is, of course, no guarantee that the equipment that is eventually selected will obtain cost-effective support from a broadband network. In some cases, however, a sophisticated broadband network may be cost effective now and, in these cases, the extra flexibility may be worth some increase in initial costs. It is probably for these reasons that a survey by "Data Communications" in 1982 found that over 70 per cent of data communications managers considering local networks preferred broadband systems.

The 'best available network' option

The option of making the best short-term choice allows the organisation to benefit from new products as soon as they become available. This is, however, likely to lead to the installation of incompatible networks at different sites. Incompatibilities at the lower levels of the OSI model will prevent equipment being moved between sites. But communication between sites will be possible if there is compatibility at the higher levels, usually at and above the OSI transport level. But even this measure of compatibility is currently difficult to achieve, except for the connection of terminals to computers.

Comparison of the options

Probably no single policy option will be right for all organisations. However, we believe that three guidelines may be applied:

- —Organisations that have to build multi-supplier systems for technical or political reasons should install Ethernet and move to OSI protocols at the higher levels.
- —Organisations that want the security of staying with the main supplier's architecture should wait until that supplier's local network is proven.
- —Organisations that wish to retain flexibility should choose the most cost effective solution to their problems. However, it would be wise to accept a small increase in total costs in order to use broadband if a satisfactory broadband product is available.

THE STRATEGIC SIGNIFICANCE OF MICRONETS

Most large organisations are beginning now to suffer from a proliferation of electronic office machines, particularly word processors and microcomputers. This proliferation has resulted from a combination of the low cost of equipment, an unwillingness to concede to management services the right to control developments, and a lack of any systems strategy which would justify restrictions. Yet management services staff are worried by these trends in information systems. They suspect that they may have to resolve the problems of incompatibility in the future.

In very few organisations is central data processing so effective and responsive in providing mainframe and minicomputer systems that there are no opportunities for personal computers. And, even in these cases, there are likely to be small local offices from which online links to central computers would be too expensive. In such cases there will be both developmental and operational advantages in using a single type of microcomputer.

On central sites the position is rather different. In some cases there will be strong arguments for the use of micro computers. In other cases there may be no such arguments, yet the line managers concerned will often have enough authority to insist on making their own choice.

The micronet provides management services with a means of providing a service that is better, or lower cost, or both, than that provided by a stand-alone machine. Also, it provides an obvious rationale for restricting the range of microcomputers that are in use, since most micronets support only a few types of microcomputer. It is, of course, easiest to exchange data and programs if only a single type, or a compatible range, of microcomputers is offered with management services support.

Where a restrictive policy cannot be enforced, the micronet may be used to encourage certain choices of hardware and software. This may be achieved by identifying several levels of local computer and providing greater support to the options favoured by management services. Figure 4.2 shows one possible set of levels, together with the support available at each.

Once installed, a micronet need not be seen as useful only for minor local systems and end-user computing. On the contrary, it should be regarded as just as much part of the organisation's systems infrastructure as the corporate mainframe. Mainstream data processing systems may be developed which use both microcomputers and mainframes where appropriate. In operating branches, for instance, micronets could provide local data collection and validation, together with online access to central transaction processing systems. Valid transactions would be transferred to the central mainframe each evening. The mainframe would then update the master database in batch mode and prepare standard reports. A micronet in head office would receive, from the mainframe, files of current data for reference and reports for printing. It would then provide analysis of the data through query languages, spreadsheets and graphics.

Figure 4.2 Possible attachment levels and central support

Level	*Network connection*	*Central support*
1. Systems developed by the computer department to corporate data and process standards.	Fast multiplex connection to micronet. Update access to all relevant files.	Fully supported and enhanced by computer department.
2. Systems developed by local on recommended local computers.	Fast multiplex connection to micronet. Fast file transfer, resource sharing, access to corporate electronic mail system.	Hardware and selected software supported by computer department. Advice on application selection and system development.
3. Systems emulating an approved protocol.	Low speed data circuit to minicomputers and mainframe. All access via TP or time-sharing systems.	Operational support for network service only.
4. Other.	No connection.	No support.

Also, interactive communication to the mainframes could be provided to access data that has not been transferred.

In chapter 3 we predicted that information systems will become highly distributed and will be based on resource-sharing local networks. We noted that current micronets were evolving in this direction. It is likely, however, that the most successful systems of the late 1980s will not be based on existing microcomputer operating systems. These have been developed for small stand-alone machines rather than for the powerful network stations and servers that will then be common. Operating systems cannot easily be upgraded to meet new requirements without losing compatibility with existing applications.

