TELECOMMUNICATIONS PRIMER

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A description of modern telecommunications devices which can be useful in inter-library communications, including their capacities, types of signals and carriers. Described are telephone lines, radio broadcasting, coaxial cable, microwave and communications satellites.

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As greater emphasis is placed on the development of regional and national library network programs to facilitate interinstitutional services, a concommitant requirement emerges to understand and apply communications technology. A great variety of communications methods has been used for interlibrary communications in the past, ranging from the simplest use of the U.S. mails up to the telephone, the teletype, the radio, and even experiments with microwave telefacsimile transmission.

Of all the different kinds of equipment used by libraries for interlibrary communications, the one which has received widest acceptance for its practical value and immediate usefulness is the teletype machine. The earliest use of the teletype machine can be traced back to the Free Library of Philadelphia, which in 1927 used the teletype as part of a closed circuit system for communicating book information from the loan desk in the main reading room to the stacks and vice versa. Following World

War II, an installation connecting distant libraries was established in Wisconsin between the Milwaukee Public Library and the Racine Public Library.

Racine's limited collection was considered inadequate to the demands of its patrons and its Director, instead of increasing the book budget significantly, negotiated an access arrangement with the larger collection at Milwaukee via teletype. Daily messenger service was instituted between the two libraries to effect pickup and delivery of library materials.

The teletype machine enabled the two libraries to have the speed of the telephone with the authority of the printed word. This advantage continues today and can be considered mainly responsible for the proliferation of teletype communications for interlibrary loan. Teletype communications between and among libraries are beginning to emerge in both informal and formal network configurations. In addition to its obvious application to interlibrary loan, teletype has also been used to augment library holdings on a reciprocal basis, to provide for general communications with other libraries, to serve as a channel for querying union catalogs, to accommodate reference questions and services, and to handle internal communications.

Perhaps the most important benefit to accrue to users of library teletype service is the ability to communicate immediately with any other teletype user anywhere in the world. Thus, it becomes possible for any participant in the teletype network to communicate reference inquiries to information points outside the formal network. (A classified teletype directory exists which lists library subscribers in the United States and Canada.) As reference demands increase, it is likely that libraries will begin to make wider use of the teletype machine even though it may have been acquired initially for a more limited purpose. In addition, expanded uses in the future are a virtual certainty both because of the low cost of teletype operation and because of the technical improvements in the equipment itself.

Although the advantages of other means of telecommunication have been known to libraries for many years, their utilization has been retarded by problems of cost and systems planning. However, in recent years, as libraries have made greater use of computers and as they have moved towards new programs of interlibrary cooperation and resource sharing, interest in telecommunications in general has grown more intense.

The purpose of this article, therefore, is to provide a brief explanation of the fundamentals of communications technology in order to establish a basis of understanding for current and future library planning.

TELECOMMUNICATIONS CAPACITY

Telecommunications may be simply defined as the "exchange of information by electrical transmission over great distances." For the past forty years, the United States, through its commercial carriers, the Bell Telephone System and Western Union, has built an increasingly effective system of wires, trunk stations, and switching centers for the transmission of human speech from point to point. The telephone network is a technological marvel despite the occasional busy signal one gets on the line. However, with the increasing use of computers and television in science, business, and industry, this network is being asked to carry digital and video signals in addition to voice, and its facilities are fast becoming overloaded. In the library field one can observe the trend toward use of machine readable data and non-print materials. These are but a few examples of library data forms that one will wish to communicate between and among libraries.

