# Chapter 7: Network technology

*"If the playing field is very uneven, there's chaos around the business, and people don't understand it: there's something significant happening."* Donald Valentine, Sequoia Capital, quoted in *Forbes Magazine, 25 October 1993, p. 137.*

Networking is *big* business. The need to link with people outside an organisation's local area network has helped fuel the explosion of interest in Internet and other types of external connectivity. An Electronic Messaging Association survey found that use of electronic mail by the employees of large corporations grew 37 percent over the last two years — from 8.9 million users in 1991 to 12.2 million in 1993. An additional 19 percent growth is anticipated in 1995.[1] In 1993, as reported by the US Department of Commerce, enterprise networking was an $8 billion dollar business and growing.[2] In the last few years, corporations have continued the trend exhibited in past years of downsizing from centralised mainframe computing platforms to personal computer local area networks (LANs). Network technologies and products are evolving. The consequence is to create increasingly heterogeneous, multi-vendor and multi-protocol computing environments. In this complex environment, more and organisations want a direct link to the Internet. What these organisations learn is that achieving the right connection can be costly, time consuming and complex.

In 1993, 39 percent of PCs worldwide were connected to networks, up from 33 percent in 1992. International Data Corp. estimated 1993 worldwide network-related revenues at $8.3 billion in 1993, up 23 percent from the previous year. The estimate includes four product categories:

- Network interface cards (NICs).
- Inter-networking devices.
- Intelligent wiring centres or hubs.
- Terminal servers.

Business sectors experiencing major growth in 1993 included inter-networking devices and intelligent hubs.

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[1] Larry Edwards, 'E-Mail is getting stamp of approval,' (Electronic Mail Special Report: Telecommunications), San *Diego Business Journal,* 7 March 1994, page 1 and 3.

[2] These and the following figures have been drawn from Mary Smolenski, Shelagh Montgomery, Vera Swann and Mary Davin, *Computer Software and Networking. Industry Overview, 1994 US Industrial Outlook,* Government Printing Office: Washington, D.C., 1994, pages 27 and following.

| Technology's challenges for the Internet | | |
|---|---|---|
| **Challenge** | **Time frame for resolution** | **Comment** |
| Security | 199.56 | Rapid development of software and hardware locks, Usable tools are available now, but can be costly. |
| Electronic billing systems | 1994-5 | Public key encryption now available. Wide range of tools will flow into market for next 12-18 months. |
| Graphical applications software | 1995 | Mosaic may be the first major Internet application tool kit. Lotus Notes or comparable groupware access widely available by the end of 1996. |
| Infrastructure<br>United States<br>Western Europe<br>Japan<br>Pacific Rim | Global: by 2025<br>2000<br>2010<br>2000<br>2025 | The Total Network will be feasible by 2035, earlier if wireless technology becomes economical viable. Physical wiring of the world, assuming funds are available, will take decades. |
| Data compression | 19954 | Standards are emerging. But most advanced technology from Iterated Systems in Georgia too costly for broad-based use. |
| Server / desktop input -output | 1997–2000 | The major problem will be moving large quantities of data from the high bandwidth pipelines to the desktop. Progress is rapid but broad deployment of a low-cost technology ranks as a major technical challenge. |
| Consumer access 'appliance' | 1997-8 | Internet access and most serious 'interactive' applications will be PC-centric. Consumer appliances such as VCRs cost hundreds of dollars. Multimedia computers cost several times as much. A breakthrough is inevitable, but will be less rapid than one might think |
| Seamless LAN–WAN–Internet connectivity | 1998-2000 | Difficult problem to resolve across different information platforms such as telephones, computer communications, broadcast television for the many types of networks in place. Vendors sell proprietary systems to capture revenue and customer loyalty. Standards are difficult and time-consuming to develop. Like I/O technology, a difficult cluster of issues. |

The LAN network operating software (NOS) market grew considerably in 1993. The total value of NOS licences shipped worldwide grew 26 percent to $2.8 billion. The number of licences installed increased 25 percent to $2.9 billion. According to San Jose, California-based Dataquest, the revenues generated in the US NOS market exceeded $1 billion. Small user group operating systems (l-10 users) was the segment of the US NOS market that expanded most dramatically with a 64 percent increase in both shipments and revenues from 1992. Globally, the major NOS product continued to be Novell's NetWare, with approximately 70 percent of the world market. Microsoft's OS/2-based LAN Manager accounted for 6 percent of the world market, while IBM's LAN Server, Banyan Vines and AppleShare each accounted for approximately 5 percent. These figures underline the size of the network markets and the strong trend to link computers within organisations and to other networks.

Most managers know that specialised, proprietary operating systems are less desirable than multi-tasking, somewhat more open operating systems such as UNIX. In 1993, Novell formed alliances with 25 leading UNIX vendors and purchased UNIX System Labs; however, the unification of the numerous flavours of UNIX remains on a distant horizon. Novell has developed an OS/2 version of NetWare in co-operation with IBM. Banyan's Vines now runs on UNIX, but the company has taken steps to move away from its proprietary UNIX by striking deals with the Santa Cruz Operation (the leading vendor of UNIX for the Intel platform), IBM, Hewlett-Packard and Sun Microsystems. Microsoft's OS/2 LAN Manager runs on top of OS/2 but is also available in a version for UNIX developed by AT&T.

More network hardware demonstrated characteristics of consumer products. One network staple, the network interface card or NIC, points the way for other network hardware and some categories of software products. In 1993 a large market for high-volume, price-sensitive products emerged; industry consolidation continued and price pressure increased. Worldwide NIC revenues rose in 1993 to $3.4 billion while shipments rose 27 percent to almost 16 million units. PC NICs accounted for almost 95 percent of total NIC revenues. Percentage growth in these NIC revenues and shipments in foreign markets in 1993 exceeded revenues in the United States. NIC shipments to the United States grew by 22 percent compared with 35 percent for Europe and 37 percent for the rest of the world.

Ethernet NICs continued to dominate the market over token-ring products. Sixty-eight percent of all US shipments were Ethernet, compared with 25 percent token-ring. According to Dataquest, 1993 token-ring revenues increased by 24 percent and shipments grew by 38 percent. Ethernet revenues grew by nine percent and shipments by 32 percent. The FDDI NIC market in the United States expanded. There were 27,000 shipments amounting to 118 percent unit growth. Revenues grew 37 percent to $57 million.

