INTERNET ACCESS VIA CABLE TV: HIGH SPEED ACCESS TO THE INFORMATION HIGHWAY

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Abstract

Internet access has become a feeding frenzy. Dial-up access to the World Wide Web just isn't fast enough. Your subscribers know that cable TV can give them access to hypertext at the speed of a bullet train, and they want it. Now what do you do?

How do you separate the hype from the hypertext? For that matter, what is hypertext? This paper will answer these questions and more, providing a framework within which to plan and implement Internet access on your system. It will give you a crash course on the Internet and show how the information highway is being created today with the Internet and cable TV.

INTRODUCTION

"Internet over cable TV will receive more general press (Information Superhighway) attention than any other carrier-based activity in 1995 and become the most important tool for work-at-home since the advent of the PC, modem and facsimile terminal"

Dr. Jerome Lucas
TeleStrategies Insight Newsletter
January 1995

The commercialization of the Internet has opened the door for access to the largest information network in the world. The Internet connects an estimated 39K networks, 4.9M hosts[i], and over 30M users in more than 127 countries around the world. In early 1994, it was estimated that on the average, a new computer was added to the Internet every 30 seconds.[ii] The growth of the Internet continues to be exponential.

The cable TV industry has the capability to provide subscribers with Internet access at speeds unmatched in price/performance by any other medium. Using the ubiquitous, existing Hybrid Fiber Coax (HFC) infrastructure in place in the US, Canada, and many countries around the world today, the cable industry can give customers high speed access at a much lower cost - a key criteria for Internet users.

Rapid access to and provision of pictures, sound, video, audio, and integrated text and graphics are all made possible by accessing Internet sites on the World Wide Web, using a Web browser program from a personal computer connected to the Internet via cable television. By using standard channels, one forward and one reverse, on an existing entertainment cable system, cable operators can offer businesses, telecommuters, doctors, teachers, students, and consumers access the state-of-the-art capabilities available on information highway today.

This paper discusses creating such networks using an Ethernet to cable TV bridge, brouter, or personal modem at each business, hospital, school, or home, coupled with a translator in the Cable TV headend and a backbone router to the Internet at one location on the network. Each user on the network has access to the Internet, as well a shared 10 Mbps access to each other. The value of the cable connection to the customer is increased by orders of magnitude.

The key is the ability of cable to provide a fully distributed network, rather than customers using expensive point-to-point leased lines for direct connection to the Internet, or slow dial-up lines for indirect connection through online services.

The goals of this paper are to explain the network technology, components, and architecture, and the methodology which will provide the cable operator with a foundation on which to plan and build such a network. Case studies of actual networks are used to illustrate possible configurations.

The convergence of the cable and data communications industries provides enormous opportunities, but carries with it the challenges of learning about each others' technologies. This paper is intended to serve as a starting point, assuming little or no knowledge of data communications or the Internet.

A BRIEF HISTORY OF THE INTERNET

The evolution of cable TV data networks can be seen to parallel the development and growth of the Internet. Both have the roots of their technology growing largely out of military applications with initial use and promotion of the technology by the education and research community, followed by adoption in the commercial marketplace, and finally reaching widespread use in the home.

A brief history of the Internet helps to understand why it is organized the way it is, and how cable networks connect to it.

In the mid-1970's, the Defense Advanced Research Project Agency (DARPA) funded research to develop a set of networking standards or protocols, that specify how computers would communicate over an internet, as well as a series of conventions for interconnecting networks and routing traffic. The result was TCP/IP (Transmission Control Protocol/Internet Protocol). During the late 1970's, DARPA also funded research into *packet switched* networking and implemented a network called the ARPAnet.

TCP/IP became the only effective way to communicate between computers from different manufacturers. It appealed to schools, institutions, and businesses, who did not want to be tied to one vendor's equipment, and who wanted to protect their investment in existing equipment.

In the early 1980's Ethernet local area networks (LANs) proliferated. Ethernet, developed by Metcalfe and Boggs in 1976, used a coaxial cable network, in which all stations monitor the cable (the ether) during their own transmission, terminating transmission immediately if a collision is detected. This created a new demand: rather than connecting to a single large timesharing computer per site, organizations wanted to connect the ARPAnet to their entire local network. This would allow all the computers on that LAN to access ARPANET facilities.

In 1986, the National Science Foundation founded NSFNET to connect its networks centered around its 6 supercomputers into a network *backbone* that ties into the ARPANET.

This network arrangement was enormously successful, and the Internet was born. With success came the need to upgrade compute resources and leased line speeds, which continues today.

