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BROAD BAND-INTEGRATED SERVICES DIGITAL NETWORK

CONTENTS

ABSTRACT

An evolution is currently taking place in our telecomminication networks: the design, development and implementation of the Integrated Serwices Digital Network (ISDN). It is by no means a coincidence that the recent advances in electronics, communications and computer technologies have brought the telecomminications and computer worlds ever closer. This is proving to be one of the driving forces in the emergence of the information society. ISDN with its successor, the Broadband-ISDN (B-ISDN), will play a pivotal role in the achievement of this goal.

ISDN will be the cornerstone of a development where computer and telecomminications users in all fields of our daily lives–in education, industry, commerce, government and entertainment-will join the global information technology (IT) village through improved computer and comminication standards and services. The concepts of the ISDN are now firmly accepted. The development of the ISDN, the related standards and technology are still part of an ongoing process. The architectural and service aspects of the networks have gained a base from which new applications can be designed.

CHAPTER
ONE

INTRODUCTION

The integrated services digital network (ISDN) is one of the hottest buzzwords today, just as the micro-chip was about fifteen years ago. A lot of development has taken place since then, in both the computing and the communications worlds. Imagine a computer sitting on your desk with which you could ring anywhere in the world and carry on a telephone conversation while at the same time accessing a remote database from within another window on your screen and using the same wall socket: your introduction to the world of ISDN. Imagine yourself then making a call to your local estate agent and scanning through their home catalogues on your screen while discussing the details with them over the phone connected to the same twisted pair cable. Imagine yourself in the office conducting a multi-party, multi-media conferencing across continents. Well, all of this technology is currently available, thanks to ISDN and the developments in data and telecommunications techniques and standards.

Local area computer networks (LANs) have become as ubiquitous in today's offices as personal computers are at home. Formerly, the interconnection of LANs to each other left a lot to be desired in that they mostly used the old analogue telephone lines and modems operating at the now abysmally low transmission rates of 9600 bits per second bps. Packet-switched data networks (PSDNs) have alleviated some of these problems, but the technology and applicafions in the LAN world have also outgrown their original bounds. What is currently needed is a method of transparent interconnection of LANs and of porting the applications developed for the relatively fast and error-ftee environments found on the local area networks across long distances over the ISDN. These services should be available to home workers, office interconnects and global LAN interconnection. Dynamically varying network topologies and virtual networks are now possible, thanks again to the ISDN. Faster speeds, a very good bit error rate (BER), end-to-end digital connectivity, support of multiple services and types of services, standardized access methods and standardized hardware and software are now a reality. For voice, data and video services supported concurrently through one global network and ubiquitous access all around the globe, the ISDN is the way forward; and, what is more, the technology is available today.

1.1 EMERGENCE OF ISDN

The invention of the transistor and the subsequent development of microchip technology has resulted in a variety of useful applications in almost every aspect of life; from home to office, from industry to commerce, from government to health care to education. This is currently progressing in two main fronts: the computer and communications technologies. When intelligent functionalities were increased in the old telecommunications networks, it came in the form of the stored program control (SPC).

This was the use of some computing function running special software to control the exchanges in the network. A multitude of services then became available-call logging, itemized bills, transfer of calls, conferencing, ring-back-when-free, etc. On the other hand, it became possible for computers with simple interface cards and modems to access the telecommunications services through their communications ports and software. Slowly, a bit of the functionality of each of these technologies became a part of the other. Today they are inseparable in many respects. Coupled with this background development are the user requirements of accessibility, flexibility, speed, cost effectiveness and new services on the one hand, and the desire of the service providers to increase the return from their invested capital, to use the economy of scales, to increase serviceability and to ease the management problem on the other. Hence the technological and market forces have required the integration of existing networks and services already provided on separate networks. This has led to the concept of an integrated services digital network, a network that would provide a solution to most of the problems in the communications world.

There are two main aspects of ISDN: the network evolution, and the services provided. As far as the users are concerned, ISDN will provide all the necessary communications services or access to the services provided by other networks in a transparent fashion. As far as the service providers are concerned, the services may be provided by one homogeneous or several heterogeneous interworking networks. This does not change the view of the ISDN from the outside: that of a uniform service provider through standard interfaces.

