What Is TCP/IP?

Part I

By Stephen Force

This two-part series examines Transmission Control Protocol/Internet Protocol (TCP/IP) and the Internet, which are becoming more prevalent in traditional MVS and VM EDP shops. This article discusses the emergence of TCP/IP, examines the principles of TCP/IP in relation to Open Systems Interconnection (OSI) and presents a brief discussion of the Internet.

Introduction

More and more articles are being written on TCP/IP. Until recently, most of these articles were of little interest to IBM mainframe systems support staff, since TCP/IP seemed more oriented toward other operating systems and networks.

Perhaps now is the time to look more closely at TCP/IP. We have all seen the effects of the economy in data processing (DP) departments. Downsizing, rightsizing, outsourcing and cost-effectiveness are just a few of the most common terms used today, but what exactly do they mean?

DP departments need to know what these terms mean to survive. It is not enough today to simply offer the mainframe-orientated software solutions as in the past. Computer literacy has spread to all levels of the organization, bringing with it an awareness of what computers can (or cannot) offer.

DP departments are in a unique position to thrive in these trends. It doesn't matter which hardware platform applications run on, the basic DP philosophy still applies. Data needs to be regularly backed up and quickly restored, if necessary, and secure storage still needs to be obtained. Networks, regardless of topology, need to be installed, maintained and kept running reliably and optimally. DP departments have years of experience in dealing with data (backup, recovery and security) and network operations, and can offer the manpower and physically secure areas needed for its customers.

It is always interesting to develop applications using new technology. It is exciting to see these applications actually work, but after the glamour wears off, who is there to make sure that it is available, day after day, other than the DP operations staff?

How Does TCP/IP Fit In?

TCP/IP is becoming the networking system of choice in a multivendor, disparate operating system environment. It offers a ready-made, fully supported solution to organizations that need to network not only their systems, but also access other systems on other networks.

TCP/IP is fully integrated into all variations of UNIX, is available for most operating systems at an affordable cost (including IBM MVS, VM, OS/2 and AIX systems) and limited support has been integrated into the Microsoft Windows/NT operating system.

More and more users are requiring access to the vast options offered by the Internet and by services such as Compuserve.

Several LAN mediums are supported by TCP/IP, forcing vendors to either lower their prices or build in more functions to compete.

An example of this is Ethernet vs. token-ring. An Ethernet network card for a PC costs (street price) around $130, with data transfer speeds up to 10MB per second. Contrast this to the a token-ring adapter card, which costs approximately $500, with a 16MB per second data transfer rate. This does not mean that Ethernet is a better solution for organizations, but rather it is a viable alternative.

So, fierce competition among vendors writing excellent applications on all platforms, sharply lower prices for hardware, coupled with creative solutions using the power of TCP/IP from users outside of the DP department is forcing traditional IBM EDP shops to face the probability of implementing TCP/IP in the mainframe operating systems.

This article deals mainly with the MVS implementation of TCP/IP; however, the general concepts also apply to VM. Also, for brevity, most examples in this article refer to interaction between MVS and the PC-DOS operating system, even though the functions are also available on other platforms (OS/2, UNIX, AIX, etc.).

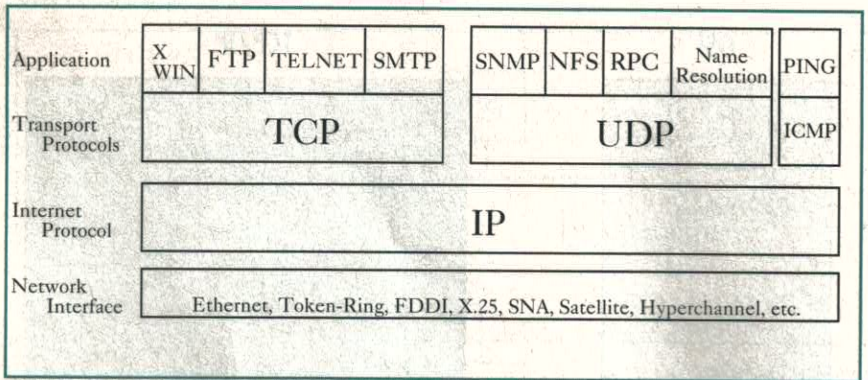
The Evolution of Business Electronic Data Processing (EDP)

Business EDP is an evolving discipline. A few years ago, it was rather unusual to see a terminal on a users' desk instead of in a terminal room.