Voice can be efficiently transmitted over telephone lines, but data, like the digital language of the computer or the video language of the television camera and facsimile scanner, need a broader band-width for their efficient transmission than the narrow-band-width telephone line can provide. Band-width is a measure of the signal-carrying capacity of a communications channel in cycles per second. It is the numerical difference between the highest frequency and the lowest frequency handled by a communications channel. The broader the band, the greater the signal transmission rate. The tens of thousands of bits which make up a computer message or TV picture, if sent by telephone, have to be squeezed through the narrow line over a longer period of time to transmit a given message. This consumes telephone capacity that would normally be used to carry other conversations. A good example of the problem can be illustrated with the "picture-phone". This is the telephone company service now being tested which permits a caller to see and hear the other person at the distant end. The two-way picture part of this dialogue requires more than 100 times more telephone transmission capacity than the voice portion. There are 100,000,000 telephones in the U.S. today. Thus, if only 1% of the subscribers had picture phones we would theoretically exhaust our national telephone capacity for any other use.

Fortunately, the problem of telecommunications capacity is not without solution. New channels of communication are being opened that do provide capacity for broad band-width exchange. The new technology of laser communications, for example, stands in the wings with a long-range answer. The word LASER stands for Light Amplification by Stimulated Emission of Radiation. Its theoretical beginnings go back half a century, but fifteen years ago scientists working in high-energy physics learned how to amplify high-energy molecules so as to produce a powerful, narrow, coherent beam of light. This strange kind of light remains sharp and coherent over great distances and can therefore be used as a reliable channel or pipe for telecommunications. All other long-distance transmission systems tend to spread or disperse their signals, but laser beams provide a tight, confined highway over which signals can travel back and forth.

A few years ago seven New York television channels, in an experiment, transmitted their programs simultaneously over the same laser beam. In terms of telephone conversations, one laser communications system could theoretically carry 800,000,000 voice conversations! The intense pencil-thin laser beam is so powerful and reliable that it can and is being used as a communications channel for space exploration. The Apollo 11 astronauts left a laser beam reflector on the Moon's surface to facilitate future communications experiments.

TYPES OF SIGNALS

There are three principal types of signals that telecommunications systems are designed to carry: 1) Audio—originating as human speech or recorded tones and transmitted over conventional telephone lines. 2) Digital—originating with computers or other machines in which data is encoded in the binary language. The data, instead of being represented as zeros and ones, take the form of an electrical pulse or no pulse. 3) Video—originating with TV recorders, facsimile scanners, or other devices which change light particles into electrical energy in the form of small, discrete bits of information.

Each of the three types of telecommunication signals is associated with a telecommunication channel that can carry it most efficiently.

Audio, of course, was designed to travel over the telephone line. However, it can be carried just as well over the broader band-width channels. Digital and video signals are carried over the wider band-width channels because of the great number of bits that must be accommodated per unit of time. Sending computer data or pictures over telephone lines is possible if data phones are used; they convert digital and video data to their tone equivalents at the transmission end and reconvert them at the receiving end. This is, however, a very slow process and from a communications viewpoint it is most inefficient. When reference is made to "slow scan television" it means that the video signal is being carried over a telephone line. Library experimentation with telefacsimile has by and large been restricted to transmission of the facsimile signals over telephone lines. An 8″x10″ page carried by telephone lines takes about six minutes, as compared to 30 seconds if it were sent over a broad band-width channel.

A telecommunications system used for library purposes will eventually need to integrate audio, digital, and video signals into a single system. This integrated media concept is an important aspect of the design of an interlibrary communications system but it is poorly understood analytically in today's practice. The idea of an "integrated telecommunications system" became practical only during the past few years and commercial and governmental efforts are underway to provide these unified facilities as rapidly as possible.

SIGNAL CARRIERS

A number of methods exist by which audio, digital, and video information can flow back and forth for information exchange purposes. These telecommunications facilities are furnished for lease or private line use by the commercial carriers. A dedicated system may also be installed for the sole use of a particular customer. For example, the U.S. Government has more than one dedicated system: the Federal Telecommunications System (FTS), which is available for official use only by civilian agencies; and it has similar dedicated facilities for use by the military. Large companies, such as General Electric, Weyerhauser, and IBM, have exclusive-use telecommunications systems also. In all cases, however, private or dedicated systems are planned in such a way that they interface smoothly with commercial dial-up facilities—thus increasing the overall distributive capacity of any one system. As might be expected, the tariff structure for these combined interconnections is very complex. The Federal Communications Commission is reviewing the overall question of cost for voice and data communication and is also investigating the policy issues raised by the growing interdependence of computers and communications.