MANAGEMENT OF THE INTERNET

The Internet has evolved from a loose federation of networks, to a network with a character all its own. There is no central management, but rather a group of organizations who steer its activities. These groups include the Internet Architecture Board (IAB), the Internet Society (ISOC), and the Internet Engineering Task Force (IETF).

Another unique aspect of the Internet is that, as it is not owned by any one party, it is also not paid for or funded by any one organization. NSF, which subsidized its development is phasing out its $11.5M subsidy. Privatization of the Internet remains a hot topic. Many third party Internet access providers have sprung up to offer Internet access to businesses and individuals.

THE COMMERCIALIZATION OF THE INTERNET

Those who stand to gain most from the commercialization of the Internet are small businesses, K-12 schools, home workers, and recreational users. Corporations, research institutions, and universities have been using the Internet for many years. Big business has also been using private *wide area networks (WANs)* for years as well. (WANs being essentially company-owned internets.)

Prior to the commercialization of the Internet, small businesses, schools, and individuals could not afford the high price of private WANs, and were not allowed access to the Internet. Commercialization opens the door for access to resources previously only available to large organizations. It also opens up a whole new range of possibilities. Virtual corporations and electronic shopping malls are not only possible, but possible on an international level. Internet marketing and advertising will change the way products are promoted.

The commercialization of the Internet will forever change the future of both small business and worldwide commerce. It will also forever change what the Internet is.

WHO ARE THE USERS?

Users of the Internet include companies, universities, colleges, K-12 schools, research groups, and individual users.

The majority of universities and research facilities have Internet access. Many companies also have access. There is now a major initiative to connect K-12 schools. Individual users are largely an untapped market, as until recently, acquiring Internet access required specialized knowledge of *UNIX* and TCP/IP.

The popular press is rife with articles on the wealth of information available on the Internet, as well as on the need for a national, as well as global, Information Highway. This has sparked a feeding frenzy of interest in connecting up to the Internet. To people today, the Internet *is* the Information Highway.

WHAT ARE THE APPLICATIONS?

Applications on the Internet started out with simple text-based applications, such as electronic mail. Today's applications are highly visual - containing color pictures, sound, graphics, video, and other data-intensive information formats. It is the increase in such applications that drives the need for the "big pipes" that cable TV can provide.

Electronic Mail

The most commonly used application on the Internet is *electronic mail*, or *e-mail*. Each user has a unique address and can be reached by anyone else with email access to the Internet.

Electronic mail is a low-bandwidth, text-based application. It is a *store and forward* service, meaning it does not require communicating users to have an *end to end* communications path set up at the time the message is sent. The message is forwarded and stored on subsequent computers until is reaches the recipient.

Traditional low-bandwidth, store and forward applications such as e-mail, do not necessarily require the high-bandwidth capabilities of a cable TV network.

The World Wide Web

The *World Wide Web,* or *Web* is the newest and most often talked about application on the Internet today.

The World Wide Web provides easily accessible, organized access to the huge amount of data available on the Internet. The Web uses *hypertext,* in which displayed information contains highlighted words which can be "expanded" with the click of a mouse, providing links to other information or files. These links can be to text, pictures, video clips, audio clips, graphics, etc.

The Web is a *client-server* based application. Information databases are stored on computers called *Web servers*. In order to access the Web, a user's computer needs a piece of software installed called a *client*, or in hypertext terminology, a *browser*.

Multimedia, client-server based applications like the Web are the future of the Internet, and fuel the need for cable TV speeds. It is becoming commonplace for small business, schools, and municipalities to have their own Web servers. This trend necessitates high-speed *symmetrical* access, meaning that access speed is the same in either direction, which cable TV is in a unique position to provide.

Wide Area Information Servers (WAIS)

WAIS provides a means to search indexed material using a string of text supplied by the requester. It allows the user to easily look for information regardless of where it is located on the Internet. WAIS is one of many such search tools, which instead of browsing randomly, allow a user to locate specific information.

Gopher

Gopher allows a user to *tunnel* through the Internet and access information without having to know its address. Using gopher is like having a library card catalog to access information, rather than having to search for it randomly.

News

News allows users to access information on a variety of topics or special interests, and is analogous to a discussion group or bulletin board.

File Transfer Protocol (FTP)

The File Transfer Protocol (ftp) is a client-server based application used for copying files from one computer to another over the Internet. Ftp sets up a *real-time* connection between the two computers while the copying is taking place.

Telnet

Telnet is another client-server application that allows a user to log in to another computer on the Internet. It can allow users to access databases, public information, and library card catalogs.

Summary

One of the primary lamentations of Internet users is the inability to get high speed access to applications such as the World Wide Web from their desktop (particularly from home) where a dial-up line may be the only available option. A dial-up line may be fine for e-mail, but it is totally unsuitable for applications such as the Web. The time it takes to download an image is just too long for the average user to endure. Symmetrical access is also key, as small companies, schools, and home-based businesses set up their own Web servers.

