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Networking through the New Phone System
The Future of Telecommunications*

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1. INTRODUCTION

The need for networking between laboratories has increased steadily over the last decade. With the advent of a terminal or PC on almost every desk, and larger and larger mainframes at laboratories, there is a driving need to communicate with not only on-site computing facilities, but to share other computing facilities because of the large amount of physics data being generated by larger and more complex detectors. When you add to this communications load, the need for people to data-conference with each other, share data bases and use interactive graphics, high speed networks going literally everywhere are required. Today, we consider 9600 baud a minimum data speed. Ten years ago, we thought 300 baud was a luxury. The need for higher speed networks required no proof, but 35 KBPS or 1.544 MBPS could solve many of our immediate problems. In the longer term, data speeds of 10 or 100 MBPS and eventually 1 GBPS or more can be readily justified. Super computer centers are now being constructed and multi-megabit speeds will be required to efficiently use cycles on these super machines. Many 9600 BPS networks exist today, but they are connected in random ways. One could spend his days locating the gateways between these networks to find a communication path to a facility. Higher speed networks, whether satellite or fiber, are being planned and built now. These networks will provide the ability to transmit video and graphics as well as data and voice. These kinds of networks will also provide the facilities for mixing various modes to provide a true high-speed information transfer Internet.

This paper traces the history of the telephone system from 1850 to present, and describes the "new" telephone companies. The immediate problems of 56 KB data and 64 KB voice channels are discussed together with their proposed solution. The Integrated Digital System Network concept (IDSN) is described, and the proposals to build a true end-to-end digital telephone network are described. The Stanford University–Northern Telecom information test facility is described.

The current and planned networks in the U.S., and around the world have also been included in this paper.

2. HISTORY

A brief history of communications from 1850 to the present is helpful in understanding where the telephone systems have been and where they are going in the U.S.

1850 – SFB Morse developed the telegraph.

1874 – Invention of time - division multiplexing by Baudot.

1876 – Invention of the telephone by Bell.

1880 – Invention of the photophone by Bell – speech sent over beam of light.

1899 – Marconi sent radio signals across the English Channel; in 1901 he sent radio signals between U.S. and Europe.

1928 – Nyquist investigated the relationship between bandwidth and sampling rate and published his famous account of digital transmission theory. "*The Nyquist Sampling Theory*".

1936 – Reeves discovered the noise immunity provided by quantizing the amplitude of a voice signal and expressing the result in binary form. This led to Pulse Code Modulation (PCM) as a practical transmission system when transistors were utilized.

1948 – Shannon linked noise theory with digital transmission which led to his famous expression for information capacity on a digital channel.

1962 – Bell System introduced the T1 cable carrier system. It had a capacity of 24 PCM voice channels and a transmission rate of 1.544 MBPS.

1966 – Kao proposed the use of low-loss glass fibers for practical optical waveguide. In 1970, Corning developed and introduced practical fiber cables having a loss of a few db per km.

1968 – Carterfone decision allowed other than Bell system equipment to be connected to the phone line. Called by some, the initial change that eventually led to the Bell system breakup.

1974 – U.S. Justice Department filed an antitrust suit against the Bell system, which went to trial in 1981. In 1982 AT&T and the Justice Department agreed on a settlement in which the Bell system would be dismembered and the antitrust suit would be dropped. This settlement was effective January 1, 1984.

3. BELL SYSTEM BREAKUP

The breakup caused the following actions:

1. Seven regional Bell Operating Companies (BOC) were set up. (There were 22 operating companies before).
2. AT&T was free of market restrictions (they could compete with local BOC's).
3. AT&T became two companies: Communications (Interstate long-distance network) and Technologies (Research, development and manufacturing of customer premises equipment and enhanced services).
4. BOC's must provide equal access to all long-distance carriers.
5. BOC's cannot provide long-distance services, other telecommunication services or customer premises equipment.
6. BOC's cannot discriminate between AT&T and other equipment suppliers of transmission and switching equipment.

7. BOC's must form a centralized organization for coordination of national security and emergency preparedness.

The seven (7) BOC's are:

- NYNEX – New York and New England.
- PACIFIC TELESIS – California and Nevada.
- U.S. WEST – Oregon, Washington, Idaho, Montana, Arizona and New Mexico.
- S.W. BELL – South Central States.
- AMERITECH – North Central States.
- BELL SOUTH – South Eastern.
- BELL ATLANTIC – Middle Eastern.

4. PULSE CODE MODULATION AND T1 CHANNEL

A voice channel is 4 kHz wide and is sampled at 8 kHz (Nyquist Theory). Each T1 frame has 24 digital words of 8 bits each plus a framing bit for a total of 193 bits (Fig. 1).

A 4 kHz voice channel is sampled 8,000 times a second. Each sample therefore has 64,000 bits (8,000 $\times$ 8 bits). This is defined as a DS0 channel and when combined with 23 other channels is called a T1 frame with a bit rate of 1.544 MBPS. This is called a DS1 channel. Each channel is encoded sequentially after the framing bit and contains the 8 bits for that sample.

The synchronizing information is sent as part of the data stream. The voice channel is encoded in 64 KB format but occasionally the 8th bit is forced to another value to indicate signalling conditions or transmit a needed "1" for channel timing. This is similar to SDLC coding where bit stuffing is used to keep more than six "1" or "0" from being sent sequentially.

B8ZS (Bipolar 8 Zero Bit Substitution) is used when 8 zero bits are to be sent. The 8 bits are replaced with N–bit sequence code word with bipolar violations, that is, it violates the alternative polarity. Missing pulses are a violation. The receiving end then replaces the special code word with the original
code word.