Then came the paperless concept. Terminals replaced punch cards, online list viewing replaced printed listings. Mainframe networking became progressively more complicated because businesses demanded more network flexibility and availability. As businesses prospered or failed, the computing resources of the acquired or merged enterprises needed to be integrated.

Meanwhile, due to competition and

• • FIGURE 1: The TCP/IP Architecture



• • FIGURE 2: The OSI Reference Model

The OSI reference model consists of seven layers:

Layer 7 Application	User Programs
Layer 6 Presentation	The way data is represented on the computer.
Layer 5 Session	Provides connecting services such as establishing and maintaining a session.
Layer 4 Transport	Provides reliable user-to-user communication and error checking.
Layer 3 Network	Responsible for addressing, routing and relay control information required to control the data flow.
Layer 2 Data-Link	Provides host-to-host delivery across a LAN. Protocol examples: Ethernet, token-ring, SLIP, FDDI.
Layer 1 Physical	Actual electrical process of transferring data.

technological advances, the cost of PCs dropped steadily. Coupled with a new generation of computing professionals and a better selection of software products, the PC became more prevalent in companies. Programs were written on PCs, sometimes even compiled and tested before being loaded onto the mainframe. Programs and data were sent from the PC to the mainframe using a file transfer program. Terminal emulation software and file transfer programs, both for the PC and the mainframe, were written so the PC could communicate with the host.

LANs became more widely used and several EDP shops opted for the IBM token-ring since it was supported in the IBM terminal control units and the SNA network.

PCs could then use the token-ring to not only communicate with each other, but also with the SNA world. More SNA protocols became available for general use so that the implementation of hierarchical networks became less necessary [witness APPC (LU6.2) and APPN (LU2.1)]. Now, mainframes, AS/400s and PCs can communicate on a peer-to-peer level. And, using the wonders of modern networking techniques, PCs can network over tremendous distances using the SNA network as the backbone (APPN).

Enter TCP/IP

Meanwhile, outside of business EDP, other operating systems were being used. IBM was not the only game in town. Universities, research agencies, corporate engineering departments and many other sites were using minicomputers with the UNIX operating system as their system of choice. Others used PCs for their work and then sent their data to the UNIX systems for processing. Other users logged on to UNIX systems, using their PCs as terminals (running a emulation program). Still others were storied their files on remote systems, then accessed them as if they were located right in their computer.

Other computer companies were developing their own systems and networking solutions. With so many non-standardized and diverse systems being developed, it was difficult to connect these systems together.

Recognizing this problem in the mid-1970s, the U.S. Government Defense Advanced Research Projects Agency (DARPA) provided research funding for a interconnecting protocol. The result of this research is TCP/IP, a still-evolving protocol that took its current form around 1977-1979.[1]

Around 1980, using the existing ARPANET as its backbone, DARPA started connecting its TCP/IP capable systems together. Known as Internet, this networking technology along with TCP/IP made tremendous strides culminating in January 1983 when the U.S. Government Office of the Secretary of Defense required that all computers connected to long-haul networks use TCP/IP.

To encourage university researchers to adopt and use these new protocols, DARPA made an low cost implementation available.[2] Due to the availability of this implementation, along with the popularity of the UNIX operating system, Internet soon became a U.S. and Europeanwide network linking literally thousands of TCP/IP-capable computers together.

TCP/IP Source Code Availability

For IBM users a major reason for TCP/IP's popularity has been the availability of open protocols and source code.

TCP/IP and Open Systems Interconnection (OSI)

TCP/IP is a peer-to-peer architecture. All systems, regardless of size, appear the same to all other systems in the network. TCP/IP-capable systems are logically paired in a client/server relationship. The client, or local host, issues TCP/IP requests that are forwarded through the network to the server or foreign host. The server then executes the function, returning the result to the client.