THE CASE FOR INTERNET ACCESS VIA CABLE TV

"...sometimes it makes sense to back out of the driveway at 900 miles per hour."

Vint Cerf
co-author of TCP/IP/Internet designer

Communications mirrors society, as well as changes the way society interacts. Both data networks and cable television evolved to bring information to people in physically distant locations. People and networks have become more decentralized. An outgrowth of the ability to communicate over wide distances has fueled the growth of virtual companies, telecommuting, distance learning, and other phenomena. Key to these models are the fact that the people using networks can be either producers or consumers of information, or *prosumers*. This societal model, coupled with the need to access the data-intensive applications used in these activities requires high-speed symmetrical network access.

Key to the commercial growth is the ability to provide users in remote locations, at small companies, and at home with the same high speed access to information both on community networks and on the Internet that they are used to having in the workplace.

As Vint Cerf, one of the founding fathers of the Internet, points out, "The information superhighway model, with low-speed access to a high-speed backbone, is flawed. My experience with data networking is that sometimes it makes sense to back out of the driveway at 900 miles per hour. We need to support both low-speed and high-speed access. For that reason, narrowband, 128-kb/s integrated services digital network connections are not bad, but developments like cable TV-provided 10-Mbps Ethernet links are even more interesting."[iii]

Standard telephony lines simply do not have the capacity to bring the same bandwidth to the home as cable TV.

HOW DOES INTERNET ACCESS VIA CABLE TV WORK?

Data networks use devices such as repeaters, bridges, and routers to extend, as well as segment, local area networks.

A *repeater*, as in a cable TV network, connects two segments of network cable. It retimes, regenerates, and forwards a digital signal. Repeaters, however, can only extend a high-speed LAN a few thousand yards.

Bridges are used to connect two networks which use the same network signaling and the same media access-control protocol, such as Ethernet.

Routers are used to connect two different types of networks, in this case to route IP datagrams.

Internet Backbone

Routers are also used to connect LANs to WANs, and make up the Internet *backbone.* A backbone is a central network to which other networks are connected.

It is important to remember that in the same way that a Local Area Network is a network of computers, the Internet is essentially a network of networks, consisting of thousands of computer networks interconnected by routers. It is also important to make a distinction between an Internet backbone router and a router on the community Ethernet network, or on the customer LAN, as illustrated in later scenarios.

Sample Cable TV Networking Protocol

An example of a protocol in use today for extending a LAN by cable TV is *UniLINK*™, developed by LANcity Corporation, which:

- provides two-way, symmetrical data transmission at a signaling rate of 10 Mbps
- extends Ethernet beyond its distance limitation of 2.2 miles out to 160 miles
- coexists with entertainment and other services on a commercial cable TV network
- provides the same data rates and services that an Ethernet provides.

The cable data modem is specifically designed for cable TV networks. It uses a bidirectional single or dual cable plant to provide symmetrical data transmission at a signaling rate of 10 Mbps. It uses *Quadrature Phase Shift Keying (QPSK)* and has a spectral efficiency of 1.67 bits/Hz. The data modem is frequency agile, allowing it to operate in any available standard 6 MHz channel, over a transmit frequency range of 10 MHz to 174 MHz and a receive frequency of 54 MHz to 550 MHz, with a bit error rate (BER) of 25 dB C/N: <1 in 10^9.

Hosts, Nodes, Gateways, and Routers

Internet backbone routers were originally called *gateways.* Gateways were developed to deal with the fact that for internetworking to work, computers communicating across multiple types of networks needed a way to talk with each other as well as to talk to the intermediary networks in between in order to pass packets. What was needed was an *end-to-end protocol.*

An assumption was made in protocol design that the networks themselves could not be modified in order to internetwork them. Therefore the gateways had to handle such things as differing maximum packet lengths and error characteristics among networks. The gateway would know about the end-to-end protocol used by *hosts* (end user computers) communicating across multiple networks.

Other terms that may be encountered include *nodes*, or *packet switch nodes (PSNs),* which were also originally called *interface message processors (IMPs).* These terms all refer to packet switches in the Internet backbone. An important distinction is that the term node when talking about the Internet means something entirely different than it does when talking about an Ethernet. A node in Internet terminology means a router; a node in Ethernet terminology is the end user computer, or the Internet's equivalent of a host.

Cable Internet Brouters[iv]

A cable Internet brouter is a combination bridge/router designed to work over commercial cable TV channels, and has a form-factor similar to a standard set-top box.

