TELECOMMUNICATIONS TECHNOLOGIES IN DISTANCE LEARNING

Prof.Dr. Don Flournoy
Ohio University
College Of Communication

I. Introduction

Arthur Clarke, the father of space communications, asserts that the problems of communication today are not technological. They are economic and political. "It seems to me," he said in a satellite-based interview at CNN, "we can already do almost anything we want technologically. What is holding us back (in terms of a more equitable information society) is money and political will."(Arthur Clarke, 1995)

Clarke is right. Given financial resources and political will, great strides can be made in applying technologies to the solution of societal problems, including problems in education. Even with little or no money and only modest cooperation or support from governments, many things can still be done to impro ve access to education and enhance the quality of the educational experience. But it helps us to understand what technologies are out there, whether we can afford them or not, for the mere existence of a tool shapes how we think about the possible.

In the toolbox of distance educators today there are many options.These include tools for transmitting educational programming to al most any point on the globe or for distributing information only within a school district or building.

Educators now have the capability to transmit from a single site to many receivers, or only from point to point, as in one desktop to another. Such transmissions can be one-way or they can be interactive. They can be synchronous, that is, they can be live, direct and in real time or asynchronous, to be responded to later.

They can be symmet rical, with an equal volume of voice, video or data information going both ways, or asymmetrical, in which a greater volume of information travels in one direction and a smaller volume travels in the other.

Teaching at a distance can be instructor-controlled or learner controlled, or a combination of the two. Educational materials can be pre-produced, packaged for high-impact with carefully considered educational/entertainment value, or generated on-the-spot, as with Web searches and creative problem solving. Thus, the cost of preparing educational materials and the lease or purchase of the channels by which they will be distributed can be quite expensive, or quite modest. How does today's educator know which technologies should be included in the distance teaching toolbox? How does one know which are the right tools for the particular educational need? What follows is a brief examination of a wide range of telecommunications technolo

gies with special attention given to those most likely to impact educational access.

II. Media For Communications

Which technologies of telecommunication are best suited to distance teaching? What do these technologies have to offer? The tech nologies we first think of are those we have traditionally used for this purpose: radio and television broadcasting, satellites, cable television, computer communications and the Internet. We also think about the portable media such as tape and disc. But, what we now realize is that all these technologies are rapidly evolving. Not only are their capabi lities undergoing radical transformation, everything in the toolbox is becoming increasingly interconnected, interoperable and interdepen dent, the result of digitization. Technologies of telecommunication today are becoming more po werful partners for distance teaching not just because education demands it but because these same technologies are demanded by the consumer market in general, which will insure that they are afford able. The future promises that these technologies will be more acces sible to all persons, whether at home, school, work or on the road, and they will be more robust, more interactive, more userñfriendly, more responsive to individual interest and need.

Broadcasting Technologies

Radio/Television: Open broadcast technologies have long been used to deliver instructional programming to schools and colleges located within reach of radio and television stations. These same over-the-air technologies have also been used to reach learners in homes and businesses.

For many years, AM/FM/shortwave radio and VHF/UHF TV stations have successfully addressed the educational needs of home schooled pupils as well as those in public and private schools. Community development programming has also been directed at the general public to teach them about their heritage, building pride in local history and culture, encouraging them to greater tolerance, as in appreciation of the needs of the handicapped, or to give practical information such as how to purify water.

Public broadcast stations such as the BBC in the United Kingdom, the NHK in Japan and the CBC in Canada, have broadly defined educational and cultural missions, often to include the mission of providing formal instruction directed at the schools. This is a common function of broadcasting the world over whe re stations have helped local organizations reach their audiences with public service messages, helped high schools to expand their curricula and helped universities to target underserved segments of the community.

Although the oneñway transmission of information from station to individual receiver provides no easy way for the listening and view ing

audience to talk back, this lack of a feedback channel is not a li mitation for many educational applications. The broadcast media, whether radio or television, are uniquely suited to capture attention so that information can be provided. Gifted teachers and content experts with specialized knowledge can be made available to a mass audience. Classroom teachers, community leaders and parents don't have to be knowledgeable and expert in all areas.

DAB/DARS: A new form of radio, known as digital audio broadcasting or digital audio radio service, will be available in many parts of the world by 1999.

Whereas conventional AM, FM and shortwave radio signals have been delivered from terrestrial transmitters using analog waves, nextøİ □□ İgeneration radio will be digital and much of it will be picked up from the satellite. In Europe, terrestial DAB stations are already transmitting highñquality digitally-encoded audio signals to both fixed and mobile radio receivers. The potential of digitally transmitted radio will be quickly seen by educators.