This evolution of LANs from simple work group and departmental systems into local platforms for enterprise networking and connections to the Internet, remains the driving force behind the continued expansion of the inter-network market in 1993. Inter-networking device companies faced extremely competitive conditions as more than 60 vendors competed for a worldwide market which grew 38 percent in 1993 to almost $2 billion, an estimate that includes bridges, routers and specialised PC LAN equipment.

The US share of world revenues declined slightly from 52 to 51 percent, but US FDDT Inter-networking equipment revenues increased 67 percent to $156 million, suggesting that organisations are moving from traditional cables to networks incorporating more advanced, higher bandwidth capacity technology. Networks will support imaging and video at some point in the next 3-7 years.

Routers, which selectively forward data from different protocols, were among the most successful networking products. Worldwide revenues grew 62 percent to $1.5 billion. Routers are displacing remote bridges because most routers now have integrated bridging functionality, enabling them to link to networks whose protocols they do not support. In 1993, worldwide remote bridge sales decreased by 25 percent to less than $150 million in revenues. In contrast, local bridge revenues increased by seven percent. Router technology now handles some functions once reserved for bridges. The march of technology assumes that Internet connections will become a plug-and-play solution before the end of the decade.

The worldwide market for intelligent wiring centres grew 37 percent to $2.3 billion in 1993. Hubs or concentrators are the primary building blocks of networks, combining different topologies and media into one concentrator. An intelligent hub or wiring centre is the focal point for network management, handling such multiple access methods as Ethernet, token-ring and FDDI under a common system of management and control. FDDI wiring centre shipments to the United States increased 29 percent, while revenues fell ten percent to $3 1 million demonstrating the impact of commoditisation of certain network products upon margins. FDDI technology is entering the mainstream. In fact, FDDI wiring centre per-port prices have dropped by almost 50 percent since 1990 to $1,260 in 1993. Hub technology is incorporating both router and bridge functionality. The hardware required for inter-network links is becoming more capable and cheaper. Links to an internet will become a standard feature in most organisations.

Newer alternative high-speed technologies began to emerge in 1993, such as asynchronous transfer mode (ATM), a high-speed cell-switching technology originally developed for wide-area networks and loo-megabits per second Ethernet or Fast Ethernet. Dataquest predicts that these technologies will co-exist with FDDI rather than replace it. FDDI has a competitive advantage over ATM, primarily because of cost considerations.

Rapid change is under way and is likely to continue for the next two to three years. Network technology is fuelled by a robust global market and customers with network-related needs.

## 1. An Internet information void

For many organisations, it is still difficult to find specific information about certain network-related issues; for example, pricing of telecommunications is particularly slippery. This is due in part to the complex nature of many telecommunication providers' pricing formulae and the large number of variables associated with what appear to be basic network components.

The phenomenal growth of the Internet has been enabled by technology that is largely invisible to the average user. Even experts in personal computer technology lack the knowledge required to penetrate network technology beyond their local area network.

Journalists who reason that computer cost-effectiveness rises by the square of the number of computers connected to networks, have never attempted to link networks economically. Despite the advanced state of the networking art, navigating through the many different problems networking poses is difficult, complex and comparatively primitive. Despite the vast bandwidth available, certain advanced applications such as automated online retrieval and formatting of information and real-time videoconferencing, remain beyond the reach of most individuals and organisations.

The reasons range from the cost of the hardware and software to lack of technical expertise. One of the most unpleasant surprises a manager must face is the failure of the technology to support the application. Advanced information applications are built on technology and, for many network activities, the technologies are being invented and refined with startling speed. In such a volatile environment, decision making becomes difficult. An error can have profound consequences.

There are numerous networking protocols, and until recently they were islands populated by people who spoke mutually unintelligible languages. At some time in the distant future, there may be one protocol that will unify the computing platforms. Now gulfs can be bridged, but not always easily and economically.

## 2. TCP/IP: the Internet protocol

The explosion of interest in the Internet appears to make the Internet Protocols a candidate for protocol of choice. But many vendors are claiming their proprietary stacks are best for enterprise inter-networking even as the Transmission Control Protocol/Internet Protocol (TCP/IP) is garnering more attention, support and re-spect among those who once dismissed it as a secondary option. The market share of TCP/IP is making it many network administrators' inter-networking protocol of choice.

Strong market forces operate to keep an already complex subject muddy. Not surprisingly, network administrators are coming up against rival vendor claims in selecting TCPAP stacks on each user's desktop. Engineers must evaluate such well-known terminate-and-stay-resident implementations from Novell, while weighing those against Windows-based DLL (dynamic link library) products and the newer Microsoft VxD (virtual device driver) software. Implementing the protocol stack as a DLL, TSR, or VxD program can have a dramatic impact on network performance. Also at stake is the usage of scarce memory resources and compatibility of current applications.

There is an overall trend to allow different networks to link to one another as required by the network owner. These ad hoc links create virtual networks. Organisations will want to use their networks for new and different applications. At the same time, the networks are growing in size and complexity. Historically, flexibility has not been a concept associated with networking, regardless of type. But the demand for new services is fuelling a technology renaissance in many different network-related areas. New services make different demands on a network compared with what has been required in the past. These new applications — groupware, videoconferencing, real-time sharing of images and distributed data-base access — demand a path for different elements of applications over which to communicate. In turn, these customer needs require network bandwidth to be kept as free of bottlenecks as possible.

The leading protocols have been in widespread use for some time, and the fact that they work is generally accepted. But they often do not work well with one another. Vendors have taken steps to maintain proprietary aspects of their networks in order to capture customers. It has been only within the last few years that tools to integrate different network protocols and data types have become more widely available.

The growth rate is staggering, yet information about connecting remains hard-to-get, fuzzy or unavailable.[1] Most discussion of the Internet sidesteps the many issues associated with links to the Internet from different enterprise LANs. There are several reasons for this common omission:

- Networks are collections of computers. The collections of computers have layers of software that are structured to meet the particular needs of a particular organisation or user community. Making the different layers communicate seamlessly — that is, transparently and without the need for the users to take special actions — is a technically-complex undertaking.

- Until recently, software tools to facilitate interoperability between UNIX and MS-DOS computers were difficult to use and costly. New products from Syntax (Federal Way, Washington), Locus Computing (Inglewood, California) and Beame & Whiteside Software (Raleigh, North Carolina) ease the problems.[2]

- Telecommunications technology is a distinct discipline unto itself and still largely the domain of specialists. Unlike some technologies, it is difficult to appreciate or express the subtleties of differences between a T-3 and a SONET OC- 12 connection.