Existing minicomputer and even mainframe operating systems will have a place in these future systems, however, probably in support of multi-user applications rather than personal computing. But no existing minicomputer operating system can exploit the power of the individual workstation to provide support to individual workers. We believe that this will be done most effectively by specially designed systems (such as Smalltalk) and derivative commercial products (such as Apple's Lisa).

There is therefore no current micronet choice which will ensure a smooth transition to the systems environment of the late 1980s. A major break in compatibility seems inevitable if really advanced systems are to be exploited when they become available. Accordingly, users should look for micronets to cover their costs within three years and should prefer standard operating systems such as Unix and CP/M as providing their best hope for a smooth transition.

CHAPTER 5

SELECTING A LOCAL COMMUNICATIONS FACILITY

In this chapter we discuss the selection of local networks. First, we list six main questions that will help to identify the type of network required, relating each question to appropriate local networks. Next we examine the main issues relating to network control. We then classify the key attributes of broadband and baseband networks and describe the relationship between local and wide area networking. Finally we summarise the main findings from our research into local network selection.

DETERMINING THE REQUIREMENTS

The selection of micronets often is made primarily on the basis of the microcomputer operating system, which implies the range of software available. However, when local networks are selected as communication facilities, different selection criteria apply.

Our research has identified six main questions relating to network selection:

—What are the requirements for video communications? (Must any video communications be integrated with other communications?)

—Is there a need for voice-data integration?

—Does the site need several incompatible networks in the same area?

—Is there any need to support computers and workstations that need fast file transfer or resource sharing?

—How many host computers must be supported and with what interfaces?

—How many terminals and other simple digital machines must be supported? (What interfaces and protocols do they use? Where are they and how much will they be used? How often will they be moved and how quickly must they then be connected to the network?)

The answers to these questions will usually determine the best choice of network. But in some instances there will be special needs which will sharply limit the range of possible solutions. These special needs include:

—The need to operate in industrial areas with high risk of fire or explosion. This will usually indicate the use of optic fibres.

—The need to support specific items of equipment. For example, the choice of an Apollo CAD system implies the installation of a Domain LAN.

—The need for very high network availability (in excess of 99.98 per cent). This requirement can be met only by networks that can support multiple independent routes between nodes with automatic re-routeing. Several specialised networks of this type have been developed for use in military systems or for the real-time control of nuclear power plants. In an office or light industrial environment, the requirement for high availability would indicate a resilient LAN product such as Planet or SILK.

The needs of particular sites must be determined individually in the light of the policy for communications and digital systems. Those involved in network selection should start by establishing the current equipment base and communications pattern. Discussions with users, system designers and any local information systems staff may be interpreted in the light of network trends (discussed in chapter 2) to answer the questions listed above.

IMPLICATIONS OF DIFFERENT REQUIREMENTS

Answers to the requirement questions will indicate a particular type of local network. We now discuss each of these requirements in turn.

Video requirements

The most widespread use of video communications in business is in security and surveillance applications. This is likely to remain true for some years. Since security cameras are not usually installed near office equipment, there is rarely a need to combine security video and data networks.

If video requirements are extensive, then a cable TV network will be required. If such a network already exists in an organisation, it will sometimes be possible to upgrade it to a broadband data network for a modest cost. If the cable TV network does not exist, however, then it will not be much more expensive to install separate cable TV and baseband local networks if this is done at the same time.

Most organisations have no real need to integrate TV and data services, and this situation is unlikely to change during the 1980s. A low level of integration (for instance, the use of data signals to control a remote security TV camera) may be obtained conveniently on a broadband network. Higher levels of integration, which might be required in an advanced television studio, will best be provided by digital video. (Special engineering is currently essential for this.) The CARTHAGE network, under development at the Centre Comun d'Etudes de Télédiffusion et Télécommunications in Rennes, France, will provide integrated transmission and switching over an optic fibre ring.

In the longer term, the use of video communications presents one of the biggest uncertainties. It is certainly possible that the use of full-motion teleconferencing, educational TV and other video applications will grow rapidly from the middle of the decade. But rapid growth does not seem very likely. The European market has not shown much interest in teleconferencing of any sort and seems unlikely to pay the high costs of inter-site video transmission on any large scale. When teleconferencing is used, it is likely to involve specialised conference rooms and only very exceptional sites will be likely to have more than one.