The integrated services digital network (ISDN) is evolving from the integrated digital network (IDN) concept and is taking shape worldwide. The IDN provides the integration of the switching and transmission facilities and extends it to the subscriber loop by digitization in the network. It also provides for the common channel signalling which is based on the transmission of the control and signalling messages on a packet-switching network designed for this purpose and is part of the public switched telecommunications network (PSTN). One of the fundamental concepts in the creation of ISDN is the provision of a multitude of switched and non-switched services to the users within the circuit, packet of frame modes of access, through the use of a small set of standard user-network interfaces (UNIs). Apart from fast switching, which is possible because of the end-to-end digital connectivity, the ISDN utilizes common channel signalling (CCS), allowing the selection of different services through the use of a standard signalling protocol at the UNI. Furthermore, the ISDN provides multiple channels to the user at the UNI. The main multiplexing technology used in the digital telephony world is time division multiplexing (TDM). Multiple channels at the ISDN user-network interface are formed by assigning one or more time slots (TSs) within a TDM frame to a channel. The TDM technology lends itself easily to circuit switching (CS). Hence, circuit switching is inherent to ISDN, and it is one of the earlier services available in ISDNs.

More recent technological developments taking place in the ISDN world are the frame mode services, based on the more efficient use of the ISDN technology, and the broadband ISDN services, based on the asynchronous transfer mode (ATM) and the fibre optic technology. These will bring a drastic improvement in the way most current services are provided. For example, the frame mode services are proposed as the main method of LAN-LAN interconnection in the very near future. The ATM technique is proposed as the main technology for multi-megabit services including high-definition TV and video conferencing.

Some of the factors affecting the development of the ISDNs are:

- **Basic technology** Among developments in the sophistication of electronic components, the current very large-scale integrated circuit (VLSI) chip technology allows the implementation of many more functions in hardware and firmware. For example, silicon chips are available accommodating the high-level data link control (HDLC) protocol for layer 2 of the OSI reference model (CCITT 1988a; ISO 1984). Developments in the fibre optic technology is another factor.

- **Increased use of computers** Computers are nowadays used in almost every walk of life, including government, commerce, banking, education, research, industry, and tourism and leisure. The development of sophisticated applications requiring more and more hardware capacity and communications bandwidth means that the computer and telecommunications technologies have to deliver. The availability of on-line information services and large databases, and the demand for electronic shopping and banking facilities, mean that more and more data networks will be built. Although currently the data services amount to only a very small percentage of the whole telecommunication sector, this is hound to change in the near future.

- **Increased use of communications services** The whole public and commercial life of individual countries and companies nowadays depends more than ever on the use of communications facilities. This provides instant access to information on a national and global basis. The whole trade and commerce sector is now completely dependent on the availability of telecommunications and computing services. For example, one cannot conceive of a just-in-time type stock provision without telecommunications and computing facilities.

- **More time and money to spare** With current developments in the economic and social spheres, most people will have more time and money to spend on technology and leisure. They will want more TV channels and easier access to electronic services and teleconferencing facilities.

- **Working from home** With the increase in computing and communications facilities, 'home commuters' are growing in number. This especially suits people who prefer to work at their home rather than the office environment or who have a good reason not to travel. It also suits some businesses, allowing them to cut down on office space, heating costs, etc.

- **Information technology** The current state of information technology has reached such a level that the storage of information is no longer the limiting factor; rather, it is the access and manipulation of the information. Hence faster and bener communications facilities are needed.

- **Computer-aided production and support** Most industrial output is nowadays controlled by communicating computers. The move is to lock the parts manufacturers, stock suppliers, engineering design, manufacturing and servicing centres, as well as the distributors, into one work environment based on suitable standards, software, services and a global computer and communications network. An example of this is the Computer-Aided Logistics Support (CALS) progrmme of the US Department of Defense (LMI 1989, 1990).

1.2 THE DATA COMMUNICATIONS REVOLUTION

A revolution has been taking place since the early 1980s whereby the individual cdmputer with its own domain of information and work is no longer a preferred solution to computing. Today, computers have become much more friendly and accessible. They have become tools for productivity rather than simply pieces of scientific equipment. Distributed computing based on workstations, personal computers and their networks has become the norm. This has resulted in the proliferation of the local area computer networks (LANs). Next has come thc departmental LAN, connecting whole departments, and the company LAN, formed by the interconnection of the departmental LANs throughout a company. In parallel, a more widespread revolution has taken place; that of the internet. The interconnection of company or institution LANs to each other via a special wide-area computer network using special communication protocols has meant that a concatenated network of networks can be formed. This is called an internet if they all support a common internet protocol at the network layer of the Open Systems Interconnection (0SI) reference model.