- Computer networks come into play in different ways at different levels of the organisation. Organisations may operate private networks to connect different offices, and managers familiar with this type of network do not see the importance of an Internet connection. Because many commercial networks provide Internet services, staff may believe that enterprise-wide access is a relatively simple matter. Even technical staff may be unaware of network opportunities external to the organisation.

- Traditionally, only specialists have had to concern themselves with such distinctions among networks as wide area, wireless, Ethernet, cable, satellite, private, public, virtual and their siblings. Distinguishing among networks becomes difficult for a person who is an occasional user of a single type of network.

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[1] To locate technical subjects, consult the listing of subject trees at the Yale University gopher. The address is *yaleinfo.yale.edu*. Look for information under the directory listings *Internet Resources.* For information about networking computers consult the Pacific Systems Group's gopher at *gopher.psg.com* under the category *Networking.* A number of newsletters about networking are available: use *ftp* to *nigel.msen.com* and use the path */publ/newsletters/networker/.*

[2] Dave Trowbridge, 'DOS and UNIX cozy up on the Net,' *Computer Technology Review*, February 1994, page 14 and following.

- The terminology is unfamiliar. The glossary in this report provides definitions of a number of the more frequently-encountered terms used to describe Internet networks.

The domain of the network engineer has been a highly focused one. The issues associated with 'networking' have traditionally been largely unintelligible to anyone other than another network engineer. Because there are many different 'networks,' it is difficult to know what particular technologies, proprietary suppliers and application suites comprise a particular network. What has become evident within the recent past is that these individual networks are being connected; despite the fact that many of the underlying technologies are different, engineers and technicians are hooking networks together. When an office has two personal computers, one of the steps staff take within a year is to link the two machines. Now that most organisations have internal networks or LANs, the networks are being linked. One might conclude that some higher law is operating that decrees, 'Thou shalt interconnect.'

The Internet, 'the mother of all networks,' has propelled the arcana of networks into the executive suite. General managers want to know about the *backbone* federation of high-speed network links operated by different companies. It is now important for non-engineers to understand that one of the major providers in the United States is MCI Communications, but the flows of data to and from the 'backbone' depend upon networks operated by Regional Bell Operating Companies, AT&T and hundreds of other organisations. Many people want access to the technologies required to allow an individual to dial a local telephone number and gain access to an image stored on a computer linked to the Internet in Geneva, Switzerland. People from non-technical backgrounds want to know how the individual pieces of the technology puzzle have to fit together thousands of times an hour so invisibly that only a system breakdown calls attention to what makes the simple act of copying a file so trivial. There is a growing fascination with the fact that messages arrive with a high degree of reliability because the technology of the information packet has been designed to find a route to the destination regardless of mishaps that might occur in the physical network itself.

In the past, network experts often acted as though users did not need to know about these technologies. Today, it is important for professionals to have a working knowledge of the principal technologies because making informed decisions depends upon understanding the implications associated with certain options. A company that attempts to connect to the Internet without a full understanding of the challenges associated with connecting an IBM SNA network to an Internet server running AT&T's version of UNIX, or deciding between an ATM or a switched 56 Kb/s telecommunications link, may be taking a considerable financial risk.

## 3. Connecting an organisation's network to the Internet

The immediate question in the mind of most mangers is, "Can my organisation be connected to the Internet?" The answer is, "Yes. There are many options available. Some easy and inexpensive. Others of considerable cost but with correspondingly more robust capabilities."

There are two general approaches to consider, the first being that an organisation can set up a dial-up connection to the Internet.

### *3.1 The basic network: one computer to a remote computer*

A single computer may be equipped with a modem and a telephone line link to another remote computer. In a sense, the single computer joins the larger collection of computers, software, information and users only temporarily. A connection is made for the purpose of retrieving electronic mail or locating information. The cost for a basic connection can be as low as several hundred dollars per year, to several thousand dollars, depending on the number of users and type of connection selected.

Setting up and operating a connection from a single PC to a computer located in a different location can be maddeningly complex to a user unaccustomed to the intricacies of communications software, log on procedures and the commands required to make the remote system perform as desired. Despite significant advances in dial-up connections, many marketers believe the process is far too complex with too many chances for problems, so dedicated front-end software is provided for making connection painless.

Today, dial-up connections rely upon physical wires. Tomorrow, wireless communications between portable computing devices and remote computers will open new markets for electronic messaging and information retrieval. MCI Communications is one of several major US telecommunications firms to have invested heavily in wireless technology. The MCI investment of $1.3 billion in Nextel Communications foreshadows the inevitable blending of hard-wire and wireless network links. California will be among the first states with a digital wireless service.' Although dial-up connections have been available for more than 20 years, significant potential for growth remains. A high-profile announcement from Microsoft and McCaw Cellular spelled out plans for a global wireless network built on 840 satellites.[2]

Furthermore, hardware and software tools that simplify the process of establishing a connection to a remote computer will proliferate.

### *3.2 The dial-up connection*

The technology required for this type of link is straightforward. A modem is connected to the enterprise's server. Anyone connected to the organisation's network can dial up an Internet access provider host and gain access to the Internet.

If the users want access to electronic mail, the access provider can be an online service such as MCI Communications Mail or CompuServe.

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[1] David Bank, 'MCI invests in wireless network,' *San Jose Mercury* News, Business, 1 March 1994, page 1 -E, 10-E.

[2] 'Microsoft's Gates, Craig McCaw throw support behind Teledesic's 840-satellite, $9.55 billion global system,' *Telecommunications Reports,28* March 1994, page 1.

However, the electronic mail software on the internal network may not interface seamlessly with the electronic mail functions of the access provider. A new service from AT&T may offer organisations that use electronic mail software compatible with Lotus Notes an alternative. The AT&T Global Link services provide seamless integration with Notes. But most local area network electronic mail services — cc:Mail or Microsoft Mail and the particular network environment-use their own protocols and data formats. Users will have to create mail messages using the access providers' tools or create messages offline in flat ASCII. The Delphi Corp. (Cambridge, Massachusetts) provides its users with access to a full suite of Internet tools, including *ftp*, *telnet* and various locator software such as *archie*, *gopher* and *jughead*.

Users log on to the access provider using communications software such as Procomm for Windows (DataStorm Technologies) or other software that emulates a VT 100 terminal. The organisation's network is here essentially a transparent link to the access provider. No special software or hardware is required.

The drawback is that access providers charge a monthly fee per user and often additional charges for storage and special services. In a short period of time, Internet access can become a significant cost.