Using a cable Internet brouter, all packets that are destined for users on the Metropolitan Area Network (MAN), or the community network, are transparently bridged using the IEEE 802.1D Spanning Tree protocol. In other words, packets destined for the community network are handled by the bridge portion of the Brouter.

Routing tables, which determine where to send packets that are destined outside the community network, or somewhere out on the Internet, are maintained using a routing protocol called RIP1. RIP1 is an *interior gateway* protocol used to execute distributed routing and reachability algorithms with other routers.

For packets going out to destinations across the Internet, or IP packets, the cable Internet brouter conforms to specific Internet protocols including the Internet protocol (IP), Internet Control Message Protocol (ICMP) and others when required. This ensures that other computers in the network receiving the data packets will be able to process and route them to their destination, i.e. that they "speak the same language".

The brouter interfaces between an Ethernet LAN and the cable TV network and performs required functions such as encapsulation and decapsulation of the data (i.e. putting the data in an envelope with an address on it, and taking it out of the envelope), sending and receiving datagrams, performing IP destination address translation, and network flow control and error handling. All of this takes place transparently to the user, but internally a complex system of data transmission, traffic control, and error handling ensures that data reaches its destination intact, and in a timely manner.

The brouter receives and forwards Internet datagrams, providing buffer management, congestion control, and fairness. This activity allows data waiting to be sent to be stored in holding areas, or buffers, and ensures that each user "gets a turn" to transmit or receive data when the network is being heavily used, or is "congested", the equivalent of a system of onramps and traffic lights to control traffic during rush hour.

The brouter also chooses a *next hop* destination for each IP datagram. This means that the network chooses which computer to send the data to next. Each computer in the chain from sender to receiver is called a *hop.* Internally, the network keeps track of the best routes for data at any given time, dependent on various conditions in the network. For example, it may have detected that a certain computer is not operational. Even though taking this route may be the fewest "hops", and hence the natural first choice to send the data to, it will choose an alternative route.

For non-IP packets, the Internet brouter uses the Spanning Tree algorithm and automatically learns the locations of devices by listening to network traffic, forwarding packets only when necessary. Packets that are not forwarded are *filtered.*

Realizing that a standard communication protocol is needed for cable TV based broadband communications networking, the IEEE 802.14 working group was formed.[v]

The 802.14 protocol will define multiple physical layer protocols, a MAC layer protocol, cable topologies supported, and other criteria.

CABLE DATA NETWORK MANAGEMENT

Largely due to the decentralized nature of the Internet, there is no central network management. Each IP network is responsible for managing itself. Out of necessity, evolved a common technology used to manage the individual components of the Internet, which, like many other protocols originated for the Internet became adopted as the standard for non-Internet networks as well.

This management framework is called *Simple Network Management Protocol (SNMP).* SNMP evolved from the *Simple Gateway Monitoring Protocol (SGMP)* which was designed for monitoring IP gateways in wide area networks.

SNMP is the defacto standard for network management today. By using SNMP network management, cable Internet brouters and bridges are fully integrated with the network management of all of the other IP networks on the Internet.

SNMP allows the collection of network statistics from widely diverse network components by defining the minimum amount of information that each IP device should provide, via a structure called the *MIB (Management Information Base).* An SNMP *agent* is the software which interfaces between the MIB and *the network management station (NMS)* and processes all of the MIB and management requests and responses to a device. It uses the SNMP protocol to package the request and responses.

In a cable bridge or Internet brouter, the implementation of an SNMP agent supports MIB II objects (an extended MIB to cover different types of network devices) and includes proprietary extensions to the MIB for management of cable TV objects. Also included are the UDP and IP protocols required to exchange SNMP packets with a network management station.[vi]

It should be noted that these network management capabilities offer cable operators an added benefit by providing additional information for troubleshooting the physical cable plant and thus improving reliability of the entertainment network as well.

CABLE DATA NETWORK SECURITY

Once one computer is connected to another, some security risk exists, no matter how slight. It is often said that the most secure network is no network at all. The more connections there are, the greater the risk, and the greater the potential that the network can be broken into by a *hacker.*

Security can have many different definitions, but basically includes the areas of data integrity, user authentication, and privacy.

According to Al Hoover, vice president of information and application services at ANS, there are three questions you want to ask[vii]:

- What are you protecting?
- Why are you protecting it?
- What are you protecting it from?

The most common security risk in a computer network is also the easiest to overlook: password security.

The first level of security planning is also the toughest: ensuring that users do not pick passwords that are easy to guess, such as the names of family members. Password generation programs are sometimes used to inhibit this. Hackers will sometimes use stolen password lists in what is referred to as a "dictionary attack". Another possibility is that the hacker has a password capture program, whereby when a legitimate user logs in, his or her password is "captured" and reused by the hacker. Training users on password security is a key factor in creating a secure network.

