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Integrated Services Digital Networks, Standards, and Related Technology

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Preface

This report describes Integrated Services Digital Network (ISDN) concepts, status, and technologies. The ISDN is expected to be a major architectural concept in the future. Awareness of the ISDN by the military is important because the commercial sector is already beginning to evolve in this direction on a national and international scale, and important new technologies are involved.

This report is submitted as partial completion of a study being conducted for the U.S. Army's Communications Systems Agency at Ft. Monmouth, New Jersey, under project order number 105 RD. It is one of a series of reports on a multiphase project to analyze requirements and evaluate alternatives for the Defense Communications System in Europe.

Administrative and technical monitoring of this project was performed by Mr. R. Brynildsen of CSA. Technical and management supervision of the program at ITS was provided by Dr. P. M. McManamon and Mr. R. F. Linfield.

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INTEGRATED SERVICES DIGITAL NETWORKS, STANDARDS, AND RELATED TECHNOLOGY

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National and international work toward an Integrated Services Digital Network (ISDN) and the progress toward its implementation is described. Standards activity and technology relating to the ISDN, in the United States and abroad, are presented.

Key words: common channel signaling (CCS); digital connectivity; digital subscriber loops; Integrated Digital Network (IDN); Integrated Services Digital Network (ISDN); integrated voice and data

1. INTRODUCTION

1.1 Background

As telephone networks have developed in an evolutionary manner, so it is expected that the ISDN will evolve while building on available and developing technology.

Telephone networks around the world have evolved through two distinct stages, and are embarking on a third. The first stage was completely analog, both transmission and switching. The second stage started to evolve with the introduction of digital transmission and switching, while the third stage will encompass end-to-end digital connectivity. The three network stages are called the Integrated Analog Network (IAN), the Integrated Digital Network (IDN), and the Integrated Services Digital Network (ISDN) (McDonald, 1981).

IAN - Switched network providing voice or voice-simulated services where cost is managed through the synergistic application of analog transmission and analog switching technology.

IDN - Switched network providing voice or voice-simulated services where cost is minimized through the synergistic application of digital transmission and digital switching technology.

ISDN - Switched network providing end-to-end digital transparency where voice and data services are provided over the same transmission and switching facilities.

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Note that in the definitions of the IAN and IDN, the integration is that of transmission and switching technologies. In the ISDN, the integration is that of services which so far are only partially defined. Circuit-switched and packet-switched networks should be considered part of the switched network services.

Before dealing with the topic of a commercial/civil sector ISDN, one might ask, "Of what interest is an ISDN to the military?" There are three parts to the reply. First, a significant amount of ISDN-related technology has been generated for civil purposes of which the Department of Defense should be aware. Second, the domestic ISDN is the result of effort by domestic common carriers. These carriers exchange information with foreign telephone and telegraph organizations through conferences and standards meetings. This impinges on foreign and domestic network interconnection and interoperability. Although there may be variations between ISDN's in different countries, the development trend will be in a similar direction. Third, many of the problems which are being solved by the carriers for national communications systems can also be used to solve military communications problems at base, area, theatre, or tactical levels.

There are three factors motivating ISDN development. They are: 1) the new or expanded services which can be offered, 2) the economy or lower cost of offering the services because of digital network characteristics, and 3) new technology which can permit the new services to be offered at reasonable cost, combining these results in economic benefits through service integration. The interaction of these factors is shown in Figure 1. The ISDN is to be market rather than technology driven in its evolution from the current analog and digital systems.

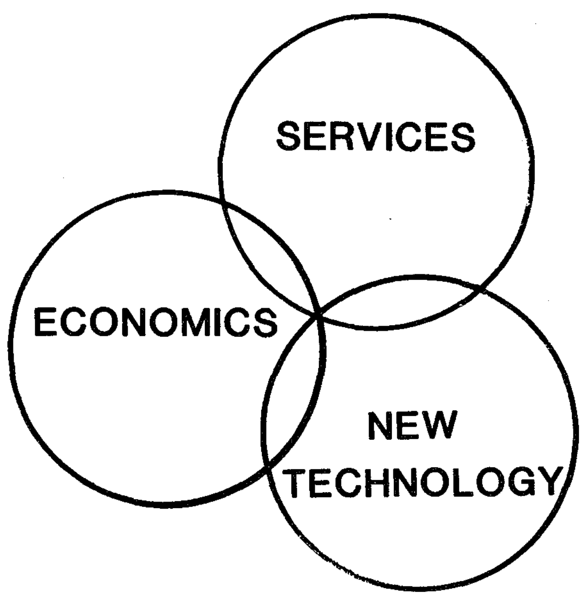


Figure 1. Motivating factors for ISDN's.

Interest in the ISDN is prevalent around the world. This evolution toward the ISDN encompasses hardware, software, and standards (i.e., interfaces, protocols). The economic benefits of integrating digitized voice with data in a packet-switched system has been documented for the Department of Defense (Gitman and Frank, 1978).

Some countries are better able to implement a total digital approach than others because they do not have a large plant investment in the latest analog switch technology. In the United States, the U.S. common carriers are adding interfaces to end-office analog switches to permit digital operation while some countries (e.g., France) can, in some ways, leapfrog a technological generation and move directly to digital. The U.S. common carrier approach has an economic basis which dictates that a digital telephone network in the United States should develop in an evolutionary manner by using existing plant facilities and adding new features.

The digital switching and transmission costs are advantageous because the need for first-level multiplexing and demultiplexing equipment within a switching office is eliminated. Similar multiplexing properties of a time division switch and TDM trunk are exploited by connecting a digital TDM trunk directly to the first stage of a TDM switch. The 4 kHz baseband interface is not needed (Bellamy, 1982, p. 404). Thus, lower costs encourage the use of an increasingly digital telephone network by directly connecting TDM transmission lines to TDM switches, and in this example, an element of the IDN.

1.2 Purpose and Scope

The purpose of this report is to survey the current national and international efforts toward an Integrated Services Digital Network (ISDN), ISDN standards that are being considered within the United States and abroad, and new technology that can have a bearing on the future of ISDN's. This report considers near term (1980's), and long term (1990's) aspects of digital networks, ISDN's, related standards, and technology.

Within this report, there are discussions relating to ISDN planning in several countries. These are for integrated voice and data techniques, digital connectivity, progress toward digital networks, use of satellites, and standards from the American National Standards Institute (ANSI), the International Telegraph and Telephone Consultative Committee (CCITT), and the International Organization for Standardization (ISO). Technology that is described includes electronic switching systems, particularly the No. 5 ESS digital subscriber loops and transmultiplexers, all of which are considered significant steps toward an ISDN. Others (Linfield, 1979; Bellamy, 1982) have already established the significance of common channel signaling (CCS) and stored program control (SPC). These are also discussed in this report.

1.3 Organization of this Report

Succeeding sections within this report describe the evolution toward a domestic ISDN (Section 2) followed by foreign ISDN concepts and services (Section 3). Standards activities toward the ISDN are described as they change in terms of definitions and increased understanding of services (Section 4). ISDN-oriented technology is described in Section 5.

2. DOMESTIC ISDN CONCEPT AND SERVICES

The Integrated Services Digital Network (ISDN) services are anticipated to be widespread by 1990 and universal by the year 2000 (Dorros, 1981). The main motivations for the domestic ISDN are the economies and flexibilities which would be nurtured by the integrated services. Economies are due to the digital nature of many new services which can be combined with existing services.

Although all ISDN services have not been defined or envisioned, the ISDN services are expected to fall into the following categories (Skrzypczak et al., 1981).

- Digitized Voice. Parts of the U.S. common carrier network currently have digitized voice. Voice encryption is a future possibility. This would have a direct application for military use.
- Facsimile, Graphics. Both are likely to be influenced by easily available digital techniques.
- Video. Television can be provided, but its importance in the ISDN is not clear. Broadcast video requires a 4.5 MHz bandwidth (BW) as an analog signal. Conversion to digital video, without compression, requires 90 MHz. Compression can reduce this BW to 6, 3, or 1.5 MHz.
- Other Services. Telemetry, videotex, software transfer, electronic mail, data base access for word processors, computers and other terminals.

In the United States, the emerging ISDN will evolve from the current and developing technology which includes digital switching, digital subscriber loops, digital transmission via lightwaves, satellites, digital data services such as

TWX, Telex, Telenet, Tymnet, and Dataphone Digital Services (DDS), Common Channel Interoffice Signaling (CCIS), and CCITT Signaling System No. 7.

Other countries such as Canada, France, Germany, Italy, Japan, the Scandinavian countries, and the United Kingdom have embarked on an ISDN course.

Qualitatively, the ISDN appears to include a number of functional requirements (Dorros, 1981):

1) A variety of data speeds.
2) A wide range of holding times.
3) A wide range of calling rates.
4) The economic transport of bursty and continuous data.
5) A customer ability to control costs and services.
6) A fast call-setup and clear-down time.
7) A low error rate.
8) Low transfer delay times.
9) Various levels of secure transmissions.
10) A variety of service grades.

An important factor in these functional requirements will be the flexibility to adapt to rapidly changing user requirements (Kennedi, 1981). As the ISDN evolves there is a need to have standard, simple, customer interfaces within the network. A loss of flexibility would occur and higher costs would result, if a proliferation of interfaces occurs in the marketplace. These same principles also apply to military needs in an evolving communications system. An example of existing conflict is the number of interface standards between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE). These are the EIA RS-232-C, EIA RS-449, CCITT Recommendation X.21, and more recently, the new EIA "mini-interface," and a universal physical interface for ISDN, all in the civil sector.

An ISDN topology may consist of the concept illustrated in Figure 2. The subscriber is a customer of ISDN services in the United States. Initially, the U.S. ISDN will use parallel operation of circuit switched networks (CSN) and packet-switched networks (PSN) for the digital bit-stream. As the network and services evolve, the switching nodes can consist of hybrid switches permitting integration of voice and data. The U.S. ISDN network may interconnect to non-U.S. ISDN's, private networks, International Record Carriers (IRC's), value-added networks (VAN's) and local area networks (LAN's). A multibandwidth "digital pipe" is used to transfer control and user information among the interconnected networks.

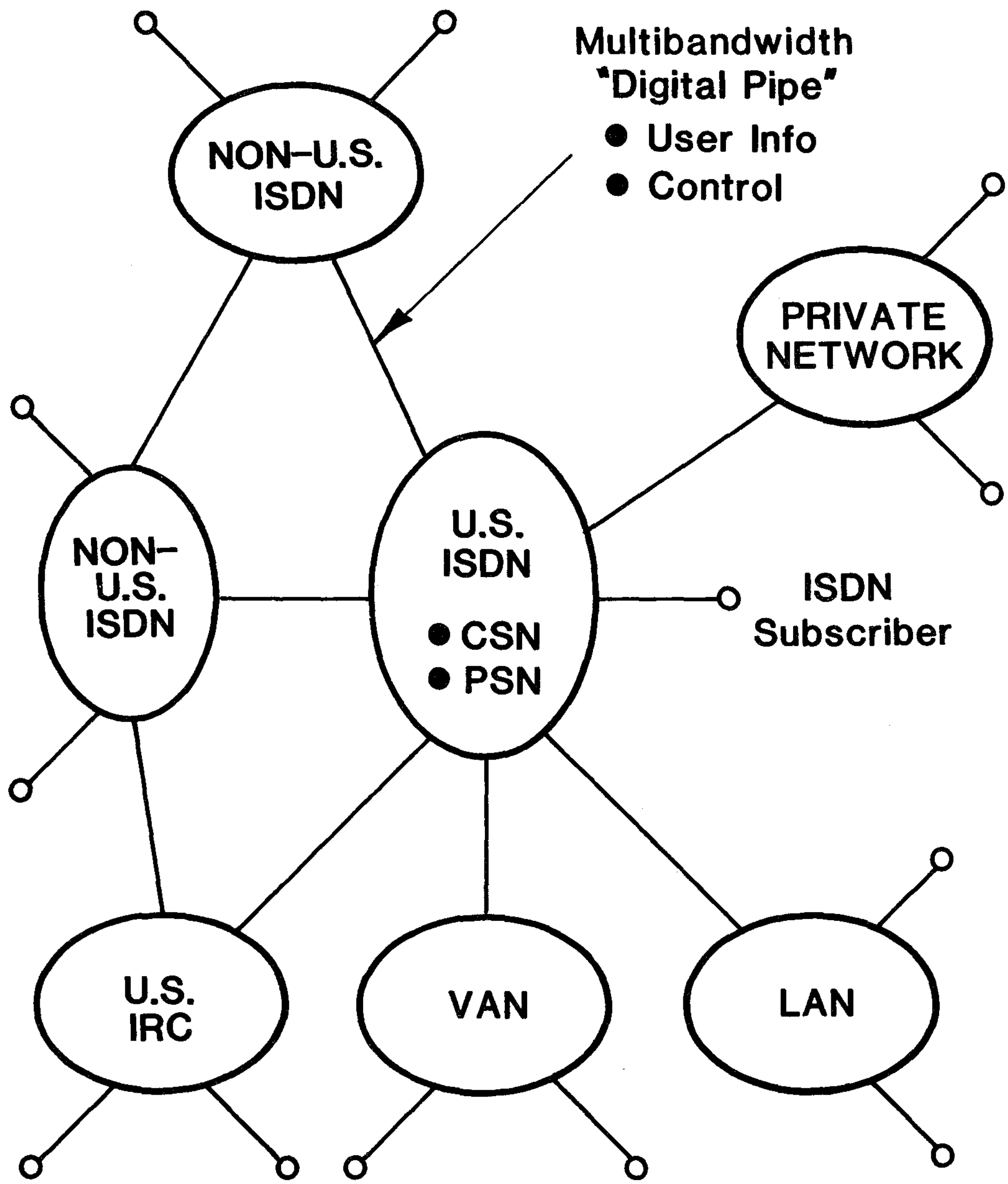


Figure 2. An ISDN topology.

A variation of this topology would be to consider its application for military purposes in Europe. Referring to Figure 2, assume that the private network and the local area network are a military network and a base communications system connected to an overseas ISDN. Communication satellites would permit a "pipeline" to the United States.

Figure 3 provides more detail in describing the ISDN concept and local access. The customer controller provides a standard interface protocol from the customer's premises to the multibandwidth digital pipe. The dynamically assigned bandwidth of the pipe is variable and will depend on the customer's needs for each transmission. The variable bandwidth concept is also used for transmission between the serving center, other networks and customers.

The transmission medium may be copper or may use optical fiber as the system evolves. The serving center may incorporate the circuit, packet, or hybrid switching techniques. New protocols will be needed to provide control signals for 1) messages to different data bases and data terminal equipment, 2) voice announcements and tones for digital telephones, and 3) control information for host computers and CRT terminals.

Briefly, the ISDN is characterized by an evolution to

1) a digital information transfer system using variable bandwidth assignment,

2) use of common channel signaling with flexible routing and control at switching nodes,

3) development of new software architecture for routing and control, and

4) a new switch architecture.

2.1 Evolution to a Digital Network

The domestic telecommunications network is characterized as having five major elements in conjunction with terminal equipment located on customer premises and the signaling system that ties the five elements together. The five major elements are local loops, local switches, interoffice facilities, tandem switches, and intercity facilities. All seven elements are shown in Figure 4 and described in the following sections.

2.1.1 User Premises

This has evolved as an area of user or non-network responsibility (Skrzypczak et al., 1981). The equipment on the customer premises which can be owned by the

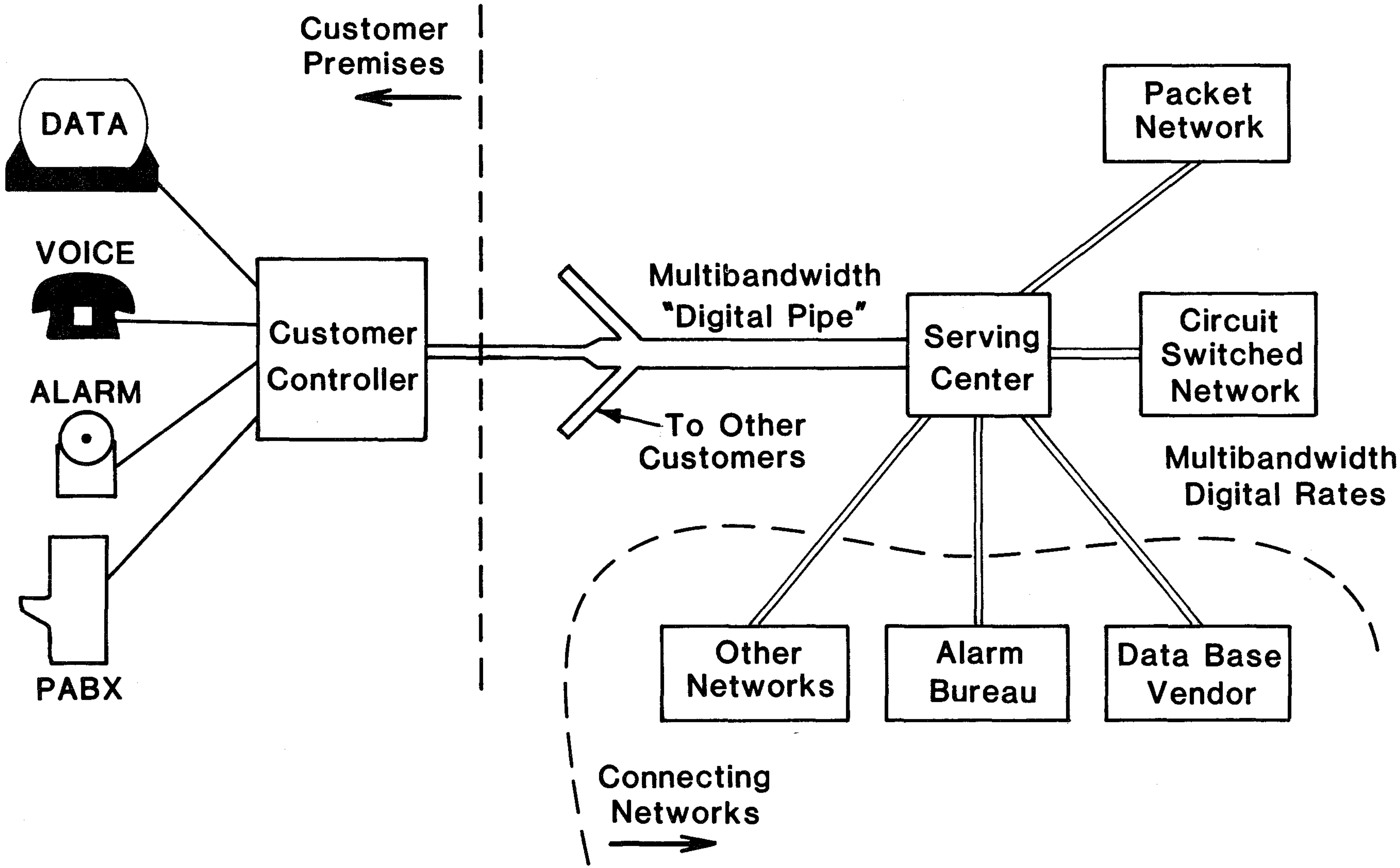
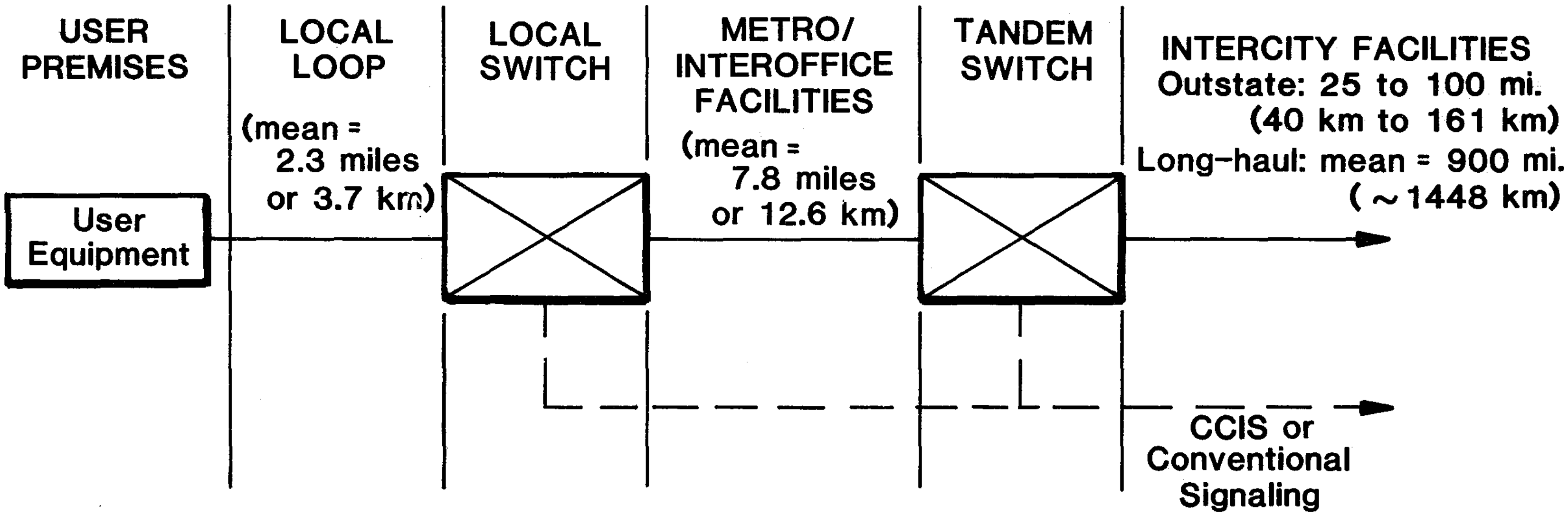


Figure 3. ISDN local access (after Dorros, 1981).



User Premises	Local Loop	Local Switch	Metro/Interoffice Facilities	Tandem Switch	Intercity Facilities
• Host Computers • Terminals • Modems (1) • PBX's (1)	• 2-Wire • 4-Wire • SLC (2) • SLM (3)	• No. 1A ESS(4) • D-Channel Bank • No. 5 ESS (4) • No. 5 EAX (5) • DMS-10 (6)	• T1, T1C, T2 Wire Carrier	• No. 4 ESS (4) • No. 3 EAX (5) • DTM (7)	• TD2 Analog Radio • Coaxial • Light Guides

Notes: (1) Determined by user/customer preference whether it should be a telecommunication carrier or user responsibility.
(2) Subscriber loop carrier.
(3) Subscriber loop multiplex.
(4) AT&T.
(5) GTE.
(6) Northern Telecom.
(7) Stromberg Carlson.

Figure 4. Telecommunication network elements and facilities (after Skrzypczak et al., 1981).

user consists of PBX's and modems, as well as computer hosts and terminal equipment. Previous rationale placed the modem and PBX as the carriers responsibility at the user's option. The DTE/DCE interface was, and at times still is, considered the user/common carrier interface point (Glen, 1981).

To illustrate the shift to digital technology, digitized voice and data PBX's will account for 1% of total PBX sales during 1982. By 1985, expectations are that 95% of all PBX's sold will be digital (80% voice data) and "by 1990, the analog PBX will be virtually extinct" (Hoard, 1982).

Currently, there are two types of PABX's that combine voice and data; those that were designed for both and those that are retrofitted. Examples of the former approach are the Anderson Jacobsen IOX-1000, the Datapoint ISX, the Intecom IBX, and United Technologies Lexar Corporation LBX. Examples of PABX's with add-on modules are the GTE-1000 and 4600, the Harris Corporation D1200, the Rolm Telecommunications Corporation Model 6000, and the Northern Telecom Corporation SL-1.

The ANTELOPE digital PBX is under development at Bell Laboratories. An add-on module for integrating voice and data on the existing AT&T Dimension PBX is reported to be under development.

2.1.2 Local Loops

Local loops are often considered a restraint to digital capabilities. However, digital techniques can be used to overcome the deficiencies that currently exist in metallic local loops. The following alternatives are used to improve the capabilities.

- o Four-wire baseband used in the Dataphone Digital Service (DDS).

- o Pair-gain systems such as concentration and multiplexing, or a combination of both, can be used to meet increased loop demand. This extends the distance at which a digital bit stream can be supported. Examples of the pair-gain are the subscriber loop multiplex (SLM) and the subscriber loop carrier (SLC) (e.g., SLC-40) that use delta modulation and not PCM which exists in T-carrier systems (Bellamy, 1982). The more recent subscriber loop carrier (SLC-96) uses PCM. The increased cost of copper is making digital pair gain an attractive approach for lowering costs and increasing loop efficiency while providing digital capability. The prove-in distance for this alternative is being decreased to 15,000 feet (4,572 m) from 30,000 feet (9,144 m) from the central office.

- o Low bit rate above voice, such as data over voice (DOV), and digital subscriber lines are being studied. These are possible in the early 1980's while four-wire baseband and pair-gain systems are in use today.

Eighty percent of the Bell local loops are nonloaded. This has a significant application for digital use.

A loading coil is used to combat voice signal amplitude distortion on 3 to 15 mile wire pairs by inserting artificial inductance into the line. The loading coil attenuates the frequency response as shown for a 24-gauge wire pair in Figure 5. Nonloaded pairs have higher frequency response which can be used to advantage in a civil or military environment.

Use of nonloaded loops extends 56 kb/s operation relative to wire gauge and loop distance (Table 1). Lower data rates can be used at these or longer distances.

2.1.3 Local Switches

Stored program control (SPC) is integral to end-to-end, circuit switched digital capability for time- or space-division switches. Digital switches are being installed to replace existing stepping switches. The Northern Telecom DMS-10 time-division SPC switch was introduced in 1977 for use as a local end-office switch in the United States and Canada. This was followed in 1981 by the GTE No. 5 EAX and in 1982 by the Western Electric No. 5 ESS.

These digital switches can save copper costs when connected directly to digital transmission pair gain systems. Other U.S. companies (North Electric, Stromberg-Carlson, etc), Japanese, and European manufacturers have similar equipment available.

2.1.4 Interoffice Facilities

Digital T-carrier systems appeared in the interoffice element of the network in 1962. The T1 carrier uses TDM-PCM to handle 24 voice channels while T1C provides 48 voice channels and T2 carrier supplies 96 (Linfield, 1979).

Table 1. Bit Rate Capability for Wire Pair Size and Distance

Bit Rate (kb/s)	Wire Gauge	Wire Length kft	(km)
56	26	12	(3.7)
56	24	18	(5.5)
56	22	24	(7.3)
<56	26, 24, 22	>24	(>7.3)

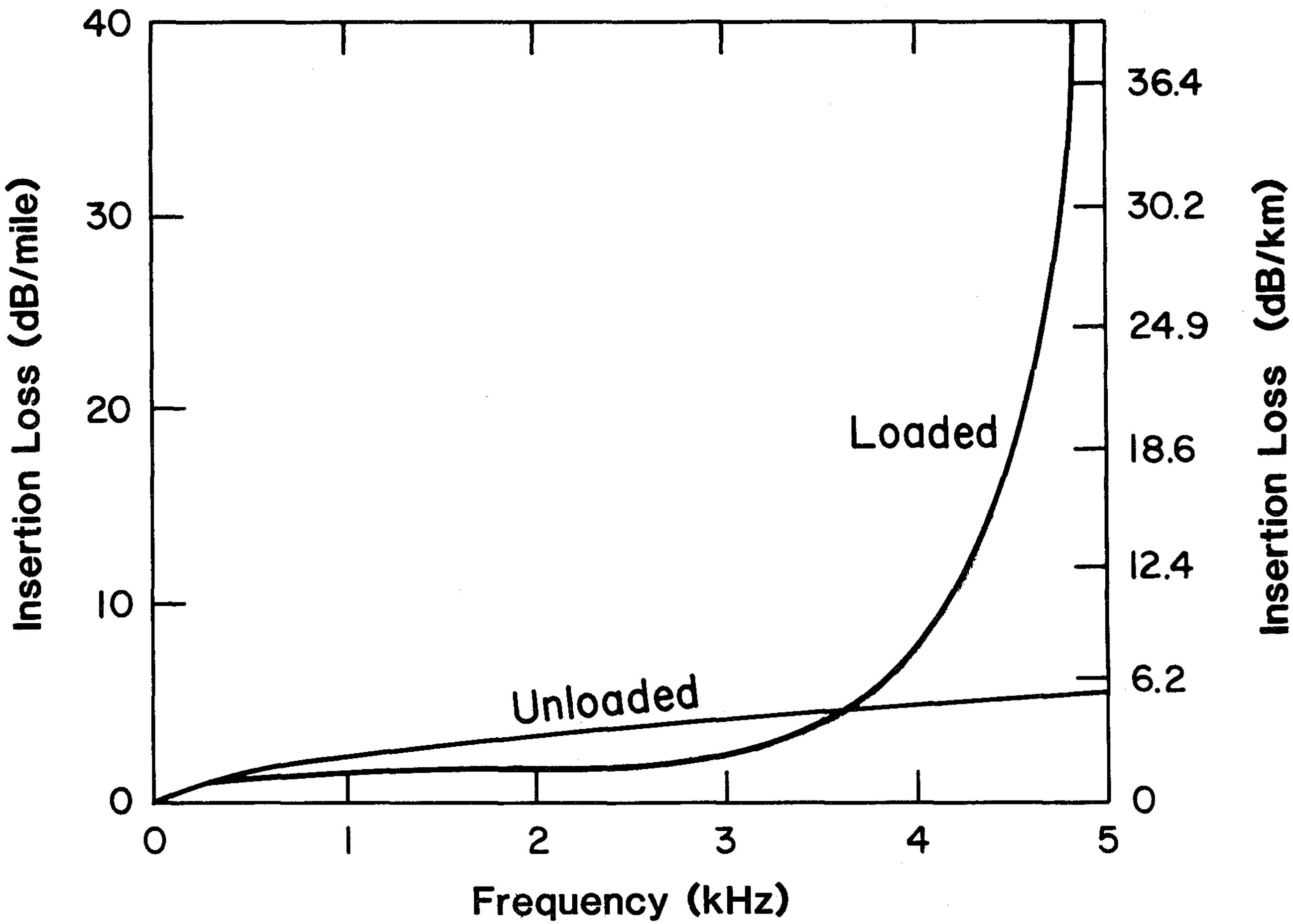


Figure 5. Effect of loading on 24-gauge cable pair (after Bellamy, 1982).

As TDM switches proliferate, the cost of transmission decreases. The elimination of analog-to-digital, and digital-to-analog interface components reduces the network costs when digital signals can connect directly to digital components. The T1 carrier proves-in at 3 miles (4.8 km) when terminated in space division switches that require an analog termination. However, when a TDM switch is used to terminate the carrier, the economic choice today is a digital carrier whatever the distance.

2.1.5 Tandem Switching

Just as with local switches, SPC is an integral part of end-to-end digital connectivity when used to control either time or space division tandem switches. In its evolution to an ISDN, the Bell System will rely heavily on the No. 4 ESS digital switch that was introduced in 1976. Digital technology is an economic choice in tandem switches because the No. 4 ESS costs 80% less than switches with an analog carrier termination. Other tandem switches are the GTE No. 3 EAX and the Stromberg-Carlson DTM.

2.1.6 Intercity Facilities

Contrary to the economic advantages of digital technology at shorter distances (local loops using pair-gain to local switches, interoffice facilities and tandem switches using direct connections for digital interfaces) analog facilities are less costly for intercity facilities. Although analog intercity facilities are often cheaper than digital intercity facilities, that lower cost must be balanced by higher termination and multiplexing expenses associated with analog systems. Due to lower cost digital termination factors, the prove-in distance is usually at 100 miles (161 km) and may prove-in at up to 250 miles (400 km). Analog is definitely less costly beyond 250 miles (Skrzypczak et al., 1981).

The Bell System provides Data Under Voice (DUV), a digital offering, by modifying the current long-haul facilities. Data Over Voice (DOV) from Farinon and 20 Mb/s terminals from Vidar are being introduced in the Bell System.

A significant hindrance to end-to-end digital technology for an ISDN would appear to be the economic and more efficient bandwidth advantages of in-place analog long-haul systems. Facilities for digital connectivity are described in Section 2.2.6.

2.1.7 Signaling

CCIS was introduced in 1976 for signaling between central offices on tandem switches. It will be extended to local switches in 1982 because of optimized signaling message throughput and delay performance.

Migration from the existing Common Channel Interoffice Signaling (CCIS) to the CCITT Signaling System No. 7 will start in 1985. By 1990, 95% of the trunk signaling will be ISDN-compatible common channel signaling.

A combination of CCIS (similar to CCITT Signaling System No. 6) and CCITT System No. 7 will co-exist in the evolution toward an ISDN (Skrzypczak et al., 1981) despite fundamental differences between the two signaling schemes. An important advantage of CCITT Signaling System Nos. 6 and 7 is that these two signaling schemes are designed for common channel signaling between digital switch nodes with SPC (Linfield, 1979, p. 130).

2.1.8 Deployment of Digital Technology for 1980 and 1990

The evolution toward ISDN services is based on the placement of digital technology within the telecommunications network (Table 2). However, forecasts of this type are tenuous and could accelerate, or even diminish, depending on user demand for services requiring network elements with digital capabilities. What is clear is the further confirmation that digital systems will predominate in the future.

The United Telephone System has projections that indicate a similar trend as in the Bell System (Kennedi, 1981). Their projected digital conversion rate for the next 20 years is shown in Table 3. Note that while the number of switches is decreasing by 6%, the number of lines in the system is increasing by 113%.

The Lincoln Telephone and Telegraph Company started conversion to digital switches in 1978, and will complete its conversion program in 1992. PCM continues to be installed, as are digital radio links (Schleufer, 1981).

Continental Telephone has been using digital switches since 1976 and at the end of 1980 had installed 223 units. The company will continue to install digital switches and other digital equipment based on "good performance, high availability, and ease of maintenance (DeWitt, 1981).

2.2 Implementation for a Digital Network

Plans have been announced by AT&T to make available an end-to-end, all-digital system on its analog telephone network by 1984. The public Switched Digital Capability (SDC) will allow users to send and receive analog voice and digital data alternatively on the same local loop. Two other capabilities leading to an eventual ISDN are called the Local Area Data Transport Capability (LADT) and the Data Bridging Capability.

2.2.1 Public Switched Digital Capability

The Switched Digital Capability (SDC) will be implemented with a new interface that will connect user-provided terminal equipment with network-terminating

Table 2. Current and Anticipated Digital Technology (Bell System) (1)

Network Elements	Percent Digital	
	1980	1990
User Premises (PABX's) (2)	< 1	~100
Local Loop (3)	80	90
Local Switch (4)	40	90
Interoffice Facilities (5)	40	90
Tandem Switch (6)	25	90
Intercity Facilities (7)	1	30
Signaling (Common Channel) (8)	--	95

Notes: (1) The digital deployment may be greater in 1990 than shown, depending on the rates and scope of evolution to an ISDN (Hoard, 1982).

(2) Based on sales projections of integrated voice/data PABX's.

(3) 1980 digital capability based on digital potential of nonloaded lines. The 10% increase will be met by digital pair-gain, and 33% of digital loop demand will be based on pair-gain systems.

(4) Based on number of lines served. In 1990, the 90% is based on 20% time division, 70% space division, both with SPC.

(5) Digital lightwave is expected to include 25%-30% of interoffice facilities in 1990.

(6) In 1990, digital tandem switching will be composed of 78% time division and 12% space division, both with SPC.

(7) Based on economics of current analog and voice transmission system. Fiber may alter this projection.

(8) In 1990, the common channel signaling will include CCIS and CCITT Signaling System No. 7.

Table 3. Digital Conversion Rate Forecast for United Telephone (Kennedi, 1981)

Year	Switches		Lines	
	Total	% Digital	Total (10^6)	% Digital
1981	1142	8	2.4	9
1985	1129	37	2.9	39
1990	1106	66	3.5	66
1995	1092	88	4.2	82
2000	1068	99	5.1	94

equipment (NTE). This will permit alternate voice and data over a public switched network (Figure 6).

The SDC (Handler, 1981; Skrzypczak et al., 1981) will be capable of full-duplex digital data transmission at 56 kb/s. It will use time compression multiplex (TCM) over digital subscriber lines (Ahamed et al., 1981; Inoue et al., 1981). Call setup will be via voice mode on a pushbutton phone at the subscriber. Added digits, along with those of the called party, will select digital transmission paths via signaling (Hirsch, 1981). An integral feature of this capability is the use of CCIS with stored-program control. The NTE will be switch-activated. Use of this procedure will allow the economical use of the No. 1A ESS switching system.

The new user interface to the network will have four wires for digital (e.g., two for transmit, two for receive) and two for analog voice transmission. The Bell System announced the specification for this interface in December 1981.

Applications for this circuit switched capability include bulk data, secure voice, facsimile, and access to packet switched networks.

2.2.2 Local Area Data Transport Capability

The evolving Local Area Data Transport (LADT) capability is intended for two types of users; the occasional user who is satisfied with not having voice communications while accessing a data base and the user who requires more continuous voice communications while accessing a data base (Figure 7).