### *3.3 One computer to other computers in one location*

Another common form of networking is using a personal computer or workstation to share a printer or electronic files with co-workers. The market leader is Novell, with about three-quarters of the world market for local area networks in businesses.'

There are two approaches to setting up a simple local area network. The traditional model uses a single machine to manage the network. Until 1985, only a mainframe had the computing horsepower to manage a network. Today, a personal computer with sufficient memory and hard disk space can manage networks of six to twelve personal computers.

One approach is based upon the client-server model. A single machine acts as a co-ordinating point for:

- shared network services
- a warehouse for certain files and software
- a switching station for other computers linked to the network.

This client-server model has in itself become the rallying cry for system managers who are building systems upon smaller, more flexible and less expensive hardware than the traditional mainframe. Because the client-server model continues to expand as a network model, market-leader Novell faces intense competition from software companies (Microsoft), hardware manufacturers (IBM and Digital Equipment) and specialised firms moving from one market niche to another (Cisco

[1] Wayne Rash, Jr., 'Protocol Cataclysm?' *Communications Week,* 10 January 1994, p. 43.

Systems).(It is important to recognise that the distinctions between mainframe, minicomputer, workstation and personal computer companies are difficult to draw precisely. There will be applications that require the various functionalities associated with a large, dedicated computer or cluster of computers. A more useful way to view the galaxy of computing platforms is as components that can be assembled to handle specific tasks. There is no one way to solve problems as there was when mainframes were the only computing platform.)

A variation is to link two or more computers together with each machine handling the various tasks associated with file management and messaging. In many work groups, distributed networks provide an economical networking solution.

The computers on the network within an organisation can be linked together in different ways, in what the network experts term *topologies*, ranging from rings to stars. Regardless of internal network topology, the link to the outside world raises four issues:

- *Security* and access. Certain information may be shared while other data may not. When machines are linked, a question of authorised or appropriate access becomes a significant issue.

- Software. In order to let people connected to the network share information, the data must be in common formats. Standardising on some basic software becomes important if users are to leverage the interactivity and communications capability of the network.

- *Response time.* When a user wants information from another computer linked to the network, the network must deliver the requested material in a timely way. Delays associated with information retrieval are less common on a stand-alone personal computer. When the PC is connected to the network, the user can encounter delays when the request for information is issued, when the data are retrieved from the remote computer, and when the data are transmitted from the remote machine to the local PC. Each input / output step the data require places a burden on the system.

- *New capabilities.* The network brings electronic messaging, scheduling and other applications to a work group. These must be learned and their use co-ordinated.

### 3.4 A direct link to the Internet

For many organisations, particularly those interested in providing customer service and direct marketing via the Internet, the enterprise's local area network will be linked directly to the Internet.

The organisation will have to arrange with an Internet access provider to obtain a port. The cost for a port varies from location to location and country to country.

Fees begin at about $2,500 per year and up depending upon type of access and telecommunications link required because of traffic volume.'

A telecommunications link is required between the organisation and the access provider. Depending upon the telecommunications services available in a particular area, a number of different lease line options may be available. Usually a line can be shared with other organisations. Such arrangements are often described as *fractional* leases, or shared lines.

To complete the process, the organisation sets up a computer — for example, a UNIX server — that acts as a gateway to the Internet. This server, located at the organisation, runs the software to support direct TCP/IP connections to the Internet. The enterprise becomes an Internet node with the various responsibilities for directory maintenance, file forwarding and inter-network support that the connection requires.

If the cost of a dedicated server is too great, it may be possible to modify the existing local area network to support the Internet gateway. There are a number of security issues to address, but it is possible to link a Novell NetWare local area network to the Internet. However, despite Novell NetWare's popularity, few believe that the IPX protocol is particularly good for inter-networking LANs across the enterprise. It works well on individual LANs, but the Internet Protocol has less overhead associated with it. Therefore, IP is probably a better choice when flexible internetworking is a requirement.

The TCP/IP software runs on each workstation connected to the local area network. This software will create the Internet data streams. A router, a computer with the ability to send particular data streams to particular telecommunication lines, then sends the data to an Internet host.

In some enterprise networks, routers may be in place. Routers act as gateways for the computers connected to the enterprise's network to link to the Internet. Depending upon the class of Internet licence the organisation has obtained, the number of addresses will vary. In general, one router can handle up to 40 simultaneous users. If network response slows to an unacceptable level, additional routers may be added.

Each workstation connected to the network requires TCP/IP communications software. Novell provides LAN Workplace, but there are many products available; for example, AIR for Windows from Spry (Seattle, Washington), producers of Internet in a Box for stand-alone PCs.

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[1] New integration services are appearing, such as Meckler's. For a flat annual fee of $25,000, a company's data will be placed on the Internet and managed by the Meckler media company (Weston, Connecticut).

The TCP/IP software hooks the workstation to the appropriate NetWare software. When loaded, the workstation can execute *ftp* and *telnet* commands in a format that permits the router to send to TCP/IP servers on the Internet.

Other housekeeping chores are required to ensure the communication flow is seamless. Each workstation must have access to a table containing Domain Name Service data. With the proper name tables, the routers can forward the message correctly.

### *3.5 The messy reality: mixed environments*

In many large organisations, there is no single network. Over time, the organisation acquires different computing platforms, network systems and software.

Linking two different internal networks — for example, a work group consisting of Macintosh computers running AppleTalk and an accounting network running on IBM RS/6000 workstations with an AS/400 — can be a challenge. Making the connection may require that the organisation acquire different types of hardware and software to link the two networks. It is rare that different vendors provide systems that connect seamlessly with another vendor's products. The marketing literature may promise *interoperability* but the reality is often quite different. Special machines called *bridges* let data from one network move to another network.

When the volume of data flowing on the network exceeds the capacity of the network, the network administrator must take steps to provide sufficient bandwidth or capacity to the users, otherwise the system becomes sluggish and, in instances when very large files are being transferred, the system may fail. Numerous options exist to expand the capacity of networks. Physical connections can be upgraded to handle more traffic more rapidly. Specialised devices such as routers can be used to direct the network data flows more efficiently.

It should be apparent even to those with little knowledge of networking that these challenges are difficult technically, and they require the services of engineers who can navigate through the technology options to arrive at a solution that is cost-effective and reliable. Many organisations find themselves with several different and incompatible networks.

## 4. The evolution of a connection

An organisation's connection to the Internet moves through several stages: first, individuals make a connection. Recent graduates who had access to the Internet while at university often want to continue to use the electronic mail and USENET resources. These early adopters establish individual accounts with local access providers. Some may retain their university accounts and use them for a short period of time. Although network administrators may be told of the dial-up connection to the Internet, each account is managed by the individual user.