The TCP/IP architecture can be modeled in four functional layers. Each layer performs a particular function, as illustrated in Figure 1.

Examples of TCP/IP application programs include:

X-win: X-Windows application
FTP: File Transfer Protocol
TELNET: Terminal Emulation
SMTP: Simple Mail Transfer Protocol
SNMP: Simple Network Management Protocol
NFS: Network File Server
RPC: Remote Procedure Call
Name Resolution: Internet Host Table
PING: Packet Internet Grouper

Transport Protocols provide the end-to-end data transfer. The protocols used are:

TCP: Transport Control Protocol. It provides connection orientated, reliable sequenced data transfer. TCP guarantees successful data transfer to destination.

UDP: User Datagram Protocol. It provides "unreliable" data transport. UDP does not guarantee successful data transfer, meaning that the application using UDP must take this into consideration.

ICMP: Internet Control Message Protocol. ICMP sends error and control information from hosts or routers to the message originator. ICMP is both a user of and a part of Internet protocol (IP).

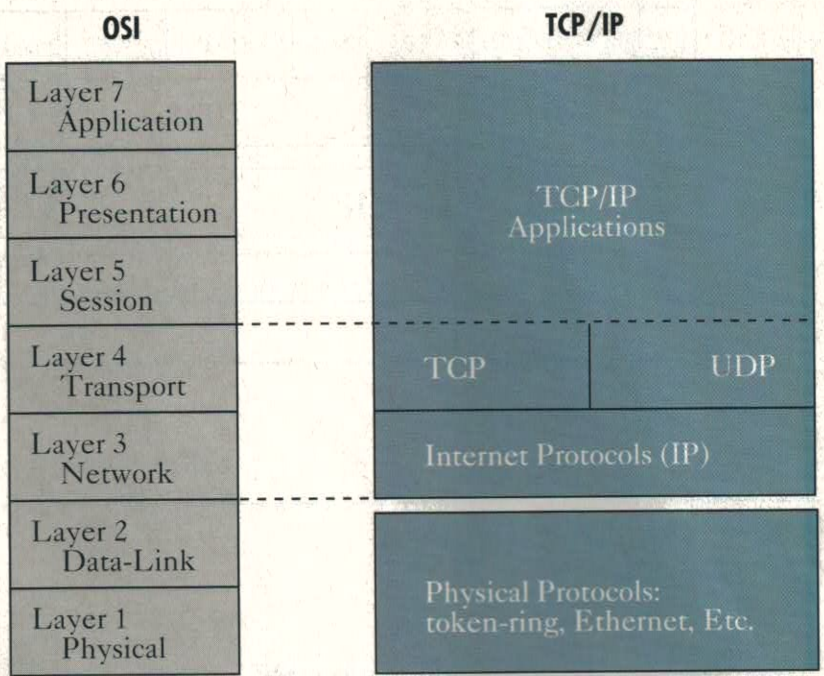
Internet Protocol: The Internet Protocol (IP) assembles data bits into an IP datagram, then chooses the best route to send the packet to its destination.

Network Interface: The interface to the network hardware. The network interface can be one (or more) of several types of LAN media, such as Ethernet, token-ring, SNA, FDDI, X.25 etc.

Description of OSI

In the mid '70s, the Paris-based International Standards Organization (ISO) started defining a framework and structure for a set of rules or protocols. By adhering to these protocols, vendor-developed systems could connect and communicate. These ISO protocols are now known as the Open Systems Interconnection (OSI) standards.