Without B8ZS coding, a T1 channel can only send 56 KB of data and 64 KB of PCM (voice). This standard is well established in the U.S., but a newer standard has been proposed in Europe known as ZBTSI. This code acts on the complete T1 frame. B8ZS can be retrofitted into existing equipment by substituting interface codes. The complexity of ZBTSI would likely require additional external equipment. Also the zero-code and clock circuitry would have to be modified in all equipment to support ZBTSI.

5. INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

ISDN is an interconnect and performance standard which combines digitization and signaling functions (see Fig. 2). ISDN permits open system architecture for voice and data and is meant to be a global standard. ISDN provides for access functions, which are separate from the network core functions, so that the user can access all network functions from his location. The "Basic Rate Access" is call 2B+D where B is defined as 64 KB for PCM data and D is specified as a 16 KB packet communication channel. The " Primary Rate Access" is 23B+D or 30B+D. 23B is compatible with T1 when B8ZS coding is provided, 30B is compatible with the European level one standard of 2.048 MBPS. It should be noted that "D" is 64 KBPS not 16 KB as in the "Basic Rate Access". User access is to be provided on an existing local loop (one pair from user to the Central Office). To utilize ISDN's full capabilities, users must have "smart terminals" since the terminals must provide the signaling functions as well as send and receive various types of information. Network services will require a network database change but should not require any major user terminal changes.

The Big "D" signaling rate is still under discussion. The Big "D" concept would transmit digital signal at 10 to 25 MBPS. As LAN's become better understood, new packet mode services will probably evolve.

ISDN's trials and pilot services are a hot bed activity area around the world. Canada, the UK, Italy, Japan, Sweden and the U.S. all have been working with the ISDN concepts since 1985. In the U.S., ISDN trials, in one form or the other, have started during 1986 and will continue through 1987.

The local BOC's have large investments in 1AESS (CO Analog switches) which cannot handle ISDN signals. The temporary solution is to install "front end digital adjunct equipment" to bypass the old analog switches until new ISDN compatible #5ESS (Electronic Switching Systems) equipment can be installed. In the meantime, larger customers in the U.S. are installing their own class-5 switches and using bypass long-distance carriers to provide the interconnecting network. Some companies are using satellite networks, which provide a wide variety of services to/from virtually any place in the U.S.

The earliest forecasted date for 50% of the lines to be connected to ISDN is 1995. Most people feel that while ISDN is a natural evolution of the network, we will not reach 50% in this century.

6. ISDN TRIALS

Almost all of the BOC's are testing ISDN in one form or another. Most of these tests are on local (subscriber) loops to one or several Central Offices (CO).

6.1 PAC BELL'S PROJECT VICTORIA

Project Victoria began in 1986, and comprised several hundred homes in Danville, California. Each customer received two voice channels and five data channels transmitted simultaneously over standard twisted-pair wiring. These services are provided by multiplexer located at each customer's residence.

These services can be located up to 18,000 wire feet from the CO using 26-gauge wire. In the Danville tests, participants received a 512K MacIntosh, and could access MCI mail, Chronicle Information Services (a local San Francisco newspaper), a Bay Area database featuring dining, entertainment and shopping guides; and Dow Jones Information Services for national financial news.

Also, Pacific Gas and Electric Co. offered an energy conservation service, including experimental time-of-use rates and in-home energy audits and Security Pacific National Bank provided home banking services. Pac Bell feels that this type of offering will best serve the small business and residential customers, but this test is proof that a variety of services can be furnished over a copper local loop. The first phase has been completed. Phase two will offer a tariffed service to test public acceptance of these facilities.

Pac Bell, in San Francisco, has demonstrated an ISDN service between its Execution Communication Center (ECC) to a nearby CO and return. Several Workstations, IBM PC's, NEC PC's, FAX machines, and telephones are connected on opposite ends of the room using two 2B + D local loops to the CO. The CO is a #1AESS switches, which is typical of many central office switch and handles only analog signals.

They have installed a "Digital Adjunct" unit made by NEC to handle all digital and voice signals to and from the ECC so that analog voice signals are handed off to the analog switch while digital signals bypass the switch. A future test will link three CO's in the Bay Area.

The "Digital Adjunct" scheme will be used by the BOC's and AT&T to handle ISDN service until all of the #1 AESS switches can be replaced by #5 ESS (the modern solid-state electronic switch). With the investment in #1A CO's, this could take many years. The Digital Adjunct will be connected to the far end by T1 carrier equipment so that, in effect, the telephone companies will be bypassing themselves!

7. THE FUTURE OF HIGH-ENERGY PHYSICS NETWORKING USING ISDN

The ISDN concept, as applied to future networking, determines what is possible, not what is needed or wanted. This section discusses some possibilities for high-energy physics networking when the ISDN concept is in place in the U.S. and Europe.

Today, we are besieged by ever increasing amounts of information which must be assimilated - information not only from physics experiments, but information from all parts of our own laboratories as well as other laboratories. To mention just a few; memoranda and articles which cross our desks, meeting memos, phone calls and actions resulting from them, material inventories, schedules, Purchasing/Receiving paperwork, mail and personal records. Much of the information available is potentially useful, but taken in total - it threatens to swamp us, leading to personal anti-progress. Thus, we need to become more productive in dealing with information. We must be able to access or reject, assimilate and/or store it more effectively than we do today, and telecommunication services which help to meet that need will be in great demand.