Then, as awareness of the Internet increases, staff want to leverage the Internet as a mechanism for customer service, sales support, marketing and competitive intelligence. At this point, the organisation begins to formulate plans for an Internet connection. The application and the number of users determines the type of Internet link the organisation pursues. Choices are abundant. In general, the higher the price, the greater the capacity. Costs can range from a hundred dollars a month for dial-up access to a local provider offering 9600 baud connections, to a dedicated T-l link costing several thousand dollars per month and upwards.

The third stage is deployment of the Internet resource throughout the organisation, including at various sites. The organisation may have different types of Internet access at different sites in order to balance the costs with the capacity requirements of each location.

As an organisation moves from no Internet link to the full integration of Internet into the organisation, a number of technical issues must be addressed. These include:

- Internet maintenance.
- Protocols.
- Directory services.
- Bandwidth.

The surge in interest in the Internet is in part a reaction to the ready availability of low-cost (or at least reasonable) hardware, software and telecommunications. But much of the interest is a reflection of a keen desire to know what can be done with this global web called the Internet.

As individuals and organisations become more familiar with what they can do with the Internet, many of the technical issues will be easily decided. The form follows the function. At the outset of the discovery process, however, the technology is a significant part of the decision-making process. For many organisations, the potential of the Internet cannot be tapped because the technical issues are too difficult, costly or resource-intensive to be addressed at a particular point in time.

The network technologies — as complex and arcane as they are — are well on their way to resolution. The more troublesome questions hinge upon what an individual and organisation wants to accomplish.

## 5. Internet maintenance: an often overlooked cost

Where organisations have made a significant commitment to leveraging the Internet, one or more individuals manage the technical issues. The Internet administrator works with others on staff to:

- determine the type of Internet connection required
- integrate the Internet connection into the existing network infrastructure
- maintain the Internet services; for example, a gopher, directory services, a World Wide Web server, and so on.

The technology to manage an Internet network connection is still developing. Significant opportunities will exist for several years to manage network connections to the Internet, optimise internal and external Internet resources and monitor interconnections.

Because commercial organisations are beginning to link to the Internet, the majority of the effort and resources are expended upon determining what first steps to take and what use to make of basic Internet functions. Organisations may wish to include in their planning sufficient resources to build an appropriate infrastructure that includes hardware, software and staff.

## 6. Special considerations

The world of electronic information has many languages. Few of them are easily understood by systems speaking a different tongue.

The emergence of the Total Network pivots upon the ability of different systems' ability to understand rapidly what other systems are saying. Delays are not acceptable because of customer demand for fast response and the costs associated with building holding tanks for information backed up because of a bottleneck.

Most academic and research institutions use variants of UNIX for their network operations. These systems have significant complexities. Speaking broadly, UNIX networks can exploit the standard protocols of the Internet; that is, TCP/IP.

### *6.1 SNA from IBM*

Significant problems arise, however, when a large corporation relies upon IBM's SNA (Systems Network Architecture). IBM's engineers designed hardware and software that operated under a single controlling architecture. The top-down approach of SNA meshes with the host-centric architecture of mainframe computing operations.

It is, however, almost the direct opposite in structure and operation to the distributed networking approach that underlies the Internet and most downsizing activities. The Internet and TCP/IP is a federation of sub-networks; the SNA network operates by dictating the routes data will follow. The transport protocol of TCP/IP uses an algorithm that dynamically adjusts bandwidth use to use the network connection speed; SNA expects a certain bandwidth to be available once the connection is established. The TCP/IP approach assumes that system administrators can fine-tune the system to meet the specific site requirements; TCP/IP requires that new nodes be individually configured, unlike popular LAN protocols such as AppleTalk which discover new nodes. Scaling or expanding a system can be difficult as well.

The major drawback of TCP/IP is the number of addresses it can support. With the 32-bit address space and the surge in demand, the combinations are likely to be exhausted sometime after the turn of the century. When the Internet runs out of addresses, it can no longer assign new nodes. A number of proposals are under review by various Internet committees to provide an address space of 160 bits. In the short term, an 'address space' crisis may be at hand.

Rapid changes in network technology can have a considerable financial impact. Representative of the new developments in interconnectivity is McDATA Corporation's Advanced SNA/IP transport technology. The Advanced SNA/IP software permits the transport of SNA data over an IP network regardless of the type of router used. The IETF assigned RFC number 1538 to the Advanced SNA/IP transport technology, making it the first available end-to-end open protocol for routing SNA traffic over an IP network.' A number of companies have embraced this technology, including Novell, Network Software Associates (NSA) of Laguna Hills, California, Barr Systems of Gainesville, Florida and Adacom Network Routers (ANR) in Carrollton, Texas. Before this development, a cost-effective link to the Internet was beyond the reach of most companies with IBM's SNA architecture.

Other challenges exist when linking Digital Equipment's DECnet, Novell's Internetwork Packet Exchange (IPX), Apple Computer's AppleTalk, and products used extensively by small business such as LANtastic. Despite rapid advances in network devices that can handle data streams from different computers, many network administrators attempt to standardise on one or two platforms. The challenge of integrating hardware and software from many different suppliers can be daunting.

In an effort to lock-in customers, suppliers often try to sell proprietary systems, architecture or range of products. Many companies adopt a standard and then discover that it is costly and complex to link one supplier's 'standard' to another 'standard.'

Easy interconnections are becoming a reality. AT&T offers a range of services to business that allow dial-up connections to powerful electronic information resources such as Lotus Notes and the Internet. In a few years, most interconnectivity headaches will go away. For the near term, linkages to the Internet will require careful attention.

## *6.2 Technical factors to consider*

Each network protocol uses different data formats. In order to send information from one type of network to another, the data formats have to be made mutually intelligible. Today, in order to achieve links, additional layers of hardware and software have to be added between the organisation's network and the outside world. For example, an organisation using Digital Equipment's Local Area Transport, a part of DECnet, must add special bridging devices to connect to a multi-protocol inter-network.