Technically speaking, there are five means by which audio, digital, and video signals may be carried to their destination and returned: by telephone line, by radio, by coaxial cable, by microwave relays, and by communications satellite. An explanation of each is given below and they are presented in ascending order of their band-width capacity.

Telephone Lines

The telephone as a means of communication is beyond compare. It is simple, quick, reliable, accurate, and provides great geographic flexibility. Quite often the telephone can supply all the communications capability required for an information system, especially when it is coupled with the teletypewriter.

A good toll quality telephone circuit has a frequency response of about 300-3400 cycles, which is adequate to supply good quality and a natural sounding voice. Regular telephone lines are referred to as narrow band carriers because of the low cycle range needed to carry human speech.

Radio Broadcasting

As the word "broadcasting" implies, signals are radiated in all directions and the omnidirectional antennas which are used in radio broadcasting are designed to have this effect. Frequencies used are 500 to 1500 kilocycles for AM (amplitude modulation), and 88 to 108 megacycles for FM (frequency modulation). The number of radio waves that travel past a point in one second is called the frequency. The number of waves sent out by a radio station each second is the frequency of that station. One complete wavelength is called a cycle. A kilocycle is one thousand cycles and a megacycle is one million cycles. Broadcasting, in general, is used as a one-way system. Any radio or TV set equipped to receive certain frequencies can tune in to a particular station or channel. Low-frequency systems, in the kilocycle range, require less power to operate. The signals are propagated close to the ground and the effective radius of reception is small. With ultra-high frequency, vast distances can be covered by striking upper layers of the atmosphere and having the signal deflected to earth; this can happen more than once before the signal is received. High-frequency systems, however, are subject to atmospheric interference, which causes fading.

Coaxial Cable (and CATV)

A remarkable extension of the carrier art was provided by the development of the coaxial cable. Within the sheath of most coaxial cables are a number of copper tubes. Within each tube is a copper wire, supported by insulating disks spaced one inch apart. The name coaxial reflects the fact that both the wire and the tube have the same axis.

Coaxial cables can carry many times the voice capacity of telephone lines and are thus considered to be broad band-width carriers able to accommodate digital and video data with equal efficiency. The coaxial cable has the additional advantage that the electrical energy confined within the tube can be guided directly to its destination, instead of spreading in all directions as is the case in radio broadcasting.

To provide necessary amplification along the route, repeater stations are placed at designated intervals. Repeater stations are unnecessary, however, within a half-mile radius and many libraries, planning new buildings, are including special ducts to accommodate known or potential requirements for communication between computer units, terminals, dial access stations, etc.

The technology of Community Antenna Television (CATV) incorporates extensive use of coaxial cables. CATV operates very similarly to the way a closed circuit television system works. A company in a locality sets up a powerful receiving antenna capable of importing television signals from many cities hundreds of miles away. On a subscription basis (about $6.00 per month), it will run a coaxial cable from the receiving station to the subscriber's home. Subscribers benefit in several ways: 1) the incoming signals are sharper and clearer because there is no atmospheric interference; 2) a roof-top antenna is unnecessary; 3) more channels are available than a local TV station normally provides (some CATV stations already offer the potential of 20 channels); and, 4) CATV stations have close interrelationships with Educational Television Stations (ETV) and by law are required to make available to subscribers at least one channel for "public service" and "educational" purposes.

The latter benefit has special implications for libraries. School libraries in a town or city where CATV is proposed might well inquire whether the operator is willing to provide a school library programming service.