With digitization, radio provides a very high quality audio signal at low cost to both sender and receiver. And one of the unique capa bilities of the satellite is that it can reach widely dispersed popula tions, as with indigenous language programming for cultural groups located outside their home country.

Beginning in 1998, WorldSpace Inc., a Washington D.C.-based satellite radio company, initiated an internationally-oriented DAB service which will soon be capable of reaching as many as 80 percent of the people on Earth, focusing principally on developing nations. Three WorldSpace satellites will transmit 100 or more channels of music, news, entertainment and educational programming from multiple providers. (Castel, 1997, p. 14)

The company estimates that 180 million people will buy the specially designed digital handñheld radios at $100 apiece within the first 10 years of service. (Saunders, 1996, p. 26) Radio receivers will operate in the L-band (1467-1492 MHz), but will also be equipped for tuning standard AM, FM and shortwave radio reception. Digital fax, e-mail and messaging services will also be available through these receivers.

DTV/DVB: As in audio, major changes are about to occur in television broadcasting. The European version of digital television is called DVB which shares the same objective as the North American DTV: to provide better sound with higher-resolution pictures on a wider screen. But DTV/DVB promises much more. As a data distribution system in which audio and video signals are treated as bitstreams, the new digital television opens the door to entirely new approaches to management of content, whether entertainment, information or education. Since the world of computing and personal computers are bridged to broadcasting and TV sets, TV transmitters can be used to relay multiple streams of information at varying data rates, setting the stage for a new age of

transactional Internet and on-demand video, audio and data services. (Spring, 1998, p. D1)

There are several ways in which this can be done in a broadcast format. One is the upgrading of an old technology, teletext, in a digital format. WavePhore Inc. has been awarded a patent on a data broad casting technology which inserts and transmits high-speed digital data over an analog television signal using the vertical blanking interval. The VBI service takes advantage of the electronic space between the visible pictures to send data to home computers equipped with TV tuners. In the United States, the FCC permits broadcasters to utilize the VBI technology to transmit ancillary data to home or businessñbased personal computers or to provide enhanced services along with their broadcast signals (TV Technology, 1997, p. 6). In the United States, the Public Broadcast Service has inaugurated a National Datacast Service, called The WaveTop Channel, to use the transmitters of 265 PBS affiliated stations to reach more than 99 percent of TV households (TR Wireless News, 1997, p.4). One advan tage of this approach is that the data doesn't travel over the Internet, therefore providing a more secure environment for children (Taylor, 1997, p. 27) .

IVDS: The Interactive Video and Data Service is a new return path for broadcast TV programming, approved for FCC spectrum auction in 1994. IVDS receiver/transmitters go into homes, schools and businesses in the form of setñtop boxes. Each box hosts a wireless radioñfrequency modem and remote control through which customers can interact with the transmitting station. Cell-tower receivers located throughout the broadcast area gather signals from interactive video users and relay them directly to the station or via satellite to a central collection point.

The IVDS technology is seen as a way to give added value to the TV broadcasts of local stations. With the prospect of a viable con sumer-to station return path in the local market, IVDS will be an option under consideration as the newly installed DTV/DVB television stations look for new ways to increase interactivity and exchanges among their digitally-equipped audiences.

III. Geo/Leo Satellite

Satellites are already well-established distance education tech nologies Communications satellites located in geosynchronous orbits 36, 000 km above ther equator are serving as wide coverage receivers and retransmitters for a variety of educational applications.

No technology can match the wide geographic coverage of the satellite footprint. Satellite signals can be anywhere or everywhere: local, regional, or global. They can be point-to-point, as with delivery of sales training from corporate headquarters to distant offices, or point-to-multipoint, as with the broadcast of lessons fom a teacher to multiple home-schooled pupils. With

modern satellite technologies, it matters not whether those addressable locations are in homes or hos pitals, in urban areas or rural, on one continent or several. With today's satellite systems users can quickly be brought on-line.

Direct-to-home (DTH) systems can now be installed in a single day and they can be quickly disconnected and moved from one location to another. While truly interactive systems via satellite are not yet a common home product, rapid connection to broadband media services is already a selling point for educational applications in schools and businesses. Education/Training Networks: Several countries including China, Indonesia, Japan and Turkey have established open high-school and university systems which employ satellite. The Open High School ini tiated in 1993 by the Turkish Ministries of Education and Radio/ Tele vision offers both degree and non-degree programs throughout Western Europe. Although satellite technologies have been used, other distance education delivery systems such as broadcast TV, videocassette and printed materials have been the primary media used. (Demiray et al., 1997, p. 5; İşman, 1997)