Another development in the public domain has been the adoption of network access standards by world standards organizations for the use of national and international packet- switched public data networks (PSPDN). An example to this is the CCITT Recommendations on the X-series of protocols (e.g. X.25 and X.75*)*. Parallel to this, other standards organizations, such as the International Standards Organization (ISO) and the Institute of Electrical and Electronic Engineers (IEEE) in the United States, the British Standards Institute (BSl) in the UK and AFNOR in Germany, have been active in the definition and acceptance of other data communications and networking standards. One of the most important sets of standards are the ISO's Open Systems Interconnection (OSI) standards on computer communications (Day and Zimmerman 1983). OSI standards cover only the data applications. However, work in the telecommunications world is converging to that of the computer world. Therefore, standards covering the overlapping area need to be defined. Indeed, today more than ever before, there is a need to provide standards for multi-service and multi-media networking.

Today's networking covers a wide spectrum. It involves computer-to-computer as well as computer-to-other-digital-device communications like disk storage devices, tape drives, printers and even industrial machinery. To cope with specific applications, Technical and Office Protocol standards (TOP) and Manufacturing Automation Protocols (MAPs) (General Motors 1988) have been developed in some sectors of the industry.

Computer communication is necessitated by various needs. Some of these are:

- **To share data and information** Inaccessible data is not useful. The ability to share information and exchange data is vital in today's work environment.
- **To share resources** Expensive and vital resources can be shared between users and computing machinery. Examples are the expensive supercomputers, laser input or output devices, line printers, tapes and disks.
- **To increase reliability and extend services** A distributed system can be made to have increased reliability over a single resource as a result of the replication and extended services.
- **To control remote devices** Sometimes devices that need to be controlled by computers can be situated at long distances from the control centre. In this case a computer network may be installed with the appropriate hardware and software. Data collection and transmission is also required.

Many computer applications are now available using computer communications and networks. These include electronic mail, remote login, file access, file transfer, remote windowing, remote database access, computer conferencing and computer-aided telephony.

1.3 INTERNETWORKING IN THE ISDN ERA

1.3.1 The background

The first computer systems consisted of a mainframe forming the central hub of a star network serving user terminals and other peripheral equipment. The communications between a central computer and its peripherals formed the first data communications as such. These islands of computing systems were soon found to be wanting in many respects. The need for computer communication arose mainly from the need to share information and resources. This led to the formation of local computer networks. However, the need for inter-site, inter-city, inter-country and global data communications has resulted in the establishment of private, national and international computer networks. Examples of these are the networks of individual banks or companies (e.g. IBM's VNET and DEC's Easynet-see Quarterman and Hoskins 1986), national research and educational networks (e.g. ARPANET in the United States, JANET in the United Kingdom (Kirstein et at. 1989), European Academic Researe Network (EARN) and RARE (Quarterman and Hoskins 1986)).

As computers entered every aspect of human, economic, production and administrative activity, so too did the industrial, commercial, financial, educational, governmental, health and even recreational applications of computing become widespread. As the number of computer networks at the local or wider areas increased, the need for interconnectivity and interworking between different networks is becoming more acute.

For data communications between computers, a set of procedures, rules and conventions defining different activities needs to be established. These are called the communication protocols. Most networks are designed as a series of layers or levels, each one built upon its predecessor. This provides structured design with reduced complexity. A set of layers an protocols is called the network architecture (Tanenbaum 1989). The International Standards Organization has been working towards the establishment of world-wide standards collectively known as the Open Systems Interconnection (OSI) standards, based on the principle of layering. This principle helps the structured design of computer networks. The OSI reference model (OSI-RM) (CCITT 1988a; ISO 1984), defines seven layers and is used as a guide for all network architectures conforming to the open system principles (see Fig. 1.1). Open systems are systems that are open for communication with other systems conforming to the same principles.

In the OSI-RM, each system is decomposed functionally into a set of subsystems and is represented pictorially in a vertical sequence. Vertically adjacent subsystems communicate through their common interfaces, while peer subsystems collectively form a layer in the architecture. Each layer provides a set of well defined services to the layer above, by adding its own functions to the services provided by the layer below (Day and Zimmerman 1983; COrIT 1984).

The layers of the model are partitioned as follows:

1. **Physical layer** Achieves the transmission of raw data bits over a communication channel (medium).

2. **Data link layer** Converts the raw transmission facility into a line that appears free of transmission errors to the network layer. This is done by grouping level 1 bits into data frames and delimiting them. This layer may also include access control to the medium, error detection and correction.

3. **Network layer** Performs the routing and switching of data between any two systems across multiple data links and subnets.