The upper half of the figure shows alternate analog or low speed data through the interface to an analog switch. This user can seize a port on a statistical multiplexer at a central office by pushbutton telephone and then send 1200 b/s data through a modem from the terminal. The user terminal will need X.25 support, based on the International Organization for Standardization (ISO) Open Systems

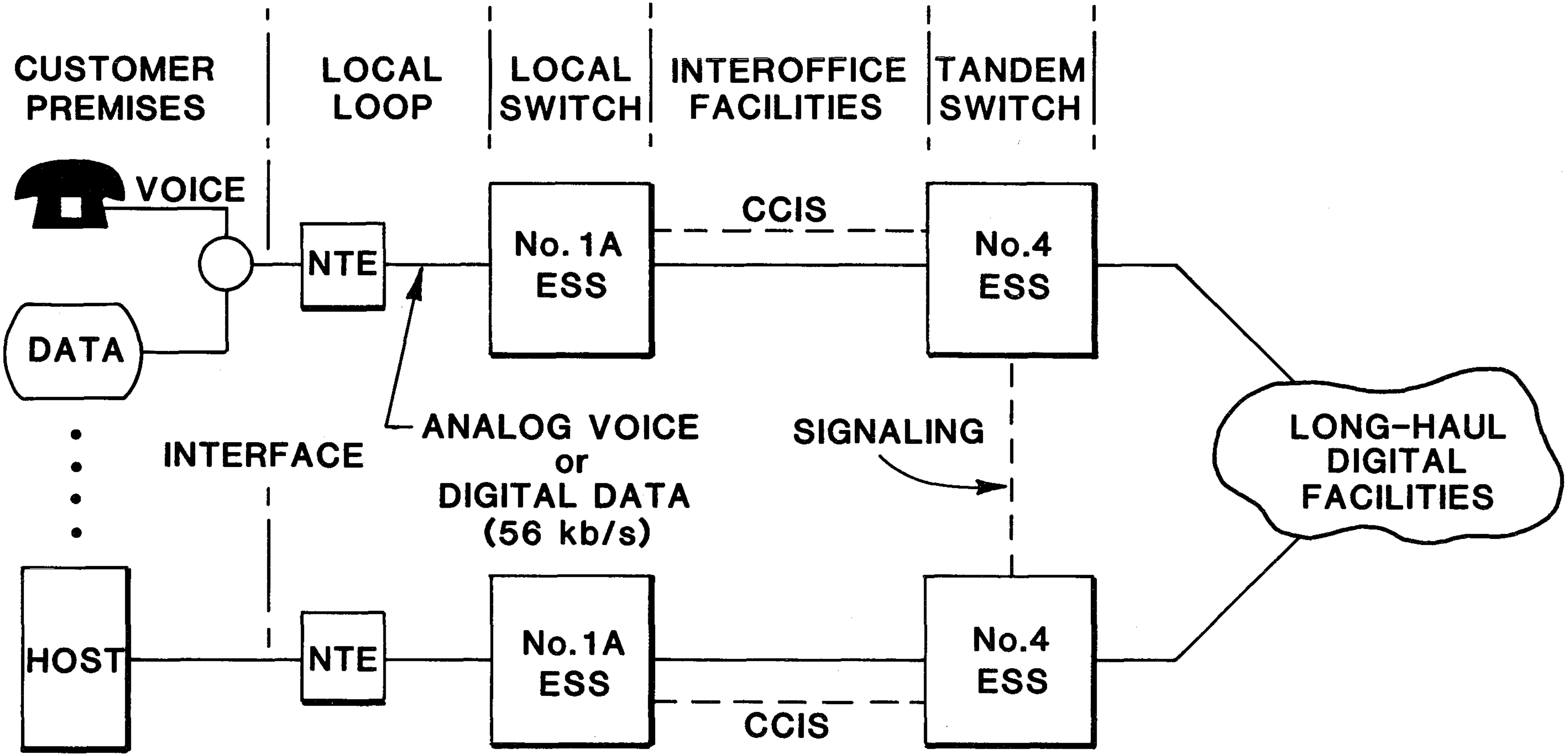


Figure 6. Public switched digital capability (after Handler, 1981).

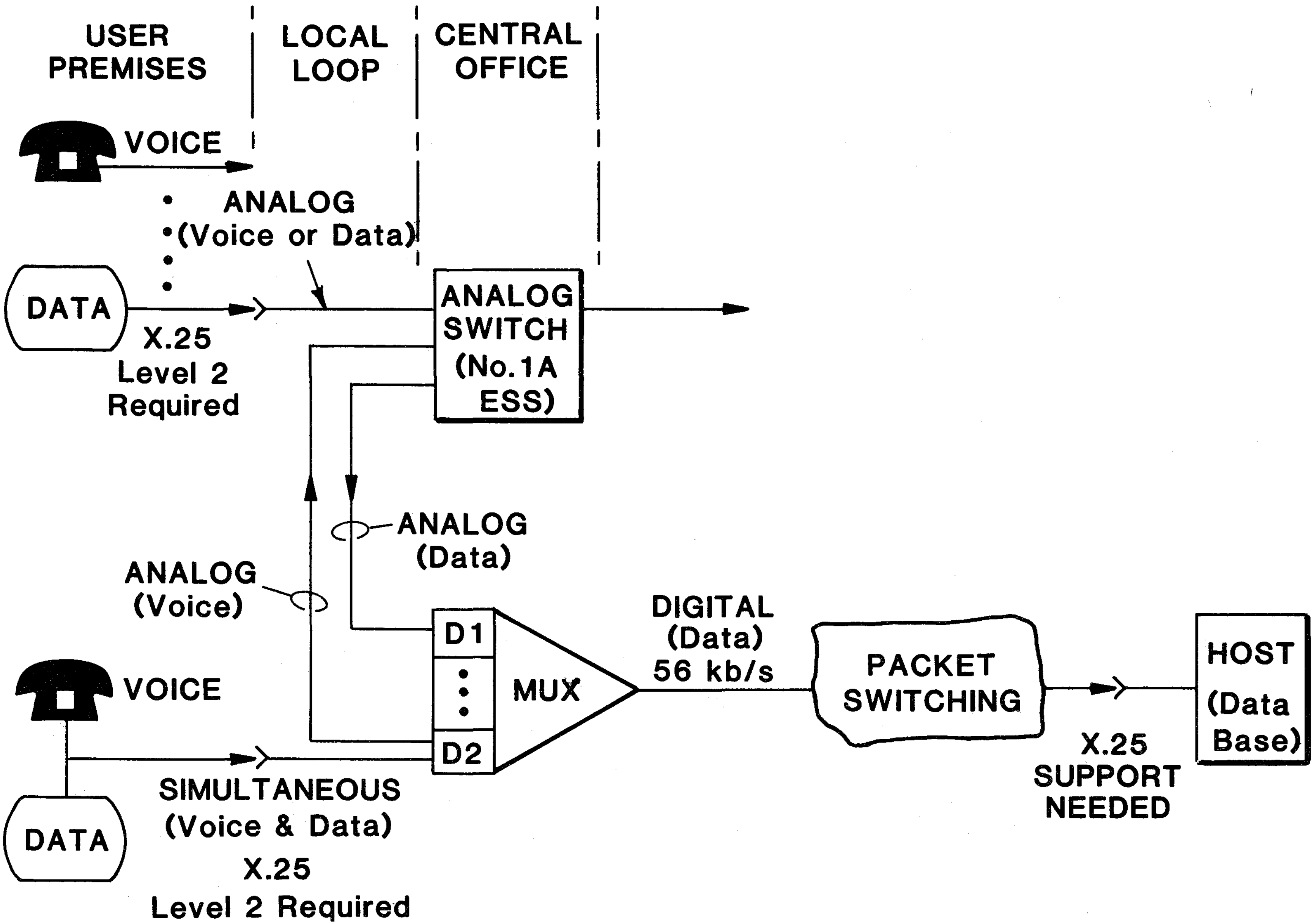


Figure 7. Local area data transport capability (after Handler, 1981).

Interconnection (OSI) reference model, Level 2, Link Layer. Packetized data will then be sent between the user and the data base through a packet switch. The multiplexer will concentrate incoming data from multiple users so that data is sent at 56 kb/s to the packet switching facility.

The second component of the LADT capability permits simultaneous analog voice and digital data. A user who requires more continuous voice service along with data transmission can reach the statistical multiplexer through a dedicated line by using the data over voice (DOV) concept. Through appropriate equipment at both ends, up to 8 kb/s digital data (e.g., 4.8 kb/s data) can be sent while analog voice conversations are routed to the analog switch.

Further implementation of this concept is shown in Figure 8. Data subscriber loop carrier (DSLC, a pair-gain system) equipment at the user location combines voice and data on a voice frequency channel while other DSLC equipment at the central office separates the two. Separation of voice and data by the DSLC-multiplexer arrangement conserves analog switch capacity during data calls.

Use of this simultaneous capability permits accessing other data and packet networks, utility and security monitoring of a customer's premises, and interactive communications such as videotex. A packet switch, located at a phone company central office acts as a data network interface (DNI) to packet and other data networks. The packet network that is accessed may be from a value-added carrier.

Both SDC and LADT have application at a military base and could save extensive capital investment costs for new plant facilities.

Although the LADT capability is not considered an ISDN, the evolution toward functional ISDN features is evident (Figure 3).

2.2.3 Data Bridging Capability

The data bridging capability provides a service where there is a need to transmit digital data, such as graphics or teleconferencing, from one user location to several. A data bridge can be added to a No. 4 ESS switch that would route data from a single input to multiple receiving sites. The input data could come over a standard analog loop at 4.8 kb/s, or at 56 kb/s, through the public switched digital (Section 2.2.1) or LADT (Section 2.2.2) capabilities.

2.2.4 Packet Switched Capability and the Advanced Communications System

The circuit-switched telephone network can be connected to telephone or non-telephone company supported CCITT Recommendation X.25 packet-switched networks. This service is useful for accessing remote data bases which provide user information services. Packet assembly and disassembly is expected to occur outside the packet-switching facility.

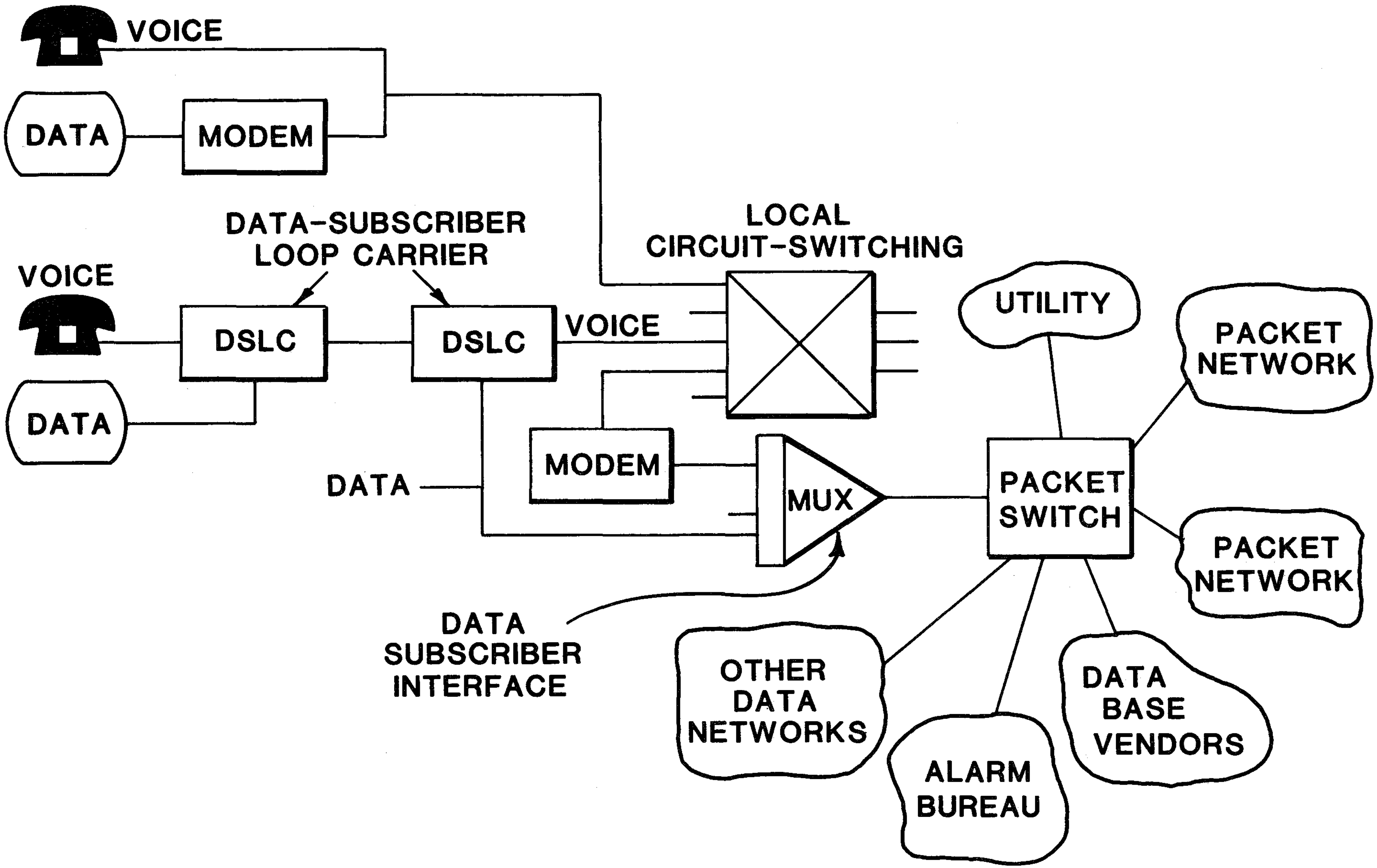


Figure 8. Potential LADT configuration (after Handler, 1981).

The Bell System Advanced Communication System (ACS) will make use of an AT&T X.25 switched network and use 56 kb/s lines (Newsfront, 1982). The concept of the current ACS proposals fits the evolutionary or phasing-in approach of service offerings that were previously described, although not called ACS.

The ACS concept resembles part of the LADT capability which consists of the multiplexer, digital data 56 kb/s line, and packet switching which supports CCITT Recommendation X.25 (Figures 7 and 8).

The purpose of the current ACS proposal is to provide a shared, enhanced service. Diverse terminals and computers will be capable of communicating through code conversion, protocol conversion, and data rate matching. Polling and contention, asynchronous and synchronous modes, cluster control, and computer host capabilities are to be supported (EH, 1982). These features are under data processing, storage, management, and transmission in Figure 9. User entry can be through public dial-up ports, which is another similarity to LADT.

During September 1981, the Bell System announced support for CCITT Recommendation X.25 and the availability of an X.25 interface specification. A previous ACS was filed with the Federal Communications Commission (FCC) and then dropped. The ACS has now been refiled with the FCC to be operated under a separate subsidiary.

2.2.5 Summary of Capabilities

Combined circuit and packet switched networks are composed of four capabilities which make intrinsic use of digital switching and transmission while evolving to an ISDN (Figure 10). The four elements and their features are summarized below. These capabilities are expected to be available and proven by 1990. The switched data capability will not be supported until 1984. The LADT and the other capabilities should be available then, or shortly thereafter, depending on demand.

1) Public Switched Digital Capability

    Applications:
        Bulk data transport
        Secure voice
        Facsimile
        Private line backup
        Occasional access to packet-switched networks
    Line Speed:
        56 kb/s full duplex on local loop
    Features:
        New interface
        Alternate voice and data

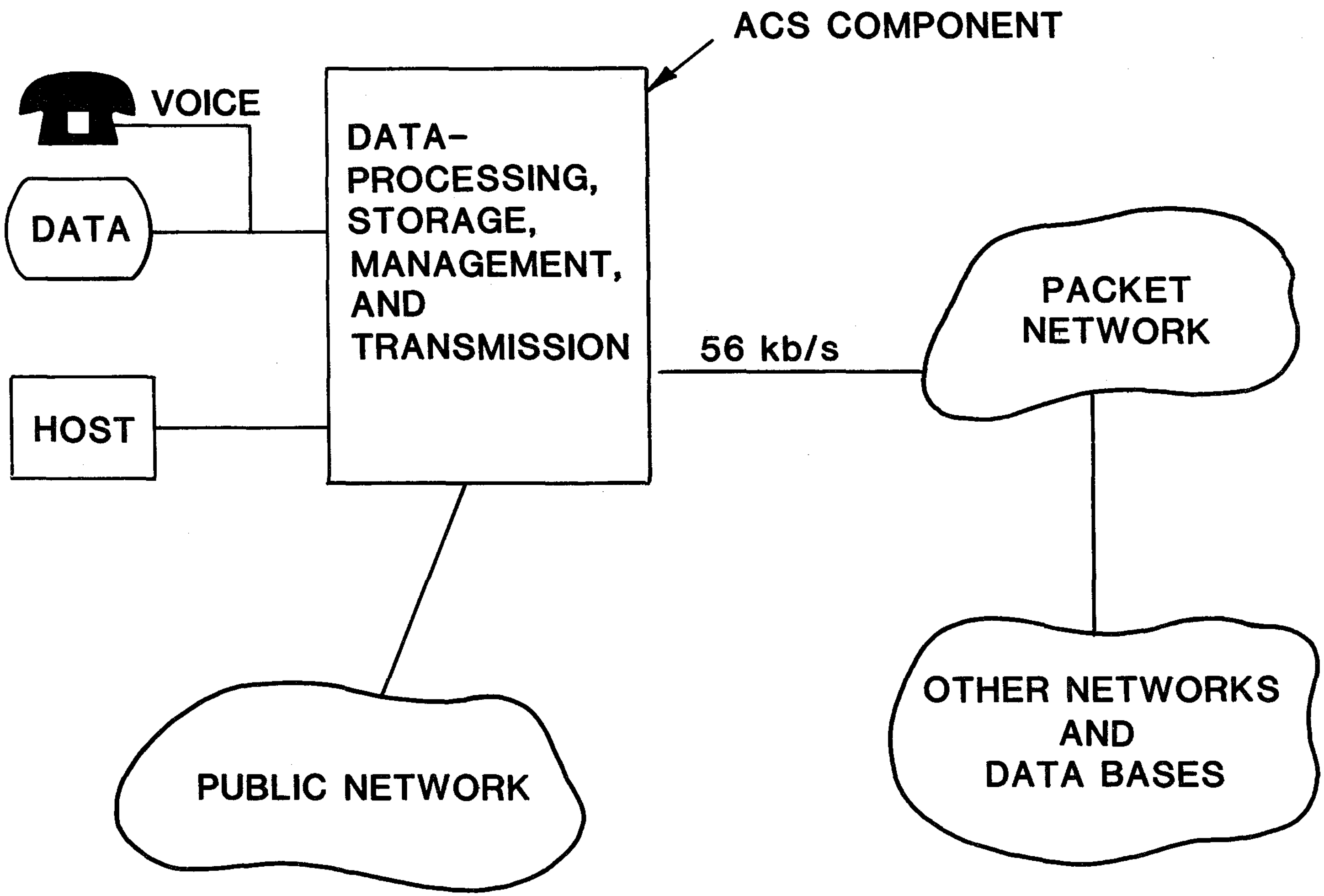


Figure 9. Advanced communications system.

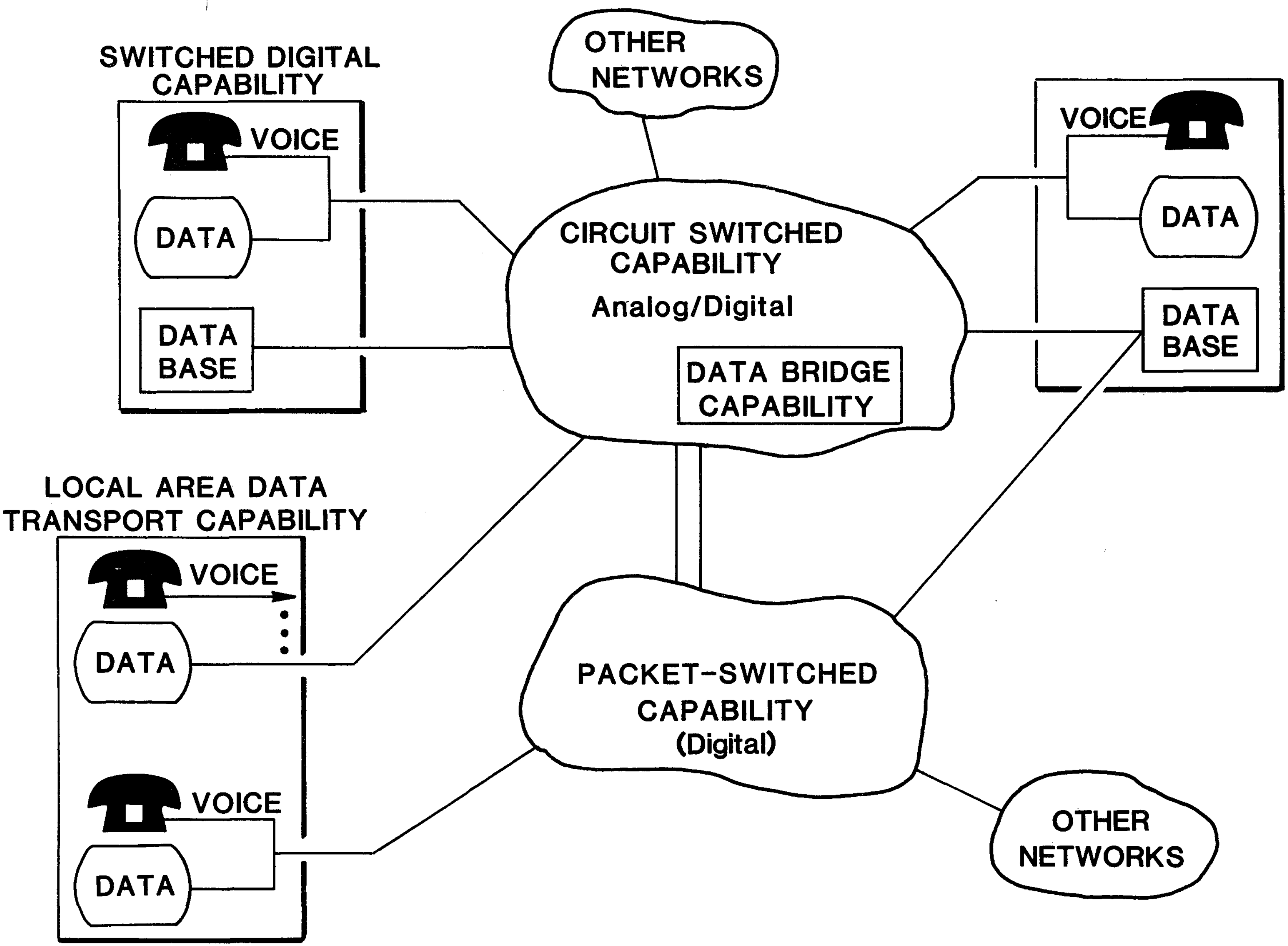


Figure 10. Capabilities for circuit and packet switched networks.

2) Local Area Data Transport Capability

Applications:
- Data base access
- Security
- Utility monitoring

Line Speeds:
- 1.2 kb/s analog data
- 4.8 kb/s digital data

Features:
- Packet-switched access at 56 kb/s
- Simultaneous or alternate voice and data

3) Data Bridging Capability

Applications:
- Teleconference
- Facsimile/Graphics

Line Speeds:
- 4.8 kb/s analog
- 56 kb/s digital

Special Features:
- CCITT Recommendation X.25 Support
- Access via SDC or LADT

4) Packet Switching

Applications:
- ACS potential
- Remote data base access

Line Speed:
- 56 kb/s

Features:
- CCITT Recommendation X.25 support.

2.2.6 Facilities for Digital Connectivity

A number of current and future facilities for digital connectivity were shown in Figure 4. These are within the local loops, interoffice facilities, and intercity facilities which consist of out-of-state and long-haul transmission systems. Table 4 summarizes characteristics for local loops, metro/intercity facilities and long-haul systems.

A pair gain system such as the SLC-96 is economically attractive because it uses the same voice digitization techniques (i.e., PCM) used by T-carrier systems, can be directly connected to digital end-offices, and is capable of combining up to 96 voice channels on three digital transmission lines (Browne et al., 1981).

Present and proposed facilities are in wire pair carriers, optical carriers and digital radio. Data rates of 45 Mb/s and 90 Mb/s are being sent on optical systems. Digital radio is capable of 45 Mb/s, but data rates of 90 Mb/s became

Table 4. Facilities for Digital Connectivity (after Williamson, 1981)

o Local Loop

Copper: 2-wire, 4-wire

Digital Pair Gain: SLC-96

o Metro/Intercity Facilities

Digital Wire Pair Carrier: T1, T1C, T2

Digital Optical Carrier: FT3

Digital Radio: to 90 Mb/s

o Long Haul

Transmission Rate (Mb/s)	Facilities
1.5, 6, 20, 45	Analog Radio (TD2)
140	Coaxial
45	Lightguide (FT3)
90	Lightguide (FT3C)
$\geq$ 60 Mb/s per Transponder	Satellites

available in 1979 and 135 Mb/s in 1981. A transmission rate of 140 Mb/s can be sent on coaxial cable (Williamson, 1981). Boning and Schiff (1981) report that 60 Mb/s and 84 Mb/s data rates can be supported by 36 MHz bandwidth satellite transponders depending on modulation techniques used.

Lightguides, also referred to as fiber optics and optical waveguides, are proving successful in varied civilian and military applications (Stover, 1981). The FT3 lightguide digital transmission system operates at 45 Mb/s. A 90 Mb/s system, the FT3C system, is scheduled for installation in 1983 in two locations; between Oakland, San Francisco, and Sacramento, California in the West and between Washington, D.C. and New York in the Northeast Corridor. The FT3C is to be extended to Boston in 1984.

Satellites are another important facet in long-haul digital connectivity. A number of satellites such as the WESTAR and COMSTAR have been in geosynchronous orbit for a number of years. TELSTAR 3 satellites are to replace COMSTAR and launches are scheduled for 1983, 1984, and 1985.

3. FOREIGN ISDN CONCEPTS AND SERVICES

In many ways the foreign ISDN concepts are similar to those which are visualized within the United States. However, the term ISDN will cover a range of network configurations, despite common principles, and will differ among countries while changing during the passage of time. The following sections will describe the concepts which are expected in Canada, France, Germany, Italy, Sweden, the United Kingdom, and Japan. Technical papers from these countries show a concern based on standard models, interfaces, and speeds based on CCITT Recommendations.

3.1 Canada

Canada's evolution to the ISDN is planned to be through the IDN. The IDN, with common channel signaling, makes new, enhanced service offerings possible. This section presents Bell Canada's view of progress toward an ISDN.

Bell Canada provides service to the provinces of Quebec, Ontario and eastern parts of the Northwest Territories. The population of this area is 15 million people, 90% of whom live within 160 km of the border common with the United States. Approximately 9.5 million telephones in 5.7 million main station locations are served. This is 60% of Canada's total, in terms of population and telephones (Harvey and Barry, 1981).

3.1.1 Digital Capability

The evolution toward digital capability exhibits plans for significant progress from 1980 to 1990 (Table 5).

Current high penetration of digital facilities into local networks is attributed to the use of T1 and LD-1 carrier systems since 1965. There will be an increasing use of lightguide systems during the next 10 years. These will involve DS-1 (24 voice circuits, T1 paired cable), DS-2 (96 voice circuits, T2 paired cable), and DS-3 (672 voice circuits, 3A-RDS 11-GHz radio) digital TDM signals.

Almost all growth of intertoll (interoffice/intercity) services is attributed to use of a DRS-8 digital microwave system between 1980 and 1990.

3.1.2 Signaling

Bell Canada has chosen CCITT Signaling System No. 7 for common channel signaling. Signaling System No. 7 will be known as CCS-7 in Canada. The CCS-7 will initially operate at 56 kb/s, but will eventually be at 64 kb/s according to CCITT recommendations for an ISDN. All digital trunk groups are expected to use CCS-7 through associated or non-associated signaling methods. Up to 100 digital switches at major nodes are expected to be equipped with signal transfer points (STP's) through retrofit procedures by 1985.

Table 5. Digital Technology (Bell Canada)

Network Elements	Percent Digital 1980	1990
Local Loops (1)	50	65
Local Switch (2)	1	40
Interoffice/Intercity Facilities (3)	17	65
Tandem Switch (4)	5	85
Signaling (Common Channel) - All Major Nodes by 1985		

Notes: (1) Also called local facilities.

(2) Based on the number of local lines terminated by the switch.

(3) Also called intertoll facilities.

(4) Also called toll switch, although use of term "tandem" is becoming prevalent. Estimates based on the number of trunks terminated at the switch.

The digital switches referred to are the DMS-100 and DMS-200. Studies are underway to evaluate integrating SL-10 switches and digital links used in Canada's Datapac packet switched network, with the DMS switches.

3.1.3 Integration of Services

A first step toward integrating voice and data uses 2-wire subscriber loops and data over voice techniques. Data rates of 1.2 kHz are superimposed above voice at 22 kHz and 36 kHz using frequency shift keyed (FSK) modulation. Non-loaded loops are required. This applique strategy is to be replaced by overlay and replacement strategies, depending on bit rate requirements and marketplace demand (Harvey and Barry, 1981).

3.1.4 Services

Value-added services such as text messaging, voice messaging, videotex, telemetry, and directory services are current and potential service offerings in Canada. However, providing these services may be limited by the amount of processing power that can reside within a communications network node. The concept of a facility center is advanced to take advantage of commonality within services and add intelligence to a service through a node or network of nodes. Access to a facility center may be through switched telephone services, dedicated lines, packet-switched and circuit switched data networks (Figure 11). Information storage, retrieval and processing would take place at these centers. User access to facility services would be direct or through a distribution center depending on routing criteria. Access to other vendors services could be routed through similar common carrier facilities.

3.2 France

France, under the auspices of the Centre National D'Etudes des Telecommunications, (CNET), has taken significant steps toward an ISDN. In 1971, the telephone system was considered obsolete. Now it is considered one of the most modern as the result of establishing a national priority, coupled with massive development and investment plans. The previous backwardness of the telephone system was called advantageous by Bernard (1981) because it permitted skipping a generation of equipment such as the latest analog switching. New equipment embodies the latest technology in the TELEMATIQUE program of the French P.T.T.

3.2.1 Digital Capability

Digital switching and transmission are a cornerstone of the new communications systems. Common channel signaling is another. As of 1981, 85% of the telephone exchanges which were ordered were digital. This will increase to 92% in 1982.

Digital connectivity between all major French cities is to be achieved during 1982. Time division switching and digital transmission are to provide complete digital links between any pair of time division exchanges in 1984. The rate is to be 64 kb/s.

3.2.2 Network Evolution

As in other countries, the progress toward an ISDN is considered a long term evolution. The three main steps of an ISDN evolution are 1) digital connectivity, 2) integration of voice and data services, and 3) providing wideband services or "videocommunication" as part of an ISDN (Guenin et al., 1981). Another aspect to consider is the role of satellites within the ISDN (see Section 3.2.3).

3.2.2.1 Digital connectivity

A number of dedicated networks that provide services such as circuit switched data, packet switched data, and telex already exist. During step one, users on these networks will require digital connectivity toward an ISDN. This required digital connectivity may be provided by 1) an external terrestrial network which is a system parallel to the public network named, 2) an external satellite network for digital interconnection between local exchanges, and 3) a subset of the

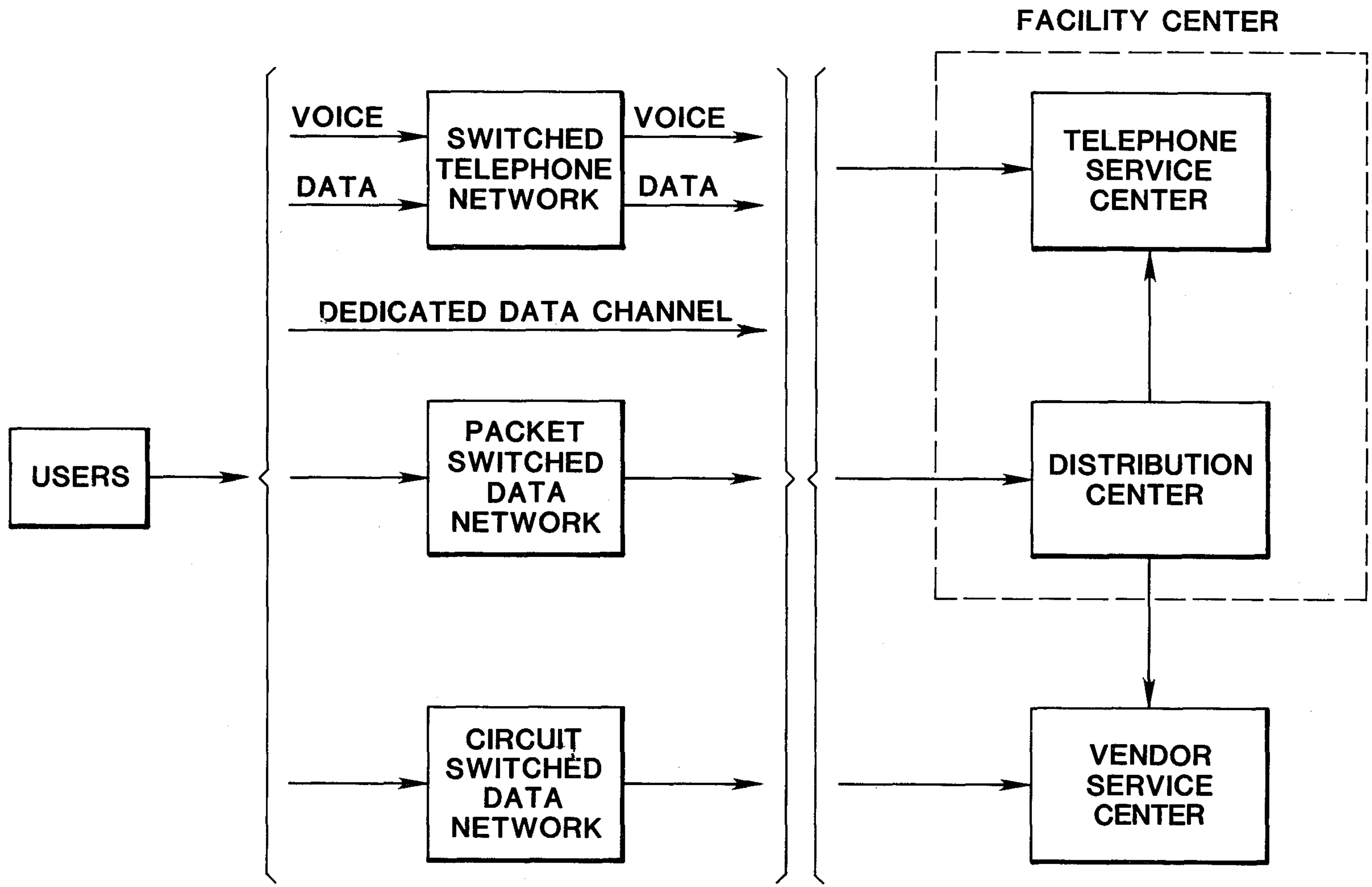


Figure 11. Facilities center (after Harvey and Barry, 1981).

telephone network which would provide internal end-to-end digital connectivity to the user.

Existing two-wire loops will be used to provide digital services to the user through digital or hybrid access. Hybrid access consisting of data over voice (DOV) is called the NOSTRADAMUS system. It is to be available soon.

CCITT Signaling System No. 7 is to be used for common channel signaling in this first main step.

3.2.2.2 Integration of voice and data

The goal of the second step is to integrate voice telephony and digital data services through a multiservice network. Subscribers with remote subscriber units, using hybrid or digital access, will be interconnected between networks through a multiservice switching exchange (Figure 12). Internal or external digital connectivity will be provided between networks through terrestrial, satellite, or a mixture of both systems.

3.2.2.3 Wideband services

In the third step of ISDN evolution, wideband services, known as "videocommunications" such as videophone and television broadcasting, are considered. The impact of new technologies such as optical fiber or optical switching is not defined, but expected to have an influence.

3.2.3 Satellites in the ISDN

The role of satellites in the ISDN will be significant. Small earth stations located near a user's premises can provide quick response digital connectivity. Broader bandwidths on the order of n x 64 kb/s can be provided, whereas the terrestrial network is generally limited to 64 kb/s.

Time division multiple access with full demand assignment on the satellite provides flexibility in serving a user's capacity requirements. Variable data rates from 2.4 kb/s to 2 Mb/s will be provided on request. Satellite resources will be reallocated on demand to provide optimal connectivity between locations. Satellite system facilities are considered a transit (tandem) switch that provides system control, access ports via TDMA earth stations, and a connection matrix through TDMA framing.

As the ISDN matures, the role of satellites may change, but broadcast services and point-to-multipoint link communications should remain.