Japan's University of the Air was begun in 1985 to develop an effective collegeñlevel learning system which could be made available to the greatest number of people in Japan. In the beginning, the UOA used local UHF-TV and FMñradio for distribution of course materials, but in 1995 the Ministry of Posts and Telecommunications recom mended that the Open University program move to a new high-powered satellite shared by Japan's public broadcast station, NHK. This move would interconnect about 50 universities in Japan. (Demiray, 1997, p. 12-15) The Star Schools program in the USA was funded at $100 millionø from 1988-1992 to ensure more equitable access to education. This federal project, administered by individual states and regions, offered a variety of educational opportunities including course instruction in the sciences, advanced mathematics, foreign languages and economics for schools too remote or too poor to provide these subjects. (Krebs, 1997, p. 56-63;)

NewsRoom is a free educational service provided by the inter national news provider, CNN, making use of the Turner network of satellites to broadcast specially edited and anchored news segments to American public and private schools. The daily news feeds, which are made available without commercial advertisements, are transmitted to schoolñbased antennas in the early morning hours, taped on site and made available for social studies and other classes during the day.

The National Technological University (NTU), based in Fort Collins, Colorado, is a private, accredited, non-profit institution of higher education which offers instruction exclusively via satellite. NTU hosts 13 Master of Science degree programs as well as non-credit short courses, to meet the advanced educational needs of busy, highly mobile engineers, scientists and technical managers.These telecourses are transmitted to onñsite locations of

such high-profile companies as General Electric, Intel, Motorola, Hewlett-Packard and Texas Instruments (Manasco, 1996, p. 30) . The NTU network uses MPEG2 compressed-video transmission and addressable receiving equipment which converts analog video to a digitally coded data stream and modulates it for satellite delivery. In 1997, NTU began transmissions aimed at subscribers in Pacific Rim countries. Some 1, 350 working professionals and technical managers were registered in the degree programs; its non-credit short courses exceeded 100,000 students. (Wegener, 1997, p. 102)

Ford Motor Company has set up a private satellite network, FORDSTAR, for communicating with its manufacturing facilities and automobile dealerships. Training of employees is a major function of the network. One-way broadcasts of digitally compressed video information are sent to multiple sites with a return data feed from the students using the One Touch response keyboard, by which both audio and data are relayed back to the instructor in real time. The One Touch technology allows students to register a call asking questions of the instructor and provides the means by which the instructor can collect answers to true/false or multiple choice questions. (Careless,1996, p.26-7) VSAT/TSAT: Lack of interactivity has been a historic limitation for satellite-delivered education and training. Numerous spectaculars have been staged in which two-way point-to-point or point-to-multipoint satellite events, conferences and meetings have been held involving more than one distant site. Except for those special occasions when the high costs can be justified, such opportunities have been too expensive and too technically complicated for on-going operations. With the rapid adoption of the very small aperture terminals (VSATs) in the data distribution business, some solutions to the interactivity constraints of satellite have begun to appear.

VSATs are small (2 meter or less), inexpensive satellite dishes with electronics and software for providing voice, facsimile, and data exchanges among distant points via satellites operating from geosyn chronous orbit. VSATs are principally used by retail chains for credit card verification, pointñofñsale information, and inventory mana gement, such as just-in-time restocking. But they are also used by banks, travel agencies and government bureaus to replace dedicated terrestrial telephone lines with faster, more flexible and more econo mical means of communication. VSAT transactions, such as checking for airline availability, can occur almost instantaneously, exchanging digital data in real time or downloading data to onñsite computers for later use (Bandy, 1996, p. 276) .A typical VSAT communications channel handles 64 Kbps of digital information, which is enough for transmitting text with some graphics capabilities. Higherñspeed VSATs that support the T1 data rate of 1.544 Mbps, sufficient for videoconferencing, are called TSATS. These channels can be leased from VSAT pro viders when the higher data rates are needed. (Katz,1997, p. 115) Because of their ability to provide voice, data

and now video communication of multiple types, VSATS are being used to im prove the economic situation of rural areas. Not only do VSAT terminals allowø businesses to operate in areas where terrestriat communications are underdeveloped or non-existent, there are instances when government and non-government organizations, such as remote hospitals and schools, can take good advantage of the presence of the satellite overhead. One of those applications is telephony; another is inter connection to the Internet.

Internet via Satellite: From the perspective of the home, satellite services have consisted largely of one-way broadcasts of entertainment and informational programming received on big TVRO receive-only backyard dishes to be viewed on home TV sets. This model is about to undergo some changes. Already, it is possible for home, school and small business users in most of the developed nations of the world to subscribe to high-capacity Internet delivered via satellite, with upstream communications travelling by means of telephone modems through local Internet Service Providers. By the beginning of the Millennium, more than one geosynchronous (GEO) and low Earth (LEO) orbiting satellite service provider will be marketing Internet services to residential, school and business users which byñpass the local terrestrial networks.