For a community-wide Ethernet network connected to the Internet, security is addressed on several different levels.

Closed User Groups

From the community side of the network, security can be provided via a system of *closed user groups*, as implemented in the UniLINK protocol. Using this system, users are assigned to one or more user groups. Ethernet data from one bridge or brouter can only be read by another bridge or brouter if it is a member of the same user group. This system allows multiple users to share the same RF channel, but operate as if they are on different networks, essentially creating multiple *logical* networks on one *physical* network. Schools could be on one logical network; hospitals, medical centers, and doctors' homes on another, and a business and its telecommuting employees on a third.

Filtering, Authentication, and Scrambling

Security is also provided in a community Ethernet network via features such as IP address filtering, traffic type filtering, broadcast and route filtering. In addition, built-in security features, including user authentication and passwords are provided to prevent tampering with the cable TV receive and transmit frequencies.[viii] The fact that the data is modulated using QPSK and the data is scrambled using changing seed patterns means that it would be extremely difficult to decode.

Firewalls

One security device often used in corporate networks is a *firewall.* A firewall creates a safety mechanism whereby all traffic on the network must pass through the firewall computer, and only authorized traffic is permitted to pass. A firewall can be between two private networks, or between a private and a public network, such as the Internet.

Application-Layer Gateway

Another security option is an application-layer gateway. With an application-layer gateway, the user is not directly connected to the Internet, although to the user it appears as if he is. The gateway actually executes the user commands. The gateway can also examine the source and destination address and commands entered. A user accessing the Internet must pass an authentication process to gain access through the gateway. The gateway can also be set up to prohibit a user from using certain commands which could pose a security risk to the organization.

Tunneling

One risk to firewall security is the practice of *tunneling*. Tunneling can have positive uses, or can be used to circumvent security. Tunneling refers to the practice of encapsulating a message from one protocol in another, and using the facilities of the second protocol to traverse some number of network hops. At the destination point, the encapsulation is stripped off, and the original message is reinjected into the network. In a sense, the packet burrows under the intervening network nodes, and never actually sees them. There are many uses for such a facility, such as encrypting links and supporting mobile hosts.[ix]

REGULATORY ISSUES

The legal and regulatory environment in the cable and telco world, coupled with the growth of data networks like the Internet, has created the need for major reform in telecommunications policy in the US, Canada, and countries around the world. The regulatory environment is politically complex, and the need to relax existing cable and telco regulations in order to build a global information infrastructure is recognized.

The Internet, on the other hand, is currently unregulated. This is in keeping with the fact that common carriers are considered natural monopolies, and therefore are regulated, but services provided over common carriers are not. This regulatory policy is not consistently administered, however, since services provided over telco lines are regulated. This has caused some public interest groups to call for similar regulatory requirements for the Internet.

The issue of universal access is also integrally tied to the debate over regulation of the Internet. The concern is that the Internet not create a society of "haves" and "have nots" on the global information infrastructure. The current thinking is that a certain level of "basic service" should be available to all citizens for a modest fee. But the debate rages on as to what defines "basic service" and how to subsidize such universal access.[x]

Given the high "public good" quotient that such networks bring to municipalities, schools, and the general citizenry, in addition to businesses and for-profit enterprises, it is unlikely that government regulatory agencies will regress into imposing a stricted-regulated environment that would hinder the growth of the national information infrastructure.

COMPARISON OF INTERNET ACCESS OPTIONS

The term "Internet access" is often used as if there is only one type of access available. In fact, Internet access runs the gamut from low speed dialup access to high speed dedicated network access. Below are some of the primary alternatives.[xi]

Dedicated Access

Dedicated access is appropriate for institutions and businesses who want to be hooked up to the Internet. For dedicated access, the user needs:

- a dedicated leased line (56 kbps or faster)
- a router

This kind of connection in the US costs at least $2,000 initially, with monthly fees starting at $1,500 per month to much higher charges as line speed increases. Dedicated access allows all computers, and all users on a Local Area Network (LAN) to connect to the Internet through the router. It allows users access to the full functionality of the Internet. Because of the cost of a dedicated connection, this is not a practical option for home users.

SLIP and PPP

A less expensive option is to use standard phone lines and high-speed modems, and connect to the Internet using the Serial Line Inter-net Protocol (SLIP) or Point to Point Protocol (PPP). For dial-up access, the user needs:

- SLIP or PPP software
- a high-speed modem (V.32 or higher)

With SLIP and PPP, the user has full access to Internet resources, but saves on the high connection costs of a dedicated leased line. With these options, the user is actually "on the Net", as opposed to accessing it through another system. They are suited to connecting an individual or home user to a larger LAN, which has dedicated access to the Internet. This solution is not appropriate to connect a network of any size to the Internet, due to the line speeds.