3.2.4 TELECOM-1

The TELECOM-1 is a domestic satellite communication system that will be operational in 1983 (Bernard, 1981). It is planned to be a part of the French ISDN by

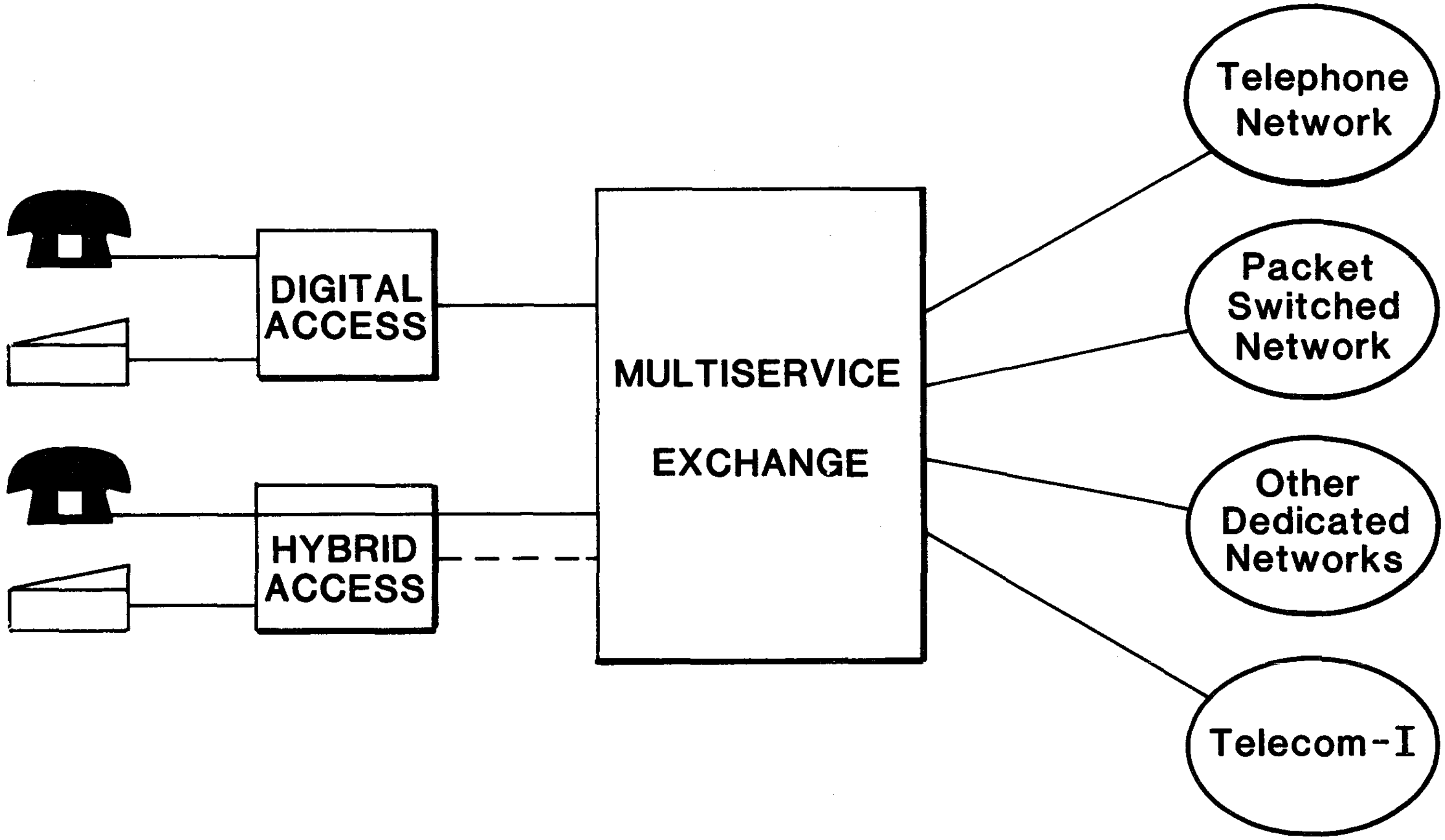


Figure 12. Multiservice switching exchange (Guenin et al., 1981).

providing for variable data rates, telephone, and television traffic. Operation will be at 12 to 14 GHz, with five transponders, each with a bandwidth of 25 MHz. The system is designed to provide full interconnectivity between 256 earth stations. CCITT Signaling System No. 7 will be used for common channel signaling. The bit error rate should be better than 10^{-6} during 99% of the time.

3.2.4.1 Services

Services to be provided through TELECOM-1 are the basic (telephony, etc.) and transparent digital services. Each will be offered two ways: circuit switched on a call-by-call basis, and reserved leased lines for a given period of time (Guenin, 1981). Services, bit rates, and CCITT recommendations for interfaces are shown in Table 6.

The design of TELECOM-1 is such that services to be provided will also be those of the ISDN. It is designed to take into account the possibility of new services and interfaces appearing later.

3.2.4.2 Satellite network

Flexibility is part of the TELECOM-1 design for access (terrestrial network) and satellite network portions. The design incorporates the following principles.

The terrestrial network should 1) permit access to satellite or terrestrial links, and 2) user equipment should translate between common channel and user interface signaling. The satellite network is conceived as a switched network. The control system between the terrestrial and satellite networks should have switching capability to allow interworking with other networks.

Table 6. TELECOM-1 Services

Service	Data Rates	CCITT Recommendation for Interface
Reserved Leased Line	Low Speed Data (2.4 kb/s to 9.6 kb/s)	V.24
Reserved Leased Line and Circuit Switched	Telephony and Medium Speed Data (n x 64 kb/s)	X.21 or V.35
Reserved Leased Line	High Speed Data (2 Mb/s)	G.703

The TELECOM-1 satellite and terrestrial networks are shown in Figure 13. The terrestrial network contains terminal equipment (TE), signal managing equipment (SME) and multiplex signal managing equipment (MSME) located at user premises. The SME manages the user's interface, translates signaling, and provides maintenance capabilities for the access link. During step one (Section 3.2.2.1) user access will be at data rates of 72 kb/s for 64 kb/s TE, and 2 Mb/s for n x 64 kb/s TE. The 72 kb/s consists of a 64 kb/s channel for data and an 8 kb/s D-, formerly Δ-channel for signaling (Section 4.2.2).

The terrestrial network connection (TNC) equipment (outside the user premises) manages transmission link and equipment maintenance and processing. Initial access will be possible as digital lines become available.

The system management center (SMC) consists of three parts: 1) The Reservation and Information Center manages user access reservations, analyzes traffic and performs billing; 2) A Switching Unit (SU) processes signaling information and controls the Reference Station (RS) for link establishment where TDMA, with Demand Assignment, is used on the satellite network; and 3) the Reference Station establishes required connections between earth stations according to control information from the SU.

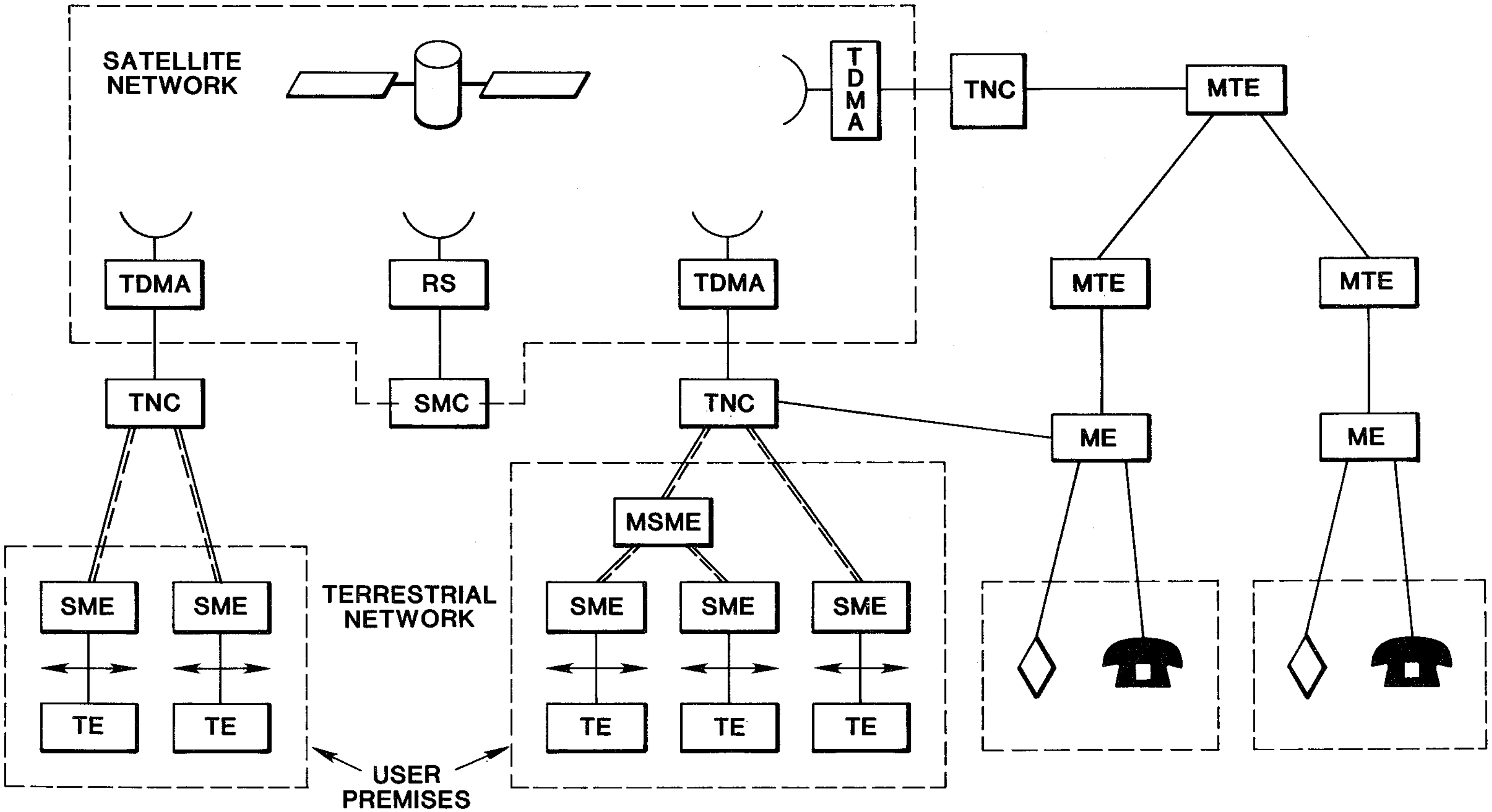
The French visualize satellites as a quick, efficient way to provide digital services to users. Satellites may be used as the first ISDN's and are expected to be integrated into future ISDN's.

3.3 Germany

In the Federal Republic of Germany, the Deutsche Bundespost has plans for transition to an ISDN that would operate at 64 kb/s at the subscriber. The Bundespost also is simulating dynamic multiplexing to determine the properties that would permit dynamic bandwidth assignment on the subscriber line for circuit and packet switched services (Besier et al., 1981).

3.3.1 Digital Capability

Germany has a number of digital transmission systems which are in place or planned (Table 7) (compare with Table 10). These are at the regional and national (supra-regional) levels. Based on this digital, long-distance transmission capability, the Bundespost predicts introduction of an ISDN at an early date. Despite this optimism, digital, local, and trunk switching systems will not be introduced until 1985. Then, time will be needed to achieve area coverage. Consideration is being given to the interconnection of public and private networks operating at 64 kb/s via the digital telephone switches that will be available.



RS: Reference Station

SMC: System Management Center

TDMA: Time Division Multiple Access

TNC: Terrestrial Network Connection Equipment

SME: Signaling Managing Equipment

TE: Terminal Equipment

MSME: Multiplexing Signaling Managing Equipment

ME: Multiservice Exchange

MTE: Multiservice Transit Exchange

Figure 13. TELECOM-1 terrestrial and satellite networks (Guenin et al., 1981).

Table 7. Digital Transmission Systems in Germany (Besier, 1981)

System	Bit Rate Mb/s	Transmission Medium	Network Level	Introduction
PCM 30	2.048	Symmetrical Pairs	Regional	1970
PCM 30D	2.048	Symmetrical Pairs	Supra-Regional	1978
PCM 120	8.448	Coaxial Cables	Supra-Regional	1979
PCM 480	34.368	Coaxial Cables and Optical Fibers	Regional	1979
PCM 1920	139.264	Coaxial Cables	Supra-Regional	1984
PCM 7680	565.148	Coaxial Cables	Supra-Regional	1984

Currently, the Bundespost has an integrated telex and telegraph data network called the Electronic Data System (EDS). It is a digital data switching system operating at 9.6 kb/s and using Germany's PCM 30D transmission system. Voice is not part of the EDS. Testing of a 64 kb/s model network will take place through extension of the EDS network.

3.3.2 64 kb/s Model Network

The model network will be available in late 1983 to 4000 subscribers in 10 cities. The cities are:

1. Berlin
2. Dortmund
3. Dusseldorf
4. Frankfurt
5. Hamburg
6. Hannover
7. Mannheim
8. Munich
9. Nurnberg
10. Stuttgart.

Users will have 64 kb/s on an end-to-end basis based on ISDN recommendations of Study Commission XVIII of the CCITT. The network will operate at 2.048 Mb/s (presumably the PCM 30D system).

The subscriber system, direct access portion of the figure uses nomenclature of the type that has been partially changed by the CCITT (Section 4.2). This discussion retains the author's nomenclature.

In addition to the 64 kb/s or b-channel (now v-channel), each subscriber loop in the model network will have an out-slot or Δ-channel (now D-channel), for signaling at 2.4 kb/s. (Signaling rates of 8 kb/s and 16 kb/s are being considered.) The Δ-channel can also be used to carry telemetry and data signaling between subscribers, as well as signaling from subscribers to switching nodes.

Two access modes to the model network will be available; direct and remote. Direct customer access to the switching node would be via the 64 kb/s subscriber loop. Remote access would be via a combination of 64 kb/s and an international standard multiplex system at 2.048 Mb/s (Figure 14). Note that the Δ-channel bit rate varies as it progresses through the network.

Based on phasing of typical communications projects (Hatchwell et al., 1981, p. 53), one concludes that this model network would conclude pilot installation and test in early 1986. Initial installation of local and trunk digital switching beginning in 1985 would indicate a nationwide German ISDN in the mid-1990's.

3.3.3 Simulation of Dynamic Multiplexing

The Bundespost is considering the following information to be transmitted on the b- and Δ-channels of the subscriber loop.

b-channel (now B-channel)	o	digital voice at 64 kb/s.
	-	user classes of service in public data networks which consist of terminals operating in the asynchronous, synchronous and packet modes (CCITT Recommendation X.1).
	-	the voice and data operate on an alternate basis.
Δ-channel (now D-channel)	o	customer signaling at 2.4 kb/s, with 8 kb/s and 16 kb/s being considered.
	-	telemetry information.
	-	slow speed data possibly at nonstandard data rates.
	-	the signaling, telemetry and slow speed data would be dynamically multiplexed.

A computer simulation of dynamic multiplexing of the Δ-channel has been performed. Data showed: a) loss of slow speed data due to finite memory on the transmitting side, b) idle time due to high data rate, and c) delays of signaling information.

Extension of Δ-channel dynamic multiplexing to the b-channel is similar to the dynamic bandwidth assignment discussed in Section 2 of this report. The endorsement of CCITT Recommendation X.1 indicates that asynchronous, synchronous

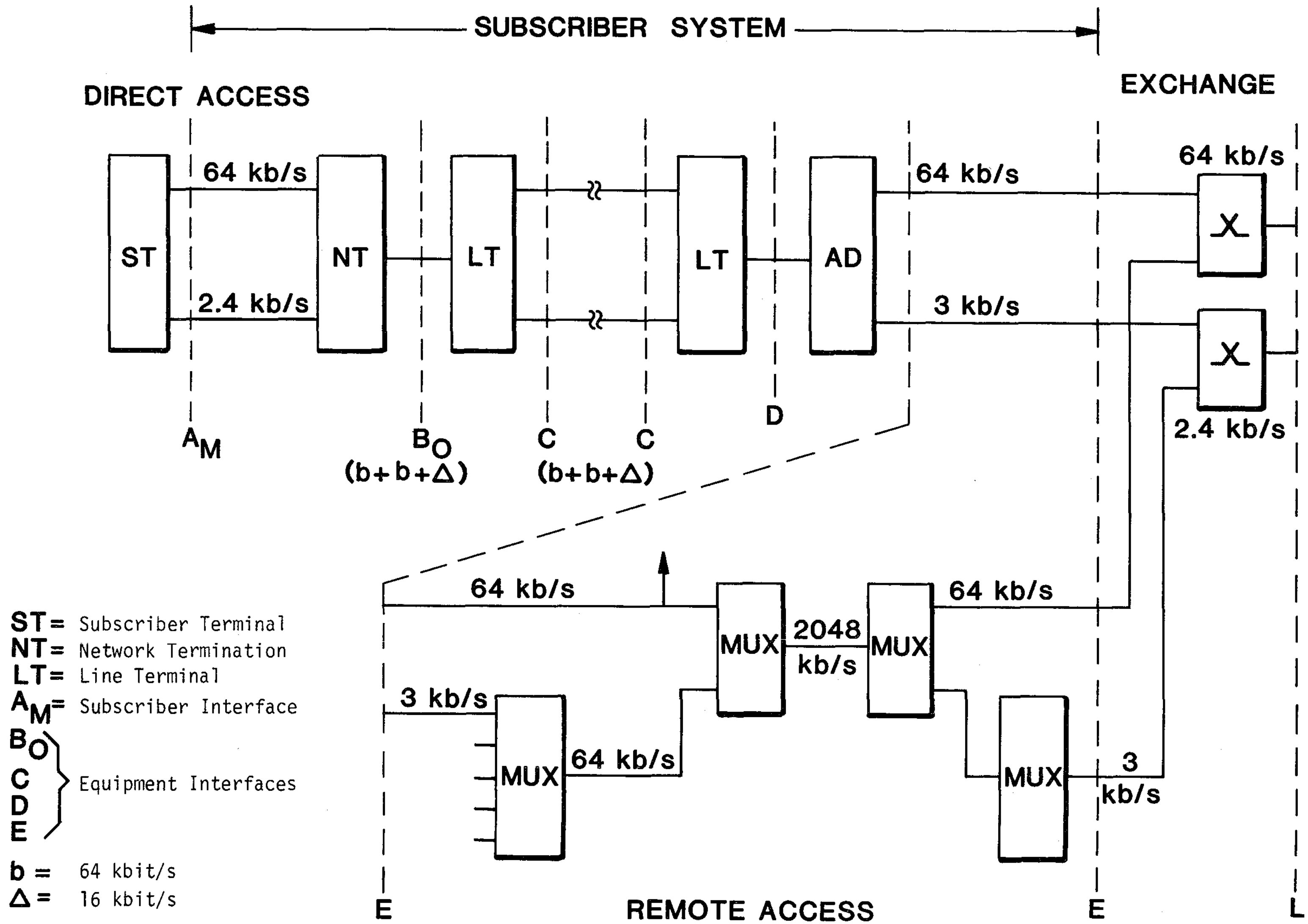


Figure 14. Subscriber area of the 64 kb/s Model Network (Besier, 1981).

and packet mode operation would be as given in Table 8. A 64 kb/s signaling rate in public data networks is not standard at this time.

3.4 Italy

Transition to an ISDN from present network capabilities has been considered through a simultaneous voice/data transition capability called Infowire (Artom et al., 1981). It is similar in concept to the Bell System local area data transport capability (Section 2.2.2).

An experimental ISDN is expected to start in Italy during 1983. One ISDN experiment is being developed by the Societa Italiana Telecommunicazioni (ITALTEL) in cooperation with the Centro Studi e Laboratorie Telecommunicazioni (CSELT). A second experiment will be conducted by FACE-ITT. The Societa Italiana per L'Esercizio Telefonico P.A. (SIP) will be involved in both. A description of ISDN features and services in both experiments is given in the following sections.

3.4.1 ISDN Features

The basic ISDN will have subscriber-to-subscriber circuit-switched digital connectivity at 64 kb/s, for voice and nonvoice traffic (Mossotto and DiPino, 1981). The fundamental ISDN architecture is expected to handle,

a) conventional analog subscriber lines,

b) subscriber access at 64 kb/s (b-channel) and 16 kb/s (Δ-channel) and,

c) PCM trunks carrying common channel signaling (CCITT Signaling System No. 7) at a dedicated 64 kb/s down to the PABX level.

The reported work concentrates on the subscriber access although the common channel signaling aspects are considered especially important. The impact of access to broadband services, presumably video, is considered small.

Table 8. CCITT Recommendation X.1 Data Rates for Asynchronous, Synchronous, and Packet Operating Modes

Mode	Data Signaling Rate (b/s)
Asynchronous	200, 300
Synchronous	600, 2400, 4800, 9600, and 48000
Packet	2400, 4800, 9600, and 48000

PCM trunks will be served by common channel signaling to support circuit switched services (Figure 15). Digital voice, asynchronous and synchronous modes will be according to CCITT Recommendation X.1. Access to packet switched facilities is expected through b-channels in a circuit-switched mode. The packet switched network is functionally separate in the ISDN architecture although data will be integrated and transmitted on the PCM trunks.

3.4.2 Services and Experiments

The services which are expected in Italy's ISDN are to consist of digital voice services, circuit-switched data transmission, packet-switching access, teletex, videotex, and facsimile. Information processing and data storage will be accessible by circuit- and packet-switching modes. A summary of services and implementation for the two experiments is given in Table 9.

As noted in the table, the services within each experiment are not the same. Another difference is the type of switch to be used in each experiment. The ITALTEL/CSELT experiment will use a digital switch, the UT-10/3. The ITT-FACE experiment will use a 1240 digital switch complemented by a number of ISDN modules. An important difference between the two experiments is that the former

Table 9. Services in Italian Test Networks

Capability	ITALTEL/CSELT (3) Experiment	ITT-FACE (4) Experiment
Telephone (1)	Digital Telephone	Digital Telephone
Circuit-Switched Data Transmission (1)	Slow-Scan Video	Digital Facsimile
Circuit-Switched Access to Packet-Facilities (1)	X.25 Computer	None
Message Oriented Data (2)	Videotex	Teletex
	Interactive Data Terminal	Teleprinter

Notes: (1) Will use b-channel at 64 kb/s.

(2) Will use Δ-channel at 16 kb/s.

(3) Will use ITALTEL UT 10/3 digital switch.

(4) Will use ITT-FACE 1240 switch.

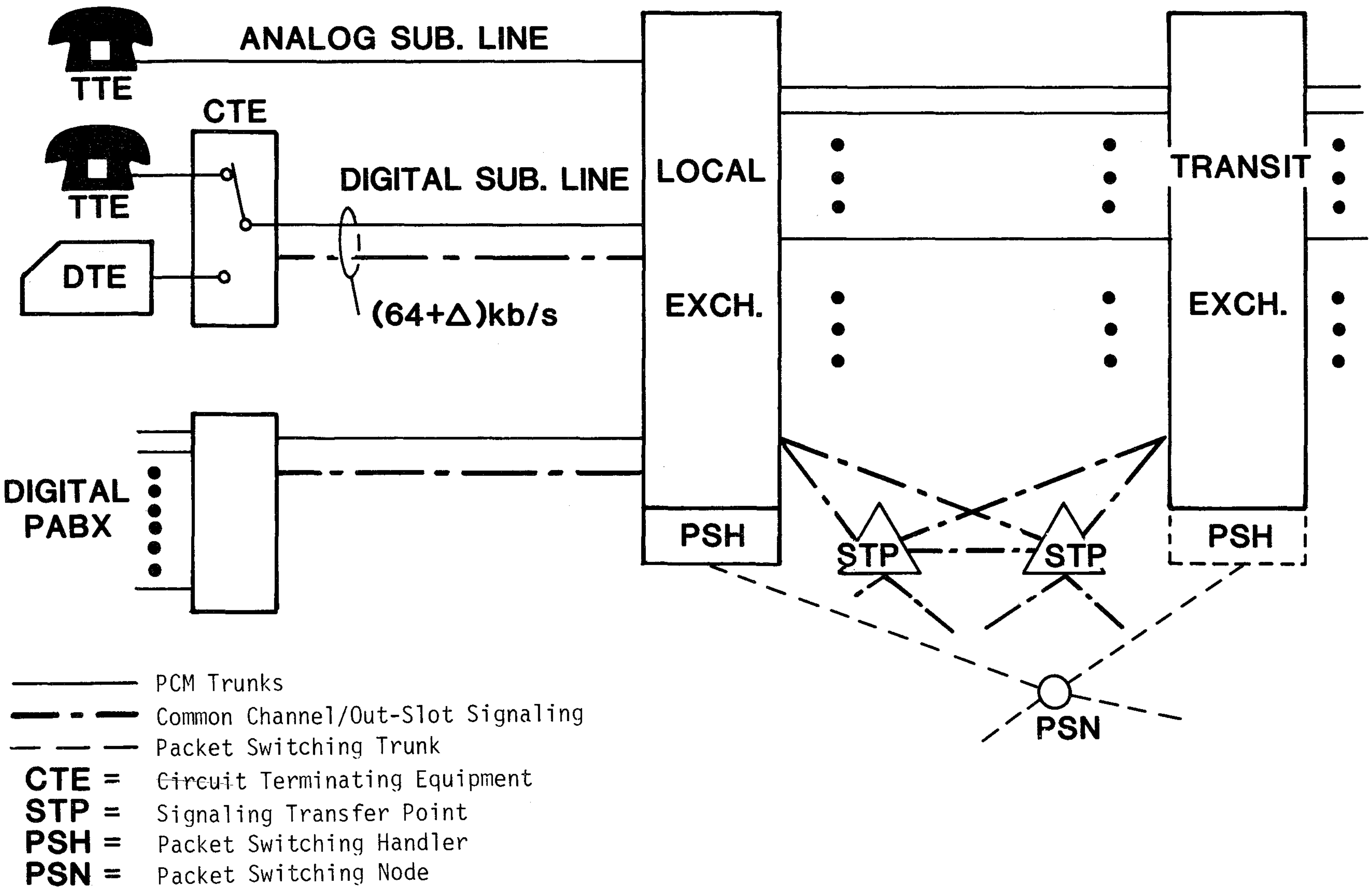


Figure 15. ISDN network architecture (Mosotto and DiPino, 1981).

will use time compression multiplex on a bi-directional digital line. Data will be at 80 kb/s (b + Δ) in each direction. The latter experiment will use a hybrid circuit with an echo canceller to test its features and services.

3.5 Sweden

The Swedish Telecommunications Administration intends to evolve toward an ISDN starting with a telephone-based IDN. The ISDN is intended to emerge by progressively adding new functions and features over an extended period of time. This is based on modernization through installation of digital equipment which replaces systems that have been operating as long as 50 years (Ackzell and Rassmuson, 1981).

A Swedish modernization policy has been established for an ISDN. It will replace equipment in a slow-growth industry: a slow growth industry with a penetration of 80 telephones per 100 residents. There are of 6.6 million telephones in the country.

The telephone network modernization policy consists of the following features:

a) Gradual digitization of the phone network and use of SPC.

b) In interim, satisfy service demand on a custom basis.

c) All new equipment purchased will be digital. Old dismantled equipment will be reused as required.

d) New capital investment will be determined by the demand and revenues of new services.

e) Conversion to digital will be directed toward the business community because of potential market demand.

3.5.1 Digital Capability

Digital transmission systems have been installed in Sweden since 1970. More are planned between now and 1990 (Table 10). (Compare with Table 7.)

At the end of 1980 there were approximately 600 2-Mb/s systems in operation with 1300 expected in 1985. By 1985, 10% of the long distance network will be digital. Use of satellite communications is planned, if the need arises.

Digital switching was introduced for Telex in 1977 (Table 11). By 1990, 50% of all telephone subscriber lines will be connected to AXE digital exchanges. Two million lines will be installed at the rate of 200,000 to 300,000 per year. Another .7 million subscriber lines will be connected to analog switching.

Table 10. Digital Transmission Systems in Sweden
(after Ackzell and Rassmuson, 1981)

System (Mb/s)	Transmission Media	Introduction
0.7	Pair/Radio	1981
2.048	Pair/Radio	1970
8.448	Pair/Coax/Radio	1978
34.368	Coax/Radio/Fiber	1979
2 x 34.368	Radio/Fiber	1982
139.264	Coax/Radio/Fiber	1982
2 x 139.264	Radio/Fiber	1985-90
565.148	Radio/Fiber	1985-90

Table 11. Digital Switching Systems
(Ackzell and Rassmuson, 1981)

System	Introduction
AXE Telephone Switching:	
- Digital Group Switching	1980
- Fully Digital	1984
- Rural Version (500 to 10,000 Lines)	1985
- Remote Digital Concentrator (300 to 2,000 Lines)	1984
- Mobile Telephone Exchange	1981
Various Digital PABX Systems	1979
AXB, Data Switching	1980
AXB, Telex Switching	1977

The CCITT Signaling System No. 7 (called CCS in Sweden) will be introduced in 1983 for common channel signaling between all AXE exchanges. About 1985 CCS will exist in the area of the three largest cities, Stockholm, Goteburg, and Malmo.

The first digital PABX's introduced in 1979 were a version of Canada's Northern Telecom SL-1. Fifty percent of the digital PABX's are connected now via digital transmission lines to public exchanges. The CCS for the PABX's will also be introduced about 1985.

3.5.2 Services

New nonvoice services have been introduced according to Table 12. The digital circuit-switched data network is a common development of the four Nordic countries. It is based on CCITT Recommendations X.1, user signaling rates; X.2, user facilities; and X.21, physical level interface.

The philosophy is to have the services prepared for the ISDN. At this time, as in other countries, all demands and services have not been fully defined.

3.5.3 ISDN Features

The basic user access to the ISDN will be at 64 kb/s. The digital network will be fully interconnected with the analog telephone network (Figure 16). Illustrated are analog telephone, combined voice and nonvoice ISDN terminals and digital telephone services.

The CCS will be used between nodes. The out-slot (Δ-channel = 16 kb/s) signaling for customer access will employ a technique comparable to CCS. The in-slot

Table 12. New Nonvoice Services
(Ackzell and Rassmuson, 1981)

Service	Introduction
In Data Network:	
- Circuit Switched Data (X.21)	1980
- Teletex	1981
- Packet Switched Data	1983
In or Via Telephone Network:	
- Data Base Access	1980
- Telefax	1980

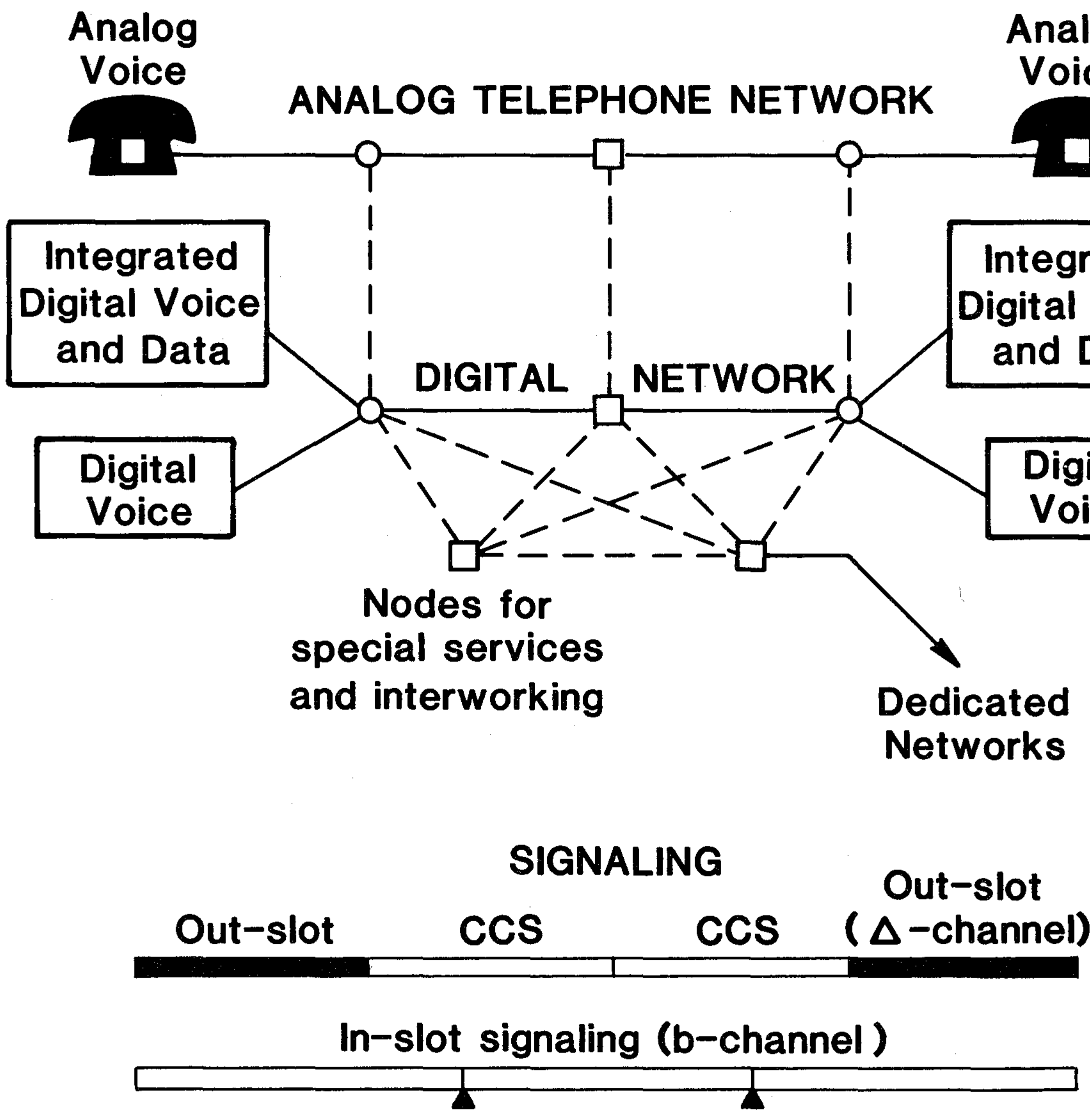


Figure 16. ISDN features (after Ackzell and Rassmuson, 1981).

(b-channel = 64 kb/s) signaling may be used to access nodes from terminals requiring special services, such as access to dedicated networks and packet-switched networks. (Note the lower part of Figure 16. The out-slot/CCS signaling and in-slot signaling align with respective nodes in the upper half of the diagram.)

3.5.4 Interfaces

The possibility exists for using CCITT Recommendation X.21 as customer data access to the ISDN. However, a universal ISDN physical level interface, designated A_x (now called S interface, Section 4.2.1), is recognized as desirable to accommodate digital telephones, data terminals, and combined voice/nonvoice ISDN services.

Depending on various data signaling rates needed to handle alternate or simultaneous voice and data at the A_x interface, some frequency combination of b- and Δ-channels will have to be considered. Usually the b-channel = 64 kb/s and the Δ-channel = 16 kb/s. Subdividing the Δ-channel results in Δ- and b'-channels at 8 kb/s each. Hence,

$$\left.\begin{array}{l} b + \Delta \\ b + b' + \Delta \end{array}\right\} = 80 \text{ kb/s}$$

or

$$b + b + \Delta = 144 \text{ kb/s.}$$

(See Section 4.2 for further information.)

It is not known whether consideration has been given to bi-directional lines using time-compression multiplex.

3.6 United Kingdom

The British Telecom (BT) has proposals for entry to an ISDN within the United Kingdom. The ISDN concept is attractive with attendant problems. How to introduce a new digital system in the presence of existing networks? One method is to replace plant facilities of a limited geographical area with new digital equipment. Although the ISDN could be available immediately within the area, outside communications would be difficult. British Telecom has chosen a second method.

3.6.1 Implementation

Since digital communications are needed throughout the U.K., British Telecom has chosen to develop a nationwide overlay network. The ISDN is scheduled to start service to 500 subscribers at one exchange in London in 1983/84. This will be expanded to 20,000 subscribers by 1986/87 (Brown and Mason, 1981). An overlay network will take shape, through a combination of offering out-of-area lines and installation of new SPC digital switches, based on British System X. Common channel signaling in the customer loop is to be used. The ISDN coverage is expected at 30 switching centers by 1987, and 200 centers by 1990.

3.6.2 ISDN Features

As in other countries, the basic customer interface will be at 64 kb/s (b-channel). Signaling will be at 8 kb/s (Δ-channel), and another 8 kb/s (b'-channel) will be a data channel.

Frequencies supported for various services are based on CCITT Recommendation X.1. CCITT Recommendations X.21 (DTE-DCE interface for synchronous operation on public data networks) and X.25 (DTE-DCE interface for terminals operating in the packet mode on public data networks) will also be supported.

The X.21 procedures which exist between the user and network interface are transformed in network termination equipment so that control signaling is transmitted within the common signaling channel and data within the data channel (Wedlake, 1981).

The X.25 supported packet switching exchanges will be accessed by ISDN subscribers on a switched or dedicated line. However, the packet services are not considered an integral part of the ISDN.