As with VSAT systems, installation of home subscriber equip ment -the dish, the receiver and computer interface- can be accomp lished in a day or two. With the mass marketing and ready availability of digital DBS services, the costs are coming within reach of users who have a need to download Internet data at faster speeds. Because of its availability, digital satellite now has the advantage over cable modems and digitized phone lines.

Hughes Network Systems, a satellite manufacturer who entered the direct-to-home digital broadcast business with a product called DirecTV in 1994, markets a related home service called DirecPC. Hughes DirecPC takes advantage of the fact that Internet corridors have become congested, and the public perceives the need for a faster channel for downloading large files, especially from multi media-enhanced web sites.The user searches for information via standard modems and telephone lines but any requested information is forwarded to the Hughes server, whe re it is uplinked to the satellite and relayed to the user at 400 Kbps, 15 times the speed of a 28.8 Kbps modem.

David Basham is director of the Navajo Learning Network, a plan to give Internet access to members of the Navajo Nation, a 26,000 square mile Indian reservation within the Western states of Arizona, New Mexico and Utah. Half of households do not have telephones and most of the dialİ □□ İup lines that are available to schools can only handle low speeds, around 28 Kbps. With help from the National Science Foundation and NASA, Basham is installing the DirecPC Network Edition, a satelliteñbased Internet access

product for networked schools and businesses. Basham is putting into place a Navajo Nationñwide network which will enable dial-up connections to the Internet from homes, schools and colleges campuses in remote areas that previously had limited or no access with return path delivery directly from the satellite (T.H.E. Journal, 1998, p. 60)

DirecPC signals are oneñway only. There are constraints to this hybrid satellite/twisted pair telephone line configuration. Customers can order up material from heavily-loaded Web sites and great quantities of text, graphic, audio and video information can be quickly delivered. But were users to wish to send large files, the outpath is likely to be the same slow telephone lines that forced them to the satellite option in the first place. Direct return to the satellite of home or school-originated transmissions is possible but, for the moment, not yet a product for mass consumer use.

Multimedia via Satellite: More than one low earth (LEO) orbiting satellite system is approaching launch. These constellations of interconnected satellites will orbit 500 or so miles above earth mostly providing telephone coverage for business travellers and to those with no access to telephone. Included are Iridium, a 66-satellite system sponsored by Motorola and partners, to begin offering international service in 1998, and Globalstar, a 48-satellite system sponsored by Space Systems Loral and partners, to start up in 1999.

Teledesic, a 288-satellite constellation sponsored by media entre preneurs Bill Gates and Craig McCaw, is scheduled to be operational in 2001 providing on-demand Internet access, videoconferencing and inter active multimedia to both fixed and mobile receivers literally anywhere in the world. Satellite telecommunications can serve areas not yet reached by broadband terrestrial providers or which cannot be coveredø economically using traditional terrestrial infrastructures. These near-Earth orbiting satellite systems, such as Teledesic, are especially suited to providing bi-directional asymmetric services as they offer a very short round trip propagation time, enabling them to more easily share common communication protocols, applications and standards with terrestrial networks.

Looking to the LEO multimedia satellite services under develop ment, it is assumed that anywhere connectivity, providing on-demand delivery, will be seen as an asset for the distance educator.

IV. Terrestrial Microwave

Satellites and terrestrial wireless technologies share many of the same microwave (1 Ghz or higher) frequency bands. The earliest microwave applications were in point to point communications in which bundled telephone messages were relayed on microwave towers bet ween switching offices. Those same towers were used to relay the video signals of networks to

affiliated stations around the country. Now, microwave frequencies are used to connect schools and other community sites for purposes of distance education.

Since 1983, Ohio University has used 14 microwave signal towers to connect its main campus and five regional campuses. The Ohio Higher Education Microwave Services (HEMS) network is an interactive system providing full-motion video and audio exchanges for instruction, contin uing education and staff development and increased access to univer sity resources by business and community members.

As in the Ohio case, operations at both sending and receiving sites of the point to point microwave networks can be controlled by the instructor. Studio classrooms, equipped with cameras, microphones, videotape players and television monitors, can be designed so that it is not necessary for instructors to make major changes in their teaching styles to make maximum use of this distance teaching technology. Even though located in classrooms distant from each other, teachers and students can easily collaborate. Presentations can originate from either site. Using large screen monitors, group discussions can often lead to members forgetting that they are not in the same room. In addition to providing two-way video and audio, the microwave linkages can carry telephony and computer data traffic as well.