As the amount of information increases, we become more intolerant of circumstances which limit our ability to communicate. This simple fact has fueled the expansion of fiber, microwave, satellite and international communications services, and it will continue to do so in the future. New communications services such as high-speed data, image and full motion video services will be implemented much more expediently when the local loop to a BOC uses fiber optics rather than a copper pair. It should be pointed out that ISDN, as initially proposed, is only an intermediate solution to the total problem. Eventually, what we call ISDN should evolve to provide integrated access over wide-band "pipes" with total bandwidth measured in tens or hundreds of megabits. A user's ability to access and control this bandwidth dynamically will grow, leading to a "Universal Information Service" worldwide.

Message handling can be successfully used to bypass the busy signal by using voice mail or electronic mail service. When combined with broadcast mail services and a message waiting indication, this mode of communication can be more expedient. If the caller's number were displayed, the recipient could make a decision regarding immediate answer or store. ISDN at a facility could provide for such services when used with the proper telephone.

Voice Teleconferencing and Video Teleconferencing are not new techniques. Voice bridges have been used for many years to tie together large numbers of people for conferences or education purposes. Video Teleconferencing was introduced in the 1960's, but never became popular because of the transmission costs. The data rates used then were T1 or 1.544 MBPS. It appears to have sustained renewed interest for a "close-in" community use, *i.e.*, companies with multiple locations in a small area or a University with multiple campuses. Participants meet face-to-face often enough so that a Video Conference is a successful alternative when the installation and operating costs are low enough. Video plus voice is a good "enhanced alternative" when compared to voice alone. In the future, mobile video may also prove feasible and even useful. Video compression techniques requiring 56 KBPS can provide a useful slow-motion system. 45 MBPS or more are required, however, for a full-motion digitized channel. When you can combine a video image with voice and data, you can have a power alternative to a face-to-face meeting. ISDN can provide simultaneous transfer of information in the above situation.

Database access will become much more widespread in the next decade because of four factors: first, fiber and IC technology will lower transmission costs; second, advent of user-friendly multi-purpose terminals; third, increasing cost of distributing hard-copy output, fourth, with time, society will change. More and more people will use terminals and computers as everyday items. Here again, ISDN can provide the transmission media required for this service.

The user will be able to configure "his" or "her" network from end-to-end using the D channel. Eventually, the user will be able to parallel 64 KBPS channels in a DS1 (T1) facility to increase the bandwidth up to 1.544 MBPS as required. 64 KBPS channels can be configured for voice during the day, and reconfigured for data on off hours. This process can even be dynamically allocated on an as-needed basis.

As multipurpose terminals and ISDN facilities become available in the next decade, these and other similar operations will become commonplace in the U.S. and in Europe.

8. STANFORD UNIVERSITY – NORTHERN TELECOM NETWORK

From 1979 to December 1983, Stanford conducted studies to replace their Centrex I system which had been installed in 1974. In December 1983, the Northern Telecom SL–100 switch was selected. In October 1984, the Board of Trustees authorized a telecommunication project with total funding of $20.8 million of which $11.1 million was for the 15,000 line SL–100. At that point, Stanford, Northern Telecom and Bell Northern Research announced a collaborative development agreement, including the grant of a fiber optics system to the University valued at $1.5 million.

One of the purposes of the fiber network is to further research in information transfer to meet future University needs. A 96–strand primary fiber cable was installed as a ring around the central campus linking seven primary electronic communication huts (see Fig. 3). Secondary radial trunk cables with 18 fibers were interconnected with the primary cables at huts. The secondary system will provide wide band service to over thirty major research and administrative buildings. Extensive use of fiber optics patch panels will allow flexibility in the system. The Northern grant also includes fiber electronics for the primary ring, with the fiber modulated at 135 MBPS. Future increases in data speed will occur when new electronics and lasers are installed. Telephones are now connected to the switch with twisted copper wires. They expect the copper wires to support up to 2.5 MBPS, and even higher speeds are expected in the future. The huts communicate with the SL–100 at T1 rates (1.544 MBPS) over the fiber strands. The Palo Alto Central office is connected to the SL–100 by fiber which also runs at T1 rates. Pac Bell is the interface for most off campus networks. This network is going to be very interesting to watch in the future.

9. PBX – LAN COMPARISON

Voice or digital PBX's for voice are compared with a local area networks used for data.

PBX (VOICE)	LAN (DATA)
Short connection times.	Long connection times.
Analog voice from phone to switch A/D at switch.	Total network digital.
One user for one connection.	Many users on one connection to the Main Frame.
Channel speed is 65 KBPS.	Channel speed can be 10–30 MBPS.
Aggregate bandwidth of switch can be high (120 MBPS).	200 MBPS for LAN.
Must be real time transmission — delay must be less than 100 MS.	Time division multiplex — data delay not important.
Star configuration.	Ring or Bus configuration.
BOC owned or company owned.	Company owned.

If a PBX is to be used for voice and data, traditionally a Modem (D/A device) has been used. The local loop is usually used for voice only, and a separate local loop is used for data. Eventually voice and data will be digitized at the user's desk. The local loop will then carry both types of signals. However, voice and data signals are usually separated at the switch input and handled by separate paths through the switch. Voice is switched through a blocked system (busy signals occur when all paths are blocked, whereas data is never intentionally blocked).

ISDN, in the future, will handle each signal through an integrated network and provide an end-to-end digital path. It should be noted that the need to provide multiple voice and data services to residential customers has not been proven.