4. **Transport layer** Operates on an end-to-end basis achieving the necessary quality of service for the exchange of data between two end systems. May include end-to-end error recovery and flow control.

5. **Session layer** Allows users on different machines to establish sessions between them, and hence establishes and manages communication dialogue between processes.

6. **Presentation layer** Manages and transforms the syntax of structured data being exchanged. Is also concerned with the semantics of the information transmined.

7. **Application layer** Deals with the information exchange between end-system application processes and defines the messages that may be exchanged.

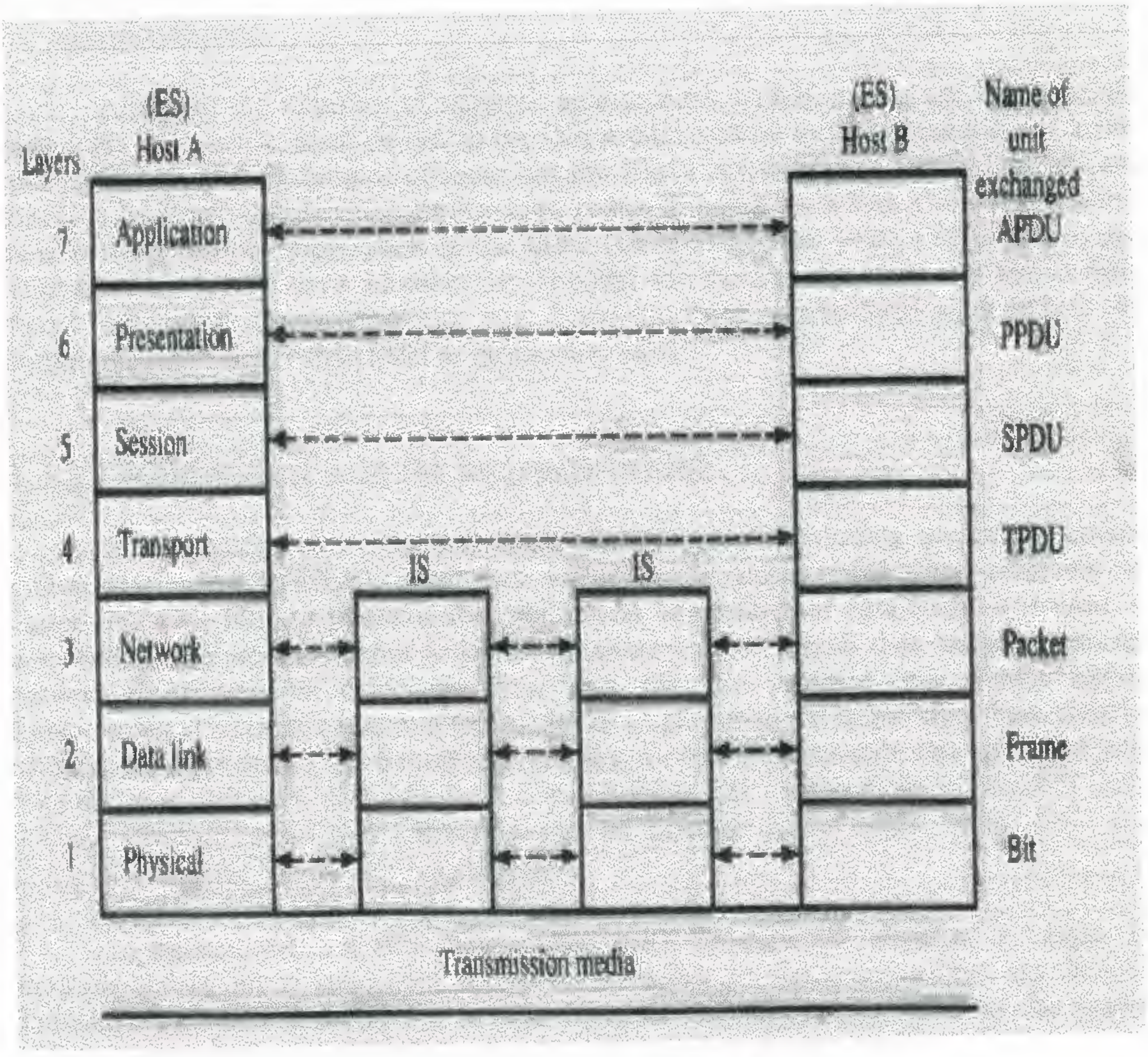


Figure 1.1 The OSI reference model

The above layering was created according to the original design principles used in the construction of the ISO model. According to this (see Day and Zimmerman 1983):

1. Different levels of abstraction are placed in separate layers.
2. Similar functions are grouped together within a single layer with each layer performing a well defined function.
3. The function of each layer is chosen so as to be amenable to the definition of a standard protocol.
4. Minimization of information flow across interfaces is a primary goal in drawing the layer boundaries.