• • FIGURE 3: How TCP/IP Layers Correspond to the OSI Reference Model



• • FIGURE 4: Division of Addresses Between Network Number and Host Number

Network Class	Network Number	Host Number
Class A	First octet	Last three octets
Class B	First two octets	Last two octets
Class C	First three octets	Last octet

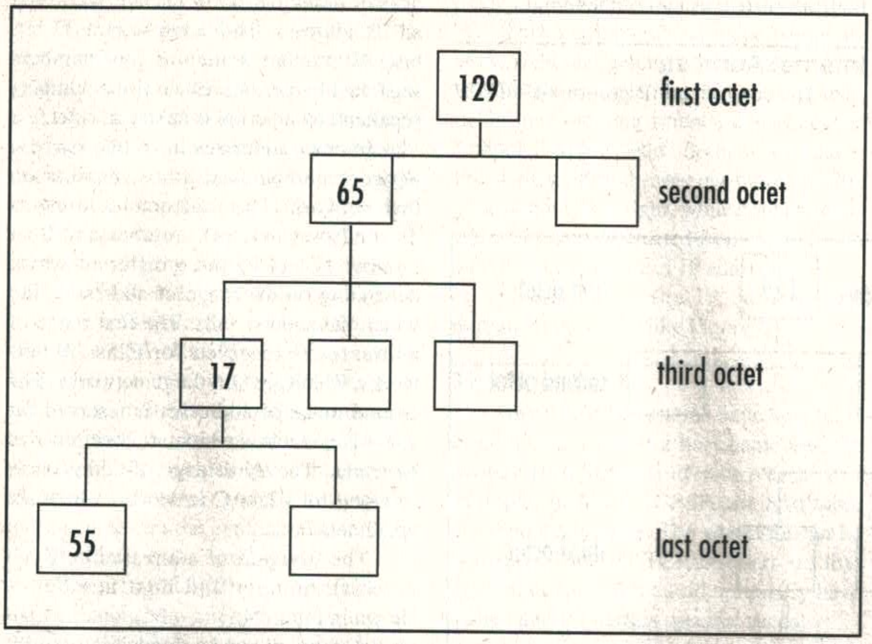
The OSI architecture is a layered concept called the OSI Reference Model, of which each layer has a name, a layer number, protocols that provide specific functions and defined services. This reference model is a complete peer-to-peer communications environment. See Figure 2.

According to the OSI reference model, all processes are initiated in the application layer, travelling downward through the stack. Each layer performs a service, passing the results to the next lower layer. Finally, at layer 1 (physical) the data is shipped across the physical link to the connected computer system. There the process reverses, traveling from layer 1 up through the layers to the receiving application in layer 7 (the application layer).

How TCP/IP Compares to the OSI Reference Model

TCP/IP can be roughly compared to the OSI model. Since they evolved separately, naturally there are differences in

• • FIGURE 5: The IP Address



both philosophy and implementation. However, it is interesting to see how TCP/IP and OSI functionally compare.

Figure 3 illustrates how TCP/IP layers correspond to the OSI reference model. The Internet Protocol (IP) maps to the OSI network layer with UDP and TCP corresponding to the OSI transport layer. Finally, TCP/IP applications map roughly to the session, presentation and the application layers of the OSI model.

Internet Defined

The term "internet" is confusing because it is used in several ways. When some people speak of internet, they are referring to a collection of packet-switching networks interconnected by gateways along with the protocols that allow them to function logically as a single, large, virtual network (or, in English, a set of connected networks that act as a coordinated whole [3]). Others think of it as the worldwide network connecting universities, government research labs, military installations and some companies. This is known as the Internet (spelled with a capital "I") and was publicized a couple of years ago as the network used by German hackers (CHAOS computer club of Hamburg) to obtain sensitive defense data. However, both are correct usages of the term.