10. THE STANFORD LINEAR DETECTOR (SLD) DATA/MESSAGE NETWORK

When the Stanford Linear Collider Detector (SLD) becomes operational, over twenty institutions in the U.S. and Europe will be linked. The initial network will utilize BITNET and electronic mail will be transferred between collaborators. The users will have access to a central database and remote printing of documentations. Remote computer output will also be available. The network will also permit remote viewing of graphics files. Initially, the network will run at 9600 baud later 56 KBPS at 1.544 MBPS is desired.

11. IEEE DATA STANDARDS

IEEE has committees concerned with many data standards. A brief list follows:

802.3 – CSMA/CD – Ethernet (baseband) standard.

802.4 – Token bus for broadband (CATV) standard.

802.6 – Metropolitan Area Network (MAN) and Manufacturing Automation Protocol (MAP – General Motors) standard.

802.7 – Broadband CATV design and testing standard.

The current 802.4 standard specifies frequency bands for the Subsplit, Midsplit and Highsplit configuration.

- Subsplit: 5–30 MHz inbound and 54 MHz and up for outbound.
- Midsplit: 5–108 MHz inbound and 162 MHz and up for outbound.
- Highsplit: 5–174 MHz inbound and 234 MHz and up for outbound.

The midsplit option is preferred. This is the option that we use at SLAC for the Accelerator control and monitoring system.

The frequency band specification 802.7 is divided into Midsplit and Highsplit.

- Midsplit: 5 to 108 MHz inbound and 174 to at least 300 MHz outbound.
- Highsplit: 5 to 174 inbound and 264 to at least 400 MHz outbound.

Dual cable systems are specified as 40 to at least 300 MHz, both inbound and outbound.

MAP which uses the 802.6 standard is based on the 802.4 standard. However, to keep the cost down, MAP has specified the use of the single-channel portion of 802.4 as being a "carrier band" with data frequency shift keyed (FSK) signals applied directly onto the cable (not a Frequency Shift Keyed modulation on a carrier). The frequencies are 5 MHz and 10 MHz for 5 MBPS and 10 MHz and 20 MHz for 10 MBPS data rates. Token passing is used, but with "carrier band," a headend is not required on the cable system. The MAN protocol is specified to extend to 25 miles and at three data rates (about 11 MBPS, 44.7 MBPS and 200 to 250 MBPS.) This system will utilize a Fiber Optics backbone link.

12. FIBER TECHNOLOGY

Fiber-optics sources normally operate at the 850-, 1300-, or 1500 nM wavelengths which is in the infrared portion of the spectrum; most fiber-optics networks transmit digitally, where maximum data rate determines the bandwidth required. Video transmissions are usually analog, but the trend is toward digital. The first practical light guides were multimode fibers. However, multimode fibers are not as advantageous as single-mode fibers for higher data rates, because multimode has more dispersion for narrow pulses and transmitted pulses tend to overlap because of differing propagation times. With single mode fiber, only the initial "ray", which is the fundamental mode, is transmitted. It is more difficult to couple light into and out of single mode fibers. LED's and ordinary semiconductors are hard to use with single mode fiber, because of their emittance angle but lasers can be coupled efficiently. Single mode fibers operate in the "long wavelength window" of 1.3 to 1.6 nM of silicon fiber. LED's are very suitable for multimode fibers, and can be more easily coupled to the fiber to achieve efficient transfer of light.

A comparison of LED and laser sources follows:

1. LED cost about $150, Laser costs $500 to $1,500
2. LED life is 20–100 years, Laser has a 5– to 20–year life
3. LED temperature increase reduces life by 2, Laser by 10
4. LED power output is -10 to -15 dbm, laser output is about 0 dbm
5. LED bandwidth is $<$ 135 MBPS, Laser $>$ 1 GBPS
6. LED produces wide angle light output, laser produces a small angle
7. LED spectral width is $\approx$ 100 nM, Laser $\approx$ 4 nM

Typical Fiber Networks specifications follows:

1. LED source is useful to about 7.5 miles at < 135 MBPS. Regenerators can extend this distance.
2. Lasers are good for > 7.5 miles (to about 30 to 70 miles) at data rates $>$ 10 GBPS.
3. Most single mode fiber used today has 125 μ Outside Diameter and 8 μ Core Diameter.
4. Multimode loss ≈ 2 db/km. Loss is proportional to distance and inversely proportional to bandwidth.
5. Present single mode networks handle 1.25 to 1.7 GBPS in 45 MBPS multiples at distances of 30 miles before regeneration is required.
6. Single mode is the choice for "backbone" networks while multimode will be used for local distribution.
7. For data rates > 45 MBPS, fiber competes with T1 Multiplex equipment (cost-wise). For short runs, it may be more cost-effective to install more copper stands and not use multiplex equipment.

13. FIBER LINKS

Fiber Optics links covering many parts of the U.S. have been built and are operational. Fiber will soon be installed in both the Pacific and Atlantic Oceans. The West Coast fiber system extends from Los Angeles to Oakland and then to Sacramento, a distance of about 500 miles. A branch has been installed across the bay to San Francisco, and a loop has been installed circling the financial area of San Francisco. This system is all multistrand single-mode fiber with high bandwidth capability. Initial use of the system was to transmit several TV satellite feeds from the 1984 Los Angeles Olympics but presently, some of the capacity is used for long distance telephone service. Excess capacity is available for video and high-speed data, as required. An Eastern fiber link covers the mid–Atlantic States and continues up to the Northeastern states. A new Hawaiian–Japan link will be installed in 1988. It will consist of single mode fibers, and be capable of carrying 7500 channels of 64 KBPS data on two subsystems. Repeaters will be spaced at 53 km and the cable package will withstand depths of 8000 meters and will be 8000 km long. These services could supplement our satellite capabilities which have been slowed since the space shuttle disaster.