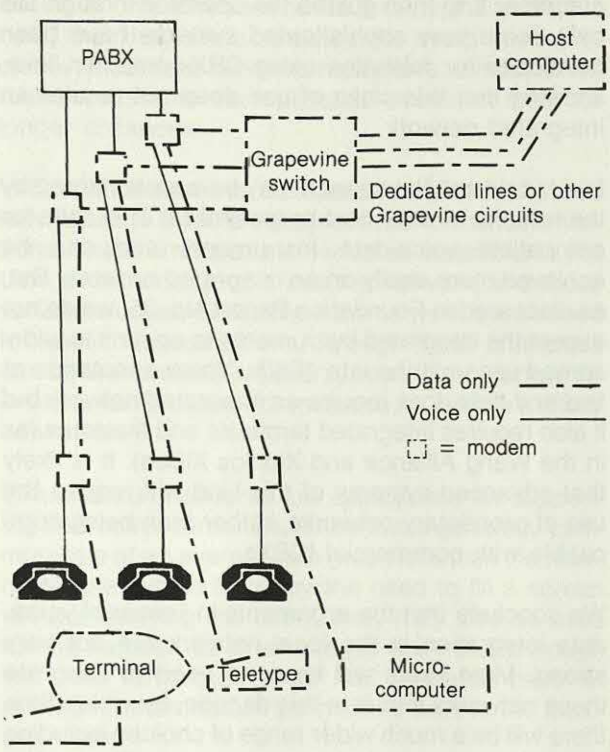
The wider use of video for animations, education and corporate communication is more likely, but it is likely to be based on cassettes, discs and intelligent workstations rather than a video network.

Requirements for voice-data integration

Requirements for voice-data integration suggest the use of either an ICBX or an integrated LAN.

Since almost every business site of any size already has a PABX, or at least a key system, the idea of using the telephone switch and its wiring for data can seem attractive. This approach avoids the need to install new cables and suggests economies in switching logic and network management. The most basic system of this kind is the data-over-voice technology developed by Teltone and currently marketed in Europe by CASE under the name Grapevine. In Grapevine (see Figure 5.1) data is carried on telephone wires at frequencies outside the voice band at speeds up to 9.6k bit/s. A separate circuit switch is provided for the data circuits. Grapevine equipment installed adjacent to existing telephones provides V.24 interfaces to which digital devices can be attached. Grapevine is a direct substitute for twisted pairs but is currently more expensive than the line drivers usually required on twisted pairs.

Figure 5.1 A Grapevine network



In an ICBX, data and voice transmission and switching are integrated, allowing transmission rates up to 64k bit/s (or higher in a few cases) and access from the data circuits to wide area telephone networks. Providing appropriate support for voice and data traffic complicates the design of the ICBX, making data support rather expensive.

The speed available through an ICBX is more than sufficient for terminal support and the transfer of small files. But it is not really adequate for resource sharing or the development of locally distributed systems. However, the use of a voice system for data attracts PTT involvement, which in most European countries is unlikely to be helpful.

Of course the ICBX does have the ability to provide integrated voice-data communication; though at the moment no current ICBX provides more than concurrent use of cables and switching facilities. There is little experience of using voice-data integrated systems but we believe that there are three main classes of use:

—Computer assisted telephone calls.

—Hybrid calls.

—Voice annotation.

On a computer assisted telephone call, the computer makes the connection to, for instance, a prospective customer and then guides the operator through the call. Some very sophisticated systems have been developed for telesales using CBX-computer links, showing that this class of use does not require an integrated network.

In a hybrid call the speech may be supplemented by the transfer of data, text or facsimiles. This calls for compatible voice-data instruments and can be achieved more easily on an integrated network. But, as discussed in Foundation Report No. 35, we do not expect the integrated instruments to come into widespread use until the late 1980s. Voice annotation of text and data does require an integrated network but it also requires integrated terminals and filestores (as in the Wang Alliance and Xionics XiBus). It is likely that advanced systems of this kind will require the use of proprietary networks, rather than being compatible with commercial ICBXs.

We conclude that the arguments in favour of voice-data integration in the local network are not very strong. Most users will have no need to integrate these networks until late this decade, by which time there will be a much wider range of choices including distributed ICBXs and very high speed office LANs.

Requirements for incompatible networks

A need for logically independent incompatible networks in the same area suggests a need for a broadband LAN on which one or more frequencies can be reserved for each network. But only in unusual circumstances, where, for instance, some networks must meet strict performance criteria, is this necessary. In most cases any network that can provide data circuits can be used, physical or virtual circuits being allocated to the various networks. Those networks may need their own access control mechanisms, but generally it is sufficient to provide this only in host computers and gateways.