A comparison of CCITT V- and X-Series recommendations of the proposed ISDN is useful (Table 13). There is close adherence between the X-series recommendations and the ISDN for the features listed.

Table 13. Comparison of V-Series, X-Series, and ISDN Interface Parameters (Wedlake, 1981)

Parameters	V-Series (Switched)	X-Series	ISDN
Transmission	3 kHz Analog	Digital at 1.3 x Data Rate	64 kb/s Digital
Maximum Data Rate	2.4 kb/s Duplex	48 kb/s Duplex	64 kb/s Duplex
Set-Up Time	5 to 25 Seconds	1 Second	1 to 2 Seconds
Error Rate	$1 : 10^{-3}$ to 10^{-4}	$1 : 10^{-6}$	$1 : 10^{-5}$ to 10^{-6}
Signaling	Slow and Primitive	Fast and Advanced	Fast and Advanced
Switching	Analogue 2/4 Wire	Digital 4 Wire	Digital 4 Wire

Note that digital 4-wire switching is indicated in the British approach. The U.S. is heavily dependent on the digital capabilities of unloaded 2-wire loops.

3.6.3 Services

The British Telecom believes it will provide capability for the various services at the given signal rates (Table 14). Services and features are similar to those of other countries, although details vary.

3.7 Japan

Studies and planning for an ISDN in Japan have been significant. An Information Network Service (INS) based on ISDN is progressing in that country. In Japan, as in other countries, the INS is made possible because digital networks are now economical through advanced techniques used in solid-state component manufacturing. Nippon Telegraph and Telephone (NTT) Public Corporation plans to overlay the existing analog network with a digital system (Morino and Kawaoka, 1981). Telephone, facsimile, data, video and telemetry services will probably be offered (Figure 17).

3.7.1 Digital Capability

The Japanese and United States digital carrier systems are based on 24 voice channels compared with 32 in Europe. The DC-100M system was introduced in 1975. It was followed by the DC-400M in 1977. By 1990, long-distance transmission links will be 100% digital, and short-haul links will be 70% digital (Iimura et al., 1981).

Digital switching will be introduced in 1982 starting with transit (tandem) switching. Digital switching with SPC will be extended to subscriber (local) switching in 1983. By 1990, 60% of the transit switches and 30% of the subscriber switches will be digital.

Metallic subscribers loops will be used for now, while optical fiber cables will be introduced as they become economically feasible.

3.7.2 New Services

Other elements, in addition to digitizing the telephone network, are involved in the transition toward a Japanese ISDN.

(1) A public facsimile communications network was started in 1981. Using store-and-forward techniques, it utilizes existing facilities at the subscriber loop and local switch levels. The facsimile system is expected to be easily integrated into an ISDN.

(2) Digital Data Switched (DDX) network services were introduced for efficient data transfer services. Circuit switched services started in December 1979 and packet switched services commenced in July 1980 (Morino and Kawaoka, 1981). The DDX networks are independent of the present telephone network.

Table 14. Services and Frequencies for a United Kingdom ISDN

Service	Signaling Rate (kb/s)
1. Asynchronous Data Transmission	.3, 1.2
2. Synchronous Circuit-Switched Data Transmission (1)	2.4, 4.8, 9.6, 48
3. Digital Facsimile (2)	8, 48, 64
4. Teletex	2.4
5. Packet Circuit Data Service (1)	2.4, 4.8, 9.6, 48
6. Packet-Switching Access	2.4, 4.8, 9.6, 48
7. Slow-Scan TV (private or public connections)	8 (32 second refresh) 64 (4 second refresh)
8. Videotex	8, 64
9. Analog Device Support o Compatible Terminals Using V-Series Interfaces	Voice Channel Rate
10. Telephony o b-channel connections between current telephone terminals of current public switched telephone network design with other phone terminals	

Notes: (1) 8 kb/s and 64 kb/s will be provided based on ISDN optimization and CCITT approval for changes in CCITT Recommendation X.1.

(2) Based on standards for Group 4 machines.

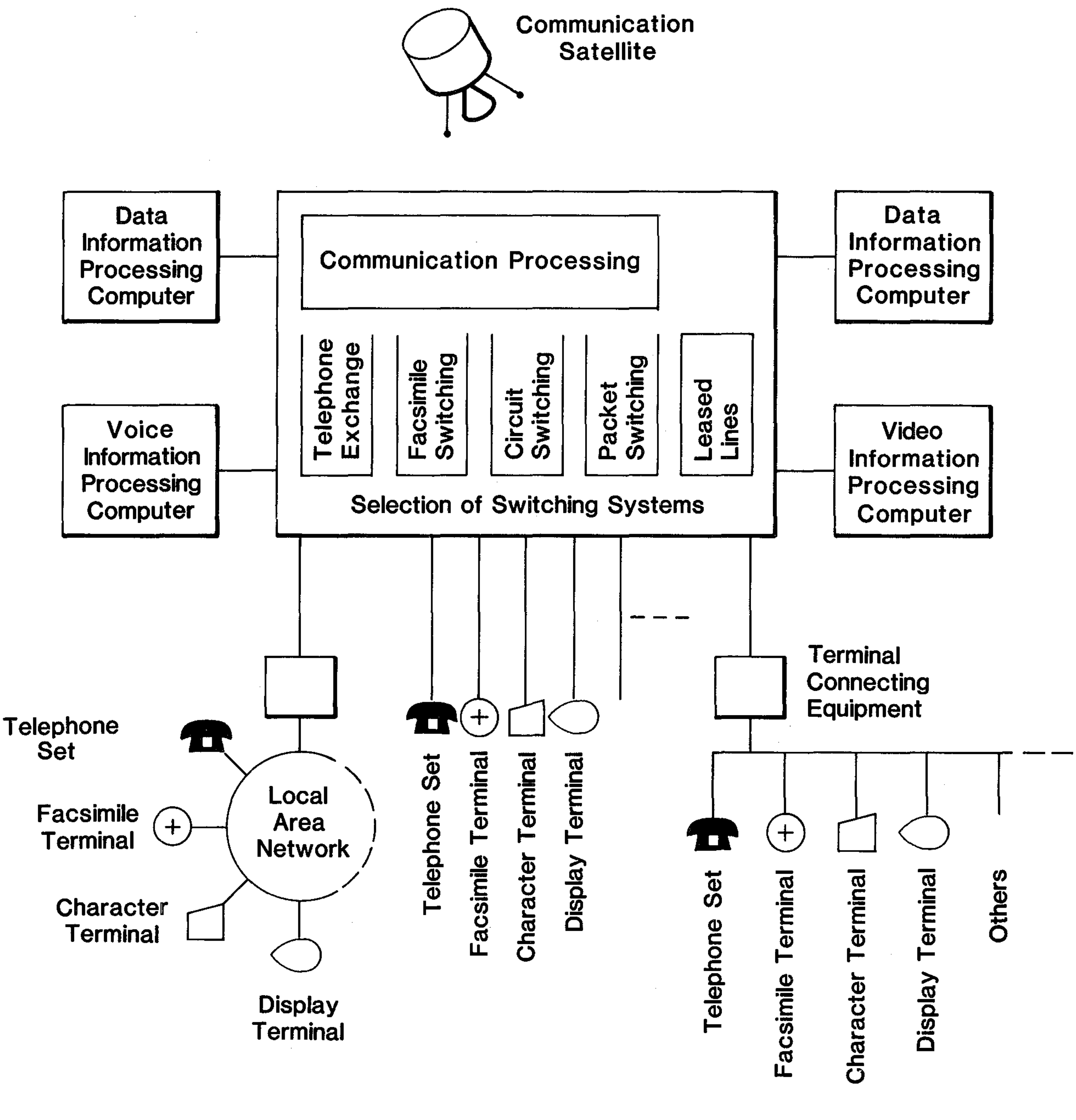


Figure 17. An information network system (Morino and Kawaoka, 1981).

(3) A wideband services network will have to be established using multiples of 64 kb/s. However, since the digital wideband components, such as time division switches and economical terminals, have to be developed first, an analog wideband network will be initially built (Iimura et al., 1981).

Merger of the telephone, facsimile, and DDX networks is planned to take place in Phase 1 of transition to an ISDN. The wideband services will be incorporated in Phase 2 as a digital wideband network is completed.

No time frame has been given for this phasing, but completion of Phase 2 would appear likely around 1990.

3.7.3 Stages of Network Integration

The present communication system basically consists of four public networks based on switching: telephone, packet, facsimile, and circuit switched. All are isolated and operate independently (Figure 18a). Communications between users on user devices exists only within a specific network.

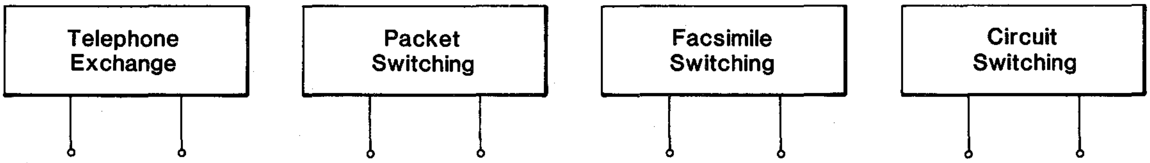
In the first stage of integration, users and user devices will be able to communicate outside their own network to users and devices on another network. Communication processing and interconnection functions will be provided through the public networks (Figure 18b). Connection of a terminal device to more than one network will be necessary because of the incompatibility between voice and facsimile systems. Switching functions are isolated in Figure 18b.

In the second stage of integration, public networks will be integrated into the ISDN. Partial integration will enable terminal devices to select switching systems through the subscriber line and require a device awareness of interworking between the public networks (Figure 18c). In the third phase, total integration will enable access to a single public network for communication processing and combined switching functions (Figure 18d).

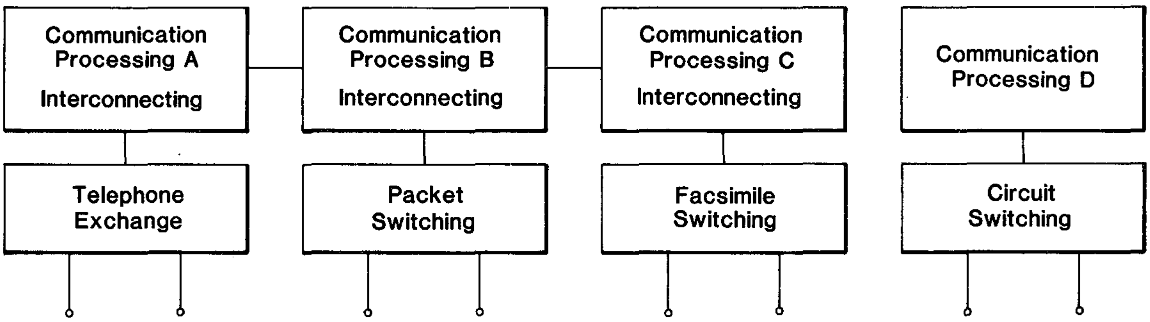
3.7.4 Model Network

A model INS network will be built to operate in 1984. It is intended to accommodate 9,000 existing analog telephones, 250 digital telephones, and 750 nontelephone terminals. The nontelephone terminals would be for data and facsimile purposes. This model ISDN capability will be connected to existing facilities through digital subscriber (local) and transit (tandem) switching systems to analog switches through appropriate interfaces (Iimura et al., 1981).

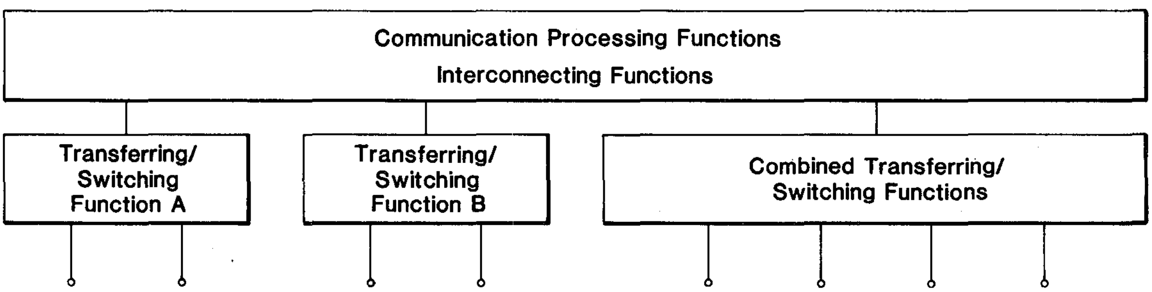
Services to be offered by the model network include teletex, telemetry, facsimile, videotex (best-suited for digitizing); video, using optical fibers on subscriber loops; message, data transfer, facsimile, and TV under existing services



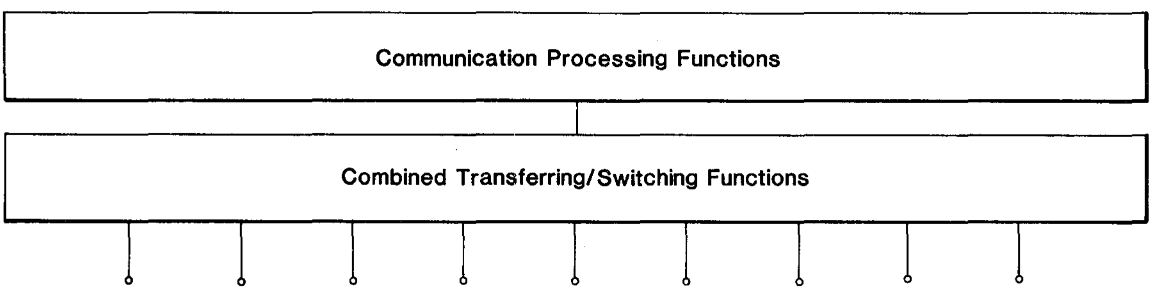
a. Isolated Public Network Stage.



b. Combined Public Network Stage.



c. Partially Integrated Public Network Stage.



d. Fully Integrated Public Network Stage.

Figure 18. Stages of network integration in Japan (after Morino and Kawaoka, 1981).

(Table 15). Note that the CAPTAIN videotex system uses store-and-forward techniques for message transmittal (Shimasaki and Itakura, 1981). Facsimile and telewriting, (a form of electronic messaging), would also use store-and-forward in the digital visual communication classification of Table 15.

3.7.5 Multimedia Communications

The services just described can be summarized as relating to voice, data, and video media (i.e., multiple media). Multimedia communications is defined as communication between end-users involving data such as alphanumerics, Japanese ideography (Kanji), or phonetic Japanese (Kana) displayed on a terminal (Morino and Kawaoka, 1981).

Multimedia communications have three classes according to input and output characteristics between terminals and communication lines.

(1) Single device multimedia communications exist when a telephone set or facsimile device is used to make an inquiry to a data base and a response is made. Response is made to the same inquiring device through speech synthesis or character display.

(2) Combined device multimedia communications exist when an inquiry is made on one communications line (e.g., from a telephone) and a response is made on another line (e.g., to a facsimile). Also, the devices can alternately use the same subscriber line.

(3) Integrated device multimedia communications exist when voice, data, and video devices are used simultaneously from one user location to another over the same subscriber line.

3.7.6 Switching and Software

Extensive, systematic development of software for protocols is needed for network integration to take place for the multimedia communications. An important aspect of systematic development is a comparison of switching systems (Table 16).

Consideration of a) call processing, b) switching resource management, c) signaling systems, and d) numbering schemes, routing and traffic control for the various switching are shown. (The common channel signaling system that will be adopted is CCITT Signaling System No. 7.) A number of conclusions are made from Table 16 (Hasui et al., 1981):

a) Call processing. Combining basic call processing systems causes deterioration of processing efficiency and redundancy of memory for each switching system.

b) Switching resource management. Common resource control is needed, but switching resources need to be managed independently due to different trunk and circuit resources.

Table 15. Services in a Model Network (after Iimura et al., 1981)

Classification		Services
Services Considered Best Suited for Digitizing	Telephone	Auto Call Transfer Add-On Conference Charge Information Calling Number Indications
	Data Communication	Teletex Information Retrieval Telemetry Telecontrol Telealarm
	Visual Communication	Facsimile Videotex (CAPTAIN) Telewriting
Services Using Subscriber Line Optical Fiber	Visual Communications	Video Response Service Video Conference High-Speed Facsimile
Existing Services	Telephone	Abbreviated Dialing Call Waiting Message Service
	Data Communication	Inventory Management Engineering Computation Telex
	Visual Communication	Facsimile (Analog) TV

Table 16. Comparison of Switching Systems (after Hasui et al., 1981)

	Telephone Switching	Data, Circuit Switching	Data, Packet Switching	Approach to Service Integration
Call Processing	Call sequence by connection changes of trunk and speech path -- call control corresponding to physical trunk	Call sequence by data terminal control protocol -- call control corresponding to logical call protocol	Call sequence by logical link (virtual circuit) -- call control corresponding to logical link	The call processing functions should be integrated according to these call processing characteristics.
Switching Resource Management	Trunk Resources Because analog trunks are used, the first-in first-out process is needed. -- resource management by FIFO chain memory	Circuit Resources o All digital circuit o The various bit rate switching is needed. -- resource management by logical map memory	Circuit Resources Logical packet links are used. -- resource management by logical link memory (not physical circuit)	Logical service network constitutions are different. Logical resource management as well as physical resource management is needed.
Signaling System	Subscriber Level signal (ON/OFF) Inter-Office MF, Common channel, etc.	Terminal X.20, X.21, etc. Inter-Office Common channel signaling	Terminal X.25, etc. Inter-Office Both data and signal are sent in packet form.	High level and uniform signaling system is needed.
Numbering Plan, Routing and Traffic Control	9 digits Far to near rotation Originating traffic control	7 digits Far to near rotation Originating/terminating traffic control (different algorithm from telephone)	7 digits Packet flow control Originating/terminating traffic control	Standard numbering plan is needed, but routing and traffic control are required to be managed according to service specifications.

c) Signaling system. Standard interfaces are needed between terminals and systems.

d) Numbering and routing. A standard numbering plan is needed, but routing and traffic control need managing according to service specifications. There is CCITT activity in this area.

Combining services into one switching system has a synergistic effect on complicating software. The concept of control space is introduced to deal with this effect in a modular fashion. Control space corresponds to a group of subsystem functions having independent control. Control space subsystems then correspond modularly to signaling, telephone service, data service, network and terminal control spaces (Figure 19). Software modularity is related to each control subsystem.

Using the above premises, extensive design and testing of ISDN software architecture is taking place in Japan.

4. ISDN STANDARDS

A number of national and international standards organizations are involved in ISDN standards considerations. Among these are the American National Standards Institute (ANSI) and Electronic Industries Association (EIA) in the United States. The European Conference of Posts and Telecommunications Administrations (CEPT) has placed emphasis on ISDN development. On the international level, there are the International Telegraph and Telephone Consultative Committee (CCITT) and the International Organization for Standardization (ISO). The CCITT has put a major emphasis on ISDN studies for the 1981-1984 Study Period.

4.1 CCITT Questions for the ISDN

The CCITT Study Groups are addressing customer accesses, services, networks, signaling, and switching. Types of services include analog telephony, digital telephony, digital data, telex, telegraphy, telemetry, low-speed data, and broadband. All of these and other areas of interest are not fully defined, but do appear as a basis for discussion and consideration.

The CCITT ISDN work is to be coordinated through Study Group XVIII (Digital Networks), which has assigned to it 19 questions (CCITT, 1981a) of interest (Table 17). Nine of the other 14 CCITT Study Groups (I, II, III, VII, VIII, IX, XI, XV, and XVII) have assignments for the development of recommendations toward the ISDN. Chief among these are the following three: Study Group VII (Data Communications

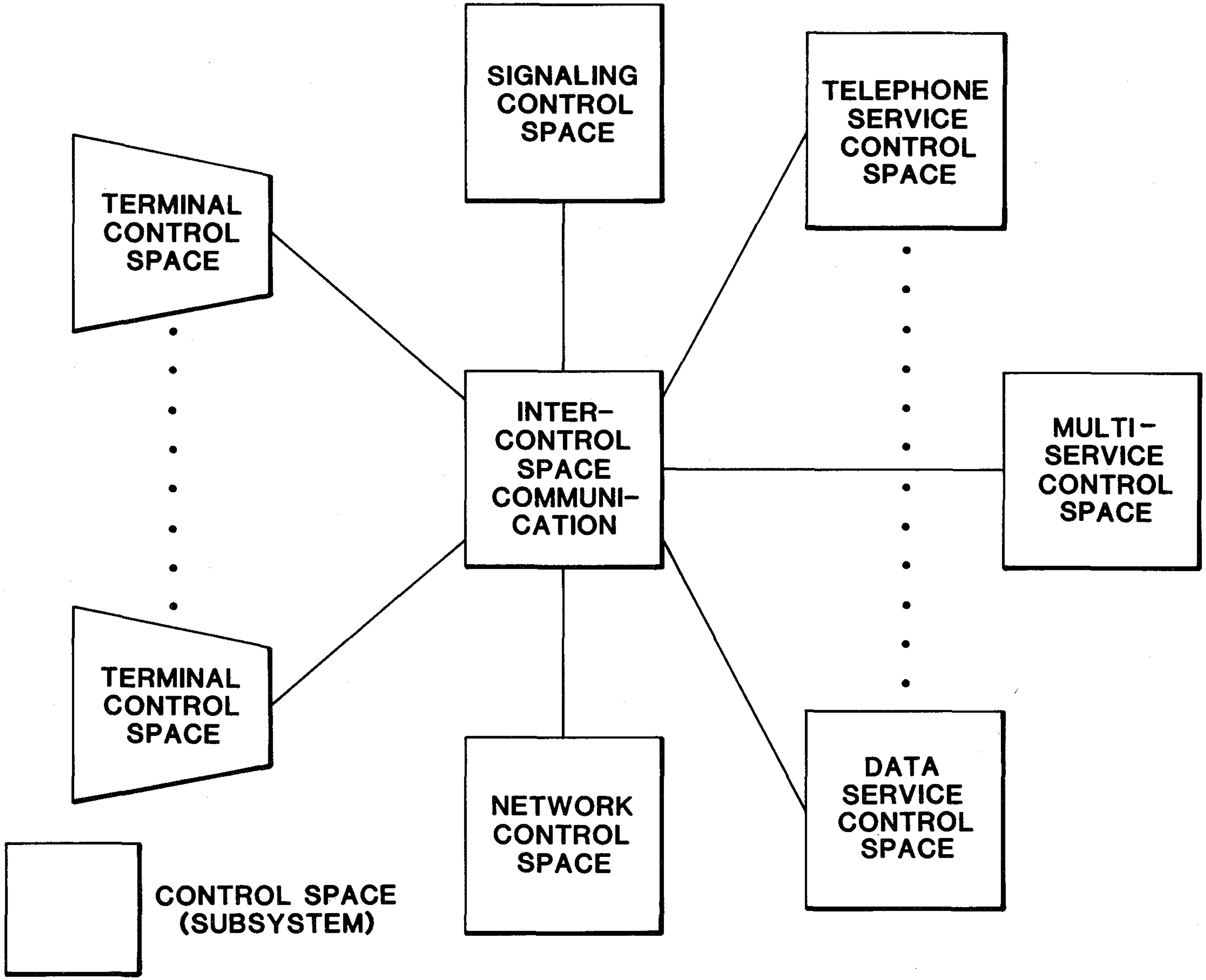


Figure 19. Concept of control space for integrated services switching (Morino and Kawaoka, 1981).

Table 17. List of Questions Assigned to CCITT Study Group XVIII for the Study Period 1981-1984

Questions	Title
1/XVIII	General network aspects of an Integrated Services Digital Network (ISDN)
2/XVIII	Customer/network interface
3/XVIII	Synchronization in digital networks
4/XVIII	Signaling for the ISDN
5/XVIII	Switching for the ISDN
6/XVIII	Definition for digital networks
7/XVIII	Encoding of speech and voice-band signals using methods other than PCM, in accordance with Recommendation No. G.711
8/XVIII	Digital speech interpolation system
9/XVIII	General network performance aspects of integrated digital networks
10/XVIII	Availability for the ISDN
11/XVIII	Characteristics for digital sections
12/XVIII	Maintenance philosophy of the digital network
13/XVIII	Implementation of maintenance philosophy
14/XVIII	Interworking between digital systems based on different standards
15/XVIII	Interfaces in digital networks
16/XVIII	Performance characteristic of PCM channels at audio frequencies
17/XVIII	Characteristics of PCM multiplexing equipment and other terminal equipments for voice frequencies
18/XVIII	Characteristics of digital multiplex equipment and multiplexing arrangements for telephony and other signals
19/XVIII	Network aspects of existing and new levels in the digital hierarchy

Networks), Study Group XI (Telephone Switching and Signaling), and Study Group XVII (Data Communications Over the Telephone Network) (Cerni, 1982).

4.2 ISDN Terminology

Previous sections described the ISDN plans for eight countries. The symbols used were based on the terminology incorporated by the authors in describing their countries' plans. However, the ISDN is in a state of dynamic change and the standards work reflects this. Nomenclature has been changed by the CCITT to avoid the use of symbols which are not considered part of a standard character set (e.g., Δ as in Δ-channel) on a typewriter. Another objective is to provide a comprehensive set of symbols which can be adapted to the changing needs. The authors of even the most recent papers have not been able to keep up with many of the changes. This section describes the most recent ISDN terminology and symbols which have been adopted by the CCITT for use in new contributions. Sections 4.2.1 through 4.2.6 are from an ANSI X3S3.7 tutorial (Scace, 1981) and CCITT Report (1981b).

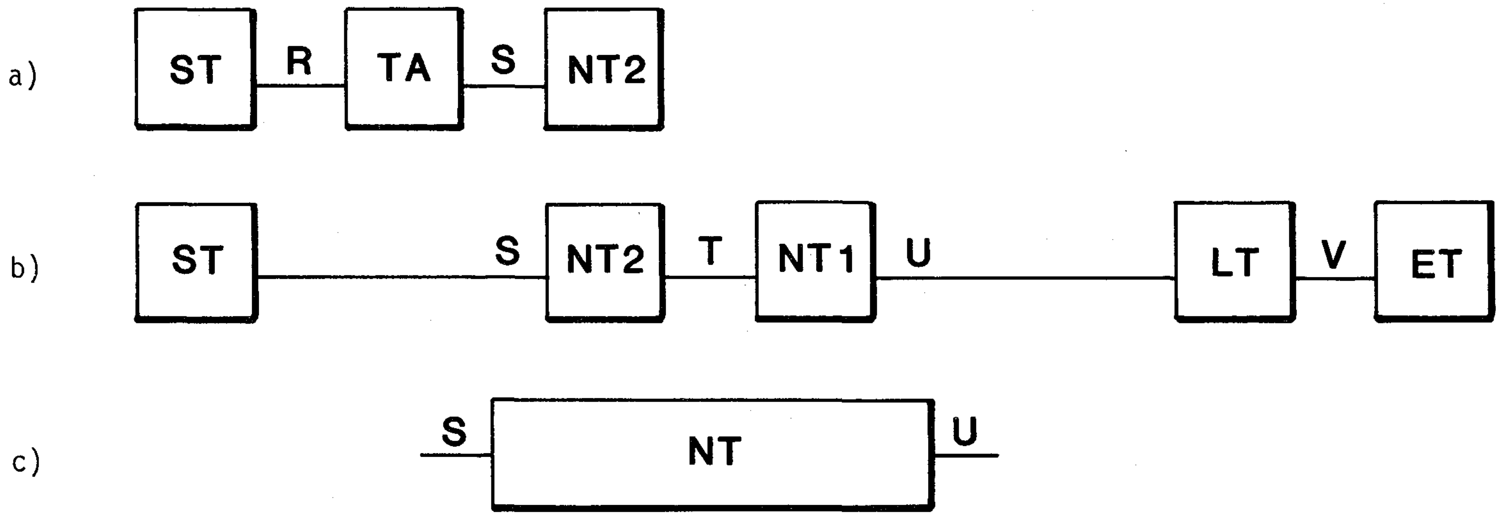
4.2.1 Definitions for User Access Model

Each box (Figure 20) represents a set of functions allocated as a unit to equipment providing ISDN services. Each set is designated with an acronym using a pair of capital letters and optionally, a following digit. These sets interface with their neighbors. The interfaces are designated by a single capital letter selected from the high end of the alphabet.

Examples for the boxes are cited below to provide illustrations of ISDN implementation. However, it is possible that all participants in the CCITT will not agree with the choice of examples since implementations can vary from country to country at different times.

ST - subscriber terminal: devices at the users location. Examples: analog telephone, hybrid telephone (e.g., analog voice plus digital data), X.25 host, asynchronous CRT, digital telephone, facsimile terminal. The ST's are of two types: pre-ISDN and ISDN. Pre-ISDN ST's have an R interface which complies with one of the current CCITT recommendations (Figure 20a). Future ST's will use the S interface.

R - non-ISDN interfaces. These interfaces are the existing standardized interfaces which are expected to work with the ISDN. Today's analog telephone has an R interface that carries analog voice plus signaling information (pulses or dual-tone multifrequency (DTMF) signaling). An X.25 host has an R interface that operates using the X.25 protocols at one of the transmission speeds specified in CCITT Recommendation X.1. Other R interface examples for data include X.21 for circuit switching, and



a) R and S interfaces.

b) Deletion of terminal adaptor; NT functions.

c) Combined NT1 and NT2.

Figure 20. Model for user access (after Scace, 1981).

RS-232C equivalent for asynchronous CRT's. The R interfaces for facsimile are those defined for Group I, II, and III facsimile equipment.

TA - terminal adaptor: used to convert R interfaces into the "universal" ISDN S interface (all digital). The TA is not present for future ST's which can match the S interface directly. Note the TA deletion in Figure 20b.

S - the all-digital interface for future ST's. The S interface will be available in a configuration which permits subsets. Basic ISDN access is through an S interface containing one or more transparent user channels and a separate signaling channel. General discussion (May 1982) indicates that the S interface will have 2 or 4 wires.

NT - network termination: provides functions necessary for the ST to access the public network through the local loop. For the United States, the NT is subdivided into two portions. The NT1 contains functions provided by the regulated carrier along with the subscriber's local loop: local loop termination, maintenance (e.g., loopback, monitoring), remote power feeding, etc. The NT2 contains functions available in equipment from nonregulated organizations, such as PABX switching and concentration.

T - interface between NT1 and NT2. In the United States, T is expected to be the demarcation between regulated and unregulated domains. In some other countries, T will not exist; the PTT may choose to provide both NT1 and NT2 functions in a single box NT with no visible T interface (Figure 20c).

U - the local loop. The ST, TA, and NT1/2 are normally located on the subscriber's premises. Metallic loops predominate today. Optical U interfaces may appear in the future, especially for wideband services.

LT - line termination: termination of the local loop in the central office. Surge protection is contained here, and the LT serves as the correspondent for NT1 for modulating/demodulating local loop signals.

V - interface to central office switching equipment.

ET - exchange terminal: central office switching equipment. In some implementations, LT and ET will be in the same box of equipment; the V interface may not be physically present in that case.

4.2.2 Channels Within Interfaces

For the ISDN user and equipment supplier, interfaces R, S, and T are of particular value. Channel types present within these interfaces are designated with single capital letters from the low end of the alphabet. Digital channel identifiers may be followed with their speed in kilobits per second. These channels are:

A -- analog telephony. A is available only at the R interface in the ISDN nomenclature.

B -- a digital channel available for carrying ST-supplied information through the network. (Formerly called the b-channel.)

D -- a digital channel primarily used for carrying signaling information for controlling the network. (Formerly called the Δ-channel.)

E (C-channel, May 1982) -- carries analog signaling for the A channel. Conventional analog telephony, therefore, comprises channels A+E at the R interface. (A new E-channel type in conjunction with the PABX signaling channel for Signaling System No. 7 has been proposed (CCITT, 1982).)

F -- a digital channel for hybrid use. The F channel carries digital signaling for analog channels, as well as data when combined voice and data are used.

A+F is a hybrid channel structure for simultaneous voice and data, for instance, at the R interface.

4.2.3 Traffic Types

For ease of reference, traffic types have been defined. Each type is designated by a single, lower-case letter, usually a mnemonic. The letter may be followed by a number to indicate a subtype. Traffic types defined are:

a -- analog voice.

v -- digital voice, as follows:

v1 -- 64 kb/s PCM using A- or mu-law,

v2 -- submultiples of 64 kb/s (i.e., 8, 16, 32 kb/s),

v3 -- 64 kb/s, but not A or mu law PCM.

Two additional "v" subsets have been proposed to the CCITT (GTE International, 1982). They are:

v4 -- packetized voice, and

v5 -- variable bit rate voice.

d -- data at CCITT Recommendation X.1 rates,

p -- low speed data ($\leq$ 1200 b/s),

t -- telemetry ($\leq$ 100 b/s),

s -- digital signaling information,

w -- ("wideband") data at n x 64 kb/s, where n is small (2 or 3),

and

u -- high speed digital streams, as follows:

u1 -- from w to 1.544/2.048 Mb/s,

u2 -- from u1 to 6.312/8.448 Mb/s,

u3 -- from u2 to 140 mb/s.

4.2.4 Channel Structure at the S Interface

The goal is to provide basic access by defining channel structure for the subscriber at the S interface in the form of:

B64 + B64 + D16.

The two B channels are independent. They may connect the ST or TA to two different ST/TA's at other subscriber locations. However, all signaling information for controlling both B channels is carried over the single D channel.

Given the constraints of operating over metallic loops, a channel availability equivalent to a subset of the above can enable a graceful evolution from the current general switched telephone network. This could be for example:

B64 + B8 + D8.

These three structures are all referred to as "basic access." Other more complex access structures may also be available. Loops, stars, and bus topologies supporting S interfaces are also being considered.

4.2.5 Channel Structure at the T-Interface

If NT2 supports only one S interface, then the T interface need carry only the same basic access channel structure as found at the S interface.

Where several S interfaces are supported by NT2, T becomes more complex. Additional channel structures under CCITT consideration include:

-- m B64 + D16, where m is between 2 and 24 or 30.

-- 1.544 or 2.048 Mb/s, structure not yet defined but signaling is carried on a common signaling channel; how this differs from 24 B64 + D16 or 30 B64 + D16 is not yet clear.

-- n B64 + D16, where n is large (much larger than 24 or 30, probably in the hundreds).

As an example, PABX's might use any of the above structures at the T interface. Remote concentrators/multiplexers are to be given access, preferably along the lines of m B64 + D16.

4.2.6 Traffic Type Allocation

A B64 channel is to carry 64 kb/s PCM using A- or μ-law coding (v1) and, 64 kb/s that is not A- or μ-law PCM (v3). The B64 channel can also carry traffic at less than 64 kb/s (v2), but at a rate that is adapted to 64 kb/s (i.e., a lower data rate padded to 64 kb/s). These rate adaption methods, to 64 kb/s based on CCITT Recommendation X.1, are still being discussed by the CCITT.

The D-channel is primarily to carry signaling information for controlling traffic (S-type traffic). Low speed traffic types such as telemetry (t traffic at $\leq$ 100 b/s) and low speed packet data (p traffic at $\leq$ 1200 b/s) can also be carried on the D-channel as long as minimal delay is imposed on s traffic. Carrying data at X.1 rates on the D channel is also possible. However, signaling information appears to have priority on the D-channel resources.

Discussions have suggested (as of May 1982) that HDLC (an adaptation LAP B) should be used as the D-channel protocol. Subsets or extensions of common channel signaling CCITT System No. 7 may be suggested to the CCITT as the protocol for signaling information.

Many other details remain to be accounted for and developed.

4.3 Some Standards Toward ISDN Evolution

Previous sections (2.1, 2.2) described the evolutionary steps which are being taken by the AT&T toward an ISDN. This effort is not restricted to publishing papers and implementation of hardware within the United States. Efforts toward an ISDN extend to the international level and the CCITT. A number of papers have been contributed by AT&T and others to the CCITT via the ANSI X3S3.7 task group, U.S. Study Group D, and the U.S. Joint Working Party on the ISDN.

Some contributions describe the ISDN from a user's perspective (AT&T, 1982a), hybrid user access arrangements for simultaneous analog voice and low-speed digital data (AT&T, 1982b), and user interface protocols for hybrid access arrangements (AT&T, 1982c). (See Appendix A for contributions.) This hybrid access arrangement is the same as the local area data transport (LADT) capability in Section 2.2.2.

4.3.1 Access Arrangements

An X.25 (Level 2) type of protocol is shown as needed for data entry in Figure 6. Details of this requirement are given in the second of the above references. The hybrid access to the ISDN is denoted as A + E (analog telephony + analog signaling for the A channel) channels. An E-channel access protocol has been proposed to be LAP C. The link access procedure now supported by the CCITT is LAP B, which operates in an asynchronous balanced mode (ABM). The first link access procedure (LAP) operated in an asynchronous response mode (ARM) (Figure 21). The LAP B has now been adopted and is supported by the U.S. Government while the LAP is phased out. The LAP C makes use of two bits in the LAP B address field which had been unused. Use of the two bits permits multiplexed multidrop operation rather than point-to-point linkage. The LAP D is another link access procedure intended for carrying signaling information on the D-channel for digital subscriber lines. While the LAP B is a subset of LAP C, LAP C is to be considered a subset of LAP D.