MMDS/MVDS: In the 1970s, a block of microwave (2.5ñ2.7 Ghz) frequencies were licensed to inaugurate wireless cable television systems. Called MMDS (Multichannel Multipoint Distribution Service), microwave signals transmitted omni-directio-nally were used to broadcast subscription-based video and other programming to homes and businesses within a 30 to 50 km range. A separate band of frequencies was licensed to school boards, universities, hospitals and other non-profit institutions in a related service called Instructional Television Fixed Service (ITFS). When many of these ITFS channels went under utilized in the U.S., the Government arranged to have many of them made available to the commercial sector to provide local compe tition to the CATV operators.

With the deregulation of the U.S. telephone companies, Bell Atlantic, NYNEX, Pacific Telesis and others invested heavily in MMDS franchises as a way to get quickly up and running as “full service pro viders” in the video and interactive data business. By 1997, however, a major telco programming venture (Tele-TV) had failed and several of its underwriters slowed the buildout of MMDS until a more suitable strategy for approaching the broadband home market was clearer. MMDS has been slow to find its place in the crowded broadcast, DBS and cable markets of the U.S.

Even so, MMDS is a telecommunications technology getting good play in cities such as Beijing, Mexico City, Nairobi, Riga and Moscow. These markets have less competition and it has been found quicker and less expensive to bring wireless cable systems onñline when system startup is little more than

an omniñdirectional transmitter installed on a high tower in line of sight of the small receiving antennas positioned on subscriber balconies or rooftop.

With implementation of digital signal processing and transmis sion, commercial MMDS operators are now in a position to offer local customers multiple channels of broadband media, including an econo mical wireless return channel capable of providing homes, schools and local businessesø broadband access to the Internet.

An upgraded European version of these "wireless cable" services is called multipoint video distribution system (MVDS). MVDS uses the higher 42-43 GHz frequency ranges and has a shorter signal range of 5 to 10 Km as opposed to 30 to 50 Km for MMDS. It offers multiple channels of high-quality audio, video and data, and can target designa ted population areas using directional transmitters and relays. Thus, it is a technology educators will wish to watch for the future.

LMDS/RLL: MMDS/MVDS are not the only broadband wireless options. There is another, colloquially called "cellular TV," approved in 1997 as a local multipoint distribution (LMDS) service. It is designed to operate in the upper microwave (28 and 31GHz) frequencies and will be available for interactive broadband service using interconnected cells in the "local loop." Each transmitter serves an area of 1 to 4 km in diameter, similar to that of cellular radio and personal communications networks (PCS). This is a digital service.

LMDS has been allocated a huge block of spectrum sufficient to provide broadband telephone, video and data services. With its two-way transceiver capabilities, it is a promising medium for Internet access, videoconferencing and PPV cable television. A Pioneer Preference license was granted by the FCC to CellularVision of New York. According to reviews, the digital service performs admirably.

Another wireless option, Radio in the Local Loop (RLL), is a communications technology currently being tested in the U.S. as a broad band alternative to wireline networks. A small number of companies are experimenting with the 38 GHz RLL frequencies for a variety of local communications services. Among the applications of this techno logy, sometimes called Wireless Fiber, are switched telecoms services for small and medium sized businesses and school systems. Some RLL companies hope to become single source local and long distance telephone and Internet providers as part of the nationwide deployment of facilitiesİ□□ İbased competitive local exchange (CLEC) services in the United States.

Not only will the Radio in the Local Loop carriers be looking to serveø as local service integrators for home, school and business customers, they hope to configure the RLL frequencies for distribution of telecom signals within customer premises.

V. Wireline Technologies

Telephone: Every urban home and business in the developed world has access to a telephone. Elsewhere, teledensities are rapidly growing. Telephone is one of the most successful telecommunications technolo gies of all time. It is comparatively cheap, convenient, useful in a variety of practical applications and widely available.

Even before the Internet, telephone lines were probably the single most widely used of all the telecommunications channels by educators. Ancillary devices, such as answering and fax machines, voice and eñmail, and audioconferencing units, are now commonly used in parent-teacher-pupil communications. And because of their ready availability and reasonable cost, telephones are seen as a natural adjunct to broadcast, satellite, cable and other distance education delivery systems.

ISDN: The historic limitation of the telephone has been the modest information carrying capacity of its lines. On twisted pairs, or loops, of copper, the telephone companies managed to carry acceptable voice communications but struggled to do more. In refinements of the cus tomer loop the telcos used techniques for multiplexing its lines back to the central office, but the final drop into the home remained the copper pair.

Analog telephony was later augmented by digital signals, ushering in the digital subscriber line. An early version of DSL technology was Integrated Services Digital Network, a switched high-speed (64 Kbps) data service.