Although the majority of network architectures widely in use are based on the principles of layering, most do not fit the OSI model exactly in their allocation of layers and protocols used. Examples of these are the IBM's SNA (Meijer 1987), DECnet and DARPA Internet (Quarterman and Roskins 1986), to name but a few. Conversely, some new network architectures, such as the MAP (General Motors 1988; O'Prey 1986) and TOP (Boeing 1988), have adopted the OSI-RM for their architecture and hence form 'open' networks. Open networks use internationally standardized procedures for communications rather than local or proprietary ones.

1.3.2 Technological base for internetworking

In computer communication three basic types of switching are used: packet, circuit or message switching. Most data networking is packet-based since, whatever the underlying switching or transmission mode used, some form of data framing is used. A data frame may be considered to be the smallest unit by which data transfer between networked elements is achieved, since data bits are grouped into frames before transmission. The packet size may be greater or smaller than the frame size. Packetization of data into units makes the fragmentation, transmission and reconstitution of the original data easier in that each unit may be accounted for by the communication protocol used. Hence, error detection and correction can be handled more easily. Also, flow and congestion control can be more manageable.

In packet-switched (PS) networking, hosts or network relays have single- or multiple-access ports connected to packet switches in the main subnet (or WAN). Transmission links between the packet switches and the access lines to the packet switches are usually permanently connected via leased or private lines.

Two modes of operation are possible in PS data communications: connection oriented (CO) and connectionless (CL). In the CO mode, first a connection termed a virtual circuit (VC) is set up across the packet-switching network to the destination. All the intermediate switching nodes must reserve resources for the new VC. Before the establishment of a VC can be achieved, a data link layer (DLL) connection must be established. This is usually done at the start-up time. Network layer (NL) packets are then transferred in DL frames.

In the CL mode of operation, no previous connection set-up is needed and network layer packets are individually routed to any one of the transmission lines over which a data link connection exists to the destination. Transmission of network packets next hop along the route is achieved by transporting them in DLL frames.

Transmission	Access	Mode
Analogue	Acoustic coupler	Switched
	Modem	Switched/leased line
Digital	Direct	Switched/leased line
	Integrated access	Switched/permanentlsemi-permanent

Table 1.1 Access methods

In circuit-switched (CS) networking, network access is achieved only after a circuit has been set up to a destination, through the intermediate network. If a packet service is required, then, once the physical layer connection is achieved, a data link connection needs to be established between the two ends. The intermediate network has no knowledge of the framing or packetization, acting solely as a 'bit pipe'. Network packets can then be forwarded between the two communicating ends. In the CS mode of networking, the delays in the establishment of physical circuits and DLL links can be time-consuming, preventing fast, on-demand set-up and removal of connections. Tables 1.1 and 1.2 show the access modes in the analogue and digital networks and the differences in the packet- and circuit-switched networking, respectively.

PS	CS
No 'circuit' needs to be set up (CL) VC must be set up (CO)	Long circuit set-up delays
Point-to-point, multicast, lsroadcast	Point-to-point
Longer queuing delays may be encounterod and packet-switching delays at every switching node en route suffered	Once the circuit is set-up, transmission and pnopagation delays are the most impoetant delays encountered
Multiplexing is inherent	Multiplexing is more convoluted

Table 1.2 Comparison of packet-switching and circuit-switching networking

In the ISDN era, fast circuit switching will be possible with end-to-end circuit set-up times of less than 1 s within a country and using terrestrial links. (Longer distances may take up to 4.5 s on average.) Hence, with the ISDN technology, on-demand circuit establishment and removal will be possible. This will lead to a novel way of operation using the circuit mode bearer services where the number of channels established to a destination can be varied dynamically as a function of traffic. If the traffic to a destination increases, causing the number of packets in a transmission queue to build up, additional channels can he established to the same destination in order to reduce packet delays. Similarly, if the traffic to a destination decreases, one or more channels to that destination can be disconnected, minimizing costs.