Requirements for fast file transfer or resource sharing

A requirement for fast file transfer, probably in support of distributed processing, may be met by a LAN or by special engineering.

A requirement for high-speed intermittent (bursty) communications to provide resource sharing between microcomputers or workstations indicates the use of a LAN or an advanced ICBX (such as the Intecom IBX). The network chosen must provide interfaces over which the required services can be accessed.

Computer interface requirements

Various kinds of network can provide a data circuit service supporting interactive terminals, RJE stations, facsimile transceivers and computers that emulate these devices. Circuit-switched networks usually offer only this basic data communications service. For speeds up to 19.2k bit/s, the CCITT V.24 interface is still by far the most common, though V.35 and X.21 are becoming more significant for operation at higher speeds. These interfaces are generally supported by microprocessors which restrict the data rate to no more than 72k bit/s and often to as little as 19.2k bit/s. Some proprietary interfaces require very high transmission rates. Communication between the IBM 3278 terminal and its cluster controller is at 2m bit/s, for instance, and can therefore be provided effectively only on a high-speed network. In other cases, the need to support uncommon interfaces such as ICL CO3 may be critical. Accepting such needs may limit sharply the possible choices of local networks.

The way in which the data circuit service may be used is also of concern. Most circuit-switched networks, and the cheaper LAN-based networks, require network addresses to be specified through a code convenient to the network. Though acceptable for small networks, this is unsuitable for large networks, or where device changes are frequent. The more sophisticated local networks, like LocalNet and Net/One, provide a name server which accepts the name of the required computer or network service and converts this to a network address. CCITT X.29 defines a rather complex dialogue between a terminal user and a switched network and is used in some local networks.

Local area networks almost always offer a higher-speed packet transmission service which can be used to share resources between attached computers. Micronets offer only this service. In the earliest networks it was available only between a central master station and user microcomputers. More advanced micronets allow all the attached microcomputers to conduct several concurrent interactions with other devices. The most advanced LANs provide both data circuit and resource sharing services, together with the ability for them to interwork. This interworking may be used to provide terminals with access to a local host or to a wide area network. It may also be used by an individual workstation user to interact with several servers which can provide this degree of flexibility.

The only interface standard is CCITT X.25 and this is available on only a few networks. Most network designers, however, believe that an interface designed for the complexities of a public packet network operating over error-prone trunk lines is too complicated for use on a LAN. So they have developed network interface units that are compatible with the buses used in the most popular computers.

In most cases minicomputer interfaces are supported by software that allows the LAN to be used for terminal support, whilst the microcomputer interfaces are supported by software that intercepts references to discs and passes them across the network to a central disc server. It is generally possible to provide additional functions (such as workstation to workstation communication) by further programming.

In the case of terminal support, it is likely that the protocols are those of the host computer operating system. For resource sharing on a micronet, the protocols are proprietary and defined by the supplier of the disc server. In some cases more general functions may be provided using published protocols — the Xerox Internetwork Datagram and ECMA transport layer are both available from more than one supplier.

In many practical situations, having to support certain machines has restricted the choice of network. Though this problem will ease progressively, it will continue to limit the options open to particular organisations for the foreseeable future.

Terminal support requirements

Where most of the devices to be supported are terminals or other simple digital devices, the distribution and usage of terminals are critical issues for network selection. If the terminals are widely scattered, a network based on existing wiring (most likely telephone wiring) is indicated. This may be a data network using spare pairs in telephone cables or it may involve the concurrent use of wires for voice and data.

If the terminals are used only infrequently, as is often the case for videotex terminals for instance, an existing PABX may be used for switching. If usage is high then a dedicated data network or CBX is indicated. However, the choice of a CBX may involve the installation of a new switch, which will generally be justified only when the existing switch has reached the end of its life.

If terminals are moved frequently, or must be moved at short notice, then a network which can be installed in every office is desirable. (This criterion is expensive to meet with baseband contention networks such as Ethernet.)

NETWORK PERFORMANCE

We now discuss the performance criteria that relate to different kinds of local network.

In a circuit-switched network, a circuit (once established) can carry data at its full speed indefinitely. There are therefore no performance problems during transmission, though congestion may lead to delay in obtaining a circuit. Most devices, however, use a circuit for only a fraction of the time (typically five per cent) that they are connected. To avoid this inefficiency, most data networks multiplex a number of virtual circuits onto each physical circuit, at least for longer distances.