ISDN is now an international telecommunications standard for transmitting voice, video and data over digital lines. (Technology Forecast, 1997, p. 96) ISDN, with transmission rates reaching as high as 1.5 Mbps in North America and 2 Mbps in Europe, is currently being used for applications such as Internet access and videoconferencing.

ISDN is not everywhere available, however, and the costs are comparatively high.With the discovery of faster DSL technologies in the late 1980's, by aø research team led by Joseph Lechleider at Bell Communications Research, the copper outside plant could be transformed into a multimegabit access network. (Flournoy ard Scott, 1998)

ADSL/HDSL: Asymmetrical Digital Subscriber Line (ADSL) and High-speed Digital Subscriber Line (HDSL) are related technologies that permit high bit-rate transmissions over twisted-pair copper wiring. ADSL will permit the customer to transmit to the telephone company at rates of 640 Kbps and the telephone company to transmit to the customer at rates of 1.544 Mbps (T1) or higher. HDSL permits two way symmetric transmissions over two copper pairs for applications such as videoconferencing at T1 rates or higher. (Flournoy ard Scott, 1998)

These DSL technologies are now becoming available for use by local access carriers wishing to enter the broadband access market, which means that

telcos are now in a better position to compete with CATV, LMDS wireless and other operators for some of the multimedia traffic that will center around homes, schools and businesses.

Fiber Optics: As the analog telephone networks and their companion digital subscriber lines have improved in performance, other wireline technologies are being extended in the direction of homes, schools and businesses. The most powerful of the terrestrial tools for transporting infor mation is fiber optics. An optical fiber is a hair-thin strand of flexible glass capable of relaying information in the form of light waves. By converting electrical signals to pulses of laser light and replacing copper wires with glass, literally thousands of channels of voice, video and data can be relayed on a single fiber bundle. By way of illustration, were a 12-volume encyclopedia encoded letter by letter, image by image, into laser pulses and transmitted along an optical cable of 2 GHz capacity, the information would arrive at its destination in approxi mately one second. Were the same quantity of information to be transmitted via a 3 KHz telephone line, the waitñtime would be nine hours.

Because of its unparalleled bandwidth and clean signal, running fiber directly into homes and schools is considered by many an idealø solution. But the splitting off of individual fiber lines carries such a big price tag that no one gives it serious consideration. Less expensive and more practical access networks can be built by extending fiber from the telephone central office to an intermediate point, called an optical network unit (ONU), using the existing copper path for the remaining distance. The portion of the network between the ONU and the central office is often referred to as the digital loop carrier (DLC). When the ONU serves a large number of homes, the access topology is fiber to the neighborhood (FTTN). When the ONU serves a smaller number of homes, it is considered to be fiber to the curb (FTTC) (Flournoy ard Scott, 1998) . All of these are different configurations for increasing the information carrying capacity and reducing the costs of telecommunications.

Internet: One of the reasons for the accelerated pace of DSL and fiber installations has to do with the Internet. Not only are the numbers of persons making use of the Internet growing, but the types of uses are more demanding of the available telecommunications channels. The number of Internet users is said to have doubled each year from 1986 until 1996. Predictions about “the Internet of the future” reveal many expecting to see an Internet which will permit robust searching and downloading of high resolution databases, collaborative multimedia production and distribution, 3D holographic teleconferencing and distance learning, all of which require more bandwith.

The Internet is a great gift for learners. The Internet is a net work of information networks, estimated 50,000 and growing, all interconnected in a way that globally distributed databases and other resources are onñcall to

Individual subscribers no matter where they are. With the introduction of the World Wide Web, in which vast amounts of information are linked, and the development of tools to access and browse the Web, learners can go out and electronically look for information.

Ohio, Duke and Princeton Universities have launched MBA Without Boundaries programs based on the internet. Some 300 colleges and universities in North America, according to Newsweek magazine, now offer virtual degrees, which is Newsweek's descriptor for degrees offered at a distance electronically. Collaborative software which gives students and faculty access to each other, electronic access to learning materials,ø eñmail and the World Wide Web are all components of the two year graduate program at Ohio University.

In President Bill Clinton's 1997 State of the Union address to the U.S. Congress, he said, "To prepare America for the 21st Century, we must harness the powerful forces of science and technology to benefit all Americans . . .(and) we must build the second generation of the Internet". The Internet II project is a collaboration among universities, federal agencies and businesses to augment the Internet for research and education. As of 1998, almost 100 American colleges and universities had signed on to participate in Internet II, a great leap forward for high capacity distance education exchanges (Markulowich, 1997, p. 29) .