The connection to the Internet is provided by a national or regional access provider. A provider like PSI or UUNET charges about $250 per month for unlimited SLIP or PPP service; alternately, there may be a lower monthly charge, with an additional hourly fee. Service providers may supply 800 numbers or local access numbers in major urban areas to minimize telephone costs.

Dial-Up Access

The low-end option for Internet access is a simple dial-up connection to a computer which has dedicated access. For dial-up access, the user needs:

- a terminal emulation package
- a modem

In this case, the user is not really "on the Net". The advantages are the it is cheap and easy to set up. The disadvantages are that the user may not be able to access all Internet services, and is dependent on the service provider for services and disk space. The user may also have to pay the phone charges, if 800 numbers or local access numbers are not provided.

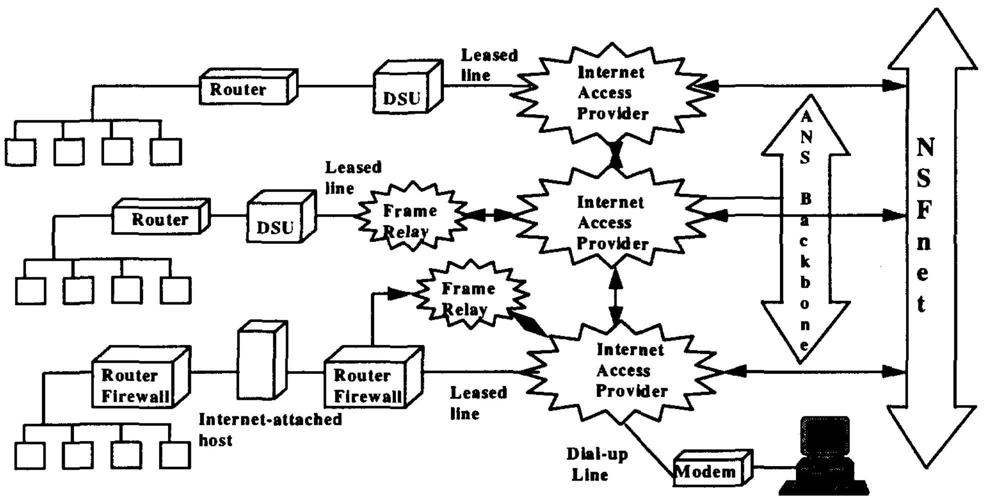
The cost of service is typically $20 to $40 per month, (possibly with some additional per-hour access fee). The cheapest rates apply if you contract for "off peak" service only (i.e. nights and weekends.

Cable TV Internet Access

The advantage to the user of accessing the Internet via cable TV is that he does not need his own leased line in order to get high-speed 10 Mbps access to the Internet. In the past, these speeds, since they required a dedicated leased line, were out of reach for all but large corporations. By connecting businesses, institutions, municipal offices, and home users into a community wide network over cable TV, performance can be improved by three orders of magnitude while cost is reduced.

COMPARATIVE INTERNET ACCESS SCENARIOS

This section depicts several typical Internet access scenarios and compares and contrasts them with Internet access via cable TV.



Source: Data Communications - April 1994

Figure 1 - Corporate Connectivity to the Internet

Telco Models

One typical method for corporate connectivity uses a router and *Data Service Unit (DSU)* to tie directly into an the Internet Service Provider's network. A methodology called *frame relay* can also be used for this purpose. Figure 1 shows a typical scenario for connecting corporate users to the Internet. In this scenario, the remote or home users can log on via modem and dial-up line[xii]

Typically, corporate users access the Internet via leased lines. The company buys one or more leased circuits that connect one or more routers at the customer premise to a router at the Internet service provider's site. Available line speeds range from 56 Kbps to 45 Mbps (T3). The Internet service provider may supply the router at the customer site.[xiii]

Pricing for such services vary. One Internet service provider, Uunet's Alternet, has pricing which begins at $795 per month for a local 56 kb link, T1 starts at $1,250 per month.[xiv]

One key point is that the customer, and not the Internet service provider, is responsible for procuring the leased lines.

Another option that may be used by small companies, who do not need the high bandwidth that leased lines provide, is frame relay. PSI and Sprint, for example, offer frame relay services. In this scenario, users need a router with a frame relay interface and leased line to the Internet Service Provider's point of presence (POP). In this case, unlike leased lines, customers only pay for the bandwidth they actually use.