Virtual-circuit networks, such as public packet-switched networks, are therefore subject to performance limitations. These limitations show up as variations in the time taken for data to cross the network, and these variations create difficulties if the network is to be used for speech transmission. Although these difficulties can be overcome, this has only been found worthwhile in exceptional cases (for instance, in certain military networks).

Virtual-circuit networks are appropriate for supporting interactive terminals, since these generally communicate at an average rate much less than the maximum rate (which is set by the need to fill a screen without delaying the user). They may also be used for file transfer, as in remote job entry (RJE), though with less advantage since RJE terminals have an average transmission rate much closer to the maximum rate.

Being packet switched, LANs are subject to the same logic. Low-speed LANs (such as LocalNet System 20) are used mostly for terminal support. One System 20 channel, operating at 128k bit/s, can support between 100 and 200 interactive terminals before significant delays occur. (The exact number depends on what the terminals are used for — transaction entry generally requires less transmission capacity than text retrieval, for instance.)

Usually, LANs of higher speed are able to support more terminals, but the number of terminals that a particular LAN can support depends on the nature of the terminals (and the LAN) as well as on the transmission speed. The Cambridge Ring, for instance, uses its capacity very inefficiently, so that it can support only half as many terminals as a contention network of the same speed. A single Ethernet should be able to support at least 10,000 interactive terminals — many more than are ever likely to be attached to a single Ethernet.

In practice LANs are run at very low utilisation (less than ten per cent and often only one per cent). Congestion is uncommon and delays are limited to a few milliseconds. The real limits on the use of LANs are determined by the hardware and software that generate and process the traffic, rather than by the network itself. For instance:

- Files may be transferred at up to 4m bit/s over a 50m bit/s HYPERchannel.

—Files may be transferred at up to 200k bit/s between Alto personal computers on a 3m bit/s Ethernet.

—Terminals can interact with host computers at up to 19.2k bit/s over a 10m bit/s Net/One.

In practice LAN performance will be a significant constraint only if the LAN is being used inappropriately — if, for instance, a terminal support network is being used for fast file transfer between minicomputers.

High-speed LANs like Ethernet and the Cambridge Ring will operate without problems unless heavily loaded with mainframe file transfers or voice traffic. But the slower micronets may encounter problems when downloading files or programs. Low-speed terminal support networks will cause increased response times if used for more than the manufacturer's recommended numbers of terminals, or for a large amount of RJE work.

In most cases, loading problems can be solved by reconfiguring the network. One advantage of a high-speed LAN is that reconfiguring is not necessary, even if the number and sophistication of the attached devices is increased greatly.

MONITORING AND CONTROL FACILITIES

Requirements for monitoring and control facilities will vary considerably, depending on the type and size of network. In a small network intended to serve a limited area, the practical minimum is probably just a means to check the continued operation of the network. In a large network the following functions will also be needed:

—Monitoring the status of all network components including reporting faults and early warning of potential failures.

—Pinpointing the physical location of a cable fault, preferably to within one or two metres.

—Restricting user access to certain resources (not every large network will need this).

—In a low-speed network there should be some monitoring of utilisation to warn network management of congestion problems before they become acute.

BROADBAND VERSUS BASEBAND

The choice between baseband and broadband LANs has been the subject of a great deal of comment, much of it ill-informed. Also, the general argument has become confused with the arguments for and against certain technologies, and even certain products. In this section we describe the attributes of broadband and baseband technologies in order to clarify the key issues.

Generally, baseband signalling is easier and less expensive than broadband. Baseband is therefore the lower cost way to provide any single service. For this reason, both the least expensive and the fastest LANs (currently, Clearway and Datapipe respectively) use baseband technology. Another, and more relevant, example may be taken from the terminal support field. Terminal support on Multilink (300k bit/s baseband) is currently less than half the price of terminal support on LocalNet (128k bit/s broadband) though LocalNet provides more functions.

In practice, this issue is complicated by two main factors. First, the cost of a broadband cable may be shared among services that otherwise would require separate cables. Second, the most talked about baseband network, Ethernet, suffers from a number of limitations which tend to increase the cost of systems based on it. These are:

—The high speed of Ethernet makes the electronics expensive.

—Ethernet transceivers must be placed within 3cm of the cable and this can cause crowding of the ducts.

—Ethernet requires low-loss coaxial cable which is much more expensive than CATV cable.