The long-distance carrier AT&T has initiated an Internet telephony service, an IP-based (Internet protocol) phone-to-pho ne voice service that weds conventional telephone services to the Internet. As an extension of this initiative, AT&T has introduced a "voice chat" offering which permits on-line PC chatters to connect by phone for voice conferencing. At the same time, chatters can share Web surfing among disperse participants. By merging the established phone network with the IP networks, multiparty communications is made much simpler. (Trager, 1998, p. 14)

CATV: The cable companies have decided they are in a good position to compete with the telephone companies for the honor of owning the most important wire entering the home. They have a much broader channel already in place and would like to do more with it than deliver TV programs. With digitization and a favorable regulatory environment, cable operators are now looking to reconfigure their coaxial lines and add fiber to the neighborhood so they can become "full service providers" offering not only interactive TV services, but Internet and telephony.

This has not been an easy goal to achieve, however. The key to the new interactive cable services is a high-speed digital modem, or setñtop box, which can manage digitally compressed program delivery, video on demand, higher data access speeds and Internet Protocol (IP) telephony. Cable personnel lack experience in the world of data communications or with telephone, which are

more exacting than video. Also, laying new cable and investing in and installing a new genration of setñtop boxes forø every customer in the system is an expensive proposition. Given an industry-wide lack of assurance that home-owners really want all these new services and are willing to pay additional fees to have them, cable operators are on-again off-again in their system conversions.

A number of cable channels are targeting education-oriented subscribers. Mind Extension University (MEU), a cable channel based in Englewood, Colorado, is doing for education what ho me shopping has done for the retail industry. MEU, which began cablecasting in 1987, reaches some 23 million homes and is carried by 767 cable systems. MEU also sends videotaped courses to people without cable access. Students can take interactive high school courses, complete baccala ureate degrees, or even earn master's degrees by watching cablecast or videotaped courses from Colorado State University. In 1993, more than 36, 000 people got academic credit for courses taken through MEU (Piirto, 1993, p. 6)

Discovery Channel, CNNfn and others have active Webñsite ser vices which take a television approach to Web content offering onñline courses, filling in background on news stories and providing all sorts of information thought to enhance their TV programming.

VI. Computer Communications

E-Mail: The convergence of computers and telecommunications has stimulated entirely new forms of student/teacher relationships. The advent of programmed learning enabled students to develop mastery over educational material sitting in front of computer workstations following lessons prepared for them. E-mail allows students to log onto computer networks at their convenience to access lectures, read assignments, deliver completed homework or to interact with teachers and fellow students. These can be selective interactions when needed from either side. For students off-campus, the technique provides a way for them to particpate in campus activities, including group projects, while carrying a full time job or attending to family responsibilities.

One of the largest private universities in the United States is a virtual university. The University of Phoenix enrolls some 31,000 students. This university is located in Phoenix, Arizona and on sevenø satellite campuses, including one in Puerto Rico, but classes are accessed on-line, thus students are less constrained by time, place or distance. The majority of students are employed concurrent with enrollment. (Sasson, 1997, p. 13) According to John Stinson, former Ohio University dean and architect of the University's MBA Without Barriers degree prog ram, “The movement to dispersed learning using information technology has significant implications for libraries. It

doesn't mean that libraries will become less important, rather they will change in form and function. The library will no longer be a place; it will be a process. Students will need to perform research, collect data, read reports, but in the main they will not travel physically to a library to perform these functions. Rather they will travel electronically. This means that there is still a need to collect information, to catalog it, and to develop efficient means for students and others to access information. The information will be stored in digital form, however, and accessed using information technology (Stinson, 1997) .

Computer Conferencing: With the addition of audio and video to computer communications, conferencing no longer need consist only of asynchronous text exchanges. Internet-delivered conferences can be live with pictures and sound, though not always with full-motion video and not the clearest of audio.

Such meetings can originate from the desktop or from more elaborately-equipped rooms linking one instructor to one student or a group of instructors or a group of students. (Communications Industries,1998,p. 27) ome say computer-based videoconferencing, whether from home, school or business, will become as common as use of the fax machine (Communications News, 1997, p. 20) .

Electronics manufacturer Sony has developed a collaborative workgroup system which has all the basic elements of faceñtoñface workgroup meetings including highñquality videoconferencing, data sharing, fullñmotion video and audio with monitor. Such systems are designed to operate over the faster telecommunications networks, such as the ISDN, ADSL, Ethernet or fiber lines being installed in corporate intranets. (VCommunications Industries Repore, 1998, p. 27)

Data Storage and Retrieval: As telecommunication channels get wider, each accommodating faster and faster data transport speeds, storage andretrieval technologies also have to race to keep up. Computer performance is to some degree determined by how long it takes to access memory. So, we can improve microprocessor speed and channel through put all we want, but unless memory capacity and speed is able to keep pace, the whole system slows down (Steinberg, 1996, p. 72) .