Depending upon the type of link desired, network administrators have choices. Some are technical&easy but expensive. Others are complex, but comparatively

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[1] McDATA's advanced SNA/IP technology adopted by networking vendors, *Networks Update from Worldwide Videotext,* February 1994.

less expensive. An organisation with a 'standard network' set up from IBM, Digital Equipment or Novell must weigh:

- *Volume of traffic* the network connection will support; for example, electronic mail, financial transactions, product information, real-time customer support.
- *Type of data* that will be transported on the network; for example, text, text and low-resolution images; high-resolution images for scientific or medical applications, video, sound, or combinations of data types.
- Level *of security* desired; for example, a relatively open system, a firewall architecture, or a Department of Defence security level B- 1.
- *Number of simultaneous users* and the type of connections they require; for example, small work groups using electronic mail, enterprise-wide electronic mail access and one or more live news feeds, or several dedicated connections each with specific requirements to support customer service and sales.

Within parameters such as these, the network administrator must juggle a number of factors; for example:

- *Telecommunication links.* Does the organisation require dial-up access, dedicated lines, or a variable service?
- Costs. What approach will meet the financial objectives of the organisation?
- *Support* / training / documentation / ease of use.

## *6.3 Novell environments*

Novell's NetWare is one of the major providers of network software to businesses. However, NetWare was designed as a local area network tool, not as an inter-networking tool. NetWare sends messages across its network to monitor traffic and the status of nodes. Messages require a response. When the load on the network increases, delays occur. In an office environment, the delays are not significant.

When Novell's product is extended to a wide area network where many different protocols are competing for bandwidth, the delays become a more significant problem. For example, if the Novell IPX does not receive a response in a specified period of time, the server retransmits the message. Bottlenecks can occur in a NetWare system. Novell has adjusted the retransmission software, and third-party products from other suppliers are making the connections easier.

## *6.4 Router and bridge* selection

Routing and bridge technology is advancing rapidly. Companies such as AT&T develop specific technologies to meet the demands of their high-bandwidth environments. Most organisations confront routing technology when their LAN traffic to a wide area network or the Internet increases to the point that users complain about system response.

A router is a computer with software and a database of *router tables*. The router looks at data streams, consults the data table, selects a specific path for those data, and sends the data on their way. Recent advances in router technology include integrating bridging or linking technology in one box. Other developments include:

- *Definable data priorities.* Certain types of information can be steered to certain communication pathways and not others. Electronic mail might receive a low-bandwidth route while videoconferencing gets a larger bandwidth — that is, higher capacity — line.

- *Data compression.* Advances in compression algorithms permit significant increases in data transmission capacity. With increasing resistance to price increases experienced by telecommunications companies in the United States, data compression represents one way to expand capacity without massive investments in new cables or other infrastructure.

- *New routing protocols* are available. CrossComm (Marlborough, Massachusetts) has developed a technology called *Protocol Independent Routing* or PIR. CrossComm software normalises differences in protocols using the media-access layer of a node, not the network-layer address.

More importantly, prices for routing technology continue to fall. One of the leaders — Cisco Systems — expanded its line of low-cost products in order to maintain market share in the face of increasing competition. Selecting a router and bridge requires analysis of performance, connectivity, price and reliability.

## 7. Directory services

After almost 30 years of operation, there is no single electronic telephone directory of Internet addresses. *Directory services* refers to lists of authorised users on a network. The international standard X.400 protocol enables disparate electronic mail systems to exchange messages. However, the protocol does not provide for automatic updating of master directories. Network administrators must perform these functions using different utilities and tools. This is a manual task and usually lags behind actual address assignments by the Internet administration.

### *7.1 Enterprise-wide network directory services*

In terms of a small, peer-to-peer network, the directory services tasks are modest. Once the system is set up, each user has access to the information and resources connected to the network. Users can protect certain files. The network operating system — for example, Artisoft's LANtastic — provides graphical, user-friendly tools to simplify the tasks.

In a client-server network, the network operating system vendors provide directory service tools. The management of the list of authorised users, their addresses and the information and resources to which each has access, is a key aspect of network operations. Most of the major vendors of network operating systems are upgrading their directory service tools; however, each of the major vendors tailors its directory services to its particular requirements. The net result is that directory services are proprietary.

The major vendors-Novell, Banyan Systems and Apple Computer among others — have updated their directory services software tools so they can run in other vendors' environments. For example, Apple's Open Collaborative Environment includes increased compatibility with Digital Equipment's networks. Banyan's VINES version 5.5 is more compatible with Novell's NetWare.

It is clear that each vendor will offer directory services that provide attractive features and make it easy for the vendor to retain a customer. But these solutions will not inter-operate seamlessly in a network in which sub-networks with different network operating systems must interact. Directory service maintenance remains a collections of processes in which software tools must be supplemented with manual inspection and data entry.

When managing directory services in an environment in which most connections are physical -that is, hard-wire connections or dial-up links — the task is to make certain that user information is complete and current. As wireless links and telecommuting rise over the next two to three years, managing the directory services will become an even bigger job. New software tools will enter the market and automate many tasks, but it is likely that these tools will be tailored to a specific network operating system.

Automating directory services across dissimilar networks is likely to remain a major technical hurdle for the foreseeable future.

## *7.2 Today's Internet directory services*

In terms of the Internet, part of the problem rests in the hands of various Internet and ITU standards committees. One approach — usually referred to as X.500 — spells out an expanded 'directory' listing for each Internet ID. The X.500 approach is gaining momentum.

At this time, when a new user ID is issued, the site administrator must manually make the addition, change or deletion. Some manual keystrokes are required before a *daemon*, the name given to the UNIX program, can handle the more tedious housekeeping tasks. There is no way for a user of the Internet in Paris to search one master directory by name, affiliation, or some other fact about an Internet user in Paradise, California, in a way comparable to looking a person up in a telephone book.

When the address space is expanded, software daemons or agents will poll Internet sites and retrieve, update and post user identification data. Intelligent hubs, agent software and X.500 header information will make this possible. However, the issue of directory services is likely to remain a problem for a number of years. At some time in the future, a single person may have a single electronic mail address. Until such time, an individual is likely to have an electronic address on a private network, one on a public network, and one or more addresses on specialised networks. Business cards often carry two or more electronic addresses: one for electronic mail (such as MCI Mail), one for a private network (such as CompuServe), and one for an Internet address.

### *7.3 Tomorrow's single global directory*

The ideal of a single global directory for Internet addresses will be partially realised where a single service has the ability to poll, normalise and build a comprehensive listing of addresses. But because of the need to keep the directory updated, the service offering this function will have to establish some reliable mechanism for automatic updating of the master file.

The flaw, of course, is that if a particular site does not have an up-to-date directory of its users, the master directory will be incomplete or incorrect. Until mechanisms are in place that permit sub-networks to be automatically polled, updated and completed, it is likely that larger concatenations of listings will remain incomplete.