—Because transceivers are needed in the ducts, it is expensive to carry the full bandwidth to every office. So walls and ceilings may have to be opened to extend the network at a later date.

—The cable configuration rules for Ethernet are complex.

For all these reasons, an Ethernet-based terminal support network may cost more than one based on broadband technology. Moreover, for terminal support, the higher speed will be of no practical advantage.

It is also said that broadband networks have a greater range than baseband networks. This is true for some commercial products but it is a reflection of the operating speed, rather than the signalling technology. For a given speed and medium access control system, the ranges of broadband and baseband systems will be very similar. Baseband networks can be extended with repeaters just as broadband networks can be extended with amplifiers.

In any case, it is difficult to see the significance of this. On large sites a broadband network often is divided into parts to aid maintenance, while networks can be linked to one another or to a site backbone network. A site backbone, with local networks serving particular departments, buildings, or working groups, is a better general model for business communications than a single comprehensive network.

Broadband technology, however, does have some distinctive advantages over baseband technology. It has greater immunity to electrical noise and there is more experience of managing large, highly reliable, broadband networks. Resilience to equipment failure also is better — a streaming modem will only make a single frequency inoperable, whilst other modems may be able to transfer to other frequencies and resume operation. It is also cheaper to provide a duplicate cable for backup. But the greatest advantage of broadband is its ability to accommodate a large number of different services such as:

- High-speed data (unswitched).
- Low-speed data (circuit switched by central frequency allocation).
- Low-speed data (virtual circuit switched and supported on a contention channel).
- High-speed data (packet switched on a token-passing channel).
- Analogue voice (unswitched).
- Analogue video (broadcast).
- Digital video (circuit switched by frequency allocation, ciphered).

In fact the range of services is limited only by the designer's imagination.

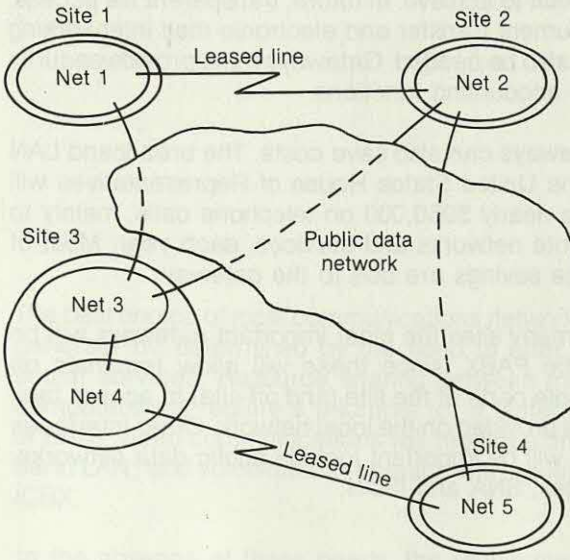
THE RELATIONSHIP BETWEEN LOCAL AND WIDE AREA NETWORKING

Local and wide area communications are influenced by different factors and should be considered separately. Transmission capacity is expensive in the wide area but relatively cheap locally. Local systems may therefore exploit high transmission rates and short delays in a way that is impractical over a wide area.

In general, wide area communications are, for reasons of economy, provided by separate data and voice facilities. Data and text traffic are usually multiplexed and packet switched, while voice traffic is circuit switched. There may, of course, be some overlap. For example, telephone circuits may be used intermittently to collect batches of data from local offices.

Local data networks need to use wide area facilities to connect to local networks on other sites, as shown in Figure 5.2. These bridges neither provide switching nor require switching from wide area facilities, but they must detect and correct any errors introduced on trunk lines. A protocol at the OSI network level is required to route traffic conveniently between sites. Protocols above the OSI network level (level-3) should be the same on all sites but services that rely on low delays will not, of course, be able to operate over normal inter-site links (bridges).

Figure 5.2 Local networks linked by bridges



Note: Six bridges are shown in this figure.

Figure 5.3 Costs of inter-site communications

	Cost ('000 dollars)	
Equipment	*Circuit switched network*	*Packet switched LAN*
Modems	303	303
Network management	126	126
Multiplexors	225	0
Bridges	0	100
TOTAL	654	529

Note: In this example the network had to support 200 devices on 5 large sites.

Generally, bridges between packet networks are cheaper than bridges between circuit-switched networks. The resulting economies may be very substantial for some large organisations. A typical example of these economies is given in Figure 5.3.