The National Telecommunications Network (NTN) is operational covering Pittsburg, Chicago, Houston and Miami. NTN is a collaboration of seven regional long-distance companies which interconnect at common cities on their network to form a coast-to-coast telecommunication network. This high-speed network will carry long distance voice, data and video communications. By 1987, 12,000 miles of network will be operational. Currently, 6,500 miles are operational including the Pittsburg–to–Houston segment.

Microtel in Florida has completed a 1,200-mile fiber network covering Florida and Georgia.

The proposed American Standard, the "Fiber Distributed Data Interface (FDDI)" is a 100 MBPS token ring backbone network to link mainframes. Initially, this network will be point-to-point, but later circuit switching capability will be added to carry voice, video and data. The circuit switched mode will handle up to 16 isochronous 6.144 MBPS channels (each channel will be Full Duplex), and dynamic assignments will be possible between the 16 channels and the residual 1 MBPS token channel to round out 100 MBPS. AT&T has just announced a 1.7 GBPS network composed of 417 MBPS channels. So already, the proposed 100 MBPS FDDI Standard seems to be obsolete! Some of the long distance fiber networks appear to be overbuilt because public interest in newer technologies is not widespread. Increasing transmission speeds have enabled users to make better use of existing fiber runs. The next big surge in fiber will occur when it becomes necessary in local loops.

14. VSAT KU BAND NETWORKS

Very Small Aperture Terminal (VSAT) networks are being studied in the continental U.S. for corporate use. These networks appear to have a more general application to many telecommunications needs.

Operating in the Ku Band (23-24 GHz), the antenna size required is smaller than at C Band (4 to 6 GHz) to produce the same gain. Antenna dishes as small as 1.2 meters can be used at the VSAT terminal. C Band satellite transponders (repeater) antennas must be larger to achieve the same gain. The C Band is commonly shared by satellite and terrestrial users, hence the allowable power radiated by the transponder is limited to reduce terrestrial interference. The Ku Band has fewer restrictions on radiated power. Ku radiated power (EIRP) is at least 10–20 db greater than at C Band systems. This increase in EIRP is neutralized by the increased Ku Band path loss when compared to C Band, but increased receiver gain, for a given antenna size, helps compensate for rain attenuation. So, where is the advantage of Ku over C Band? The advantages are Earth station receiver gain and a reduced Earth antenna size for the same received signal.

A typical network might consist of 18 clusters of VSAT, each cluster comprised of 14 VSAT terminals (see Fig. 4). (Each cluster is assigned to a carrier frequency on the transponder.) Typically, each Terminal will support four users. The 28 clusters are usually arranged in a "star" configuration, and they all communicate through a common satellite to an Earth Hub. The Earth Hub can have one or more hosts connected to it so that, in this model, 1,568, ($14 \times 14 \times 18$) users are on each network (host). The hub can support a number of hosts limited only by the bandwidth of the Ku Satellite and the size of the Hub antenna. Typical examples of equipment costs for VSAT Terminal are under $10,000.

Currently, data rates from 9,600 BPS to 1.5 MBPS are available from ten vendors. With the cost of VSAT Terminals and hubs coming down, this service will be equal to, or less than, the cost of terrestrial circuits in this decade.

15. RESEARCH COMPUTER NETWORKS

At present there are several academic computer networks, such as ARPANET, BITNET, CSNET, and UUCPnet which are used to provide engineers and scientists with convenient access to local and remote computing and information resources. A review of the above network follows:

15.1 CSNET

This network began in 1980 and is funded by NSF. The cost for universities is $5,000.00 per year. The goal of this network is to provide advanced computer network services to the U.S. computer research community. It was further hoped that this network would encourage more researchers to remain at universities and thus help stem the flow of Ph.D computer scientists to industrial research centers. This network initially adopted the Transmission Control Protocols (TCP) and Internet Protocols (IP) of the DOD. The CSNET components are: Telenet, Uninet, Arpenet, and Phonenet. CSNET provides the highest quality service and is the most expensive.

The current fixed cost of Arpanet mode (IMP) is about $150,000.00 a year. Four to sixteen hosts can connect to an IMP. A host connection to Uninet or Telenet cost about $18,000.00 per year for a 9600 baud line plus traffic charges for transmitted data. Phonenet is a telephone based electronic mail system which runs at 1200 BPS. Cypress is an experimental network at 9600 BPS over leased lines between nodes. These nodes are called IMPLET's and are to be small VAX. CSNET membership includes 127 Phonenet, 25 Arpenet and 11 public data network (Uninet and Telenet) sites.

15.2 BITNET

Bitnet (because it's time network) was started in 1981 by City University of New York and Yale. The goal was to have non-discipline specific network whose membership would be open to all degree granting institution of higher education with no volume charges. Today, more than 175 institutions and over 600 networks hosts are connected in the U.S. Many more are available through EARN, the BITNET equivalent in Europe. A university must pay for a 9600 BPS telephone line to a host computer and make at least one port available for another institution and agree to pass all traffic to/from that institution at no charge. The primary service is file transfer but interactive message and interactive access to databases are also supported. BITNET is a store and forward network, where the local computer sends only complete files to the next host. An experiment called BITNET Subnet Experiment is being constructed to use small computers as network nodes (IMPLNET's). Leased lines will connect each IMPLNET instead of connecting hosts so data bypasses the intermediate nodes.