## 8. Bandwidth

Few network technologies engender such confusion as a discussion of bandwidth. Bandwidth, of course, is engineering jargon for the amount of information a telecommunications link can carry.

The most common telecommunications link is the copper wire twisted pair or POTS, an acronym for Plain Old Telephone Service. Most professionals know that a modem connected to POTS in a hotel room can achieve speeds of 2400, 9600, or 14400 baud. A transmission at 9600 baud is supposed to be four times faster than one at 2400 baud. Actual experience often demonstrates that this is not true. The quality of the connection, the efficiency of the hubs and routers in the communications pipeline, and the demand on the remote host, can have a significant impact on the 9600 baud connection.

When one steps away from modems and hands-on experience with the vagaries of online connections, relating to bandwidth expressed in kilobits (thousands of bits per second), megabits (millions of bits per second), and gigabits (billions of bits per second) is difficult.

What one quickly discovers is that a high-bandwidth connection (say, for example, a T-l link at $2,500 and up per month) comes in several varieties. Each variety has different performance characteristics under different load conditions. Typical factors that impact the cost of telecommunications for Internet connections include:

- whether the line capacity is fixed or variable
- the size of the data packets transmitted
- whether the line is shared or dedicated
- the bandwidth required by the application.

Working through the thicket of options and determining exactly what will happen with a certain type of connection in a specific situation is a big job. Done well, the network recedes into the background, becoming invisible. Done incorrectly, the costs for telecommunications can be staggering and, even worse, the system may lack the capacity required.

Part of the confusion rests with the technology. A number of different 'flavours' are on the market. Consulting Appendix B: *Network Speed Overview,* the speed of ATM is roughly comparable to Fast Ethernet. For an organisation to adopt Fast Ethernet may be a less costly decision over the short term because much of the existing network hardware and software can be retained while an increase in throughput is achieved at the higher bandwidth of Fast Ethernet over Ethernet.

ATM, however, requires a new network infrastructure. It is more expensive and remains a less well-known network technology by most network managers. Consequently, ATM marketers have had a more difficult job educating potential customers about the longer term benefits of ATM because the vendors of Fast Ethernet have been saying, "Stick with what you know and get more throughput today with less risk."

When one moves into the heady world of high-bandwidth communications, the complexities become dizzying. Some networks support dynamic bandwidth; that is, when you need more capacity, the network provides it. Other approaches offer a maximum bandwidth but cannot guarantee that maximum capacity will be available when the customer needs it. The reason is that a single high-bandwidth channel supports simultaneous users. Of course, one can purchase, lease or build a dedicated high-bandwidth network, but the price is considerably higher than renting space on an existing network.

As organisations wrestle with these practical issues, massive investments are being made in the United States and other countries to build even higher capacity backbones. In a sense, the mythical 'information highway' already exists. George Gilder, an American futurist, has coined the phrase *dark fibre* to describe the millions of feet of unused fibre optic cable that American companies have installed but not connected.

The difficulty of bandwidth comes from several interlocking factors. First, a high-bandwidth channel requires a way to get the information from the backbone to the desktop. Moving live video from New York to Los Angeles is difficult; displaying the live video on the desk of a person in Century City is even more of a challenge.

## 9. Representative costs for bandwidth

Telecommunication prices fluctuate in the United States because of competition from other providers. In other countries, there may be one, possibly two, providers and the prices do not vary. In some situations, organisations may route international traffic from their country to another country — for example, place calls to other countries from the United States -because the leased line is cheaper than options provided by the country in which the enterprise is located. In other countries —

notably Japan — certain telecommunications costs may be subsidised in order to facilitate international business transactions. It is difficult to provide concrete information about the costs of telecommunications for networking in general, and for Internet connections specifically.

However, the cost of access is a pivotal concern particularly in the context of rapidly changing technologies.

In order to develop costs for telecommunications, an organisation must select the communication options that are appropriate for its particular situation. Estimates of the actual traffic must be made based on the type and quantity of traffic and the communications protocol that will be used. (Different protocols make use of different packet sizes. The packet size can have a significant impact on the cost of communications if it is not matched to the data type. For example, ATM uses a small packet size that easily accommodates video. TCP/IP uses larger packet sizes that make certain data-intensive applications impractical. A more detailed analysis of protocol types appears in the special report 'WAN Connections', published annually by *Network* Computing.) One formula is:

Setup Overhead + ((total traffic / packet size) x Packet Overhead)
+ Breakdown Overhead = Total Traffic.

Installation costs can be obtained from the providers. Ongoing costs are calculated based on the assumptions made. Some costing rules of thumb are:

- Calls originating from the United States are usually less expensive than calls originating in other countries.
- Packet switched services are plentiful and usually cheaper than dedicated lines.
- Dedicated lines can require long lead times and are usually the most expensive option.

## *9.1 Serial line Internet protocol (SLIP) /point-to-point connections (PPP)*

Graphical interfaces for dial-up access require SLIP/PPP access to the Internet.[1] Standard monthly fees from access providers range from $10 to $25 per month for a single user. SLIP/PPP connections vary from $30 to $150 per month and upwards. Most providers assess an hourly connect fee as well. This can range from $2 per hour and upwards, depending upon the provider. For an individual user, 50 hours of use a month at the standard rate is the fixed monthly fee. The same usage with

[1] SLIP connection allows a computer to use the Internet protocols and become an Internet member. PPP permits a computer to use the TCP/IP protocols and be a member of the Internet over a dial-up telephone line. PPP is supplanting SLIP as the direct connection of choice for users.

a SLIP/PPP connection costs about $250 per month, based on the fixed monthly fee of $150 and an additional $2 per minute.

### *9.2 ISDN*

Integrated services digital networks are more readily available in many Western European countries — for example, Germany and France — than in the United States. In other countries and geographic areas, the availability varies according to the factors particular to that country.

One US provider, Performance Systems International (Reston, Virginia) introduced ISDN access in about three dozen major US cities. The cost for the service is about $5,000 per year. In comparison, the cost for standard dial-up service is about $3,500 per year. The cost for a dedicated 56 K/bs line is about $10,000 per year. A one-time sign-up fee of about $500 is assessed as well. In the US, organisations must pay the local telephone companies ISDN fees. These range from $30 to $50 per month, depending upon service area.[1]

### *9.3 ATM*

ATM wide area network services are usually sold on a case-by-case basis. Fees are negotiated. A Class C (variable rate) ATM service, which is roughly equivalent to T-3 speed, offering three-nodes and a link between New York and Los Angeles, costs about $120,000 per month. Local access circuits are required, and these fees are paid to the local access provider.[2]

A comparable T-3 network costs about $180,000 per month. Savings can be eroded by the higher operating overhead for ATM, but the cost advantage is roughly 35 percent over T-3.[3]

### *9.4 Leased circuits*

A leased circuit between London and New York transmitting 384 Kb/s costs about $13,000 per month regardless of usage. The annual cost is about $156,000 per year. It allows only point-to-point communications, not switched communications.