PSI's Interframe includes a router and frame relay DSU installed at the customer site. Committed information rates (CIRs) - the maximum average speed of the connection - range from 56 Kb to T1. PSI's prices start at $400 a month and extend to $3,400, depending on management and equipment. Sprint offers a zero-CIR service (no maximum average speed) that allows for bursts of traffic at up to T1 for a flat rate of $400 per month.[xv]

The Cable TV Models

There are multiple alternatives for the configuration of Cable TV networks which offer Internet routing.

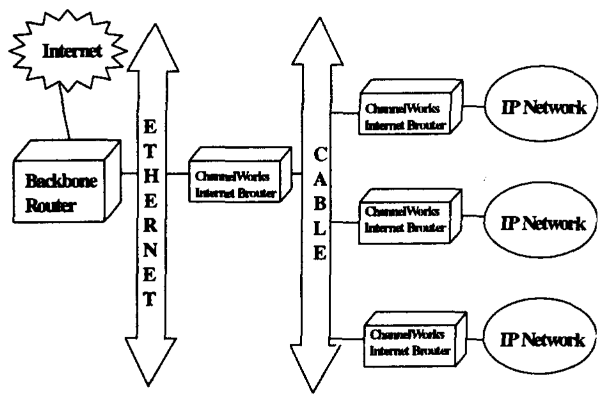


Figure 2 - Multiple IP Networks on a Cable Network

Figure 2 shows multiple IP networks on a cable network connecting to the Internet using Internet brouters. In this scenario, there are multiple IP Networks on each cable network. This is a practical scenario for a community which includes multiple IP addresses which requires IP routing with cable TV connectivity. In this scenario, each site could have its own IP network, and each would have an Internet Brouter. Each site would have its own IP address space, and its own IP administration. The security firewall would be at the brouter at each site. This scenario would allow for increased security, ease of management and administration, expansion (the ability to add more sites/IP networks), plus freedom and ease of communication.

A second scenario is having a single IP network on each cable network, as depicted in Figure 3. In this configuration, the entire cable TV network using the bridges will be a single IP network. In this scenario, all sites would share the same address space, and would have common IP administration. The security firewall would be at the single router entry point, and there would be no IP firewalls between sites.

This implementation might not be practical for a city with multiple businesses and institutions using the same network, and would require coordinated management of IP addressing for all of the users.

Ultimately, in a third scenario, multiple cable TV networks could be connected together as an IP network over a WAN, via a long distance carrier such as MCI or AT&T, or a Competitive Access Provider (CAP) such as Teleport. In this scenario, the Cable TV networks could either be bridged or routed.

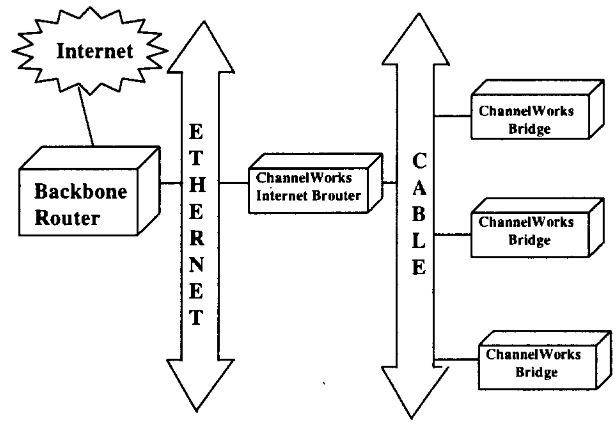


Figure 3 - Single IP Network on Each Cable Network

CASE STUDIES

Electronic Commerce Network ECnet - Phoenix, Arizona

ECnet was one of the first data networks set up over cable television. The network was developed as a collaboration between Times Mirror Cable Television, Digital Equipment Corporation, and Arizona State University. ECnet connects together manufacturing companies in the Phoenix area for the purposes of concurrent *Computer Aided Design (CAD)*, video conferencing, *electronic whiteboarding*, and access to the Internet. Companies using the network include McDonnell Douglas, Tempe Precision Aircraft, and Modern Instruments.

The backbone of the ECnet network is a 100 Mbps *FDDI* (Fiber Distributed Data Interface) fiber ring, which connects four headends. Connected to each headend is a community Ethernet network, comprised of one to three companies. Each company site itself houses its own LAN, which may be comprised of hundreds of users. Bridges are used to connect the LAN sites to the community network.