Internet Address

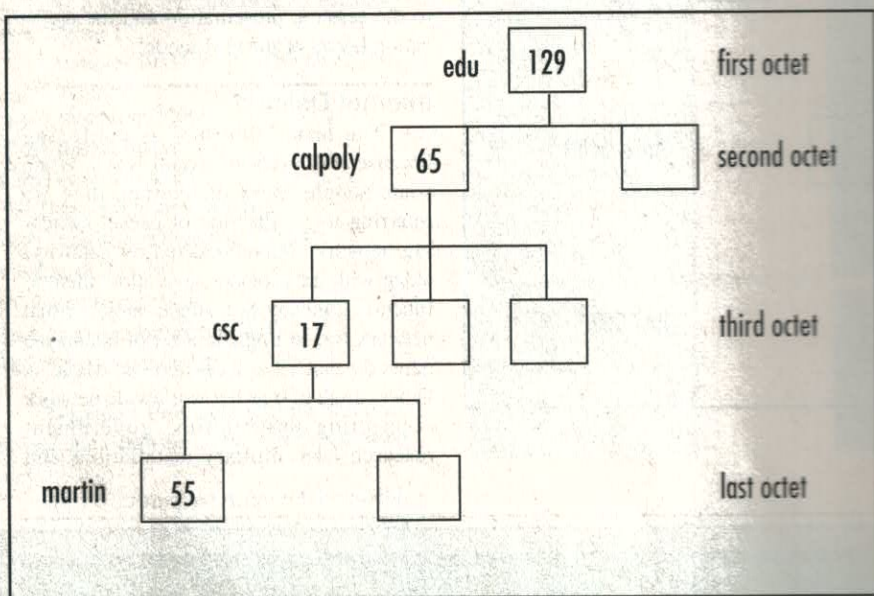
The core of the IP portion of TCP/IP is the Internet address. Each host that desires participation in an internet needs an IP address. This address is a 32-bit, base 10 number written as four numbers separated by periods. Each of the numbers separated by a period is called an octet.

Internet addresses have two parts: a network number and a host number on that network. The four-octet address is divided into network number and host number in any of three different ways, depending on the range of addresses into which the address falls. The first range of addresses is reserved for Class A networks, which are very large networks. The second range of addresses is reserved for Class B networks, which are medium-size networks. The third range of addresses is reserved for Class C networks, which are small networks.

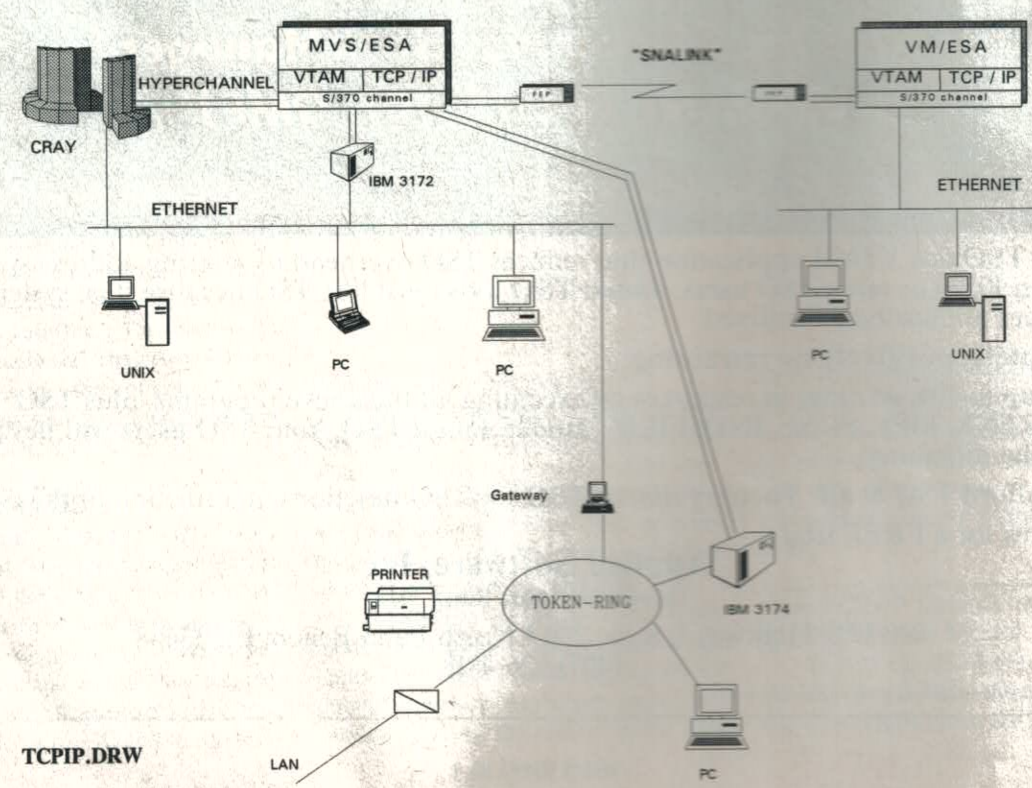
The division of addresses between network number and host number is shown in Figure 4.