## 10. Video

The steady development of network bandwidth provides an increasingly capable means of distributing non-text information objects. The most desirable 'non-text' objects are motion video and other types of high-definition imaging.

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[1] Joanie M. Wexler, 'ISDN access provides cheaper Internet links,' *Computerworld*, *22* November 1993, pages 57-58

[2] Class A service includes dedicated bandwidth, not variable bandwidth.

[3] 'Rocket science or lost in space?', *Datamation, 21* January 1994, pages 20 and following. Cost estimates appear on page 26.

The technology to permit real-time audio and motion video transmissions is generally available. It remains expensive and confined to applications in which the cost benefits are of sufficient magnitude to pay for the hardware, software and telecommunications required for satisfactory results.

The Internet Protocol Multicasting has allowed a source site to send a single copy of data to a special address. The receiving address, in turn, transmits the data to several recipients. The approach is more efficient than sending copies of the data to individual recipients.

For networked multimedia, efficiency becomes essential. Satellite networks support multicasting because receiving sites (downlinks) can capture transmissions. Experiments with multicasting have been under way since 1974. An Internet Protocol Multicast Backbone or MBone exists. Proteon Inc. (Westboro, Massachusetts) is one of the few US router vendors to support the special multicast packets.

The MBone technology has been used since 1992 to broadcast the Internet Engineering Task Force meetings. A live audiocast of an IETF meeting in Houston, Texas, was captured by more than 600 Internet hosts in more than 15 countries. Software to support multimedia transmissions is available from *parcftp.xerox.com* and *zenon.inria.fr*. The INRIA Video Conferencing System was written in France and it permits an Internet user with video hardware to create and disseminate an IP multicast.

Transmitted video is a 320x240 eight-bit image for NTSC or 384x288 for PAL. Frame rate varies by available bandwidth and system load. With a bandwidth of 128 Wbs, a rate of three to five frames per second is achievable.

User interest in motion video and in audio is increasing. Workstations from Sun Microsystems and Digital Equipment are equipped with microphones. The Silicon Graphics Indy workstation includes a full complement of audio and video connectors.

The non-profit Internet Multicasting Service (IMS), operated by Carl Malamud, broadcasts National Press Club speeches. Mr Malamud operates the Internet Talk Radio in conjunction with O'Reilly & Associates and Sun Microsystems.

Technology to support such bandwidth-intensive activities is becoming more widely available.'

It is unlikely that cable, telephone and computer industries will interlink into one smooth system rapidly. Under the US National Information Infrastructure banner, a Cross-Industry Working Team (XIWT) of 28 companies has been formed. It is a multi-industry coalition that includes Apple Computer, CableLabs, IBM and others. The purpose is to address the complex technical issues associated with blending

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[1] Steven Baker, 'Multicasting for sound and video,' *UNIX Review*, February 1994, pages 23-26, *28-29*.

the different data types associated with each industry. Integrating these industries will require the development and application of technologies which cross traditional technical boundaries.

In the telephone network, simplicity exists because a monopoly defined and controlled implementation and growth. The end user today is unaware of how the local exchange and inter-exchange networks interwork. The computer industry compounds the problem with its myriad platforms and operating systems. The XIWT established four working groups: architecture, services, portability and applications.

According to George Gilder, futurist, "This is an invasion of phones and TVs by the computer industry. The phone and TV are not converging, they are collapsing."[1]

One of the Internet's ironies is that boundless communication creates groups of stunning narrowness. The technologies to permit Total Network access will emerge with increasing rapidity in the next three to five years.

According to Apple Computer, video-enabled networks require a number of important technical advances. These include [1] asynchronous transfer mode (ATM) interface, [2] high-speed, real-time compression / decompression chips, [3] 64-bit microprocessors, [4] an operating system that can in real-time schedule events for user-defined times, [5] computer internals that handle the gigabits-per-second flows of video, [6] networked multimedia standard software to sustain new applications, [7] interfaces for multimedia communication and access to media databases, [8] high-speed storage devices for the terabytes data, [9] data encryption, and [10] billing mechanisms.[2]

## 11. Outlook 2000

Three major developments will take place before 2000. First, prices will continue to fall and computer power will increase. This means that networks will be more robust and smarter.

Second, connecting to the Internet will become easier, eventually turning into a plug-and-play application. Third, bandwidth will expand, thus enabling more image and video applications. Other likely developments include:

- Computers that perform routing functions will increase in flexibility and functionality. Internet connectivity will benefit because routers will be more intelligent — that is, automatically-configuring and dynamically updatable — and incorporate the functions of other network devices such as bridges.

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[1] George Gilder, 'Life after television updated,' Forbes, 28 February 1994, pages 94 and following.

[2] Grace Casselman, 'Visionaries gather in Toronto to shed light on info highway,' *Computer Dealer News, 23* February 1994, pages 1-2

- The management of connection-less routing protocols will be minimised. At this time, these protocols do not scale well on large wide-area internets. In the connection-less environment, each protocol manages its own route selection. When routing tables grow large, they become unstable because there is no easy way to respond to bottlenecks.

- Proprietary network operating systems will support the open architecture of TCP/IP.

- Network monitoring tools will become more robust. Tasks that now require manual intervention to work around bottlenecks or outages will be handled automatically. The cost of such sophisticated network management tools will continue to decline. More monitoring functionality will be built into next-generation network operating systems; for example, Windows NT includes a number of tools that users of NetWare must acquire from third-party providers.

- Electronic mail management across platforms will become less complex. Software tools will allow transparent conversion between sender and receiver message formats.

- Networks will be able to manage themselves. Network infrastructures will be more dynamic. Operating procedures will become more standardised as a result of consolidation in the network market and the need to engineer systems to permit seamless links to the Internet and other networks. Certain types of routine problem will be handled with the operating systems. Agent software will diagnose and alter the software to remedy or avoid the problem. Certain functions that are managed as separate functions outside of the network operating system will become integrated; for example, electronic mail, telephone systems and certain types of information retrieval.