4.3.2 Physical Level Interface

An important aspect of ISDN standards activity is consideration of a new physical layer interface which would permit replacement of CCITT Recommendations X.21 and X.21 bis (RS-232-C, RS-449). A contribution to the CCITT (EIA, 1981) has proposed a mini-interface which would be functionally equivalent of these interfaces, but would also anticipate future requirements of an ISDN. The mini-interface would have a 9-pin D-subminiature connector and be compatible for DTE/DCE, DCE/DCE, and DTE/DTE interfaces. Each direction of data transfer would consist of symmetrical, balanced, conductor pairs. One pair of "Data" and one pair of "Control" conductors would be used in each direction of data transfer. The data transfers in each direction are independent and may occur at different signaling rates. Another feature is the use of differential Manchester encoding for synchronous operation and standard start-stop for asynchronous operation (EIA, 1981, Appendix B).

As attractive as this new interface may appear, there are problems. The position of some participants has been that CCITT Recommendation X.21 should not be replaced, but rather maintained until ISDN interface requirements are fully defined. This would mitigate introduction of new interfaces. An example of a counterproposal is provided. It requests definition of user requirements for ISDN access, clarification of interfaces such as T and NT1, use of LAP B for a level 2 signaling protocol and consideration of tariffs because the ISDN would be insensitive to services carried (IBM Europe, 1981, Appendix B).

Definition of a physical layer interface is being pursued in terms of a number of objectives such as 1) support for current digital networks, 2) allowing

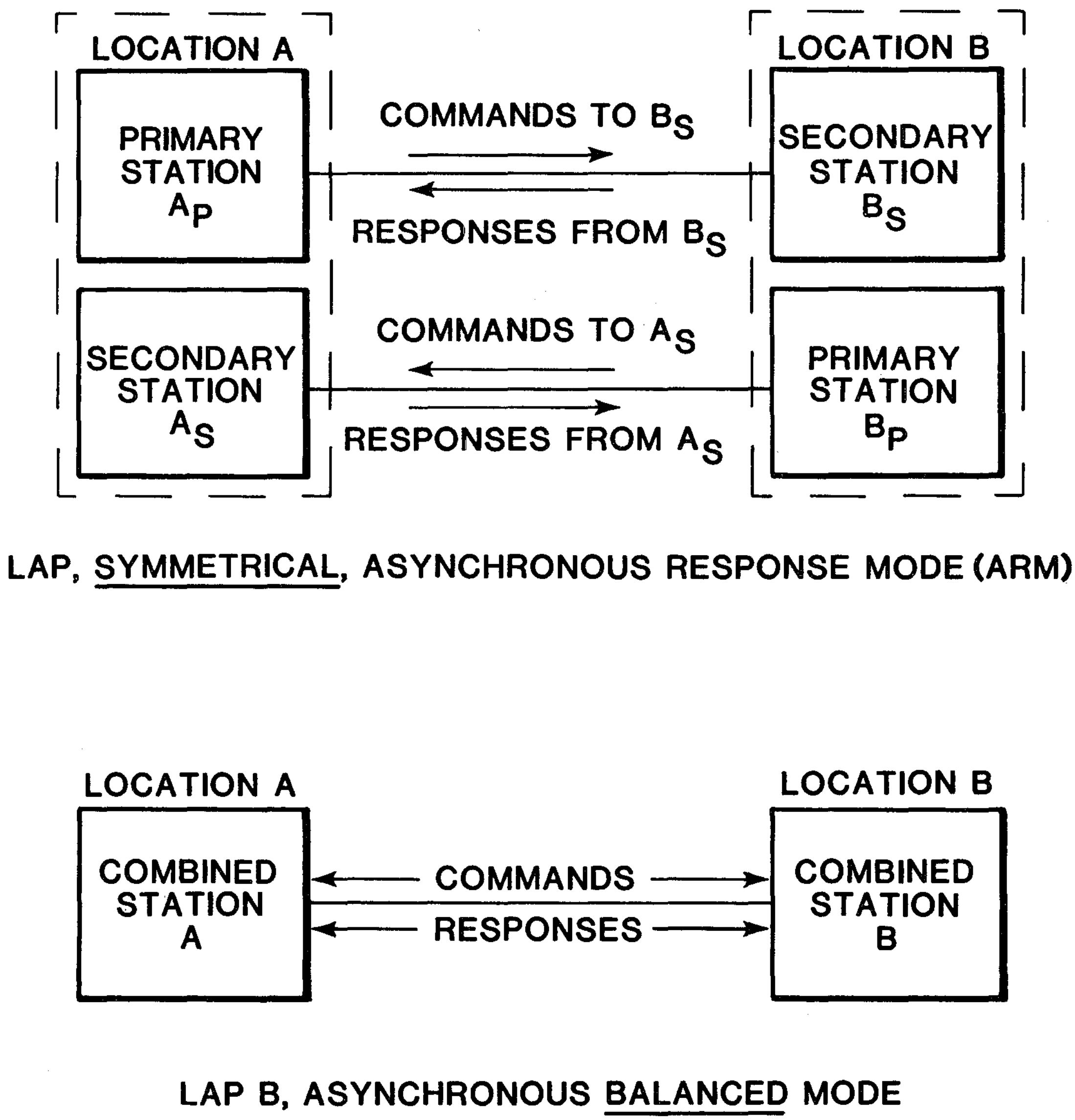


Figure 21. LAP/LAP B configurations (after Folts, 1981).

orderly migration to the ISDN, 3) minimum number of interchange circuits and other features. The objectives are to be pursued by defining mechanical, electrical, and functional aspects (AT&T, 1982d, Appendix B).

Three important CCITT Draft Recommendations are in Appendix C. The draft recommendations are: I.xxx: ISDN user/network interfaces - reference configurations; I.xxy: ISDN user/network interfaces - channel structures and access capabilities; I.xxw: General aspects and principles relating to Recommendations on ISDN user/network interfaces (CCITT, 1982, Appendix C).

5. TECHNOLOGY

There are several technologies indigenous to an ISDN environment. Satellites, fiber optics, and others have been referred to in previous sections. This section will expand on the No. 5 ESS switch, the two-wire digital subscriber loops using time compression multiplex, and transmultiplexers. All are a factor in, and progress toward, the ISDN.

5.1 No. 5 ESS

An example of the development toward the ISDN was the first placement of the No. 5 ESS local digital switch in an end office by AT&T in 1981. After testing, it became operational in late March 1982.

The No. 5 ESS has distributed processing architecture, modular software, and lightwave technology. The processing is distributed in microprocessor-controlled interface modules (IM's) which free the central processor to perform its own functions. The IM's are the basic building blocks on which lines and trunks terminate. They are directly compatible with the SLC-96 pair-gain system. The modules can accommodate up to 4096 user lines. The first No. 5 ESS's will support from 1 to 30 interface modules. Later units will support up to 127 IM's (Smith, 1982). This flexibility makes the No. 5 ESS suitable for rural and metropolitan areas.

Modular software, using the C programming language, is divided into packages, some controlling switching, while others provide calling services and features. Rewriting one package will not make it necessary to change the others.

Lightwave technology in the No. 5 ESS is used to make network connections to telecommunications traffic, to control paths for internal system messages, and to distribute timing pulses between IM's.

The No. 5 ESS is planned to be compatible with 24-channel facilities in the United States and with 30-channel facilities overseas. A switch such as this would appear useful toward compatibility and connectivity for military use in the U.S. and Europe.

Remote switching control is also possible with the No. 5 ESS. The No. 5A remote switching module can be located up to 100 miles (161 km) from the host and accommodate up to 4,000 users. It is connected via T1 digital carrier facilities (Johnson et al., 1981).

5.2 Two-Wire Digital Subscriber Transmission

An inherent problem in the evolution toward the ISDN is the transmission of high bit rates (e.g., 56 kb/s, 64 kb/s) between users over existing two-wire loops. Bidirectional digital transmission has been provided over four-wire lines such as T1. However, for economic reasons, it is desirable to avoid adding another pair of wires to most subscriber loops now in existence. A solution is burst-mode transmission which passes bit rates in a bidirectional manner on a time-shared basis.

There are three alternatives for sending bidirectional digital signals over two-wire loops (Inoue et al., 1981).

1. Hybrids - The two directions are separated by the use of hybrid circuits, a form of balancing bridge. The bit rate in the subscriber loop is equal to the data rate. A ceaseless echo cancellation is needed to prevent contamination of received data by reflection of transmitted data bits (Ahamed et al., 1981). The disadvantages are that the bridges depend on component precision and individual adjustment relative to each cable length.

2. Frequency Separation - The two directions are separated by two frequency bands. The disadvantages are increased crosstalk and the use of high-pass and low-pass filters that are less suitable for pulse transmission.

3. Time Separation - The two directions are separated through the use of time division multiplexing. Data packets are alternately sent in each direction at a rapid rate to achieve full duplex communication over a wire pair. At the sending location, continuous bit information is compressed in a memory buffer and transmitted in bursts at a bit rate that is at least twice that of the original data rate. At the receiving location, the compressed data bits are buffered, and "expanded" to reflect the original continuous bit stream. There are pause intervals between each bit stream burst. During that pause, compressed pulse bursts are sent in the opposite direction (Figure 22). Guard space is needed between each data burst. This is time compression multiplex (TCM)

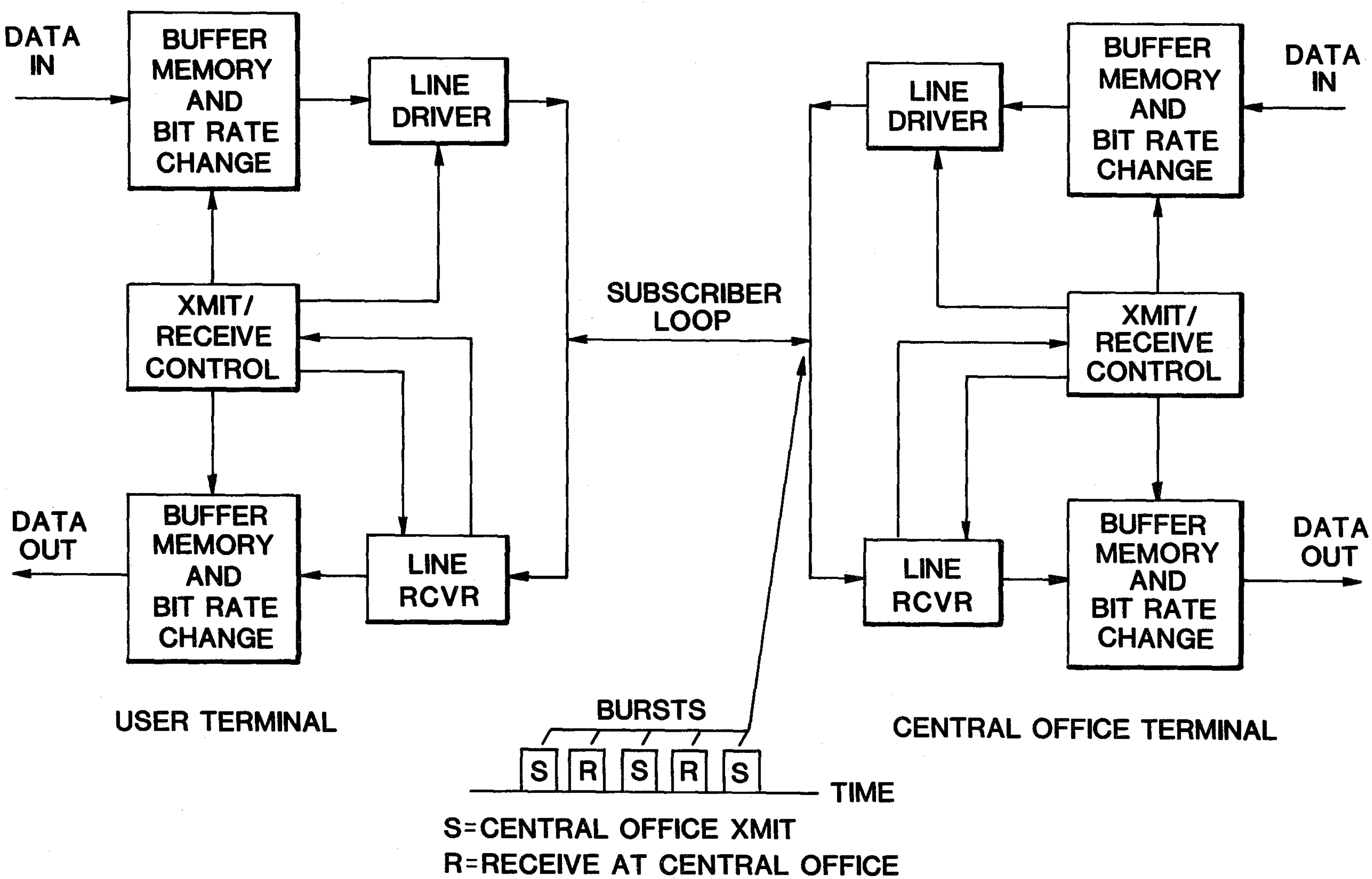


Figure 22. Time compression multiplex principles (after Inoue et al., 1981).

and has been referred to as ping-pong transmission (Cornell and Stelte, 1981). A disadvantage is higher cable loss because of higher bit rates during transmission. Reflection problems are minimized because the receiver is not activated during the burst (Ahamed et al., 1981). Although reflections are minimized it is necessary to determine that residual reflections from a burst do not interfere with reception when the receiver is activated.

5.2.1 Time Compression Multiplex Factors

Bidirectional digital transmission is limited by distance. The distance limitation is a function of bit rate, wire gauge, transmission technique, bridged taps and gauge discontinuities. Realizing full-duplex transmission at 56 kb/s or 64 kb/s is a problem because of far-end crosstalk and error rate degradation from central office impulse noise.

A calculated relationship between the maximum transmission distance and the bit rate in a subscriber loop limited by far-end crosstalk is shown in Figure 23. Shown is that the line bit rate should be less than 200 kb/s for a transmission distance of 7 km. Calculations for the figure used 0.5 mm wire, a bipolar line code, error rate of 10^{-8}, and a signal-to-noise ratio for far-end crosstalk of 21 dB. An adoption of a uniform burst repetition period is important to controlling far-end crosstalk. An example of burst organization is shown in Figure 24, and is used in an experimental system in Japan. The following parameters have been selected for use in the tests (Inoue et al., 1981). Propagation delay is 5 μs/km.

Maximum transmission length:	7 km
Line bit rate:	160 kb/s
Burst repetition period:	2 ms
Bits in a burst:	145.

Work in the United States indicates that self-induced crosstalk is eliminated when all TCM systems in a cable are synchronized and transmit together (Ahamed et al., 1981).

5.3 Transmultiplexers

Transmultiplexers enable today's analog telephone network to operate with the newer digital switching and transmission systems. Transmultiplexers convert digital TDM signals to analog FDM and FDM signals to TDM (Figures 25 and 26). A number of companies in the United States and abroad are producing transmultiplexers (Mokhoff, 1982).

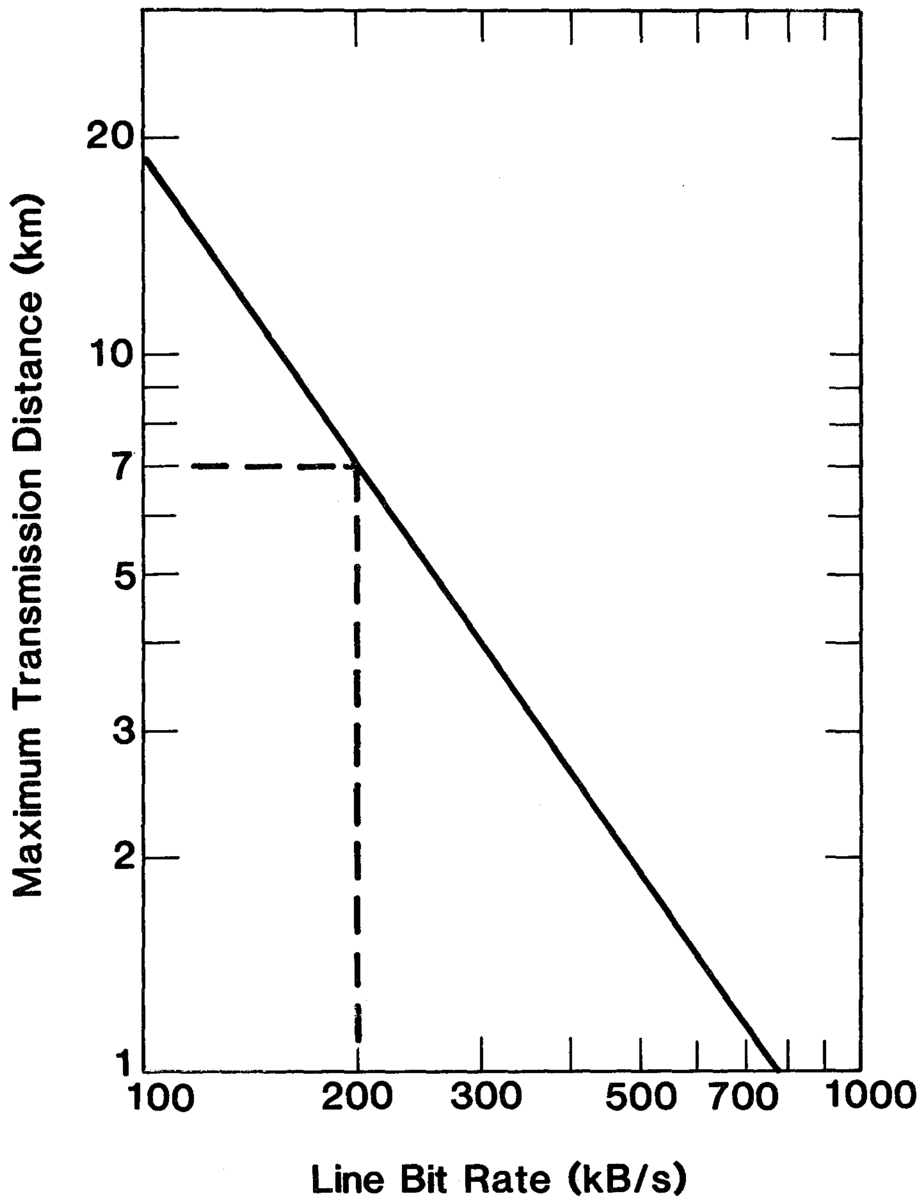


Figure 23. Maximum transmission distance for a line bit rate (Inoue et al., 1981).

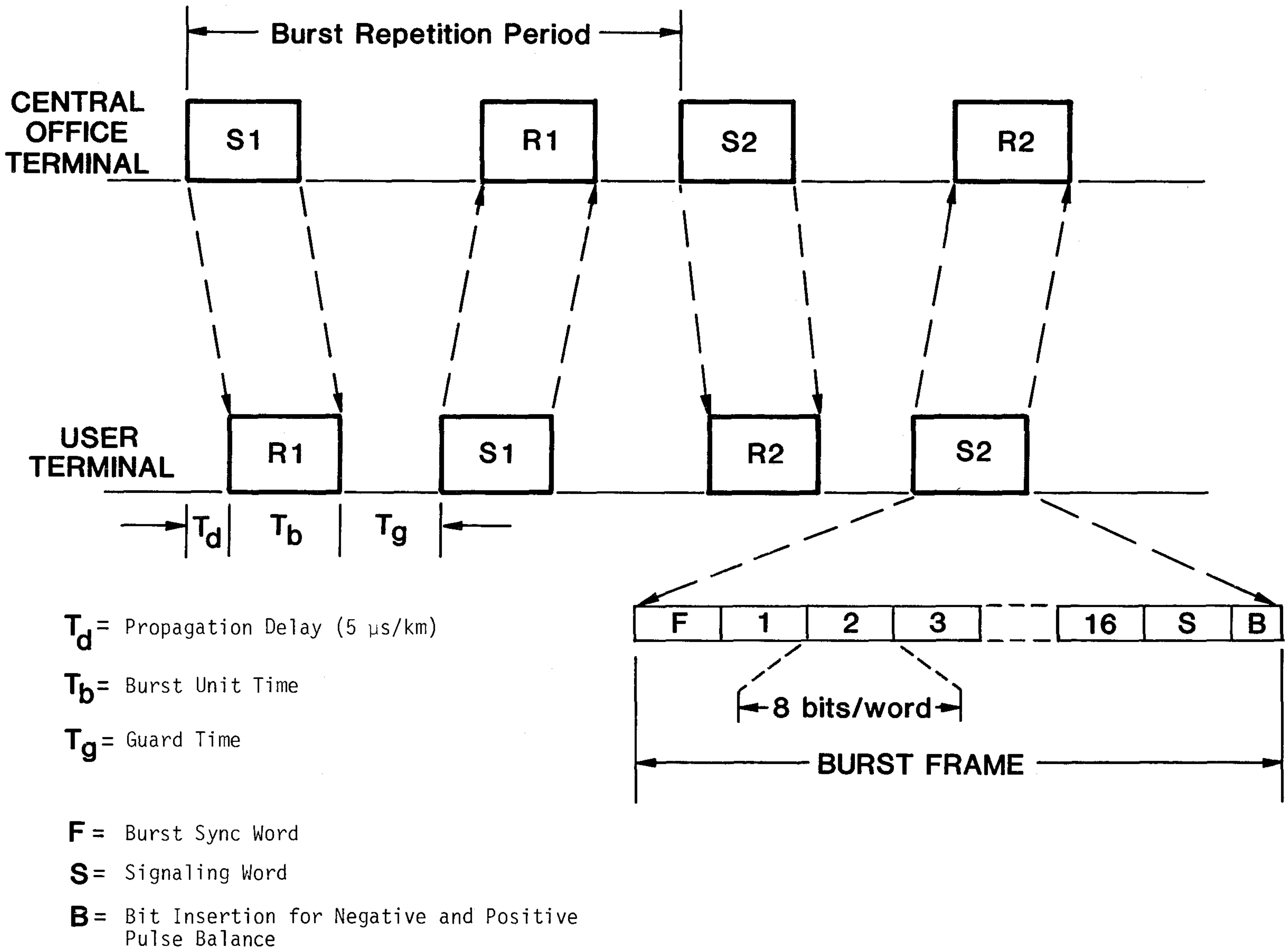


Figure 24. Burst organization for TCM (after Inoue et al., 1981).

Figure 25. Basic transmultiplexer connection.

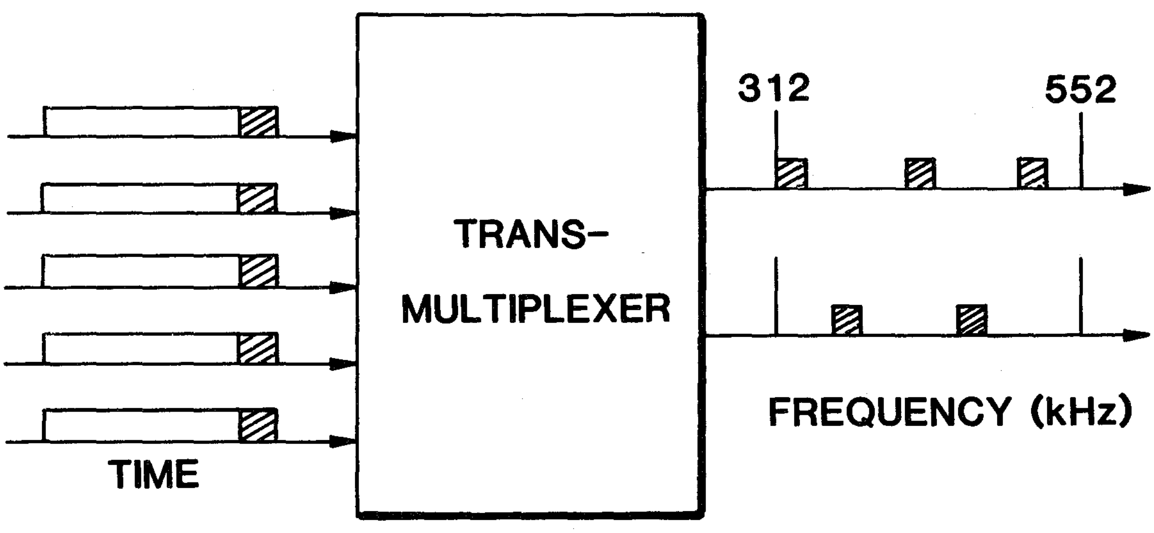


Figure 26. TDM to FDM conversion - five DS-1 signals to two supergroups (after Bellamy, 1982).

The primary need for transmultiplexers occurs at the interface between digital toll switches and long-haul analog radios such as the TD-2 (Bellamy, 1982, p. 268). A transmux can convert five DS-1 digital signals with 24 channels each and translate them into two supergroups of 60 channels each (Figure 26).

A transmultiplexer is equivalent to the back-to-back interconnection of analog-to-digital and digital-to-analog multiplexers/demultiplexers. An earlier approach to transmultiplexer implementation used analog processing techniques while the more recent approach uses digital processing. Two basic techniques for transmultiplexers are a) back-to-back interconnection of multiplexers and demultiplexers, and b) digitization of FDM signals which are subject to signal processing (including digital filtering, mixing, and amplification). Low cost, hybrid, and integrated circuit techniques have lead to increasing popularity of digital signal processing for transmultiplexers.

5.3.1 Transmultiplexer Considerations

In the United States and Japan 24-channel PCM transmultiplexers are of interest, while in Europe, 30-channel PCM units are used because of T1 and CCITT digital carrier design. Bilateral signal conversions are made from one 24-channel PCM signal at 1.544 Mb/s to two, 12-channel FDM signals at 60-108 kHz. Other PCM-FDM conversions are made for two, 30-channel PCM primary groups to one, 60-channel FDM supergroup. Another conversion example is for five, 24-channel PCM signals to be converted to two, 60-channel FDM supergroups, and vice versa. A summary is given in Table 18, and a simplified block diagram for a 60-channel conversion is given in Figure 27. In the figure, note the two pairs of PCM channel groups on the left (two inputs, two outputs). Each bit stream is 2048 kb/s in Europe. There is one FDM output and one FDM input at 312 kHz to 552 kHz for the transmultiplexer.

Table 18. PCM-FDM Conversion Summary

PCM-TDM (No. of Channels)	FDM (No. of Channels)
1 x 24	2 groups x 12
2 x 30	1 supergroup x 60
5 x 24	2 supergroups x 60

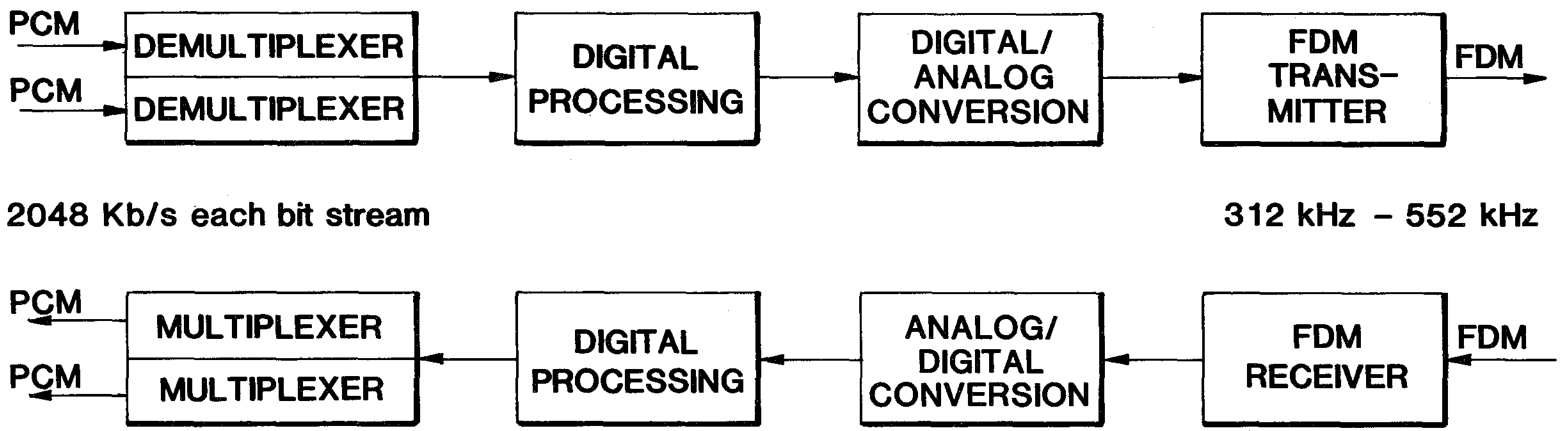


Figure 27. Block diagram of a 60-channel transmultiplexer (after Bellanger et al., 1978).

The performance specification of the analog-to-digital and digital-to-analog converters may be derived from CCITT recommendations for transmission systems (Bellanger et al., 1978). Signal and noise considerations are primary design criteria, basically the ratio of signal power level to idle channel noise within each of the blocks of Figure 27. The three main parameters of the D/A and A/D converters are dynamic range, linearity of that range, and the number of bits of resolution in the converter. Signal-to-total-distortion $[(S/D)_{max}]$ ratio as a function of input level is considered as the most important specification for A/D converters. The distortion is a function of thermal and quantizing noise.

Transmultiplexer digital signal processing functions are given in Figure 28. Shown are five elements of a 60-channel multiplexer similar to that in Figure 27, with the addition of a maintenance and alarm block.

In the PCM-FDM direction, the PCM interface consists of conventional PCM demultiplexing and multiplexing, companding and synchronization. Voice samples are divided linearly to n bits and go to the digital signal processor. The baseband filter separates the speech signal from the signaling and pilot tones. The 60 channels are then separated from each other in the Fast Fourier Transform (FFT) processor and filter-bank. A reverse process takes place in the FDM-PCM direction. Digital-to-analog and analog-to-digital conversions are made in step 3 of the transmultiplexer. Analog modulation and demodulation takes place in the FDM interfaces (step 4).

Implementation of 24- or 60-channel transmultiplexers is made mainly through use of off-the-shelf low power Schottky TTL devices (Versik, 1981; Narasimha et al., 1981; Kurth et al., 1981). Multipliers/accumulators perform the digital signal processing functions such as filtering and sample rate alterations, signal, pilot detection, and elimination. Other microprocessors are used for control and supervisory functions. The intent is to incorporate new components, as they become available, that optimize and combine functions.

As technology changes for digital transmultiplexers, so do computational techniques Previously, transmultiplexer architecture studies have concentrated on minimizing the number of complex arithmetic operations. Hardware-expensive multiplications, that are involved in converting between TDM and FDM, have been of main concern. A new approach reverses the trend away from per-channel processing. (The prevailing approach is shown in Figure 28.) Per-channel processing is signal processing of individual channels carrying a serial bit stream subsequent to companding. Hardware efficiency is obtained by implementing finite impulse response (FIR)

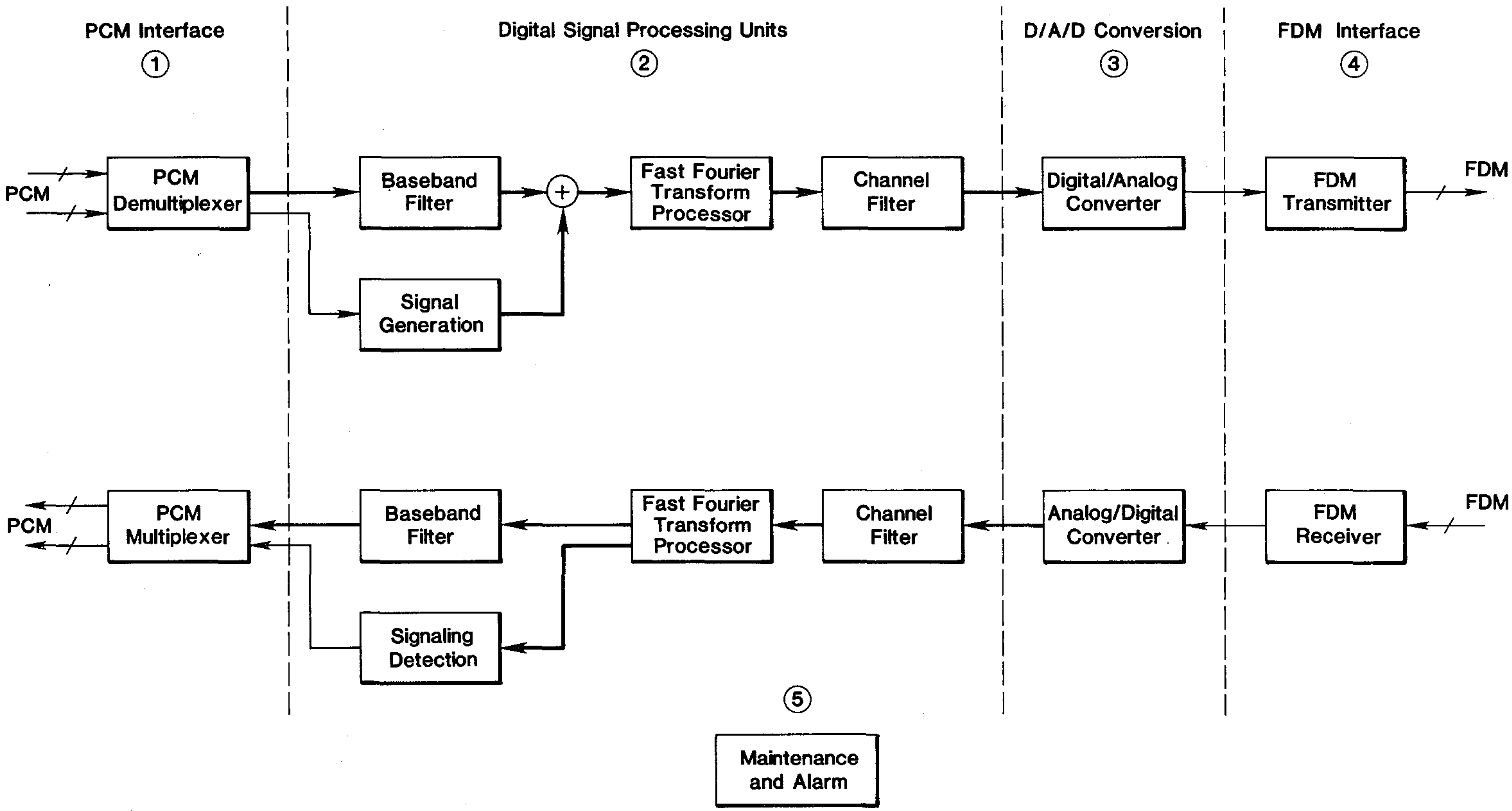


Figure 28. Elements of a 60-channel multiplexer (Versik, 1981).

filters used in channel filters in a logarithmic mode. Look-up memory tables convert the linear multiplier process to a logarithmic addition format. This results in reduced computational complexity (Kurth et al., 1981a).

6. SUMMARY

Progress toward the ISDN is expected to be evolutionary, abroad and in the United States. The exception does exist in some countries (e.g., France) where communications are considered easily improved by skipping the most recent analog switch technology because installation of the most recent digital switching techniques is more economical.

Techniques for integrating voice and data transmission have been described for the United States. Service announcements include the Public Switched Digital Capability for alternate voice and data on a two-wire user loop, Local Area Data Transport Capability for simultaneous voice and data on a two-wire loop, Data Bridging for sending data from one source to several receivers, and Packet Switching support using CCITT Recommendation X.25.

ISDN concepts were described for seven foreign countries. Experiments for implementing ISDN model networks are expected to start during 1983-1984. All countries are expected to adhere to CCITT recommendations. One of these is the 64 kb/s rates at the user location. Another is CCITT Signaling System No. 7. Many other standards, such as interfaces, remain to be developed while awaiting definition of services to be offered to users.

Certain technology, such as satellite communications, and fiber optics, is expected to play an important role. Digital switching systems, two-wire wire bidirectional digital transmission, and transmultiplexers are all a part of the ISDN progress.

Application of ISDN technology and functional concepts is advantageous for the Department of Defense as it is for various countries and organizations within those countries. The ISDN concepts (such as functional grouping) should permit improved interoperability and survivability.

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APPENDIX A: CONTRIBUTIONS TO CCITT STUDY GROUP XVIII, A USER'S PERSPECTIVE AND USING HYBRID ACCESS ARRANGEMENTS

This appendix contains copies of a number of contributions made to CCITT Study Group XVIII. The first paper describes the ISDN from a user's perspective. It submits to the CCITT a rationale for considering a user's viewpoint and general objectives of the ISDN. The next two papers are concerned with user access to the local exhange and an interface protocol to the ISDN through hybrid arrangements.

International Telegraph and Telephone
Consultative Committee
(CCITT)

COMM XVIII-No.

X3S3.7-82-11

Period 1981-1984

Original: English

Question 1, 2/XVIII

Date:

STUDY GROUP XVIII - CONTRIBUTION NO.