A network can be divided into multiple smaller subnetworks called subnets. For example, a Class B network can be divided into multiple subnets, each having the same number of hosts as a Class C network. This extension to the IP addressing scheme allows a site to be seen from outside as having one network number.

• • FIGURE 6: The IP Address and Domain Name



• • FIGURE 7: The TCP/IP Network



The Class B network could consist of multiple networks, each of smaller size.

To allow for subnet addressing, the host number portion of an internet address is divided into a subnet part and a host part. The network portion and subnet part are logically concatenated to form the subnet identifier. For example, if a Class B network had an address of 130.42, it could be divided into 254 subnetworks with addresses ranging from 130.42.1 through 130.42.254 (0 and 255 are reserved). [4]

An example of a IP address is 129.65.17.55 (California Polytechnic University, San Luis Obispo). The first two octets (129.65) are uniquely allocated to California Polytechnic University. The next octet determines the subnetworks (Subnets) at Cal Poly and the last individual machines on the campus. Graphically, the IP address looks like Figure 5.

For most TCP/IP organizations, in the beginning, the internet will be strictly departmental or companywide, with no apparent need to connect to the Internet. It is strongly advised, however, to plan ahead in selecting the internet addresses for local use, since, in the future it might be necessary to either join the (worldwide) Internet or another (local) internet. It is very difficult to change the internet addresses at a later date (just ask your VTAM system programmer about changing ACF/VTAM Logical Unit (LU), Physical Unit (PU) and gateway network names after implementation).

It is strongly recommended that all organizations obtain a unique Internet address. To obtain one, contact:

Government Systems, Inc.
Attn: Network Information Center
14200 Park Meadow Drive, Suite 200
Chantilly, VA 22021
(800) 365-3642
(703) 802-4535
(703) 802-8376 (fax)

Mapping Domain Names to Address

Although the IP address system is the basic form of Internet communication, each host has a domain name that may be used for addressing. It is much easier to remember the domain name (host name) than the IP name. All Internet communication is handled using the IP addresses. Since this address is sometimes difficult to remember, each machine has a readable name associated with it. A typical domain name might be: martin.csc.calpoly.edu

This is a hierarchical name beginning at the right and getting more specific to the left. In this example, the host name is martin in the computer science department at "calpoly" in the "edu" domain for educational sites. IP addresses get more specific going from left to right, while domain name addresses are constructed from right to left, which is the opposite of IP addresses.

Graphically, the IP address and domain name looks like Figure 6.

The Host Table

Most TCP/IP systems have host table capability to convert a host name into the proper IP address and vice versa. For example, In MVS TCP/IP, the host table is called a site table. The site table can be configured for all TCP/IP users on that system, or each user could optionally have a site table for her/his specific needs.

Name Servers

For simple TCP/IP networks, host tables will probably suffice. However, in larger networks, there are may reasons not to use host tables:

•Updating several host tables requires time.

•All tables then need to be synchronized.

•The larger the network, the larger the host table. Since the table is searched from top to bottom, one at a time, the IP address resolution might take some time.

In situations like this, it is recommended to consider implementing a name server. The name server could then serve its clients by providing an IP address to a host name and a host name to an IP address services networkwide, making only one table update necessary. MVS and VM both provide support for name server usage. [5]

Gateways

A gateway is a computer and its associated software permits two networks using different protocols to communicate with each other. For example, a gateway can be between a IBM token-ring Network and a Ethernet and/or a packet-switched public network. IP routers and TCP/IP routers are functionally equivalent to a gateway.

What Is a Host?