The problem is one of finding cheap and convenient warehouses for the data we create and getting easy access to that data when we need it. Videotape is still the most costñeffective medium for quality video and audio storage. Now that we are in the digital era, the new tape formats are also digital. But videotape is a linear medium and access, in other than a linear form, is slow. CD-ROM, on the other hand, is a laser-read random-access medium that viewers can use to either view materials linearly, or skip quickly to new topics of interest without the wait of winding forward or back.

CD-ROM is an inexpensive but high-capacity disc, in appearance similar to the CD audio disc, used to store text, data and other digitized information. It is an optical, not magnetic, storage medium with huge capacity, up to 700 Mb of data equivalent to 300,000 pages of text. The forerunner of interactive multimedia, the CD-ROM enabled the viewer to be more of a participant.

Digital Versatile Disc (DVD), sometimes called Digital Video Disc, is an even higher capacity storage medium, holding up to 17 Gb of digital data on a single side. Although it is being promoted as a new distribution medium for movies, it will also have educational uses. DVD, as a result of its capacity, will be able to provide multiple lan guage tracks along with its video programs.

Pre-recorded programs will play linearly on DVD-ROM equipped computers or on standñalone players, or can be accessed selectively.

To enhance correspondence study, CD-ROMs have been used to supplement the text materials of registered students. An example is the CD-ROM produced to accompany the Sign Language course for parents and teachers of deaf children. Signing, the making of hand signs to form words, can be shown in full motion video clips, paused and and repeated effortlessly over and over again until the skills are learned. CD-ROMs are used for many educational and business applications, for games, audio/video augmented encyclopedias and for photographic slide storage, retrieval and display.

The International Communications Industries Association (ICIA) sponsors an on-line service. One of its member services is a distance learning initiative which integrates use of the Internet and CD-ROM thus combining graphics and video with text-based quizzes and self administering tests. The ICIA expects that 3,000 members will complete its on-line training leading to professional certification in 1998. All this training is completed in front of CD-ROM and Internet-capable computers at home or in the office. The Association calculates that its on-line training is $4000 cheaper than on-site training, due to the savings of time, travel and hotel costs. (Fuchs, 1997, p. 3)

The retailer JC Penny concluded in 1995 that sending its mana gers images on CD-ROM was the more cost-effective approach, given rising satellite transmission costs. (Carelless, 1996, p. 27) This is only one of many exam ples in which portable storage media, such as tape or disc, are the simpler and more economical solution to distance information delivery

VII. Utilities

It may be surprising to many to learn that utility companies are entering the telecommunications business. The U.S. Federal Communica tions Commission in April 1996 announced that it had granted a public utility freedom to enter the telecommunications market. The specific request came from a Dallas, Texas-based company to partner with cable companies. Its

plans were to provide utility communications and demandñside management services to its affiliated electric utility companies and their customers. But it expressed intention to enter the market for cable television, telephone service, security systems and “future services” such as home shopping" (Pottinger, 1996, p. 53) In June 1996, American Electric Power (AEP) announced that it would invest in Interactive Multimedia Network fiber optic projects to be built in two cities in Ohio reaching almost 100,000 residents. The network would deliver cable TV, local and long-distance phone services and high-speed data transmission. (Communications Industries Report, 1996, p. 50)

But what is more surprising is the December 1997 announcement of U.S.ñowned electricity company Norweb, partnered with the Canadian commmunications giant Nortel, that they had uncovered a way to chan nel phone services along electricity cables. Until now, the drawback to delivering telecom services on the power grid had been the interference created by electricity. In solving this problem, Nortel said that it now had the ability to pass data at very high speeds down standard power lines.

The result of the Nortel breakthrough led to a test of the techno logy with a school in Manchester, UK. Twelve personal computers were connected to the Internet by way of the power line, all operating concur rently from just one connection, from which they obtained continuous access at speeds of up to 1 Mps. Managing Director of Norweb Communi cations, Mark Ballett, was quoted as saying, “This is the first of many schools we expect to be connected to the Internet using powerline connections.

VIII. Hybrd Systems

In the educators' toolbox are many options for improving student access to learning and for enhancing the quality of the educational experience. No one solution serves all, so choices must be made among those that are available, most suitable and affordable. The trend is toward adoption of hybrid technology systems which incorporate more than one telecommunications medium to maximize impact, inprove efficiency and reduce cost.

Many current examples point to combina tions of broadcast, cable, satellite, computer and storage technologies being integrated into a single system. Of all the technologies under use today, the Internet is proving to be the most promising for education. One reason is its ability to successfully partner with other media.

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