TITLE: The ISDN From the User's Perspective

I. Introduction

The ISDN can be viewed from the user's perspective and from the network perspective. This contribution identifies the importance of considering the user's perspective of the ISDN.

II. The Importance of the User's Perspective

1. The ISDN is a new concept in telecommunications. From the user's perspective, telecommunications networks and services must be considered in setting standards for the ISDN.

2. Much of the success of telephony networks is because of their uniformity. Uniformity was achievable because of the homogeneity of human speech which telephony networks are designed to serve.

3. The ISDN is being designed to serve a wide variety of applications ranging from low speed telemetry, interactive data, voice, facsimile, high speed data, and even video. Given this wide spectrum of applications, standards play an important role in assuring the success of the ISDN.

4. The cost to the user of information communications and handling is a primary factor from the user's perspective. The uniformity of the interface is also important. The characteristics of the small family of interfaces which affect the user's perspective, and which should be standardized include; the mechanical, physical, electrical, and functional aspects of the ISDN user interface; the logical and protocol characteristics across the interface; the characteristics of the services which will be offered at the interface by the ISDN, including the messages to signal, activate and control the services; and the performance characteristics associated with these services as provided by the ISDN.

III. General Objectives for the ISDN from the User's Perspective

1. The ISDN should provide the user with competitive price performance.

2. The ISDN should appear uniform to users over a wide range of applications.

3. The ISDN should provide a consistent set of procedures for accessing similar capabilities even though different services are used.

4. A small family of multipurpose interfaces should be provided, each covering a wide range of applications.

5. There should be a common structure for these different multipurpose interfaces, including information channels and signalling channels.

6. The same protocols should be used to perform similar functions, for a given class of terminal equipment even though different interfaces are used.

7. A choice of performance or service grades should be available for all services and interfaces to allow the user to exercise economic trade-offs.

8. Maintenance and related procedures and messages should be standardized for all applications (although not all options need be available in every application).

9. Features should be structured in an upward compatible nested structure so that simple terminals can use the simpler aspects of sophisticated capabilities and vice versa.

10. The ISDN should provide graceful evolution for terminals to migrate from today's networks including PDN and GSTN, to the ISDN.

International Telegraph and Telephone
Consultative Committee
(CCITT)

PERIOD: 1981-1984

QUESTION: 1,2,4/XVIII

COM XVIII - No.

X3S3.7-82-7

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STUDY GROUP XVIII - CONTRIBUTION NO.

TITLE: Hybrid Arrangements for Subscriber Access to the Local Exchange

I. INTRODUCTION

This contribution describes hybrid arrangements which provide users with analog voice and low-speed digital data services simultaneously. These hybrid arrangements provide a means to introduce new digital services making use of existing telephone plant to start the evolution of the Integrated Services Digital Network (ISDN). Accordingly, these arrangements should be considered in the development of recommendations for user interfaces and exchange interfaces for the ISDN.

II. MOTIVATION FOR HYBRID ARRANGEMENTS

With the rapid decreases in costs of digital technology, both network elements and terminal devices are becoming increasingly digital. The ISDN is envisioned as a network that provides end-to-end digital connectivity to support a wide range of voice and non-voice services.

There is a general consensus that the ISDN will evolve from the telephony network, and that new digital elements, and new or improved capabilities will be incorporated into the network, whenever the economics and user needs justify their introduction. Many of today's network elements, such as the loop plant and space division switching systems, can be used in the ISDN. During the evolution the network will include both analog and digital portions, and the time required to complete the evolution of the network will vary among administrations* depending on many factors such as the nature of the embedded network, geographic characteristics, local or national policies, economic conditions, and user needs. It is expected that the evolution will take many years.

* And RPOAs

When introducing new ISDN digital services, it may be economic in some cases to convert existing analog services to digital form. In other cases, it will not be economic to make a conversion, and hybrid arrangements will be necessary to provide mixed analog/digital services. These mixed services, and the access arrangements which support them, may remain in use for a long time depending on economics and user needs.

III. BELL SYSTEM HYBRID ARRANGEMENT

A hybrid arrangement has been developed which provides a digital data channel simultaneously with an analog voice channel. At the serving exchange the voice channel will be circuit switched and the low speed data channel will be multiplexed or packet switched as required for the service offered to the user. There are several ways that these channels can be handled depending on the type of switching system at the serving exchange.

Figure 1 shows a simple arrangement with equipment which separates the channels and terminates the voice channel on a circuit switch and terminates the data channel on separate systems.

Figure 2 shows a partially integrated arrangement where the subscriber interface function of the switching system in the servicing exchange separates the data channel from the voice channel and then terminates the data channel on a separate system in the exchange. In this partially integrated arrangement, the exchange switch may also provide a multiplexing function to provide for economic utilization of the circuit facilities interconnecting the local exchange with the other systems.

Figure 3 depicts a fully integrated hybrid access arrangement. In this case, the exchange switching system performs both the circuit switching and data channel functions, and the interface function which terminates the subscriber line separates the voice and data channels as necessary. It is expected that the interface function in this arrangement will also terminate digital subscriber lines.

IV. CONCLUSION

The Bell System considers the hybrid arrangement as an evolutionary step towards the ultimate ISDN. Since the transition period could be lengthy, as described in Section I, the hybrid arrangement may be used extensively over many years. Consequently, in defining interfaces at the local exchange, it will be necessary to consider hybrid arrangements which provide mixed analog and digital services.

FIGURE 1

Simple Hybrid Access Arrangement

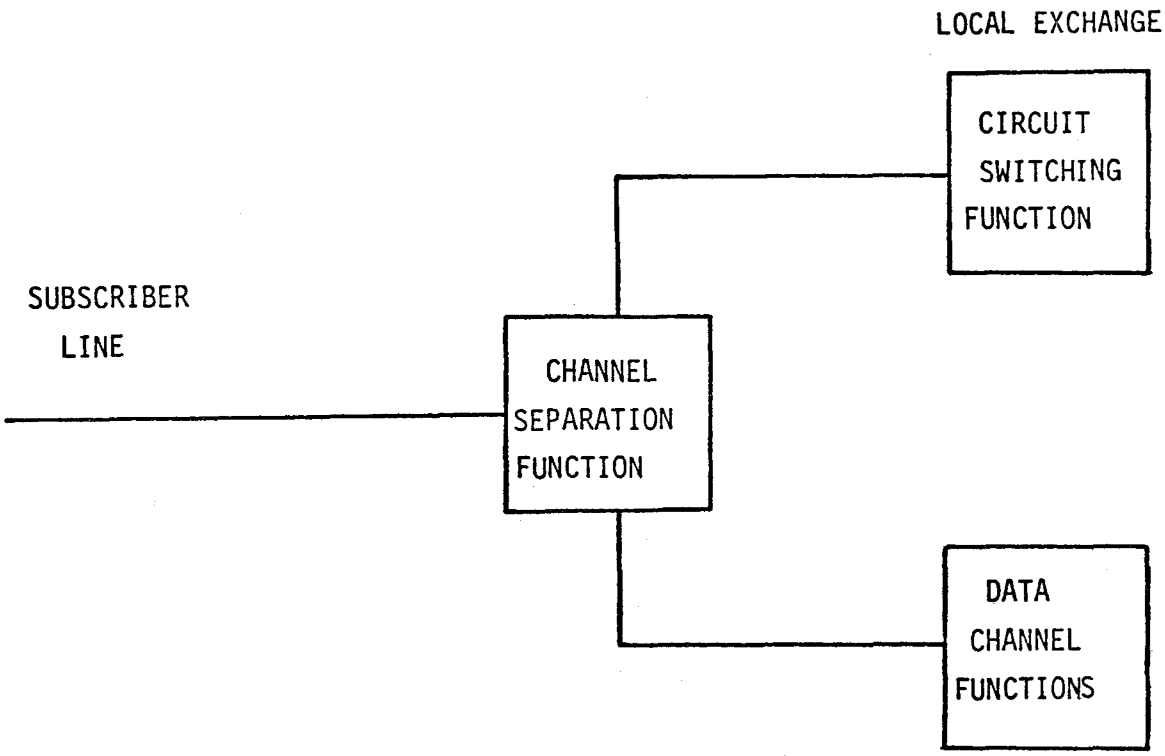


FIGURE 2

Partially Integrated Hybrid Access Arrangement

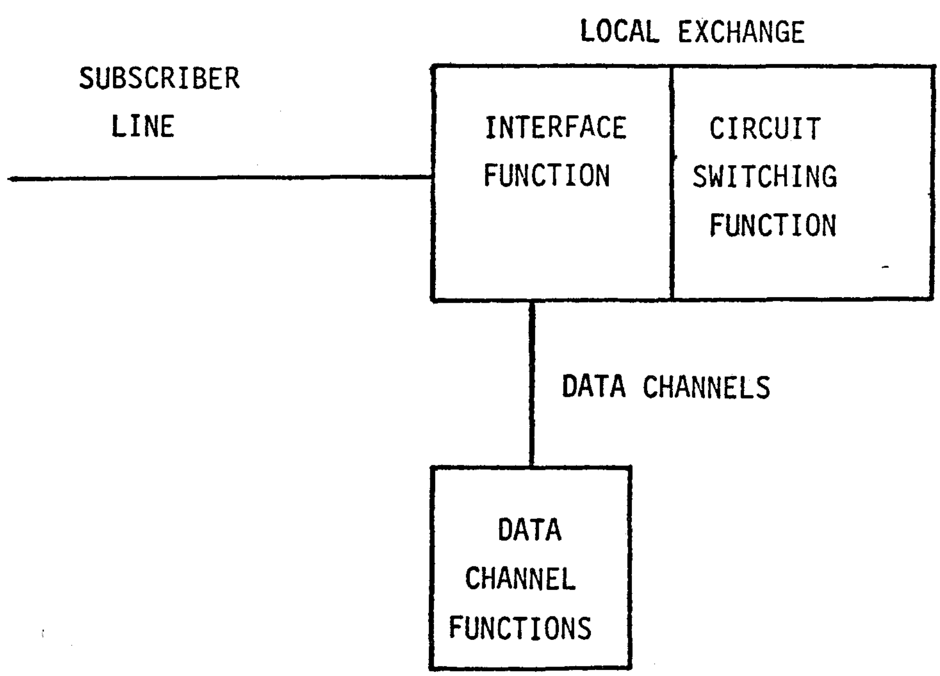
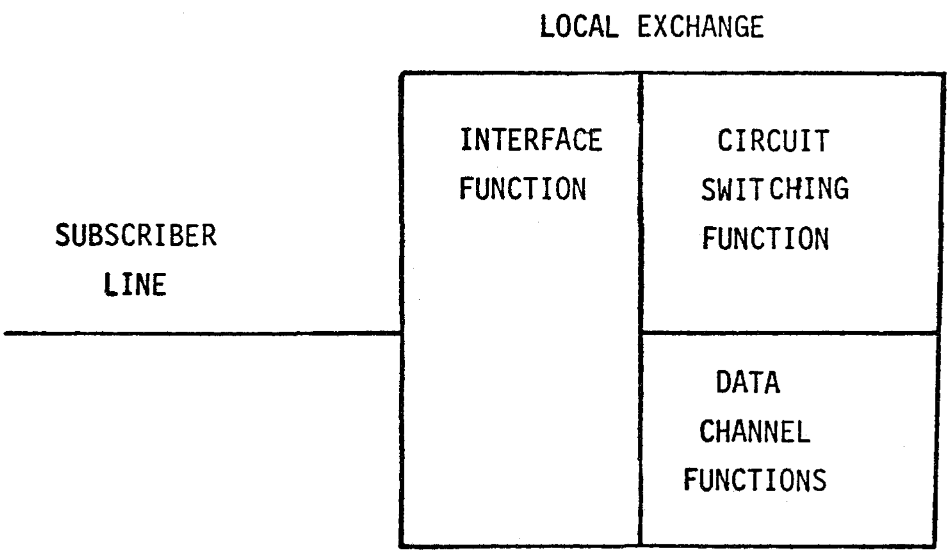


FIGURE 3

Fully Integrated Hybrid Access Arrangement



International Telegraph and Telephone
Consultative Committee
(CCITT)

Period 1981-1984

QUESTION: 1,2,4/XVIII

COM XVIII -No.

X3S3.7-82-12

ORIGINAL: English

DATE:

STUDY GROUP XVIII - CONTRIBUTION NO.

TITLE: Subscriber Interface Protocol for Hybrid Access to the ISDN

1. SCOPE OF THE CONTRIBUTION

Many ISDN contributions to CCITT have referred to the hybrid access technique denoted as A + E. This contribution will briefly describe the hybrid access system under study by AT&T, but will primarily focus on the subscriber interface protocol proposed for use with this system and that protocol's upward compatibility with the D-channel protocol of the Digital Subscriber Line. The link access protocol proposed is an extension of LAP B of CCITT Recommendation X.25, and therefore is appropriately called Link Access Procedure C (LAP C). The signalling and call setup aspects of LAP C are not addressed by this contribution.

2. INTRODUCTION

It is generally accepted that the ISDN will evolve from the general telephony network which is now in place. The ISDN will evolve with the addition of more features on a progressive timetable dictated by market needs and technical progress. The evolution plan for ISDN must take into account an initial deployment phase which will allow rapid and universal deployment, and which will take full advantage of the local distribution cable and installed base of switching equipment which are mainly telephone oriented.

2.1 Overview of the Hybrid Access

The hybrid access to ISDN has been denoted at A + E, where A indicates standard analogue voice access to the telephony network and E indicates a new, above voice band, data channel to be used primarily for new services. Technological studies by AT&T indicate that data rates up to 8 kbit/s can be achieved over non-loaded subscriber lines using any of a number of available transmission techniques, while allowing simultaneous and unimpaired transmission of voice, dial pulsing, and/or DTMF signalling at baseband.

In keeping with the broad philosophy of ISDN evolution outlined previously, deployment of the hybrid access system has certain initial advantages:

i. The hybrid access system can be deployed on any type of existing exchange with the provision of statistical data multiplexing equipment in those switching offices. In particular, it can be deployed on existing Stored Program Control (SPC) space division switching equipment which is today widespread in the Bell System Network. The data can be removed from the integrated voice/data line transmission equipment and connected to these data multiplexers. This architecture is depicted in Figure 1. This diagram is meant for descriptive purposes only and does not imply any partitioning or alignment of customer or network interfaces.

ii. Provision of standard telephone service and its associated signalling need not be initially integrated with data service. Therefore, initial provision of service does not require an immediate solution to certain near-term technical problems with Digital Subscriber Lines (e.g., power feeding), or require software addition to the existing SPC switches and networks.

iii. In some networks the hybrid access will allow initial ISDN services to be rapidly and universally deployed.

Furthermore, if properly designed and specified, the hybrid access system can be compatible with future ISDN interfaces and technologies including, but not limited to, Digital Subscriber Lines and enhanced local digital switches.

2.2 Requirements for the Hybrid Access Protocol

The requirements for the E-channel protocol are as follows:

i. The E-channel protocol should cater to a wide variety of simultaneous services. It should be capable of carrying the following information types:

a. Type s - Basic customer network signalling for control of network resources,

b. Type t - Telemetry information at low rates conveying customer alarms, remote meter reading, etc., and,

c. Type p - Customer data, which may not be of currently standardized types, and which is suitable for carrying teletex and other information.

The information should be transferred in the form of variable length messages. The information types should be accommodated by a logical or virtual partitioning of the E-channel bandwidth rather than by physical partitioning. Recognizing that not all of these information types will be implemented initially, inclusion of a logical channel capability into the access protocol should not create undue complexity in the case where only a single logical channel is needed.

ii. The hybrid E-channel protocol, as an initial access protocol to ISDN, should be upwardly compatible with the D-channel protocol of the Digital Subscriber Line. Although much work on the definition of the D-channel protocol remains, the E-channel access should be broadly in concert with the objectives and framework which have thus far been generally accepted.

iii. The protocol should cater to both single and multi-terminal subscriber applications.

iv. The protocol should be cost effective with today's technology and should be immediately implementable. The protocol overhead should not place undue burden on the cost of subscriber terminal equipment.

v. If possible, the protocol should employ or be derived from a recognized and tested international standard.

3. E-CHANNEL PROTOCOL

The above requirements have led to a specific proposal for the channel access protocol called LAP C. It will be noted that this specification for LAP C is very close to the LAP B specification with changes made as necessary to accommodate multiple addresses (logical links). In this discussion of LAP C, familiarity with LAP B will be assumed.

3.1 LAP C Multiplexing Capability

In addition to the normal LAP B functions of link initialization, error control, and flow control, LAP C provides the capability to support multiple logical links over the same physical link. LAP C is proposed in circumstances where a relatively few number of logical links are required and the complexity and overhead of a more sophisticated protocol such as X.25 is not needed.

The LAP C protocol is derived by extending the definition of LAP B. As a result, all of the mechanisms of LAP B (the frame, variables, procedures, timers, etc.) are preserved in LAP C with only non-interfering enhancements added.

Presently, the major difference between the LAP C protocol and LAP B is the addition of a Logical Link Identifier (LLID) subfield to the address field. LAP B leaves six of the eight bits of the address field unused (set to zero). LAP C makes use of these undefined bits to allow for the logical link multiplexing. Figure 2 indicates the use of the address field in LAP C. Five bits are used for the LLID, allowing addressing for up to 32 logical links. In effect, each of these different addresses is then served by a separate and independent virtual LAP B.

The use of the address field in LAP C is analogous to the original use of the address field in HDLC Normal Response Mode (NRM) for multidrop applications. The difference between LAP C and HDLC NRM is that LAP C, like LAP B, is a balanced protocol whereas HDLC NRM is an unbalanced master-slave protocol.

It should be noted that the LAP C protocol is compatible with LAP B. The LAP C protocol implementing only a single logical link (LLID=00000) is in fact identical to LAP B.

When used in a multi-terminal star configuration, a simple multiplexer can be designed to multiplex several terminals into a single LAP C data stream. This is illustrated in Figure 3. The multiplexer need not deal with the procedural aspects of LAP C, but need only perform simple distribution and queuing functions. Frames received from the lines are distributed to the terminals according to the received LLID. Frames from the terminals are buffered in the multiplexer. Use of LAP C in a multi-drop (bus) distribution is currently under study.

3.2 LAP C Procedures

The procedural aspects defined in the LAP C specification are identical to those of LAP B. With the exception of idle (transmission of 15 or more consecutive one's), the protocol procedures apply to each of the independent logical links of the LAP C physical link (i.e., each logical link has its own variables, timers, status information, state or phase). The idle condition has meaning for the physical link as a whole.

In particular, a Timer T1 exists for each logical link on the physical link. T1 is the period of time, at the end of which retransmission of a frame may be initiated according to protocol procedures. In LAP C, the value of T1 must take into account the number of logical links supported, as well as any priority mechanism which may exist.

3.3 Aspects of LAP C for Further Study

Within the LAP C specification a number of items are left for further study. These are summarized below:

i. The inclusion of such packet level functions as those implemented with the D and M bits of Recommendation X.25 is left for further study. Initial implementation of the E-channel protocol with LAP C does not require these features.

ii. The use of an extended control field to provide for extended sequence numbering or packet level functions is a subject for further study. As an alternative, the use of SABME to initialize the link with extended sequence numbering can be considered. The use of an extended address field, for example to provide more logical links, is also subject to further study. Initial implementation of the E channel protocol with LAP C will not require these features.

iii. The need for and use of priorities on the logical links of LAP C is a subject for further study.

4. COMPATIBILITY WITH LAP D

This contribution places considerable emphasis on a progressive evolution of the ISDN technology. A primary objective would be the upward compatibility of the E-channel protocol with the D-channel protocol of the Digital Subscriber Line.

This contribution recommends that LAP C be used for the hybrid access protocol. Even as LAP B is a subset of LAP C, it is important for LAP C to be a subset of the protocol selected for LAP D. Furthermore, it can be observed that all of the considerations which led to the proposal of LAP C for the hybrid access protocol equally well apply to the Digital Subscriber Line channel. Such protocol commonality will be essential in defining common access interfaces to ISDN for Level 2 and above.

Architecture For Hybrid Access

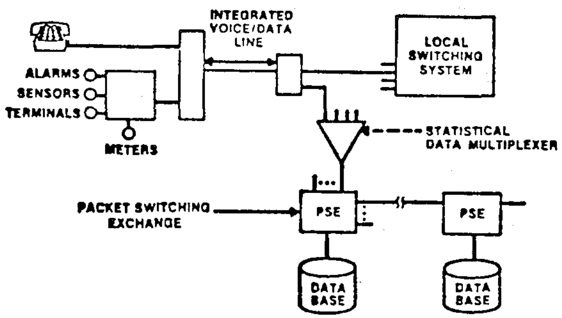
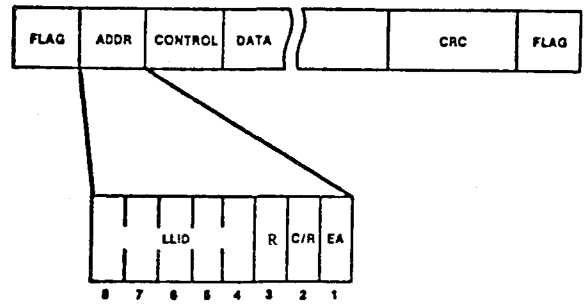


FIGURE 1

LAPC Frame and Address Field Structure



LLID = LOGICAL LINK IDENTIFIER
R = RESERVED FOR FUTURE USE (PROVISIONALLY SET TO 0)
C/R = COMMAND/RESPONSE BIT
E/A = EXTENDED ADDRESS BIT (BIT = 0 INDICATES EXTENDED ADDRESS)

FIGURE 2

LAPC Star Multiplexer

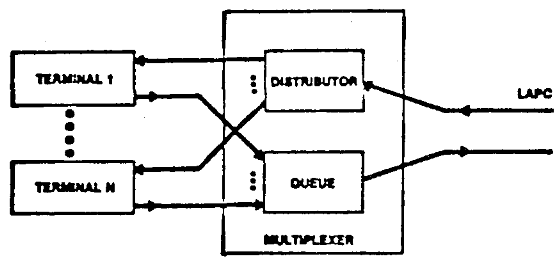


FIGURE 3

APPENDIX B: A PHYSICAL LAYER INTERFACE AND ITS DEFINITION

The three papers in this appendix consist of a description of a physical layer "mini-interface," and two papers seeking clarification of S, T, and NT interfaces of the ISDN user access model.

Source: U.S.A. CONCEPTS FOR A DTE/DCE "MINI INTERFACE"

CCITT Question 13/XVII, COM XVII - No. xxxxx, Annex 2, June 2, 1981

1 INTRODUCTION

A new standard for a DTE/DCE interface - referred to as the "Mini-Interface" - has been identified in the data communications industry and in international standards groups as being essential for maintaining long-term stable growth in DTE/DCE product areas. The Mini-Interface must provide, in a connector of fifteen pins or less, the functional equivalents of existing interfaces such as RS-232/V.24, RS-449, and X.21, and must also anticipate the future requirements of a high-speed universal interface for applications such as the ISDN (Integrated Services Data Network). A new approach which attempts to meet the above requirements is presented in this paper.

2 SUMMARY OF MAJOR CONCEPTS

1. Each direction of data transfer is serviced with two balanced lead-pairs: "Data" and "Control".

2. The "Data" and "Control" circuits are independently self-clocked, thereby eliminating the need for separate "Timing" circuits. This is accomplished with Differential Manchester encoding of all signals except the "Data" circuit in an asynchronous interface, where standard Start-Stop signaling is used. The "Control" circuit signaling rate is usually, but not necessarily, nominally equal to the "Data" circuit signaling rate.

3. The "Data" lead-pairs are used only for primary data transfer. No control signals associated with the interface are passed on these leads.

4. Each "Control" lead-pair passes serial, time-multiplexed, control and status information across the interface. The "Control" signal is segmented such that time-critical functions are serviced more frequently than others and such that expansion of functions is easily achieved.

5. The interface is totally symmetric. Data transfers in the two directions are totally independent of one another and may even be at different signaling rates.

6. The interface connector contains nine pins. The interconnecting cable crosses-over the Data and Control circuits for each direction of transfer. The same cable services DTE/DCE, DCE/DCE, and DTE/DTE interfaces with no special handling required.

7. The multiplexed control circuit supports all interchange functions presently offered by traditional DTE/DCE interfaces such as RS-232/V.24, RS-449, and X.21, thereby facilitating connections between old and new devices through active interface conversion units.

3 PHYSICAL CHARACTERISTICS

3.1 Connector

A nine-pin D-subminiature connector is used for the interface. Female connectors are mounted on all equipments and male connectors terminate both ends of all standard cables. Signals are assigned to the nine pins as shown below:

```
  5   3   1
---------------
\ o o o o o /
 \ o o o o /
 -----------
  9     6
```

Signal Name	Ckt Name	Pin #'s	Crossed in Cable to Pin #'s
Signal Ground	A	3	3
Data Out	1B	1, 6	5, 9
Data In	2B	5, 9	1, 6
Control Out	1C	2, 7	4, 8
Control In	2C	4, 8	2, 7

Note that "OUT" and "IN" directions are with respect to the device, not the communications link, and that there is no distinction made between DTE's and DCE's. Thus, in a traditional DTE-DCE configuration, the XMT DATA (data to be transmitted into the network) exits the DTE on the "Data Out" (1B) circuit, but enters the DCE on the "Data In" (2B) circuit.

CIRCUIT NAMING CONVENTIONS

Prefix	Root	Suffix
1 - OUT Direction 2 - IN Direction	A - Reference B - Data C - Control	Sequentially numbered and segmented integers to unambiguously identify time-multiplexed signals traversing the interface on a common lead-pair.

3.2 Cables

The same cable which connects a DTE to a DCE can be used to connect two DTE's or two DCE's, because the DTE and DCE interfaces are physically identical. Inventory requirements are reduced to one cable type, thereby eliminating confusion associated with selecting an appropriate crossover cable.

The "crossover" requirements of the cable are symmetric and thus mass termination connector techniques are possible when flat cables are used. This is illustrated in Figure 3.1.

```
 __                                                                      __
|  \                                                                    /  |
|   \                                                                  /   |
|    \                                                                /    |
|1    |     _        _ _                          _         _        |    5|
| o-------|‾ DATA    ‾|------------->-------------|‾ DATA    ‾|--------o  |
|    6|   |   OUT     |                            |   IN      |   |9      |
|    o-----|_ (1B)   _|------------->-------------|_ (2B)    _|-----o     |
|2    |     _        _                            _         _        |    4|
| o-------|‾CONTROL‾|------------->-------------|‾CONTROL‾|--------o  |
|    7|   |   OUT     |                            |   IN      |   |8      |
|    o-----|_ (1C)   _|------------->-------------|_ (2C)    _|-----o     |
|3    |                                                              |    3|
| o---------- (A) --><-----[ SIGNAL GROUND ]----->< -- (A) ----------o  |
|    8|      _        _                            _         _   |7      |
|    o-----|‾CONTROL‾|-------------<-------------|‾CONTROL‾|-----o     |
|4    |   |   IN      |                            |   OUT     |   |    2|
| o-------|_ (2C)   _|-------------<-------------|_ (1C)    _|--------o  |
|    9|      _        _                            _         _   |6      |
|    o-----|‾ DATA   ‾|-------------<-------------|‾ DATA    ‾|-----o     |
|5    |   |   IN      |                            |   OUT     |   |    1|
| o-------|_ (2B)   _|-------------<-------------|_ (1B)    _|--------o  |
|     |                                                              |     |
|    /                                                                \    |
|   /                                                                  \   |
|__/                                                                    \__|

DTE or DCE                                                      DTE or DCE
```

Figure 3.1
"MINI-INTERFACE STANDARD CROSSOVER CABLE

Extension cables can be provided in one of two ways, as illustrated in Figure 3.2:

1). A special "Extension Cable" is attached to the standard crossover cable. The extension cable is "straight-through" (with no crossover) and is equipped with a male connector on one end and a female connector on the other. Confusion is avoided even though there are now two cable types instead of one, because the "Extension Cable" is male/female whereas the standard crossover cable is male/male.

2). Two standard crossover cables (male/male) are joined by a female/female crossover adapter. The crossover adapter is potentially a low-cost device because the contact connections are straight-through.

With either cable-extension option, only two items must be inventoried - standard male/male crossover cables and either male/female extension cables or female/female crossover adapters.

3.3 Cable Shielding

All equipment-mounted connectors are required to have a metallic shell which connects to chassis (earth) ground. Cable shields, when required, use the connector shell to make a low resistance connection to chassis ground at one end of the cable.

The vast majority of inter-equipment cables do not require shielding. All four active circuits are balanced and thereby exhibit inherently good common mode rejection. Differential mode susceptibility is low in mass-terminated flat cables because the two halves of each circuit are on adjacent wires; susceptibility is even lower in multiple twisted-pair cables. Radiated emissions are low for the same reasons.

Two pins would be needed if the chassis-ground/shield function were to be provided inside the connector. They would be positioned symmetrically on either end of the connector - one pin allocated to "CHASSIS GROUND OUT" and the other pin to "NO CONNECTION". This arrangement would be necessary to inherently prevent the inadvertent connection of chassis grounds between two devices and the resultant troublesome "ground loops".

Adding two pins to every connector and two wires to most cables for a chassis-ground/shield-connection function which is seldom utilized would be an unnecessary waste of space and money and would also force the development of a new standard size (11-pins) in the D-subminiature connector family. Therefore, the connector shell ground is the mechanism provided for cable shielding.

```
 /‾|                  |‾\
| 1|                  |  |
|  |    STANDARD      |  |
|M |-------X----------| M|
|  |     CABLE        |  |
|  |                  |1 |
 \_|                  |_/
```

a). Connection with one Standard Cable

```
 /‾|                  |‾\    |‾\                   |‾\
| 1|                  |  |...|  |                  |  |
|  |    STANDARD      |  |   |  |    EXTENSION     |  |
|M |-------X----------| M|   |F |------------------| M|
|  |     CABLE        |  |...|  |      CABLE       |  |
|  |                  |1 |   |1 |                  |1 |
 \_|                  |_/    |_/                   |_/
```

b). Extended connection with one Standard Cable and one Extension Cable

```
 /‾|                  |‾\    |‾\                /‾|   /‾|                  |‾\
| 1|                  |  |...|  |______________| 1|...| 1|                  |  |
|  |    STANDARD      |  |   |  | CROSSOVER    |  |   |  |    STANDARD      |  |
|M |-------X----------| M|   |F |    -X-       | F|   |M |-------X----------| M|
|  |     CABLE        |  |...|  |__ADAPTER_____|  |...|  |     CABLE        |  |
|  |                  |1 |   |1 |              |  |   |  |                  |1 |
 \_|                  |_/    |_/                \_|    \_|                  |_/
```

c). Extended connection with two Standard Cables
and one Crossover Adapter

"X" - indicates crossover
"M" - indicates male connector
"F" - indicates female connector

Figure 3.2
CABLE EXTENSION OPTIONS

4 DATA TRANSFER

Primary data transfer takes place on the "Data Out" (1B) and "Data In" (2B) circuits. The data circuits are independently self-clocked using Differential Manchester encoding for synchronous interfaces and standard Start-Stop signaling for asynchronous interfaces.

4.1 Encoding of Data

The Differential Manchester binary signaling mechanism encodes data and clock into "bit-symbols". Each bit-symbol is split into two halves with the second half containing the binary inverse of the first half; a transition always occurs in the middle of each bit-symbol. A SPACE is encoded as a repeat of the previous bit-symbol, thereby generating a transition both at the beginning and at the center of the bit-symbol. A MARK is encoded as the inverse of the previous bit-symbol, thereby generating a transition only at the center of the bit-symbol. Examples of Differential Manchester waveforms are shown in Figure 4.1

4.2 Recovery of Data Timing

Recovery of timing implicit in the data is easily accomplished at the receiving side of the interface because of the wealth of binary transitions guaranteed to be in the encoded waveform, independent of the data sequence. A phase-locked loop or equivalent mechanism maintains continuous tracking of the frequency and phase of the information on the Data circuit.

Phase and/or frequency of data timing can change abruptly in some commonly encountered interface configurations - for example a multipoint master modem receiving short messages from multiple remote slave transmitters. To facilitate fast synchronization of timing for each incoming transmission, the Data circuit may be caused to assume an idle state between transmissions. Upon reactivation of the Data circuit, at least eight MARK's must be transferred before normal data transfer may be resumed. The period of eight MARK's is sufficient for re-establishing the timing phase/frequency of the new data transfer.

If future electrical interfaces are developed which utilize transformer coupling of interchange circuits, the drivers for those circuits should be capable of active transmission of a voltage midway between the plus/minus voltages used for transfer of encoded data. This intermediate voltage would be employed when the Data circuit assumes the "Idle" state, thereby insuring maintenance of zero bias in the receiving circuit during the idle period and rapid recovery of operation when the Data circuit is reactivated.

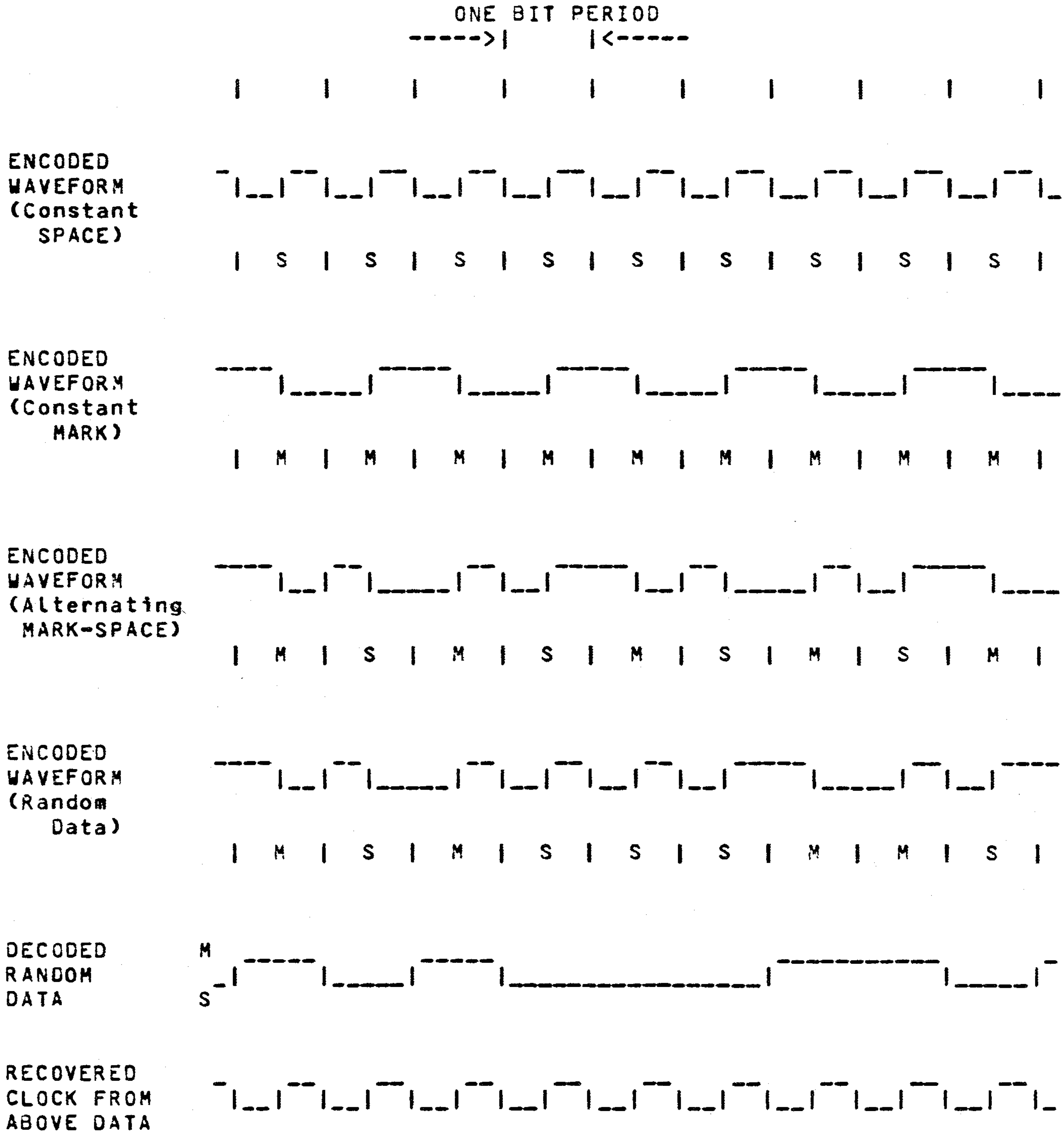


Figure 4.1
EXAMPLES OF DIFFERENTIAL MANCHESTER WAVEFORMS

5 CONTROL MULTIPLEXING

Interchange of control information takes place on the "Control Out" (1C) and "Control In" (2C) circuits. The control circuits are independently self-clocked using Differential Manchester encoding. All control information is multiplexed into these self-clocked data streams. Transfer of control information is never interrupted, even if one or both of the Data circuits assumes the idle state.