15.3 NSFNET

The goal of this network, which is being funded by NSF, is to make super computers available to the engineering and scientific community at the earliest possible date. It will use TCP and IP protocols. NSF net will initially be based on existing academic networks, particularly Arpanet. The goal is to provide Arpanet access to about 40 companies during 1987. Another network is being constructed, using satellites, to access supercomputers at the National Center for Atmospheric Research and University of Illinois. The main objective is to investigate problems with long delays caused by the path length to and from the satellite. In addition, NSF is installing a "backbone network" connecting a number of supercomputer centers, as well as Princeton and San Diego. A second phase will involve megabits or multimegabits wide-band transfer.

At this time, it is not known if that system will be fiber optics or a satellite network. Several new sub-networks are being built as experiments. One is the CSNET Cypress project, that will be similar to BITNET. They will use DOD protocols but these sub-networks will cost much less than Arpanet to operate.

15.4 UUCPNET

This network is used by thousands of UNIX systems in the U.S., Europe and Asia. A net news (USENET) and electronic mail are provided using dial-up 1200 BPS telephone lines. The routing usually must be specified by the senders although, some systems run a special software package that provides routes to known destinations. As opposed to the other networks mentioned, there is no guarantee of delivery or return of an error indication on this network. The cost of the network is limited to the cost of long distance telephone calls. Sites only pay for calls they place. Each of the networks mentioned have different architectures, protocols and user communities. Each, however, supports an electronic mail system with message formats that more or less conform to the DARPA Internet standard. This has simplified the gateways (mail relays) between the various networks.

16. OTHER INTERNATIONAL ACADEMIC NETWORKS

Academic computer networks are being planned and/or implemented in most technologically advanced countries as well as in many third world countries. Most networks outside of the U.S. conform to protocols being developed by the International Standards Organization (ISO). In many cases a national X.25 subnetwork is being supplied by the local post, telephone and telegraph agency. Some of these networks are described briefly:

- JANET – Joint Academic Network – U.K. Utilizes X.25 over leased wire running at 9600 BPS or 48 KBPS. The U.K. "Colored Book" protocol are presently used. Later, ISO protocol will be used. Several gateways are available to the U.S.

- EARN – European Academic Research Network EARN – is the European clone of BITNET. They are moving towards X.25 and ISO protocols. Presently 260 sites in 16 European countries are connected.

- EUNET – European Unit network uses the same protocol as UUDP net in the U.S. – EUNET presently links 680 institutions in 14 countries. There are several gateways to U.S.; charges are paid by the end user in Europe.

- SDN – System Development Network – In the Republic of Korea, twenty-one universities and research organizations are connected with more than 60 hosts. Leased lines with speeds of 1200 to 9600 BPS are used as well as some X.25 and dial-up lines. The network supports UUCP and TCP/IP based protocols. The network is connected to both UUCPnet and CSNET in U.S. via X.25 public networks. Several countries in the Pacific basin are connected. This part is called PacNet.

- HEANET – Higher Education Authority Network – Ireland's HEANET uses leased lines at 9600 BPS. This network is also connected to the Telecom Eireann X.25 network (EIRPAK). The net supports remote system access, file transfer, remote job entry and electronic mail to users. HEANET will be gateway-connected to UK JANET late this year. International X.25 public networks are also accessible from HEANET.

- JUNET – Japanese Unix Network – Junet is currently connected to 31 universities and research institutes with over 90 host computers. The network is based on dial-up lines and supports UUCP net protocol. Gateways to U.S. go through Kohusai Dendhin Denwg to UUCPnet via the University of Tokyo then to CSNET. There is also an experimental link to BITNET.

- ACSNET – Australia – Forty sites and 250 hosts are connected to this network. Both universities and private research labs are connected by dial-up, leased lines and X.25 public lines. The principal protocol in SUNII which has been locally defined and implemented. International connections also exist to UUCPnet and CSNET via international public data networks.
- CDNNET – Canada – CDNNET provides message services to Canadian research, education and advanced development facilities. CDNNET is based on the ISO model for open systems. Interconnection bridges to other X.400 networks offer standard message handling services. Sixty-five hosts at 30 institutions across Canada are presently connected. Gateways offer direct service to CSNET, UUCPnet, BITNET/NetNorth and MAILNET.

There are other national networks in Sweden (SUNET), Finland (FUNET), Norway (UNINETT), Nordic countries (NORDUNET) and Canada (NETNORTH). In the future, West Germany will build the DFN and Italy will build the OSIRIDE networks.

16.1 FUTURE

Little attempt has been made to coordinate networks on a nationwide basis. Users have been following the motto "Find a need and fill it". Recently DARPA, DOD, DOE, NASA and NSF have been looking into coordinating their own networks particularly for the academic-research community. The driving force is to provide supercomputer cycles to the research community. Most recently, DOE has decided that it's Magnetic Fusion Network (MFENET) will migrate towards a DARPA protocol suite which has been adopted by NSF, NASA, and DOD. It is clear that a National Research Internet will have to be based on existing academic networks rather than to be completely developed from scratch. The likely approach will be to build an Internet or "network of networks" with a common set of networking, transport and application protocols with high performance gateways between components of the system providing inter-operability and where required, to provide appropriate application relay.

Time will determine what the effect of ISDN and its widespread application will have on implementation of future networks and backbone networks. It is obvious that this too will be an interesting area to follow.