It is hardly possible to predict what effect CATV and its coaxial cables will have on libraries. It is clear, however, that many homes will soon have coaxial cables as well as telephone lines, and this implies a new capability for bi-directional broad band-width information exchange. Attachment of a coaxial cable from a CATV trunk station to the home provides an electronic pathway 300 megacycles wide. The telephone line is only 4000 cycles wide. Since a megacycle is one million cycles, the relative practical difference in an operational environment is in the order of 50,000:1. It is this significant difference that causes some people to suggest that advanced telecommunications will someday bring newspapers and books into the home by electronic facsimile, along with computer information from data banks, individualized instruction from schools, and a much greater variety of educational materials.

Microwave

The term microwave applies to those systems where the transmitting and receiving antennas are in view of each other. The word is not very definitive but generally describes systems with frequencies starting at 1000 megacycles and extending up to 15,000 megacycles, a range which includes the ultra- and super-high frequency bands of the radio spectrum. Microwave is, therefore, without question, one of the larger broad bandwidth carriers. Microwave systems are used to transmit data and multichannel telephone or video signals. Antennas are in the form of parabolic dishes mounted on high towers and lined up in sight of each other. These antenna produce very sharp beams to minimize power requirements. Since microwaves do not bend, transcontinental microwave systems consist of relay towers spaced at approximately thirty-mile, line-of-sight intervals across the country. Because of the earth's curvature, transoceanic microwave systems are hardly possible without a repeater station. It is this limitation which helped give rise to the development of the communications satellite.

Many state governments have, or are planning, private microwave systems for handling the mix of official, internal communications. Here again, state libraries might investigate the use of such systems for interlibrary communications.

Communications Satellites

The newest and most promising telecommunication development is the communications satellite. A communications satellite is an object which is placed in orbit above the earth to receive and retransmit signals received from different points on earth.

A communications satellite is launched by a conventional rocket, which sends it into an eliptical orbit with a high point, or apogee, of about 23,000 miles and a low point, or perigee, of 195 miles.

On command from earth, a small motor aboard the satellite is fired just as the satellite reaches the high point of its orbit. This action thrusts the satellite into a circular path over the equator at an altitude of approximately 22,300 miles. Subsequently, the satellite's orbital velocity is then synchronized with the speed of the earth's rotation. Thus, a satellite in synchronous equatorial orbit with the earth appears to remain in a fixed position in space. Three satellites can cover the globe with communications except for the north and south poles. Or the antennas can be squinted to focus exclusively on one country or on part of a country. Early Bird's antenna was positioned to cover Europe and the northeastern part of the United States, thus making it possible to link North America with Europe.

A satellite is not very large; Early Bird, which is still operating, is about seven feet in diameter. It contains a receiver to catch the signal, an amplifier to increase the signal's intensity, and a transmitter. Signals received from one earth station on one frequency are amplified and transmitted on another frequency to a second earth station. The satellite receives light energy from the sun, and its solar batteries convert it into electrical energy for transmitting power.

Communications satellites are, in essence, broad band-width signal repeaters whose height enables them to provide coverage over a very large area. They can be "dedicated"; that is, designed for a single class of service, such as television relay; or they may be multipurpose and integrate a mix of different signals at the same time. Generally, we tend to think of satellites as an extension of satellite broadcasting, mainly because most of their use up to now has been for television broadcasting. However, the enormous band-width capacity which they possess also makes them very attractive channels for two-way voice and picture applications for education, business, and libraries. Within the next decade, domestic communications satellites will be available as "switchboards in the sky" for just such uses.

CONCLUSION

Libraries, like other institutions in our society, have learned the hard way that the new technology must be treated as an opportunity and not as a panacea. The same is true of telecommunications. Before telecommunications can be applied effectively to interlibrary functions and services, many non-technical problems have to be solved. Librarians must answer questions such as: How shall we organize our libraries to make optimum use of the advantage of telecommunications? What segment of our information resources and daily library business should flow over these lines? Will our users accept machines as intermediates in the information exchange process? How can the copyright principle be safeguarded if libraries expand their interinstitutional communications? And, of course, how do we measure cost/effectiveness before moving ahead with an operating program? To provide answers professional librarians must become more familiar with telecommunications technology and principles.

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