A host, sometimes seen as a node, is any end-user computer system (acting as a client and/or server) that connects to a network. Examples include:

- a PC running DOS;
- a PC running OS/2;
- a PC running UNIX;
- a IBM RS/6000 running AIX;
- a IBM ES/9000 running MVS/ESA and TCP/IP;
- a IBM 4381 running VM/SP and TCP/IP; and
- a Cray system with TCP/IP support software.

The Span of TCP/IP Networks

TCP/IP supports several LAN mediums, or LAN architectures:

•**Ethernet:** a best-effort network delivery system implementing the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technology. Rated at: 10MB.

•**FDDI: Fiber Distribution Data Interface.** A fiber optic network offering 10MB data rate to approximately 200km in length (with repeaters every 2km or less). FDDI uses the token-ring technology.

•**IBM Token-Ring:** a network technology that passes a data packet, called a token, from machine to machine. A computer can only forward a data packet when holding the token. Token-ring currently offers either 4MB or 16MB data transfer speed.

•**SLIP: Serial Line IP**. SLIP is a network protocol that uses the standard PC synchronous port. The data transfer medium can either be by cable or by modem. Data transfer speed: either modem speed (baud) or a rate acceptable to both transmitting and receiving computers.

•**SNALINK:** An IBM implementation using SNA as the network transport medium.

Because of the tremendous flexibility of these mediums, a TCP/IP network can be in the same room, several rooms or span several continents. By using the mainframe TCP/IP as a router, SNA can be used as a TCP/IP backbone. This offers tremendous opportunities for SNA users since existing networks can be used rather than having to invest in new equipment and data communication lines. See Figure 7. A future article will address the SNALINK in more detail.

Services Available Through the Internet

One of the benefits of a direct connection to the Internet is information retrieval. By using either Telnet, FTP or SMTP, an Internet user can take advantage of a wealth of information made such as ARCHIE, an index for Internet archive users; online data bases; book reviews; magazine fax delivery; geographic information; and Library of Congress.[6]

Most of these services can be used in "real-time" by connecting the Telnet terminal emulation program to them. Besides the Telnet function, however, the Internet offers one of the largest collections of software available. By using the file transfer protocol (FTP), Internet sites can access huge repositories of public domain and shareware software, UNIX, MS-DOS or Macintosh software or text files.

Many commercial services support connections to the Internet for electronic mail transmission. Most will also support file transmission through protocols that allow E-mail to serve as the transport mechanism.

Compuserve, for example, offers such file transfer capabilities. To use it, both parties need to install data conversion software provided free from Compuserve. Also, according to a Compuserve representative, binary files cannot be currently transferred. But Compuserve is working on this problem. When asked if Compuserve will offer other Internet services (i.e., Telnet, RPC, real FTP), I was told it was quite possible. Since APPC might become available to Compuserve users, why not TCP/IP functions?

It is currently possible to send messages from CompuServe and MCI Mail both to and from the Internet, as well as send mail from CompuServe to MCI Mail through Internet. Since CompuServe is available almost worldwide, a savvy international organization could possibly save money by using CompuServe, TCP/IP and the Internet as its E-mail system.

Part II will conclude this series by taking an indepth look at the major features of TCP/IP and the protocols for monitoring and managing TCP/IP networks.

Footnotes

[1] Comer, Douglas E., *Internetworking With TCP/IP Volume 1, Principles, Protocols and Architecture.*

[2] Ibid., page 7

[3] Ibid., page 15

[4] IBM Corporation, *Transmission Control Protocol/Internet Protocol for MVS Installation and Maintenance*, pages 1-5 through 1-6

[5] For detailed information, please refer to either *IBM Corporation TCP/IP V2 for MVS: Installation and Maintenance SC31-6085* for MVS questions, or *IBM Corporation, TCP/IP V2 for VM: Installation and Maintenance SC31-6082* for VM questions.

[6] For more information on Internet services, please see pages 123-125 Dvorak, John C. and Anis, Nick, *Dvorak's Guide to PC Telecommunications*, Second Edition 1992 McGraw-Hill, Inc. ISBN 0-07-881787-0.

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