PCM FORMAT

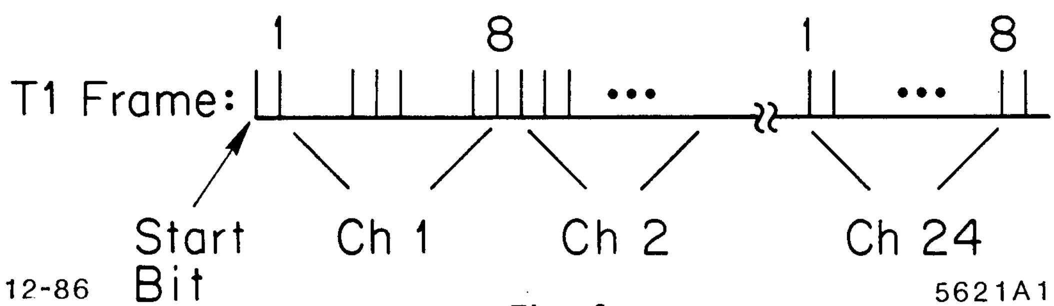


Fig. 1

FUNCTIONAL MODEL OF ISDN

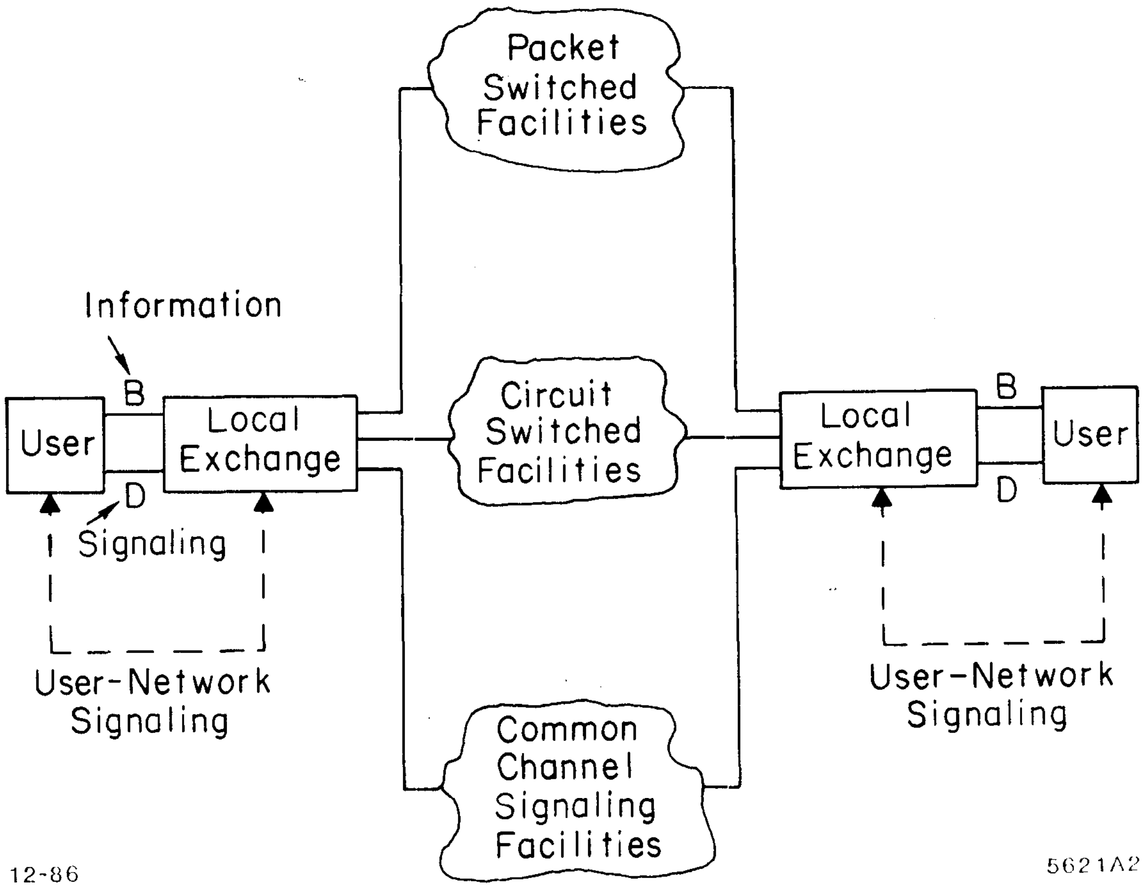


Fig. 2

STANFORD UNIVERSITY-NORTHERN TELECOMMUNICATIONS NETWORK