5.1 Framing of Control Information

Control framing is accomplished by using Manchester Violation (MV) bit symbols, which are bit-periods without the normal center-bit transition. These violations of Manchester encoding are recognized by the receiving device and used to unambiguously frame the multiplexed control information. Alternate MV violation symbols are sent with an alternating voltage (e.g. ++, --, ++, --, ...) to insure maintenance of zero bias in the interchange circuit.

Two framing options are provided: a "short frame" which provides a limited subset of control signals suitable for inexpensive DTE/DCE equipment, and a "long frame" which provides a full complement of control signals and the capability for future functional expansion.

```
                                   ONE BIT PERIOD
                                ------>|     |<------

                        -- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- -
CONTROL (C)               | MV | C1 | C2 | C3 | MV | C1 | C2 | C3 | MV | C1 |
  (Short Frame)         -- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- -

                          |<-- SHORT FRAME -->|


                        -- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- -
CONTROL (C)               | MV | C1 | C2 | C3 | C4 | C1 | C2 | C5 | MV | C1 |
  (Long Frame)          -- ---- ---- ---- ---- ---- ---- ---- ---- ---- ---- -

                          |<---------- LONG FRAME ------------->|
```

Functions associated with Frame Slots denoted C1 through C5 are summarized in Table 5.1.

Compatibility between devices employing different frame lengths is assured by use of the Manchester violation symbols. Two long-frame devices, two short-frame devices, or one long-frame device with a short-frame one are all acceptable for direct interconnection, with the only limitation being that long-frame functionality is not attained unless both devices use the long-frame option.

When a control circuit receiver detects an "MV" symbol, it is assured that the subsequent sequence of control frames is C1-C2-C3-C4-C1-C2-C5. The receiver assumes that the sequence can be interrupted at any point (including prior to the first C1 frame) with another MV symbol, which simply causes a reset to the beginning of the sequence. A short-frame receiver ignores C4 and C5 frames coming from a long-frame transmitter. A long-frame receiver recognizes the continual lack of C4 and C5 frames from a short-frame transmitter and reverts to short-frame functionality.

TABLE 5.1. CONTROL CIRCUIT FRAME SLOTS

Frame Slot	Descriptive Title	Function
C1	REQUEST DATA TRANSFER	Indicates device has Data available to transfer across the interface on the "Data Out" (1B) lead-pair.
C2	GRANT DATA TRANSFER	Indicates device is ready to accept primary channel information on the "Data In" (2B) lead-pair.
C3	NORMAL MODE	Indicates device in normal mode and able to participate in primary channel data transfers across the interface.
C4	CONTROL CHANNEL	A bit-serial, transparent, synchronous communications "channel" which may be used for control purposes.
C5	CONTROL SIGNALS	Repetitive sequence of 16 bit-slots, each representing one control signal. A Manchester Violation (MV) symbol in the first of the sixteen bit-slots provides for framing of the sequence.

Frame Slots C1 and C2 are occupied by signals nC1 and nC2, where n=1 for the OUT direction and n=2 for the IN direction. They are roughly analogous to CCITT V.24 Circuits 105 (Request To Send) and 106 (Clear To Send). The effective repetition period of these critical interchange signals is four control-bit times, independent of whether the short or long frame is used.

Frame Slot C3 provides a "Normal Mode" interchange signal analogous in functionality to CCITT V.24 Circuits 108.2 (Data Terminal Ready) or 107 (Data Set Ready).

Frame Slot C4 is occupied by signal nC4, which is a bit-serial, transparent synchronous data stream. The effective bit-rate is one-eighth that of the control circuit. The C4 control channel may be used for full duplex communications between connected units, employing bit-oriented or character-oriented synchronous protocols to implement future enhancements such as auto-dial call establishment or setup of complex test sequences. It may also be used for transferring X.21 control characters when a Mini-Interface device is connected to an X.21 device through an active interface conversion unit.

Frame Slot C5 is a serial data stream which is segmented into sixteen bit-slots. The first of the sixteen bit-slots contains a Manchester Violation (MV) bit-symbol which unambiguously identifies the positions of the remaining fifteen C5 control signals. Each of the remaining bit-slots (denoted C501 through C515 as defined in Table 5.2) is assigned a specific meaning corresponding to an individual interchange signal. The effective repetition period of each individual C5 interchange signal is 128 control-bit times.

TABLE 5.2 INDIVIDUAL C5 CONTROL SIGNALS

Bit Slot	Descriptive Title	Function
C501	DTE/DCE	Identifies sending unit as a DTE or DCE
C502	TEST MODE	Indicates sending device is in Test.
C503	LOCAL LOOP	Commands local DCE into digital loop
C504	REMOTE LOOP	Commands remote DCE into digital loop
C505	EXTERNAL CONNECTION	Commands DCE to connect to audio line, or indicates incoming call to DTE.
C506	STANDBY CONNECTION	Commands DCE to switch to alternate line, or indicates to DTE that switchover has been accomplished.
C507	ALT DATA RATE	Commands DCE to an alternate data rate or indicates same to DTE.
C508	ALT FREQUENCY	Commands DCE to use alternate signaling frequency or indicates same to DTE.
C509	NEW SYNC	Commands DCE to interpret toggle of 2C2 circuit as an indication to condition receiver for new signal.
C510	DATA QUALITY	Indicates good data quality from a DCE.
	spares	(C511 - C515)

6 TIMING

Two timing signals traverse the interface in each direction, imbedded in the encoded Data and Control circuits. The presence of these four effective "clocks" provides sufficient flexibility to accomodate all present system timing configurations. Data timing is always conveyed across the interface by the Data (1B and 2B) circuits themselves. All "system timing" (external clock) information is conveyed in the Control (1C or 2C) circuits.

Each device may choose one of the four sources listed below to derive timing for its "Data Out" (1B) circuit. A separate independent choice may be made between items one and two in the list for the source of "Control Out" (1C) timing.

1. An internal oscillator.

2. The Control (2C) circuit from the companion device at the other end of the "Mini-Interface".

3. The Data (2B) circuit from the companion device at the other end of the "Mini-Interface".

4. The source of the "Data Out" information; e.g. in a modem, this source is the modem demodulator, which reflects the XMT timing of a remote modem transmitter.

Whereas the Data circuits may have idle periods between messages and abrupt changes in timing phase from one message to another, the Control circuits operate continuously with no interruptions. Control circuit timing is required to exhibit no phase discontinuities and to maintain a limited slew rate which can be adequately tracked by an appropriate phase-locked loop or similar tracking mechanism in each device.

If a device's Data circuit bit-rate is to be derived from the "Control In" (2C) circuit, then the bit rate of the Control circuit must be an integral multiple of the Data circuit bit-rate. Otherwise, the bit-rate of the Control circuits need have no relationship to the Data rate.

7 COMPARISON WITH EXISTING DTE/DCE INTERFACES

7.1 Equivalence of Interchange Signals

Table 7.1 summarizes the interchange signals provided by the proposed "Mini-Interface", and cross-references them to analogous circuits provided by interface standards RS-449, V.24, and RS-232-C. All interface circuits provided by the referenced standards are also provided by the proposed "Mini-Interface". This facilitates the construction of interface conversion units which can be used to connect Mini-Interface equipment to RS-232/V.24 or RS-449 equipment during an interim period when mixed populations of equipments are in existence.

Interface conversion units can also be designed to allow connection of a "Mini-Interface" device to an X.21 device. Control information extracted from the X.21 device while the "C" or "I" leads are low can be passed to the Mini-Interface device on the multiplexed control leads in the C4 frame slot. The complexity of such a device depends heavily upon the as-yet undefined protocol for messages in the C4 control frame slot. If this protocol is similar to the X.21 control mode, the conversion is conceptually straightforward.

7.2 Real-Time Control of Primary Data Transfer

Transfer of primary channel information on the "Data" lead-pairs is controlled by the control signals "nC1" (REQUEST DATA TRANSFER) and "nC2" (GRANT DATA TRANSFER):

Data Circuit	Associated Control Signals	
1B (Data Out)	1C1 (Request Data Xfer)	2C2 (Grant Data Xfer)
2B (Data In)	2C1 (Request Data Xfer)	1C2 (Grant Data Xfer)

When operating in a half-duplex or modem carrier-controlled mode, delays of up to eight control-bit times can be experienced in establishing one-way communications because of the multiplexed nature of the "Request" and "Grant" signals. If the Control circuits are operating at the same bit-rate as the Data circuits, this results in a slight reduction of throughput for half-duplex or polled operation. Throughput equivalent to RS-232/V.24 can be regained, however, by simply operating the Control circuits at four-times the bit-rate of the Data circuits.

Propagation delays across the interface can exceed one bit period when operating at high data rates or long cable distances. Therefore, the control signal "Grant Data Transfer" can not locate the exact position of the first bit of primary data in the same way that "Clear to Send" does in an RS-232 interface. Note that this difference is inherent in any high-speed/long-distance interface, and is not a unique characteristic of this particular implementation.

TABLE 7.1 - COMPARISON WITH OTHER STANDARD INTERFACES

MINI INTERFACE		ANALOGOUS CONTROL SIGNALS					
		FROM DTE			FROM DCE		
Ckt. Name	Description	RS-449	V.24	RS-232	RS-449	V.24	RS-232
A	SIGNAL GROUND	SG	102	AB	SG	102	AB
nB	DATA	SD	103	BA	RD	104	BB
nC1	REQUEST DATA TRANSFER	RS	105	CA	RR	107	CF
nC2	GRANT DATA TRANSFER	none	none	none	CS	106	CB
nC3	NORMAL MODE	IS	108.2	CD	DM	107	CC
nC4	CTRL MESSAGES	none	none	none	none	none	none
nC501	DTE/DCE	none	none	none	none	none	none
nC502	TEST MODE	none	none	none	TM	142	none
nC503	LOCAL LOOP	LL	141	none	none	none	none
nC504	REMOTE LOOP	RL	140	none	none	none	none
nC505	EXTERNAL CONNECTION	TR	108.1	(CD)	IC	125	CE
nC506	STANDBY CONNECTION	SS	none	none	SB	none	none
nC507	ALT DATA RATE	SR	111	CH	SI	112	CI
nC508	ALT FREQUENCY	SF	126	CK	none	none	none
nC509	NEW SYNC	NS	none	none	*	*	*
nC510	DATA QUALITY	*	*	*	SQ	110	CG
nC511	spare						
nC512	spare						
nC513	spare						
nC514	spare						
nC515	spare						

International Telegraph and Telephone
Consultative Committee
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Questions : 1, 2/XVIII
1,16,20/VII
13/XI

COM XVIII-No. 56-E

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STUDY GROUP XVIII - CONTRIBUTION No. 56

TITLE : USER ACCESS ARRANGEMENTS TO THE ISDN

1. INTRODUCTION

IBM has noted the high degree of activity in CCITT on ISDN. IBM provides equipment that attaches to Public Telecommunications Networks, and has a great deal of interest in ISDN from a network user viewpoint. In this contribution, IBM would like to provide input to CCITT on its view to date of User Access Arrangements to the ISDN. Follow-on Contributions are planned as more technical detail becomes available.

2. BACKGROUND

The ISDN can be viewed as a public digital telecommunications network supporting a wide range of user needs. The ISDN is planned to support standard services such as telephony and teletex. It must also carry an important volume of traffic originating from user defined applications and terminals. These applications and terminals are required to allow users to satisfy their individual needs. Examples of user defined applications and terminals would include banking, point of sale, information retrieval, office system etc...

The user to network interface is an extremely important aspect of the ISDN. Any new interfaces should be simple and flexible to reduce attachment costs, allow innovation within customer premises equipment and provide migration for existing terminals. Users make major investments on network interfaces. A user could face significant economic and/or performance disadvantages if the interface was unduly complex or rigid. In this regard definition of the ISDN user to network interface(s) presents CCITT with a difficult challenge because of the multiplicity of services, customer premises equipment, and configurations involved. In particular, there are at least two distinctly different user environments that must be addressed in the course of the ISDN user to network interface definition :

- Basic User Environment : this may be a residential or small business environment where a user has a basic requirement to access a single network service with growth capability to multiple network services. Access to the network will be over one or possibly two user information channels. When multiple services are involved, more than one terminal would be required, e.g. digital telephone, data terminal, facsimile or telemetry device.

- Extended User Environment : this may be a medium or large business, school, hospital, etc., environment. There is a fundamental requirement for in-house data and/or voice communications with an additional requirement for access to multiple network services from multiple terminals. This access will be over multiple user information channels.

In both of the above environments, there will be terminals supporting standardized services, user defined applications, and terminals supporting specific user needs.

3. GENERAL USER REQUIREMENTS

3.1 ISDN Basic Access

The ISDN Basic Access should be a simple access designed to meet the requirements of the Basic User Environment.

Although this access must accommodate more than one terminal accessing multiple services, it must be recognized that there will be a significant number of single terminals requiring access to a single service. Therefore, the design of the Basic Access must provide for single terminal access that is not unduly complex.

3.2 ISDN Extended Access

The ISDN Extended Access should be designed to meet the requirements of the Extended User Environment.

Traditionally, a PABX would be an example of user equipment required in this environment for voice communications. The many varieties of communications controllers, clustered controllers and communications processors would be examples of user equipment required in this environment for data communications. These are examples of equipment providing user functions between in-house configurations and the Public Telecommunications Network. The PABX, Communications Controller and future local area network Gateways may provide transmission and signalling protocol conversion functions between in-house configurations and the Public Telecommunications Network. Much of this equipment today and in the future must be user defined to meet specific user needs.

The Extended Access should allow grouping of several user information channels to form a variable aggregate bit rate. This grouping should be provided on both a dynamic and fixed basis.

A single signalling channel should support multiple user information channels. This will allow customer premises equipment requiring access to multiple user information channels to realize the efficiencies of common channel signalling.

3.3 User to User Information Transfer

A protocol independent user information transfer capability should be available on the ISDN. This means that any user should be able to assemble information up to the offered transmission capacity with no network imposed constraints such as enveloping schemes or network defined protocols. This will permit users to optimize end to end channel usage based on application throughput and response time requirements on a per call basis. Signalling information should be carried independent from user to user information transfer.

3.4 User to Network Information Transfer

A signalling channel independent from user information channels should support the management of the end to end connection between calling and called parties. This includes call establishment and call clearing, service identification and coordination of the information transfer phase, e.g. ready for data. A change in service identification during the same connection should be part of the user to network protocol and supported by the signalling channel.

The signalling protocol should support both the basic and extended accesses. It should be HDLC based and bit rate independent in order to accommodate capacity growth that will be required in the outslot signalling channel as the number of user information channels is increased.

3.5 Common Access Arrangement

For any new ISDN Interface, a signalling access arrangement for level 1 to 3 (OSI Reference Model) user to network protocols common to all ISDN services is a highly desirable objective. Any deviation from this objective would encourage utilization of existing interfaces, rather than develop another set of service dedicated interfaces.

3.6 Migration

X.21, X.21bis and X.25 interfaces should have the option of being able to attach to the ISDN unchanged. Adaptation equipment should be minimized to the least possible amount required. X.1 user classes 3 to 11 should be supported. In particular, there should be a migration path optimized for terminals with data rates up to and including 9.6 kbit/s that provides no undue migration penalty.

It is recognized that hybrid access arrangements will exist during the transition from analog to digital. It is highly desirable that user to network protocols used during this transition are either existing protocols or the same as those protocols to be used in the ultimate all digital ISDN environment. There should be no interim protocols which would tend to introduce a proliferation of interfaces.

4. CONCLUSIONS AND RECOMMENDATIONS

The terminology and labeling used in this section is based on that developed in the Study Group XVIII meeting in Geneva, June 1981. Refer to attached Figure 1.

4.1 Basic User Environment / Basic ISDN Access

In order to support more than one terminal accessing multiple services, it is recognized that functions such as protocol handling, switching, statistical multiplexing and physical distribution/ concentration may be required between the S and T interfaces. These functions are not necessary for single terminal/point to point configurations and therefore provide undue complexity. Thus, the T interface is a more simple and efficient interface for single terminals than the S interface.

4.2 Extended User Environment/Extended ISDN Access

CCITT Study Group XVIII has acknowledged that PABX's, Communication Controllers and local area network Gateways should attach to the T interface. This appears to be the appropriate interface for equipment that performs functions such as protocol handling, switching, statistical multiplexing and physical distribution/ concentration. Much of this equipment today and in the future must be defined and supplied by users to meet specific user needs. Therefore it should be recognized that both Administrations and industry organizations will provide equipment that attaches to the T interface.

4.3 Interface Priorities

It has been observed that so far primary CCITT emphasis has been on interface S. Based on sections 4.1 and 4.2 it is clear that equal or greater priority should be given to the interface T definition.

Furthermore, NT1 functions need to be better clarified in order to understand the T interface. In principle, NT1 functions should be the minimum required to terminate transmission to customer premises from the local exchange. It should be noted that in some countries provision of the NT1 functions by suppliers other than Administrations is being considered.

4.4 User-to-Network Information/Independent Signalling Channel

One consideration for the level 2 signalling protocol should be LAP-B of X.25. LAP-B is well understood by data users. IBM has no specific comments on levels 1 and 3 at this time.

Interleaving of low throughput data with signalling information in the signalling channel needs careful study. Impacts to quality of service and interface complexity need to be understood.

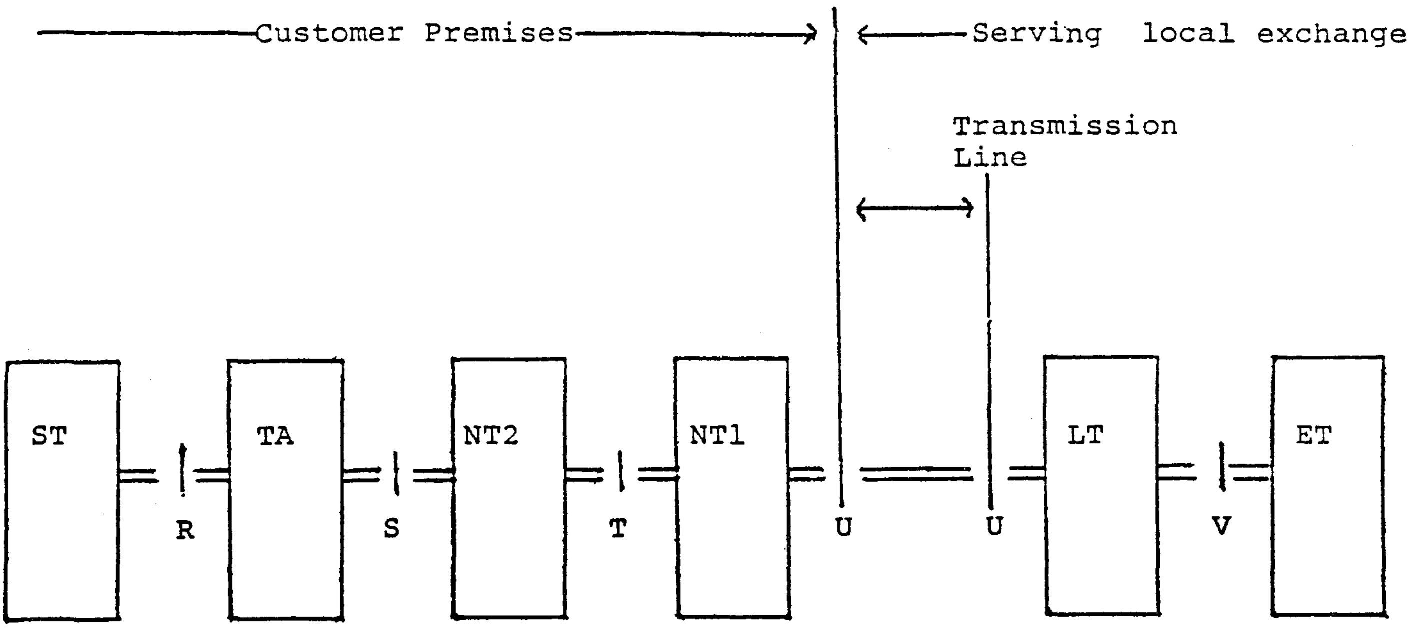
4.5 Tariff Considerations

The ISDN digital transport capability is to a large degree insensitive to services carried. This provides Study Group III with an opportunity to investigate cost based tariff structures for the ISDN which take into account that the network may be carrying a digital bit stream that is common to all services.

4.6 CCITT Coordination

The division of responsibilities for the ISDN involves many Study Groups and Working Parties within Study Groups. Because of user interest in the ISDN user to network interface, it would be helpful if this particular aspect of the ISDN could be isolated to single Working Parties within Study Groups VII, XI and XVIII. Combined meetings would minimize travel expenses for representatives attending the various meetings.

An example of the coordination problem is that this Contribution had to be addressed to three study groups.



ST	Subscriber Terminal equipment
TA	Terminal Adaptation equipment for existing terminals, e.g., X.21
NT2	Network Termination equipment to include protocol handling, switching, statistical multiplexing, physical contribution/ concentration.
NT1	Network termination equipment to include maintenance functions (e.g. test loops), power feeding, timing, line transmission termination.
LT	Line Transmission Termination
ET	Exchange Termination

FIGURE 1

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STUDY GROUP XVIII - CONTRIBUTION NO.

TITLE: ISDN Physical Layer Interface

I. Scope

This contribution discusses requirements for the physical layer interface at ISDN user interfaces, S and T. The universal physical interface (UPI) discussed in the SG XVII contribution to SG XVIII (November, 1981), appears to be applicable to ISDN and is generally supported. However, several issues are identified which should be resolved before a UPI recommendation is adopted.

II. Introduction

COM XVIII-R3 (July, 1981) of CCITT Study Group XVIII defined the location of physical user interfaces for ISDN access (Figure 1). Two interfaces, called S and T, were identified. Physical layer interface specifications are needed for both interfaces to define mechanical, electrical, functional and procedural characteristics to establish, maintain and release physical connections between the subscriber terminal and the network termination. This contribution focuses primarily on the network independent characteristics (mechanical and electrical) of the ISDN physical layer interface.

III. Objectives for ISDN Physical Layer Interface

Desirable objectives for the physical layer interface include:

1. Supporting today's digital network and data applications.
2. Allowing orderly migration of terminals to ISDN by providing a physical interface that is also suitable for connection of terminal equipment to modems used on the GSTN and to network terminations on PDNs.
3. Applicable at both S and T interfaces.
4. Minimum number of interchange circuits.
5. Provision for interface cable (cord) lengths of up to at least 300 meters.
6. Provision for powering ST from NT1 or NT2 and NT2 from ST.
7. Permitting simultaneous, information and D-channels.

ISDN will evolve from today's networks and will be capable of supporting a wide spectrum of user needs including voice, digital information, facsimile and video. However, it is expected that it will take many years or even decades to achieve a ubiquitous ISDN. During the interim, data communications over the GSTN and PDNs will continue to be used. Hence, it is desirable to have a physical layer interface for ISDN which has physical characteristics (those which are not necessarily network unique) common to interfaces of PDNs and modems on the GSTN; that is a UPI as suggested in the SG XVII contribution is desirable. It will help facilitate the orderly evolution to the ISDN.

The commonality of the S and T interfaces is important to users of the ISDN. It appears that regardless of the national policy, which defines the ownership of user premises equipment, it is desirable to permit terminals to connect at either interface depending on the configuration. Figure 2(a) shows a single terminal configuration. The NT2 function is unnecessary and can be a null if the terminal is capable of interfacing with the network at T. The same terminal could be used in a multiple terminal configuration where a controller is used. In this case, the interface is S. Figures 2(a) and 2(b) represent a possible evolution scenario where the user starts with a single terminal growing into sophisticated applications. Different S and T interfaces would hamper the growth of ISDN services by unnecessarily restricting the universal use of terminals. The commonality of the S and T interfaces has been endorsed in COM XVIII-R3 (July, 1981).

As proposed in the SG XVII contribution, the number of interchange circuits should be a minimum. With modern technology it is more economical to multiplex signals on an individual circuit than to provide separate circuits for individual signals. For ISDN, it is not envisioned that physically separate circuits for control signals will be required.

Experience with existing data services suggests that it is normally unnecessary for interface cable lengths to exceed a few tens of meters with lengths of 60 to 100 meters being adequate to accommodate essentially all applications. Likewise, for ISDN, it is reasonable to expect NT1 to be located in relatively close proximity to the appropriate interface at NT2. However, where NT2 is a null and for some S interface applications, longer interface cable lengths (perhaps as long as 300 meters) may be required.

In present telephony, most station sets are powered from the network and service is maintained in the absence of local power at the customers' locations. An equivalent capability may be appropriate with ISDN. In addition, it is desirable, for some systems (NT2) to provide power from the controller switch to some associated terminals. Also, in some local network configurations it appears appropriate to power media access equipment from the terminals. The method for providing power across the interface requires study.

ISDN is envisioned to have a D-channel associated with one or more information channels to allow simultaneous data and control capabilities. The physical layer interface should be capable of supporting this scheme.

IV. Physical Layer Interface

An early decision on the physical layer interface is needed as ISDN services are planned to be offered in the early 1980s. For example, because a UPI standard is not yet available, the Bell System plans to offer ISDN services based on an existing digital service interface which utilizes a transformer coupled alternate mark inversion (AMI) format.

Several of the objectives discussed above for the ISDN physical layer interface are not directly addressed by the UPI as described in the SG XVII contribution. We recommend that further studies be undertaken and contributions made by administrations and other participants to fully define the requirements needed to guide the specification of the UPI for ISDN application. We suggest these studies be directed toward providing contributions which address the following aspects of the UPI as it pertains to an ISDN interface:

IV.1 Mechanical Aspects

A minimum number of interchange circuits, preferrably two, one for each direction of transmission, is suggested. The physical connector should be small and must be mechanically and electrically reliable and permit easy connection and disconnection by the user. The potential for radio frequency radiation from the connector and its associated cables (cords) needs to be studied to determine whether or not shielding is required. Experience indicates that interface cables must be shielded for some applications and, therefore, the connector must provide for this capability.

IV.2 Electrical Aspects

The choice of the particular interchange circuits electrical characteristics should not be finalized until the operating environment is defined. (It is noted that the Rapporteur of Question 13/XVII is conducting a survey of administrations and others to determine the environment.) The environmental considerations include: 1) induced voltages, 2) ground potential differences, 3) noise levels and 4) potentially damaging surge voltages. These considerations are functions of other factors related to the interconnecting cable such as: the length and placement of the cable between NT1 or NT2 and ST, the electrical and physical characteristics of the cable and whether the cable is to be shared or dedicated. Also, the radio frequency interference potential of the electrical signals needs to be carefully examined. However, it is essential that the electrical signals chosen do not require shielding of interface cables to meet limitations imposed on radiated EMI.

IV.3 Functional Aspects

Control signals should be included in the D-channel and time division multiplexed onto the transmit and receive digital information signals, i.e., not provided as physically separate control circuits. Timing information should be encoded in the control and information signals so that a separate timing circuit is not required at the interface for ISDN.

V. Conclusions

As previously stated, the Rapporteur of Question 13/XVII is surveying participants to obtain information concerning the interface environment to provide a basis for defining V.11 compatible electrical characteristics with adequate galvanic isolation to provide satisfactory operation in all environments. The importance of providing an electrical characteristic suitable for ISDN physical interfaces cannot be over emphasized. Study Group XVII should be encouraged to assure that the electrical characteristics referenced in the UPI provide compatibility with the interchange circuit environment determined by its survey.

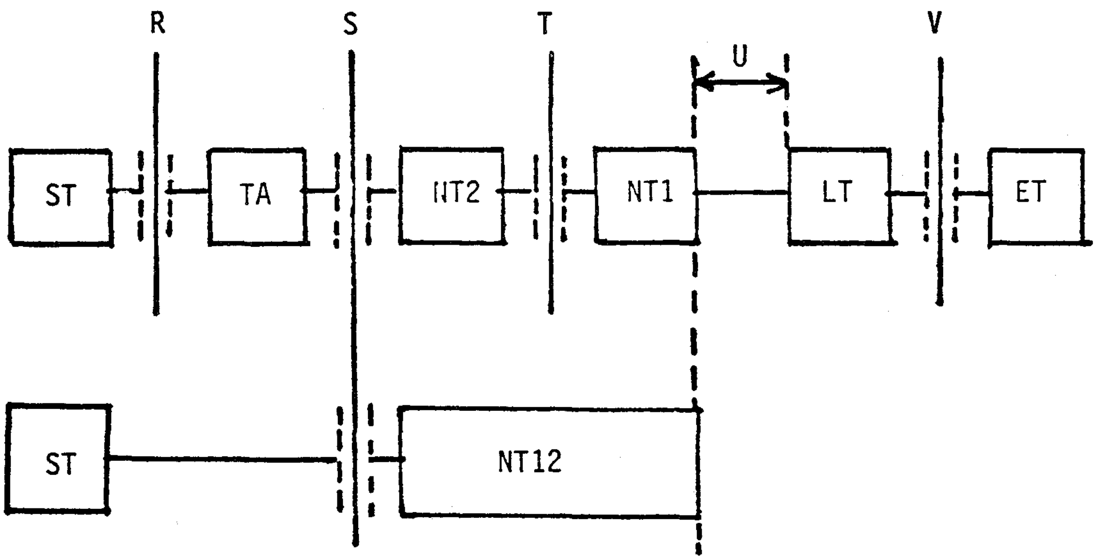


Figure 1 - Designations of functional entities and interface types

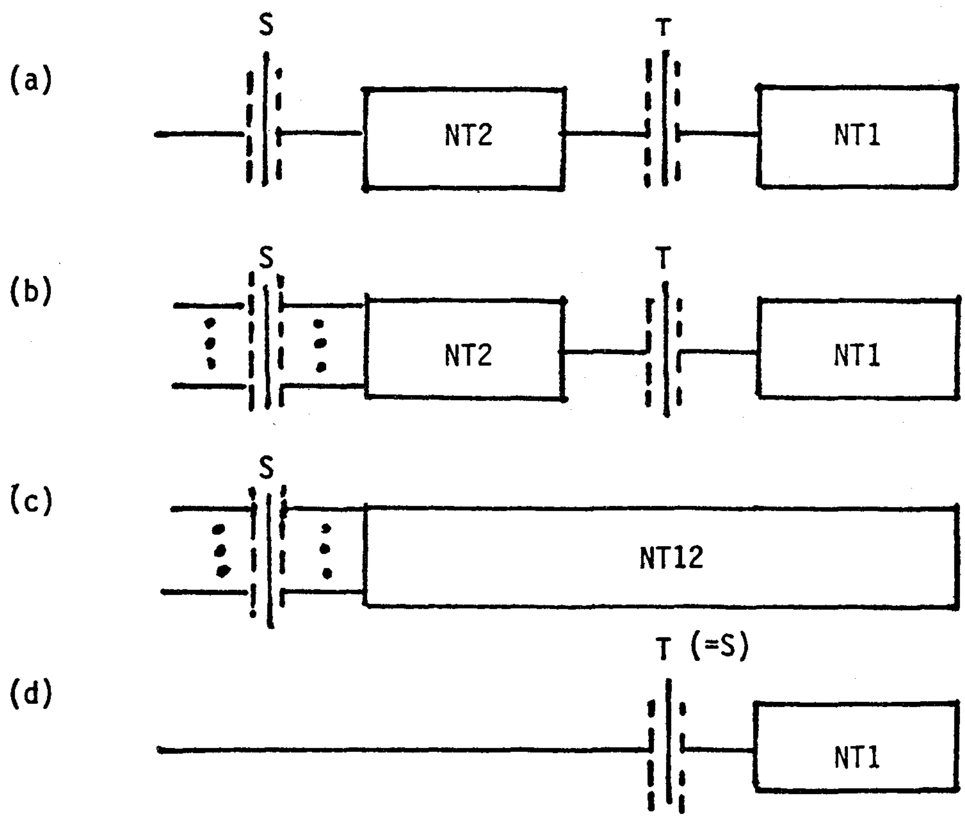


Figure 2 - Physical user interfaces for digital ISDN access

APPENDIX C: THREE CCITT DRAFT RECOMMENDATIONS FOR THE ISDN; I.XXX, I.XXY, I.XXW

The three Draft Recommendations in this appendix are provided to show the most recent considerations of the CCITT relative to the ISDN (as of May 1982).

Draft Recommendation I.xxx: ISDN User/Network Interfaces - Reference Configurations, gives the conceptual configurations for physical user access to the ISDN in terms of reference points and functional groupings. The model for user access (Figure 20) has been modified so that the ST (subscriber terminal) functional grouping has been changed to Terminal Type 1 (T1) and Terminal Type 2 (T2). The T1 functional grouping includes devices complying with ISDN Interface Recommendations for equipment such as digital telephones and data terminals. The T2 functional grouping includes devices that do not comply with all ISDN Interface Recommendations, but do comply with other recommendations such as the CCITT X-Series. The T1 functional grouping may be replaced by T2 and the TA (terminal adaptor) groupings. The TA could adapt the T2 terminals to be compatible with standard ISDN user/network interfaces.

Draft Recommendation I.xxy: ISDN User/Interface - Channel Structures and Access Capabilities, defines channel types (e.g., B-, D-, C-channels) channel structures and channel bit rates. The C-channel designation replaces the E-channel designation. The C-channel may carry telemetry, packet-switched data and signaling information.

Draft Recommendation I.xxw: General Aspects and Principles Relating to Recommendations on ISDN User/Network Interfaces, gives conceptual principles for defining the ISDN.

II.4 Draft Recommendation I.xxx : ISDN user/network interfaces - Reference configurations

II.4.1 General

II.4.1.1 This Recommendation provides the reference configurations for the ISDN user/network interfaces.

The reference configurations are conceptual configurations useful in identifying various possible physical user access arrangements to the ISDN. Two elements are used in the reference configurations : the reference points and the functional groupings. The reference points are conceptual points useful in separating functional groupings, each of which may correspond in certain arrangements to physical equipment or combination of equipment. Physical user/network interfaces may or may not appear at the location of reference points according to the specific user access arrangements. The ISDN user/network interface Recommendations apply to physical interfaces that occur at a specific ISDN reference point location. Layout and application examples of the reference configurations are given in section 2.

II.4.1.2 From the user's perspective, the ISDN is completely described by the characteristics which can be observed at the ISDN user/network interface, including physical, electrical, protocol, service, and performance characteristics. The key to defining, and even recognizing, ISDN is the specification of these characteristics. These specifications will form the basis for work on user applications and terminal equipment, as well as ISDN capabilities, services, and the many other aspects of the ISDN.

II.4.1.3 An objective of ISDN is that a limited set of compatible user/network interfaces can economically support a wide range of user applications, equipment and configurations. The number of different user/network interfaces should be minimized to maximize user flexibility through terminal compatibility (from one application to another, one location to another, and one service to another), and to reduce costs through economies in production of equipment and operation of both the ISDN and user equipment.

However, some different interfaces are required for applications with widely different information rates, complexity or other characteristics so that many simple applications are not burdened with the cost of providing complex applications.

II.4.1.4 An objective is to have the same interfaces used even though there are different configurations (e.g., single terminal versus multiterminal connections to a PABX versus direct connections into the network etc.) or different national conditions (e.g., on the boundary of the ISDN).

II.4.1.5 The implications of these objectives on the specific user/network requirements must be examined to determine whether excessive costs or other penalties are involved in meeting them.

II.4.2 Reference configurations

II.4.2.1 The reference configurations for ISDN user/network interfaces define the terminology for various reference points and the types of functions that can be provided between reference points. Figure 1 shows the reference configurations, while Figure 2 shows significant applications of such configurations.

II.4.2.2 The reference points are conceptual points useful in separating functional groupings, represented in Figure 1 as square blocks. In certain physical configurations, the reference points may correspond to physical interfaces. The I-Series Interface Recommendations apply to physical interfaces appearing at given reference points. Reference points S and T in Figure 1 are identified as ISDN reference points. Only the bit rates which relate to recommend channel structures according to draft Recommendation I.xxy apply to physical interfaces appearing at S and T reference points. R is not an ISDN reference point and may be subject to other Interface Recommendations, e.g. the X-Series Recommendations.

Note : There are no reference points assigned to the transmission line, since an ISDN user/network interface is not envisaged at this location.

II.4.2.3 Figure 1a gives the main reference configuration comprising functional groupings NT1, NT2 and T1. Figure 1b illustrates that T1 may be replaced by T2 and TA.

II.4.2.4 The functions which compose the functional groupings NT1, NT2, T1, T2 and TA can vary with the physical implementation method used for the access. It is possible for a function to be null or to be located in different functional groupings depending upon the arrangement selected. The descriptions below are given for significant examples for functional groupings. The given function lists are neither exhaustive nor mandatory.

Note : The functional groupings are described in relation to the layers of the OSI Reference Model being developed under Question 27/VII. Further study is required to assess the suitability of applying the OSI model to the ISDN (see Question 1/XVIII, point B).

II.4.2.4.1 NT1 - Network Termination 1. This includes functions that may be regarded as broadly belonging to Layer 1 (Physical) of the OSI Reference Model. These functions are intended to be associated with the proper physical and electrical termination of the network. NT 1 functions may include :

- line transmission termination;
- Layer 1, line maintenance functions, such as test loops and performance monitoring;
- timing;
- power feeding;
- Layer 1, upward multiplexing;
- interface termination, including multidrop termination employing Layer 1 contention resolution.