As well as bridges, most organisations will need gateways through which local network users can access the facilities of other networks and systems. Until the mid-1980s the services will be restricted in the main to terminal connections and file transfer. More elaborate protocol conversions will be expensive and difficult to achieve. In future, transparent file access, document transfer and electronic mail interworking will also be needed. Gateways must provide security and accounting functions.

Gateways can also save costs. The broadband LAN in the United States House of Representatives will save nearly $950,000 on telephone calls, mainly to remote networks and services, each year. Most of these savings are due to the gateway.

On many sites the most important gateways will be to the PABX, since these will allow terminals on remote parts of the site (and off-site) to access facilities provided on the local network. Other interfaces that will be important include public data networks, teletex, SNA and ISDN.

LOCAL NETWORK SELECTION GUIDELINES

We now summarise our approach to local network selection.

If there is little use of video, the selection team will have to take a strategic view of its likely development. A strategic view will also be needed for the deployment and use of minicomputers, microcomputers and workstations during the period that the network will remain operational.

The selection team must collect information on current and future communication requirements. They should pay special attention to the types of traffic and the interfaces to be supported. Exact numbers are less important — and impossible to get right.

Once this information has been collected, there typically will be only a few possible networks that meet the requirements. But the possibility of meeting the requirements by installing more than one network should not be ignored. The most likely example of this would be the use of a LAN to support workstations and microcomputers in areas with a high penetration of machines, together with an ICBX or data-over-voice network to support terminals in other areas.

Figure 5.4 indicates the various kinds of local network that meet different requirements. We stress the importance of meeting particular requirements, however, rather than following the logic of general arguments.

Figure 5.4 Indications for various types of network

Broadband cable (such as LocalNet).	Multipoint video requirements. Multiple overlapping logical networks. Terminals widely scattered with existing CATV cable. Modest requirements for high transmission speed.
Minicomputer LAN with terminal support (such as Net/One).	Substantial requirements for high transmission speeds, especially high burst rates.
Micronet with terminal support.	Resource sharing for microcomputers and workstations.
Terminal support network (such as Multilink).	Terminals and small microcomputers are the dominant office machines. Limited needs for complex terminal support functions such as encryption and protocol conversion.[1] Small area to be served. Area to be served large but consisting of several small communities of interest.[2]
Data circuit switching network (such as Gandalf PACXnet).	Plenty of spare twisted pairs.[3] Many terminals within a short distance of the switch. Most terminals are asynchronous.
Proprietary supplier's network (such as SNA).	Dominant supplier environment. Synchronous terminals. Mainframe seen as main focus of systems development.
ICBX.	Terminals widely dispersed. Terminals are infrequently used. Needs for voice-data integration in future.

Notes: [1]This reflects the fact that existing terminal support networks (TSNs) lack the capacity for these complex functions. A future TSN might have this capacity, in which case the indication would not apply.

[2]If there are many such communities of interest, a high-speed backbone network (possibly based on a minicomputer LAN) may also be needed.

[3]In the absence of spare twisted pairs, data-over-voice transmission may be used.

Figure 5.4 is a concise way of summarising the key findings of this report. It represents a framework for selecting local network facilities.

CONCLUSION

Technologically, both ICBXs and the many varieties of LAN are advancing rapidly. Advances are being made at the most basic levels (those of transmission engineering and low-level protocols) and also in the services and products that are offered on networks. A number of proven and attractive products exist but the field is very far from maturity. We expect significant advances in the technology to continue for at least the remainder of the decade, culminating in very high-speed distributed switching networks which integrate data, text, image, voice and sometimes video as well.

At present there are no standards for ICBXs, whilst Ethernet is the only established standard for LANs. Further standards (particularly the token-passing ring standard) will appear during the next two years but will still have to establish their places in the market. Standards at the higher levels of the OSI model are also being developed but will come into use only slowly because of suppliers' commitments to existing network architectures such as SNA and DECNET.

Many organisations have now reached the point where conventional local networks are causing problems. They are expensive, inflexible, difficult to extend and unsuitable for the support of microcomputers. Organisations may have one, or more, of three main requirements:

— An advanced system for computer aided design, office, laboratory or factory automation.

— A means of connecting various items of digital equipment.

— A source of computer power and data storage which can be used for a variety of purposes (a computing utility).

Since the local network will rarely account for more than ten per cent of the total cost of an advanced system, such systems must be judged on their ability to meet local processing and service needs, rather than on network technology. It is clearly an advantage if the local network in such a system can be used to support other systems. This implies that it should have a high operating speed and comply with appropriate standards.