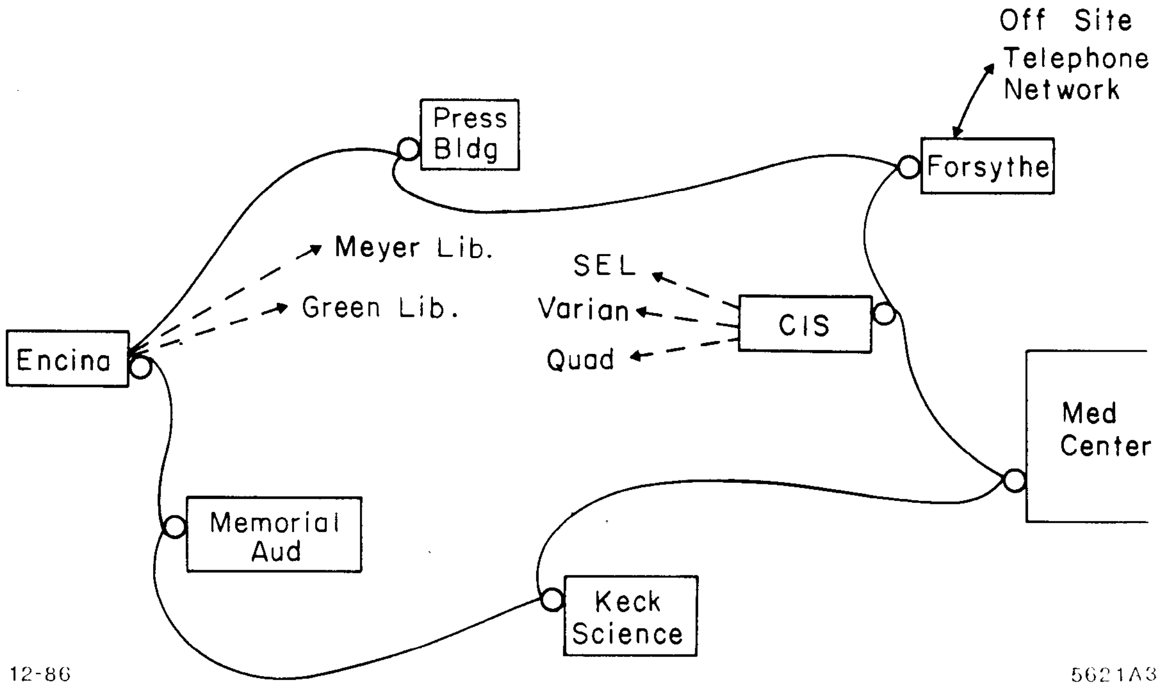
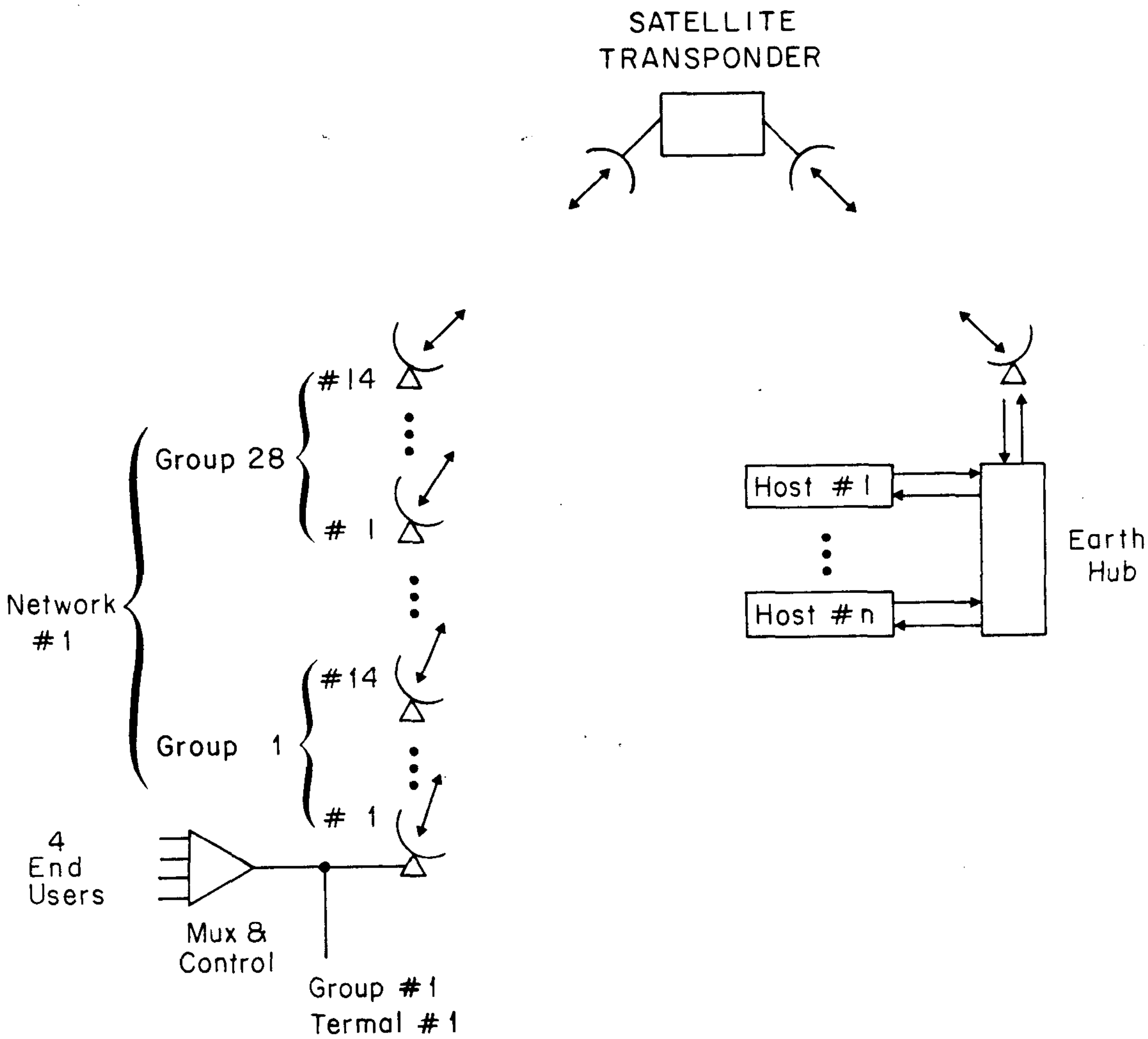


Fig. 3



VERY SMALL APERATURE TERMINAL
NETWORK

12-86

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Fig. 4