The physical media in the network include dedicated fiber in the backbone, shared AM fiber for the headend trunks, and coax. The fiber ring is supporting distances as great as 36 miles between headends, while the longest fiber/coax headend trunk extends over 15 miles to a customer site. The network operates downstream at 336-342 MHz, and upstream at channel T8 (11.75 MHz - 17.75 MHz).[xvi]

Access to the Internet is provided by Arizona State University. Security is provided which includes 24 hour/7 day monitoring, file encryption, protocol monitoring, automated alerts, and lockouts.[xvii]

Hawaii Public Schools

The Hawaii public school district includes 360 schools located on six islands. This unique geography has perhaps contributed to the Hawaii Department of Education being on the leading edge of networking technology.

Oceanic Cable, a Time-Warner subsidiary, Digital Equipment Corporation, and Convergence Systems, Inc., a Digital reseller, have collaborated on the Hawaiian school network.

The Hawaiian schools original network consisted of a T3 (45 Mbps) microwave backbone, 28 T1 (1.5 Mbps) leased lines, which didn't meet the needs of the school system. "Leased lines are expensive and they don't really provide us with the bandwidth we need for the applications we'd like to run on the network. We needed a high-bandwidth, high-speed network. With the telephone company, that would have meant a T1 line for every school, which would have been very expensive", said Kyunghak J. Kim, director of network support services for the state of Hawaii's department of education.[xviii]

Hawaiian schools are using the Internet for collaborative learning with schools on the mainland, accessing images from weather services, maps, and information from libraries and universities. "The main thing ChannelWorks™ has provided students is the ability to effectively communicate with other students in other parts of the country and the world, and the capability to access resources available in other places," comments Kim. The ChannelWorks solution has sped up Internet access considerably at Hawaii's schools: sending a message from the University of Hawaii to the mainland and back can now be completed in seven or eight seconds - which is 100 times faster than what was possible on phone lines.[xix]

HOW TO SET UP A COMMUNITY ETHERNET TO INTERNET NETWORK

Setting up a cable television network for Internet access involves both business and technical issues. To begin, a business case must be completed, and the scope, schedule, and budget for the network must be defined. A project team, project manager, installation team, and site contact for each site must be identified, and a project plan prepared.

Network Planning and Design

The next step is the network design and network map. The design must include network layout, site locations, amplifiers, channel assignments, network components, leased lines, etc.

The basic requirements to set up a community Ethernet to Internet network are:

- one forward and one reverse channel
- one bridge or brouter per site
- one translator at the headend (not required for a dual system)
- diplexors (either sub-, mid-, or high-split)
- an Internet point-of-presence (i.e. access to a backbone router on the Internet) either via one of the user sites on the network, or via the headend

Several decisions need to be made during the network planning phase, including:

1. Which sites will be in the same Closed User Groups?
2. Which sites will be on the same IP network?
3. What are the security and firewall requirements, and where should firewalls be located?

4. Where will the connection to the Internet be located? Will it be in the headend or at a user site?
5. If the Internet connection will be at the headend, who will install and manage the connection?
6. Who will procure, assign, and manage the IP addresses?
7. Who will secure the leased line connection to the Internet Service Provider? What line speed is required? How much will it cost? How will it be paid for?
8. Who will manage the data network?
9. Who will supply help desk support? What is the problem reporting procedure? What are the service hours? What are the problem escalation procedures?
10. What is the monthly service charge? What are the billing procedures?

The services of an Internet consultant or Internet Service Provider, particularly one who is familiar with cable television, may be helpful during the network planning and installation phase of the project to help answer these questions and devise the network plan.

As early as possible in the project planning, a certification of the cable plant should be done. The certification of the cable plant is an important first step. A detailed checklist is used to ensure that all requirements are met so that the network will function properly.[xx]

The first requirement for the network is that one forward and one return channel must be allocated for the network. The transmit frequency range is 10 to 174 MHz. The receive frequency range is 54 to 550 MHz. The plant must be two-way, with two-way amplifiers installed and activated, drops must be installed to all sites, and the channels to be used must have no ingress, extraneous carriers, or other signals in either channel. At this phase a 24-hour sweep on both channels is recommended to make sure there is no time-related ingress on either channel.

Network Installation

When the above steps are completed, the sites are ready for the installation of the networking equipment. At this phase, a backbone router and a leased line are installed at the headend, if required.

Network Management

Network management may be supplied by the cable operator or a third party. As a network grows in size, so does the need for network management. The plans for network management should be put in place during the planning and design phase.

CONCLUSION

The capacity of the Internet will continue to grow, as will the user systems connecting to it. Multimedia and client-server based applications, such as digital libraries, telecollaboration, concurrent engineering, and visualization will proliferate. Multicasting, taking video or audio material, digitizing it, and sending it over the Internet, will benefit greatly from cable. Videoconferencing over the Internet to the home PC or to the desktop will become possible. Cable TV can make high speed access to the multimedia Internet of tommorrow a reality today.

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