The best choice of local communications network will generally be determined by the need to offer particular services. Resource sharing between microcomputers will require a micronet (or a faster type of LAN); video communications will require a broadband LAN; and voice-data integration will require an ICBX.

In the absence of these needs, the requirement is usually for data circuits to connect terminals and other digital machines to host computers and wide area networks. There are a variety of technically sound solutions, including ICBXs and various kinds of LAN as well as conventional data circuit switches. During 1984, only low-speed LAN-based terminal support networks will be cheaper than conventional networks. Moreover, support for synchronous communications is very limited on most LAN products, so it will rarely be worthwhile using them for such traffic.

In many cases a micronet offers a low-cost alternative to an advanced workstation system. Though lacking in sophistication, it combines the advantages of low cost and a wide range of available software. Micronets also provide a cost effective way of providing computer power to office workers. With their mixture of individual processing and shared data, micronets are a natural match to the work of professional staff.

Micronets can also be attractive, both financially and in their functions, as alternatives to minicomputers and terminal clusters. Because of their low cost and great flexibility, micronets form the largest part of the local network market and their use is growing rapidly.

Also, micronets can provide strategic benefits. They form an infrastructure, through which the management services department can influence the use of microcomputers in the organisation.

The more expensive LANs and ICBXs may be cost effective in particular circumstances (for instance, where there are significant requirements for video or fast file transfer and where cable installation is expensive). These networks are difficult to justify, however, except on the basis of forecasts of future terminal populations and traffic patterns. The forecasts are difficult to make and depend on the technical strategies chosen for information systems, rather than on user requirements directly. Where a technical systems strategy already exists, the choice of local network will usually follow easily. In the absence of such a strategy (and few organisations have a credible one) the best course usually will be to choose the most cost effective system in the short term, but pay a small premium for future flexibility. Where the premium is large, we believe that most organisations should refuse to pay it.

We expect the cost of LANs to fall rapidly over the coming years and the cost of data support on ICBXs to fall rather more slowly. For reasons of economy, we expect many organisations to install LANs in areas with a high penetration of digital equipment but to rely on ICBXs and data-over-voice networks in other areas. The area covered by LANs will therefore tend to increase as time passes.

We do not expect any single network to meet all the needs on large sites. The pattern is more likely to involve specialised local networks connected through a central backbone network.

As is true generally, advances in technology offer solutions to problems, not panaceas.

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GLOSSARY OF TERMS

Baseband	A communications system in which the digital signal is applied directly to the transmission medium.
Broadband	A communications system in which the digital signal is used to vary ('modulate') a carrier signal which is then applied to the transmission medium. On reception, the required carrier frequency must be selected using filters and the digital signal extracted by 'demodulation'.
CATV	Abbreviation for cable TV (though originally it stood for 'community antenna TV').
CBX	A private automatic branch exchange with computer control.
Circuit switching	Technique by which complete physical paths between users are established through switch setting prior to sending messages through a network.
Contention	A medium access control protocol in which attached workstations may use the common communications channel when they find it free. Since this occasionally leads to collisions between transmissions, some means of resolving collisions generally is included in the protocol. An IEEE standard (802.3) exists, based on the Ethernet specification.
ICBX	An integrated computerised branch exchange (ICBX) is a PABX which has digital communications between the central switching units and the telephone and other attached devices (such as terminals, facsimile machines, etc.).
LAN	A local area network (LAN) is a local network in which a wideband digital channel is carried round the site, so that attached devices can use the full capacity of the channel in turn.
Medium access	An IEEE term for the protocol used to share the capacity of a multi-point line or LAN between stations. The main examples are contention, polling and token passing.
Open system	A system that allows a variety of different computers, and attached devices, to work freely together.
OSI reference	The International Standards Organisation model (ISO) open system interworking model consisting of seven logical layers.
Packet	An addressed data unit of convenient size for transmission through a network.
Packet switching	A technique for transmitting data packets through a network.
Polling	A flexible, systematic method, centrally controlled, for permitting stations on a multi-point circuit to transmit without contending for the line.
Protocol	The rules governing how two pieces of equipment communicate with one another.
Token passing	A kind of distributed polling in which attached devices all act, in turn, as master. It has similar characteristics to polling except that it works particularly well on rings, and its distributed nature provides resilience to breakdowns.
VLSI	Abbreviation for 'very large scale integration' referring to chips with tens of thousands of circuit elements on each chip.

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