II.4.2.4.2 NT2 - Network Termination 2. This may include functions broadly belonging to Layer 1 and to higher layers of the OSI model, such as Layer 2 (Data Link) and Layer 3 (Network). PABXs, Local Area Networks and Terminal Controllers are significant examples of equipment or combination of equipment which provide NT2 functions. These functions may include :

- protocol handling at Layers 2 and 3;
- Layers 2 and 3, upward multiplexing;
- switching;
- concentration;
- Layers 2 and 3, maintenance functions.

In certain physical configurations, NT2 functions at Layers 3 and above may be null. A network termination acting as a simple terminal controller is an example of such configurations.

In certain other physical configurations NT2 functions at Layers 2 and 3 may be null, as described in section 2.5.1.

II.4.2.4.3 T1 - Terminal Type 1. This includes functions associated with ISDN Terminal Equipment complying with ISDN Interface Recommendations, such as digital telephones, data terminal equipment and integrated services terminal equipment. T1 may also provide connection to other terminal equipment.

II.4.2.4.4 T2 - Terminal Type 2. This does not include all the functions required for terminal equipment complying with ISDN Interface Recommendations, but it includes functions associated with terminal equipment complying with other Interface Recommendations, such as the X-Series Interface Recommendations.

II.4.2.4.5 TA - Terminal Adapter. This includes interface and protocol adapting functions to allow a T2 terminal to connect at the ISDN user/network interfaces.

II.4.2.5 Figure 2 shows some significant applications of the reference configurations to certain physical implementations. The examples given in Figure 2 are not intended to be either exhaustive or mandatory. Square blocks in Figure 2 represent physical entities (equipment or combination of equipment).

II.4.2.5.1 Figures 2a and 2b show two applications of the reference configurations, in the cases where NT2 functions are null at Layer 2 and above. In particular, Figure 2a shows the direct connection between T1 (or T2 + TA) and NT1. Figure 2b describes the direct connection of multiple T1's (or T2's + TA's) to NT1 using a multidrop arrangement (e.g. a bus with Layer 1 contention resolution). This means that when physical interfaces are applied at S and T, on these cases, all of their characteristics must be identical.

Note : Feasibility and characteristics of the multidrop arrangement are under study in conjunction with the Level 1 (Physical) specification of the I-Series Recommendations.

II.4.2.5.2 Figure 2c shows the provision of multiple connections between NT2 and T1's (or T2's + TA's). NT2 may include various types of distribution arrangements, such as star, bus or ring configuration included within the equipment. Figure 2d shows a case where a bus distribution is used between terminals and the NT2 equipment.

II.4.2.5.3 Figures 2e and 2f show arrangements where multiple connections are used between NT2 and NT1 equipment. In particular Figure 2e illustrates the case of multiple NT1 equipment, while Figure 2f refers to the case where NT1 provides Layer 1 upward multiplexing of the multiple connections.

II.4.2.5.4 Figure 2g shows the case where NT1 and NT2 functions are merged in the same equipment, the corresponding merging of NT1 and NT2 functions for other configurations in Figure 2 may also occur.

II.4.2.5.5 Figure 2h illustrates the case where TA and NT2 functions are merged in the same equipment; the corresponding merging of TA and NT2 functions for other configurations in Figure 2 may also occur.

II.4.2.6 Figure 3 further illustrates examples of the correspondence between ISDN reference points and physical user/network interfaces according to possible alternative user and network arrangements.

II.4.2.7 The reference configurations given in Figure 1 apply for the specification of the channel structures and access arrangements given in Recommendation I.xxy, with the exception of channel structures for the hybrid access arrangement. For this arrangement the reference configuration given in Figure 4 applies. This reference configuration includes the analogue connection to an analogue terminal, such as an analogue telephone. T1 may be replaced by T2 and TA as illustrated in Figure 1b.

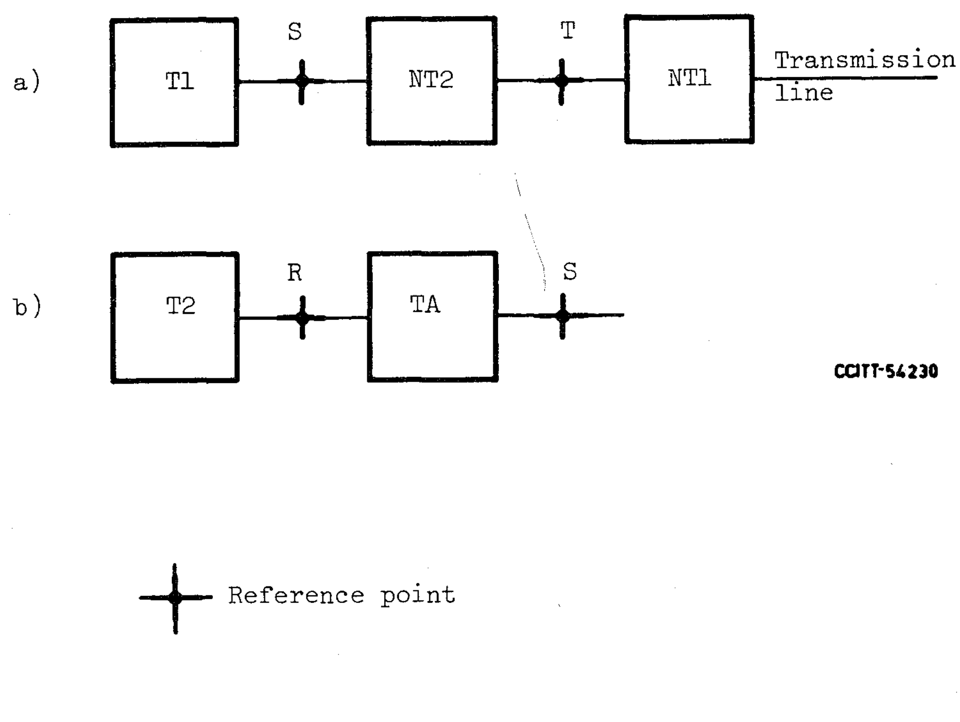


Figure 1 - Reference configurations for the ISDN user/network interfaces

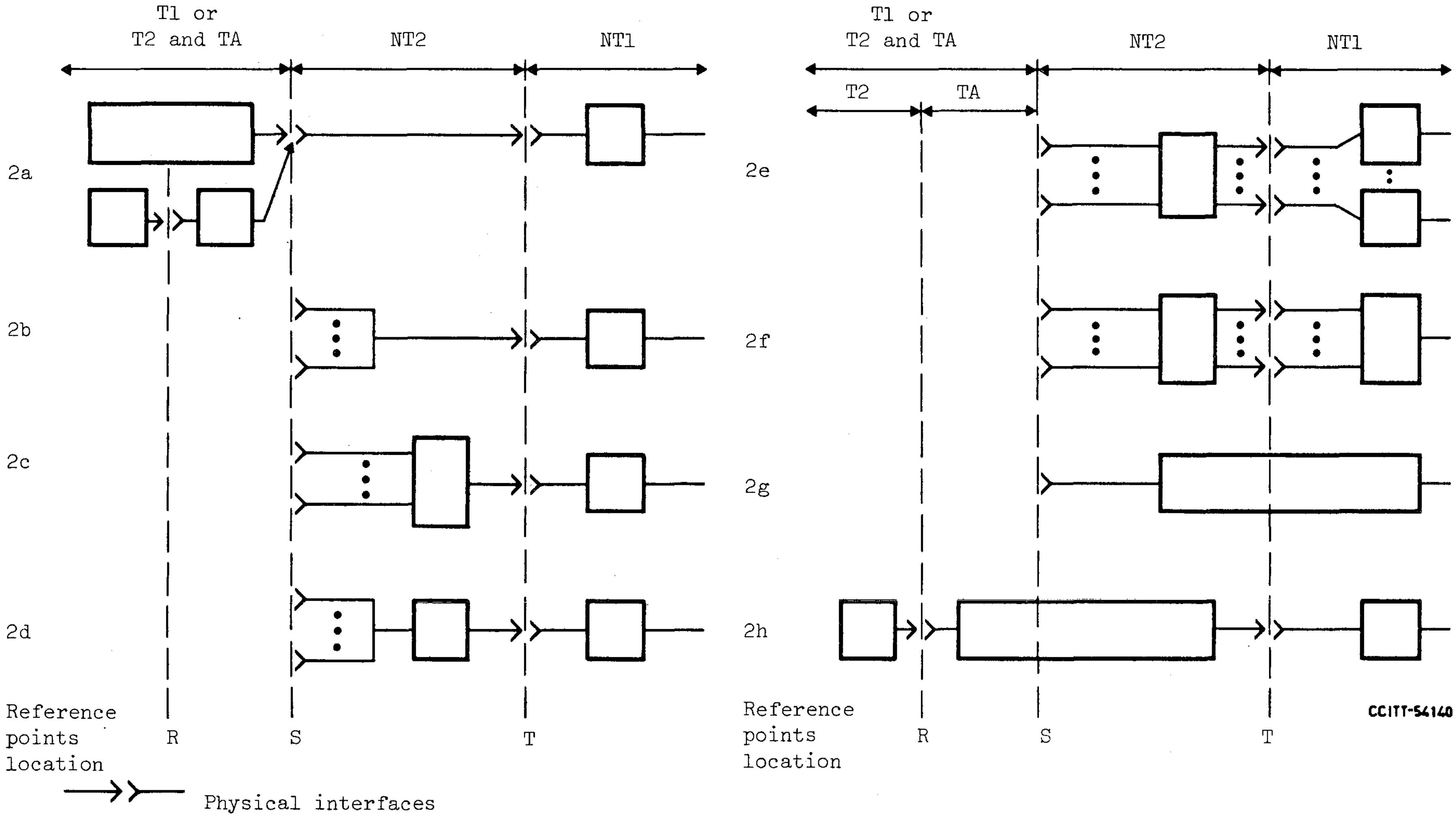


Figure 2 - Significant applications of the reference configurations for ISDN user/network interfaces to physical configurations

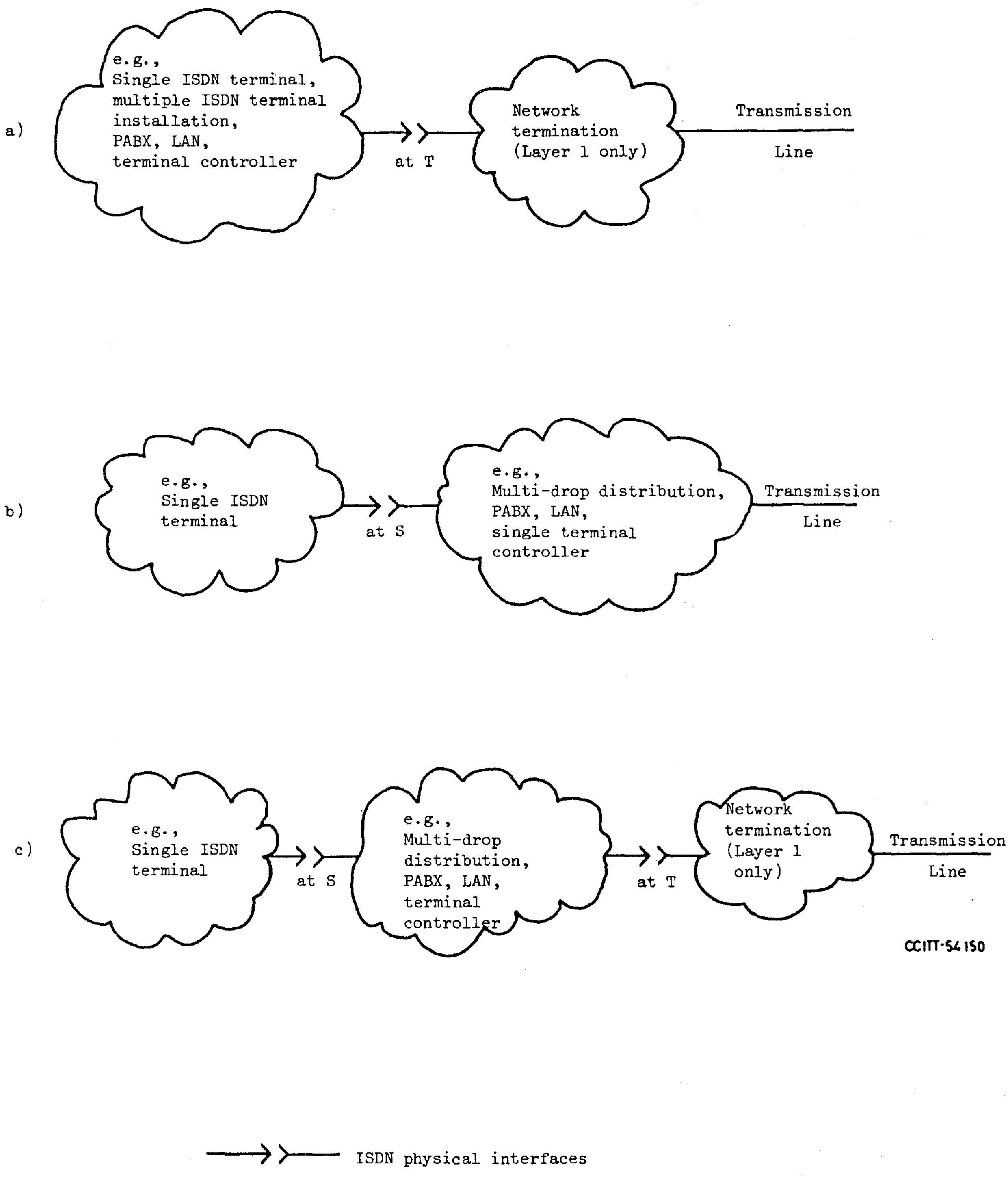


Figure 3 - Some examples of the correspondence between ISDN reference points and physical interfaces in alternative ISDN user/network arrangements

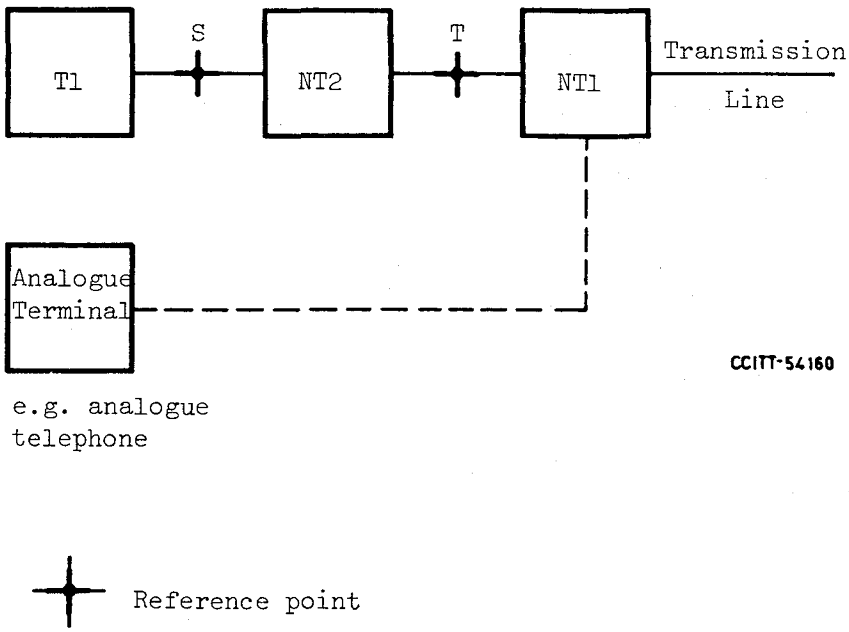


Figure 4 - Reference configuration for hybrid access arrangements

II.5 Draft Recommendation I.xxy : ISDN user/network interfaces - Channel structures and access capabilities

II.5.1 General

In order to minimize the variety of standard ISDN user/network physical interfaces this Recommendation defines limited sets of both channel types and channel structures for such interfaces.

A channel represents a portion of the information-carrying capacity of the interfaces through which it is carried.

Channels are classified by channel types, which have common characteristics.

The channel types, defined in section II.5.2, are combined into channel structures, defined in section II.5.3. As used in this Recommendation a channel structure defines the total digital information carrying capacity across a physical interface.

In an actual access arrangement some of the channels available across an ISDN user/network physical interface, as defined by the applicable channel structure, may not be supported beyond the interface. In this Recommendation the capability provided by those channels appearing across the interface that are actually available for communication purposes, is referred to as the access capability provided through the interface.

II.5.2 Channel types and their use

II.5.2.1 B-channel

II.5.2.1.1 A B-channel is a 64 kbit/s channel.

II.5.2.1.2 A B-channel may be used to carry a variety of digital information streams, on a dedicated, alternate (within one call or as separate calls), or simultaneous basis, consistent with its capacity and the applicable service capabilities. The following are examples of these digital information streams :

i) digital voice at 64 kbit/s according to Recommendation G.711;

ii) digital information streams, such as data, corresponding to circuit or packet switching user classes of service at bit rates less than or equal to 64 kbit/s, including those given by Recommendation X.1;

iii) digital voice at bit rates lower than 64 kbit/s combined with other digital information streams (see ii) above) at compatible bit rates, carried towards the same destination; and,

iv) wideband digital voice encoded at 64 kbit/s.

II.5.2.1.3 Information streams at bit rates less than 64 kbit/s need to be rate adapted to be carried on the B-channel. Rate adaption uses a two stage approach, as follows :

i) adaption to/from 64 kbit/s from/to 8, 16 or 32 kbit/s;

ii) adaption of Recommendation X.1 user rates as follows :

- bit rates of 4.8 kbit/s and below to/from 8 kbit/s;
- 9.6 kbit/s to/from 16 kbit/s;
- 48 kbit/s to/from 64 kbit/s.

II.5.2.1.4 Two technical approaches to handle multiple lower bit rate information streams, as specified in section II.5.2.1.3, should be further considered. One is based on the use of time division multiplexing techniques. The other is based on the use of statistical multiplexing techniques; application of the D-channel protocol should be taken into account. Further study should be directed towards evaluation of both approaches.

II.5.2.2 D-channel

II.5.2.2.1 A D-channel carries digital information streams using a frame-oriented link access procedure (LAP) in accordance with Recommendation I.... (specifying the LAP D protocol).

II.5.2.2.2 The bit rates of a D-channel are specified in section 3.

II.5.2.2.3 A D-channel is used to carry signalling information and may be used to carry telemetry and packet-switched data.

II.5.2.3 C-channel

II.5.2.3.1 A C-channel carries digital information streams using a frame-oriented link access procedure (LAP) in accordance with Recommendation I....

II.5.2.3.2 The bit rates of a C-channel are specified in section II.5.3.2.

II.5.2.3.3 A C-channel may carry telemetry, packet-switched data, and signalling information (which may include some or all of the signalling information for the associated analogue channel).

II.5.2.4 Broadband channel

For further study.

II.5.2.5 Other channels

For further study (e.g. channels carrying information according to Signalling System No. 7).

II.5.3 Channel structures

ISDN user/network physical interfaces at ISDN reference points shall comply with one of the channel structures defined below.

II.5.3.1 Basic channel structure

II.5.3.1.1 The basic channel structure is composed of two B-channels and one D-channel, 2B + D. The bit rate of the D-channel is 16 kbit/s.

II.5.3.1.2 The B-channels may be used independently; i.e. in different connections at the same time.

II.5.3.1.3 With the basic channel structure, two B-channels and one D-channel are always present at the ISDN user/network physical interface. One or both B-channels, however, may not be supported beyond the interface. Therefore, when using the basic channel structure, the following basic access capabilities are possible.

- 2B + D;
- B + D; and
- D.

Note : The basic channel structure may also be used in association with a conventional analogue channel in a hybrid access arrangement; see section II.5.4.2.

II.5.3.2 C-channel structure

The C-channel structure consists of one C-channel. The C-channel is associated with a conventional analogue channel in a hybrid access arrangement; see section II.5.4.2.

The bit rate of the C-channel is 8 kbit/s in some cases and 16 kbit/s in other cases, depending on the type of hybrid access arrangement.

II.5.3.3 Intermediate channel structure

For further study.

II.5.3.4 Primary rate channel structures

These structures correspond to the primary multiplexing rates of 1544 and 2048 kbit/s.

II.5.3.4.1 Multiplexed channel structures

II.5.3.4.1.1 The primary rate of multiplexed channel structures below are composed of some number of B-channels and one D-channel, nB + D. At the primary multiplex rate, the use of Signalling System No. 7 signalling channel instead of a D-channel, is for further study.

II.5.3.4.1.2 At 2048 kbit/s, this channel structure is 30B + D. The rate of the D-channel is 64 kbit/s.

II.5.3.4.1.3 At 1544 kbit/s, the two following channel structures have been proposed for further study :

i) 24B + D, where the bit rate of the D-channel is 4 kbit/s; or

ii) 23B + D, where the bit rate of the D-channel is 64 kbit/s.

II.5.3.4.1.4 The need for providing a multiple D-channel capability is for further study.

II.5.3.4.1.5 With the primary rate multiplexed channel structure, the designated number of B-channels are always present at the ISDN user/network physical interface. One or more of the B-channels may not be supported beyond the interface.

II.5.3.4.2 Broadband channel structure

For further study.

II.5.3.5 Higher rate channel structure(s)

For further study.

II.5.3.6 Other channel structure(s)

For further study.

II.5.4 Examples of application of channel structures

II.5.4.1 Access arrangement for PABX, terminal controller, local area network, etc.

Figure 1/I.xxy illustrates a typical PABX, etc., access arrangements. The PABX, etc. may use a basic channel structure for interfaces located at ISDN reference point S. The basic or primary rate multiplexed channel structure may be used at one or more interfaces located at ISDN reference point T.

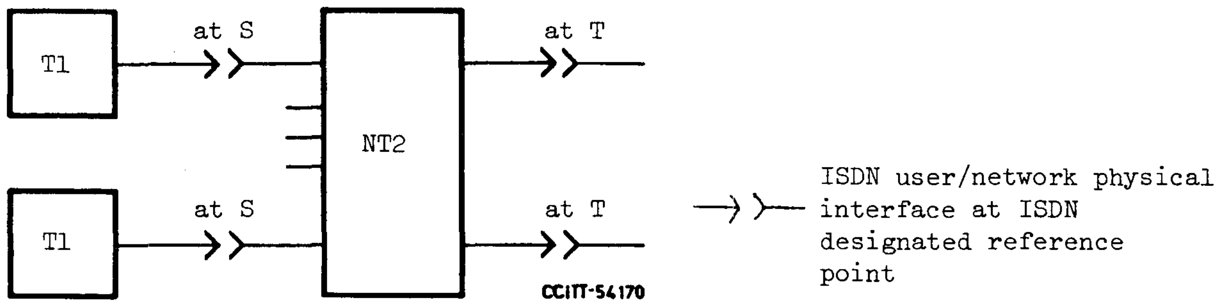


Figure 1 - I.xxy

II.5.4.2 Hybrid access arrangement

Figure 2/I.xxy illustrates a possible configuration for a variety of hybrid access arrangements. A hybrid access arrangement consists of a digital channel structure used in conjunction with an analogue channel. A physical interface is shown at ISDN reference points S and T, where the C-Channel structure or the basic channel structure may be used. In addition to the analogue channel, the hybrid access arrangement includes one of the following digital access capability :

i) C;

ii) D;

iii) B + D, and,

iv) 2B + D.

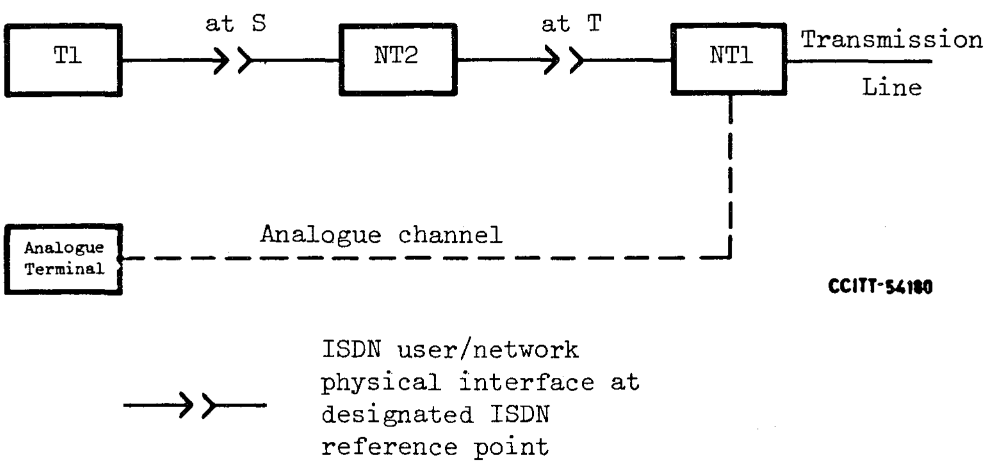


Figure 2 - I.xxy

II.6 Open issues for further study

II.6.1 Some sentiment was expressed for a more appropriate method to specify channel types. Is a channel defined by a transport capacity (e.g. 64 kbit/s), or is it defined by the link access procedure ? Should other characteristics be included such as bit sequence integrity, directionality, and inequality of bit rate in two directions ? The notation of channels could be dependent on the above characteristics. One such approach is proposed in Delayed Contribution DF (GTE International).

II.6.2 An appropriate notation for the signalling channel or channels on the multiplexed channel structure, e.g. for PABX, must be established if Signalling System No. 7 is to be used.

II.6.3 Further study has been proposed on the use of a circuit switched digital channel or channel structure on the hybrid access arrangement. This is in addition to the agreed upon channel structure indicated in the draft Recommendation I.xxy.

II.6.4 The number and specification of channel structures with bit rates above the basic will be studied. Four types of channel structures above the basic are proposed for further study.

a) Intermediate channel structure

Delayed Contribution CG (France) proposes to define such a structure at a bit rate between 400 kbit/s and 800 kbit/s, primarily for covering the needs of medium sized PABXs. A 608 kbit/s channel structure was also proposed as an example for further consideration (see Annex 1). 512 and 704 kbit/s channel structures have also been proposed. However, there was no agreement on the needs to define an intermediate channel structure for an ISDN user/network interface.

b) Broadband channel structure

This structure is intended to support broadband information. This structure could be composed of :

i) an aggregation of B-Channels;

ii) a broadband (unstructured) channel. This structure may or may not include a D-Channel and is described in Delayed Contribution CY (British Telecom, see Annex 2).

c) Higher rate channel structure(s) at bit rate(s) above the primary rate channel structure.

II.6.5 The issue of multiple D-Channels in a single multiplexed channel structure and the D-Channel notation involved also requires further study.

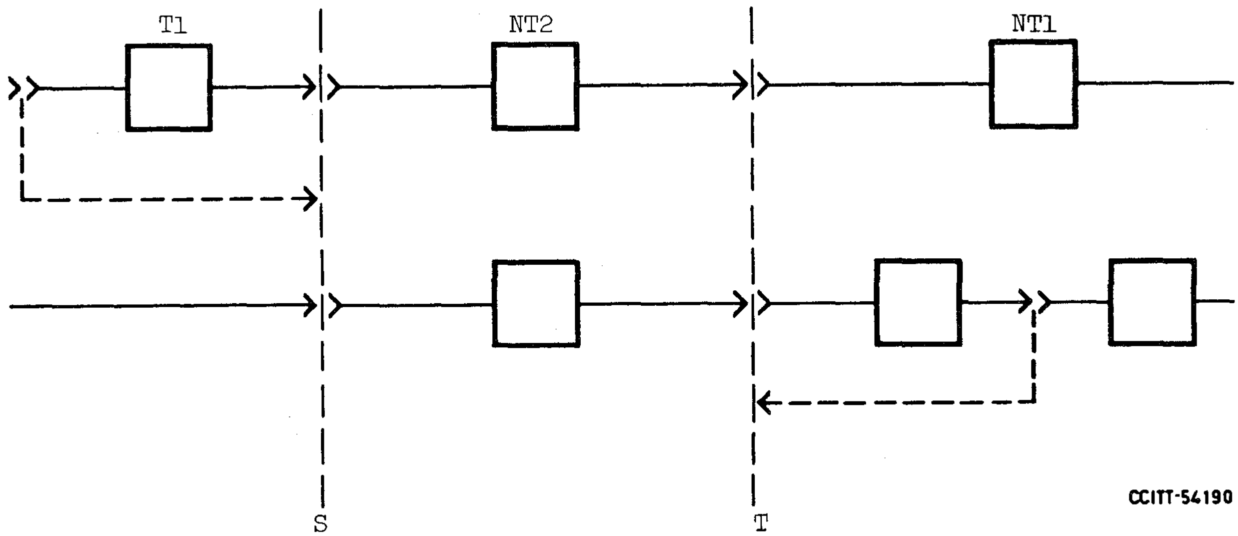
II.6.6 Further study is required to determine the appropriate multiplexed channel structure at the 1544 kbit/s primary multiplexed rate. Possibilities include :

a) 24 B + D (4 kbit/s);

b) 23 B + D (64 kbit/s).

The associated D-Channel notation must also be confirmed.

II.6.7 Additional examples of reference configurations for ISDN user/network interfaces have been proposed as shown below. This should be studied further together with any others proposed for addition to Figure 2 of draft Recommendation I.xxx.



II.6.8 Advice is sought from Study Group VII in order to determine the details of the two stage rate adaption approach as specified in Recommendation I.xxy.

II.6.9 The possible need and specification of other channel types requires further study.

II.6.10 Further study should be directed toward the evaluation of the two alternative approaches to handling of multiple lower bit rate information streams in a single B-Channel :

a) time division multiplexing;

b) statistical multiplexing.

II.6.11 Preliminary draft Recommendation I.xxw - (General Aspects and Principles) was prepared as an example of what may be included in a draft Recommendation and is Annex 3 of this report. Further study is required to determine the appropriate scope of the I. series of Recommendations. Only then then can this preliminary draft Recommendation can be advanced.

Annex 3

(to Part II)

DRAFT RECOMMENDATION I.xxw : General aspects and principles relating to Recommendations on ISDN user/network interfaces

1. Recommendation G.705 gives the conceptual principles on which the ISDN should be based. The main feature of the ISDN is the support of a wide range of services, including voice and non-voice services, in the same network by offering end-to-end digital connectivity.

A key element of service integration for the ISDN is the provision of a limited set of standard multipurpose user/network interfaces. These interfaces represent a focal point both for the development of ISDN network components and configurations and for the development of ISDN terminal equipment and applications.

An ISDN is recognized by the service characteristics available through user/network interfaces, rather than by its internal architecture, configuration or technology. This concept plays a key role in permitting user applications and network technologies to evolve separately.

The ISDN will provide a basic network transport capability for a variety of services (ranging from alarms and telemetry through voice, interactive data and bulk data, to broadband video applications) using a variety of telecommunication modes (from leased and semipermanent connections to circuit and packet-switched connections).

In addition to the basic transport capability, depending on the national regulatory arrangements, the ISDN could also incorporate information storage and processing facilities, e.g., in case of CCITT standardized communication services, such as Teletex, Videotex and others.

2. Figure 1 shows some significant examples of ISDN user/network interfaces. The following cases are identified corresponding to :

1) access of a single ISDN terminal;

2) access of a multiple ISDN terminal installation;

3) access of multiservice PBXs, or local area network, or, more generally, of private networks.

In addition, depending on the particular national regulatory arrangements, ISDN user/network interfaces may include access of :

4) specialized services networks;

5) specialized storage and information processing centres;

6) other single or multiple services carrier networks.

3. User/network interfaces standardization is required to allow :

1) different types of terminals and applications to use the same interface;

2) portability of terminals from one location to another (office, home, public access points) within one country and from one country to another country;

3) efficient connection with private networks, specialized service vendors and other carrier networks.

4. User/network interfaces should be specified by a comprehensive set of characteristics, including :

1) physical and electrical characteristics;

2) performance characteristics;

3) maintenance and operation characteristics;

4) bit-stream format, in terms of channel aggregation;

5) service and feature selection procedures, signalling procedures and protocol procedures for the information transfer.

5. In addition to the multiservice capability the ISDN user/network interfaces should allow for additional capabilities (as compared with the existing X series interfaces) such as the following :

1) a multidrop connection, possibly with socketized simple interface, to which a variety of different terminals can be connected;

2) choice of bit rate, switching mode, coding method, etc., on a call-by-call basis, over the same interface, according to the user's need on a particular call;

3) capability for compatibility checking in order to check whether calling and called terminals can communicate with each other.

6. For defining the interface characteristics a layered functional specification method should be applied, using an OSI-type of reference model, suitably adapted to allow for the specifics and requirements of the ISDN.

7. The reference configuration for ISDN user/network interfaces define the terminology for various reference points and the types of functions than can be provided between reference points. Recommendation I.xxx contains the reference configurations and shows significant applications.

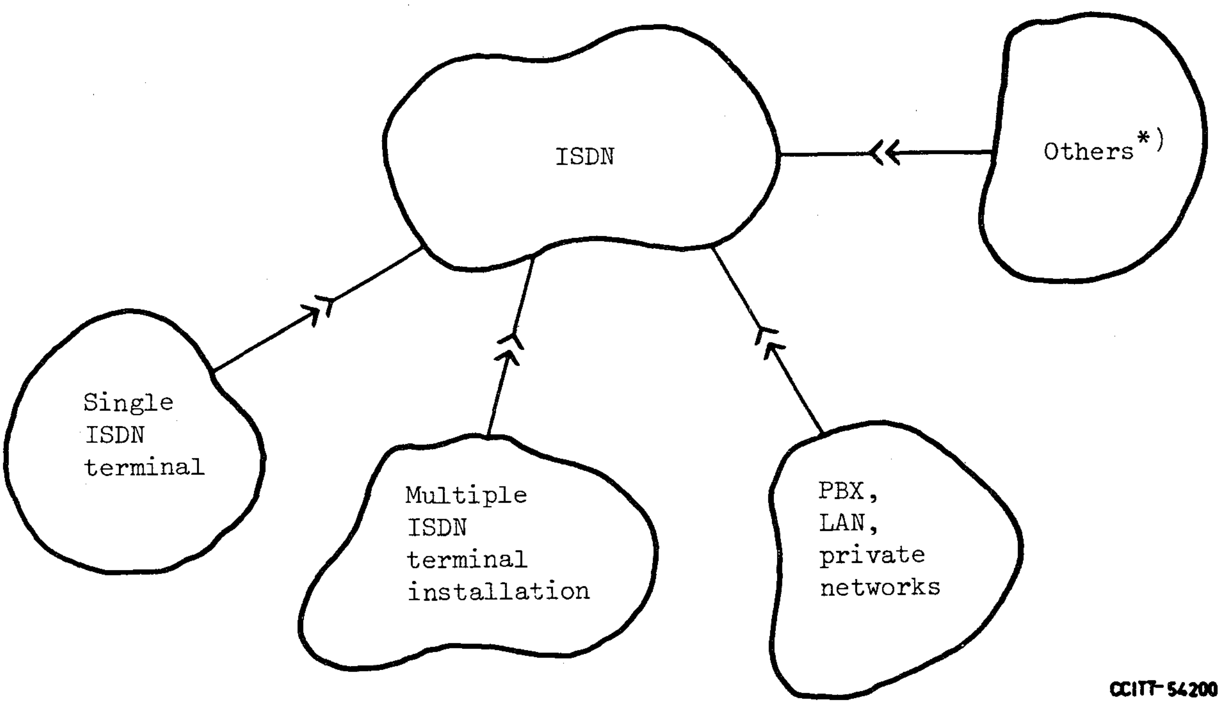
8. As an objective the number of different interfaces should be kept to a minimum. In order to meet this objective, a distinction is necessary between the channel structures supported by the interfaces, and the access capabilities reflecting the digital channels actually available and supported by the particular networks accesses.

Recommendation I.xxy covers these aspects.

9. In order to prevent an unnecessary diversification of interface characteristics, and yet to retain sufficient flexibility to meet the users and network and services providers needs, a modular approach should be applied in defining each type of interface. This is achieved by reflecting the layered functional specification method also in the structure of these Recommendations. Therefore, the Level 1 type characteristics applicable to one or various types of interfaces are given in Recommendations the I-... series; the Level 2 characteristics in the I-... series, and the Level 3 characteristics in the I-... series.

A particular type of physical interface appearing at a location corresponding to a specific reference point can then be fully specified by selecting the appropriate Recommendations applicable to the relevant functional levels (for example, for the basic user/network interface of Recommendation I.010, Level 1 of I.101, Level 2 of I.201 and Level 3 of I.301 apply jointly).

10. The principles outlined above should be applied when other ISDN-access interfaces are to be developed in the future.



*) Depending on national regulation, this may include :

1) specialized services networks;

2) other carrier networks;

3) specialized information processing centres.

Figure 1 - ISDN user/network interface examples

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National and international work toward an Integrated Services Digital Network (ISDN) and the progress toward its implementation is described. Standards activity and technology relating to the ISDN, in the United States and abroad, are presented.

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