Features	Existing networks	ISDN
Access	Separate network access to telephone, CSPDN, PSPDN, telex and teletext networks	Integrated digital access to bearer and teleservices
Signalling	Different in-band signalling for each network	Out-band common channel signalling for access to all ISDN services
Channels	CSPDN: separate 'lines' needed PSPDN: up to 1024 VCs on each 'line' is available	Multiple channels, each of which can he used for access different services and destinations concurrently
User protocols	CSPDN: usually X.21 at the PL PSPDN: X.25, LAP-B	CS-BS: ISDN protocol 1.431 (PL); PS-BS: X.25, LAP-B; APM-BS: frame relay/switching; (LAP-D)
Switching speed(s)	PSTN: upto 30s CSPDN: < I s PSPDN: fast VC set-up times	<is (typical 500 ms) en&end (terrestrial shon distances); worst<ase terrestrial: 4.5 S (mean)
Transmission speed(s)	Switched: up to 64 kbps Non-switched: 64 kbps or higher	Switched or non-switched: 64 kbps or higner
Availability	Separate subscription to services is needed, necessitating multiple sockets	Can use existing telephone network wiring giving widest coverage; single access point to all services

Table 1.3 Comparison of existing networks and ISDN

Another incentive for disconnecting unused connections is the tariff Current pricing policy of postal, telephone and telegraph companies (PTTs) mean that ISDN CS calls cost the same as telephone calls (or a simple multiple). This means that, after the basic connection charges (if any), the charging for usage will be based on distance, duration and the time of day. By contrast, packet-switched networks charge on the volume of data sent in each direction, plus connect time. Therefore, ISDN CS service will cost money even if the line is not fully utilized, as the capacity must be allocated to circuits even if they do not carry traffic.

1.3.3 Using the ISDN

ISDN services At the user-network interface (UNI), the ISDN (CCITY 1988a) provides access to both bearer services and teleservices. Bearer services provide only the basic communications services (bit transmission), whereas the teleservices provide access to value added services and other network services like telephony, e-mail, voice-mail and telex. Any of these services can be requested through the use of ISDN signalling protocols on the D-channel. The bearer services further subdivide into circuit, packet and frame mode bearer services, providing circuit-, packet- and frame-based channels to the user, respectively.

Access types Two types of access are defined in the ISDN: basic-rate access (BRA) and primary-rate access (PRA). The basic-rate access provides two user channels at 64 kbps and a signalling channel at 16 kbps on a twisted pair to the user. The primary-rate access provides 23 (in the United States and Japan) or 30 (in Europe) user (B-) channels and 1 signalling (D-) channel, each with a transmission rate of 64 kbps. Higher-rate channels, e.g. HO channel, are also available. A coaxial cable is used for each direction of transmission.

Impact of ISDN services Two types of interworking are envisaged between data and telecommunicafions equipment and the ISDN:

1. The use of ISDN as a transparent network to interconnect existing data networks by using only the bearer services of ISDN: this leads to the data-communications-oriented (DCO) interworking.

2. The use of ISDN teleservices and innate applications: this results in the telecommunications-oriented (TCO) interworking.

The differences between these two types of interworking result in different complexity requirements from the network attachment units. In DCO interworking, only the bearer service access and control parts of signalling protocols are needed. On the user channels, two options exist: the use of ISDN data mode access protocols (currently only X.25 is supported), or of user-defined protocol stacks over CCITT defined physical layer protocols. In the TCO interworking, additional signalling protocol features are needed for access and control of teleservice sessions. On the user channels, CCITT-defined protocols must be used.

Data communications over ISDN The CCITT Recommendations (Recs.) of the I-series describe four types of data services: circuit, packet and frame modes and the support of data terminal equipment (DTE). The CS data service provides only a 'bit pipe' down which data bytes can be sent, and it imposes no user protocol restrictions apart from the ISDN Physical Layer Protocol (CCITT 1988b, 1988c). The packet mode data service specifies three types of services: user signalling, connectionless and virtual circuit services. The frame mode service (also called the 'additional packet mode bearer service'-APMBS) supports frame relaying, frame switching and X.25 protocol operation. Support of DTEs provide access to the X- and V-series DThs and packet mode DTEs (e.g. X.25 and ISDN-compatible terminals). Packet mode DTEs can provide access to PSPDN services and can utilize the ISDN VC service. While the public switched packet data network (PSPDN) access defines the lower three layers of protocols, the APMBS defines only the lower two layers of protocols when frame mode services are used and offers the lower three layers when X.25-based services are used.

1.3.4 The LAN-ISDN interconnection

Users connected to the existing data communication networks may want to interconnect their local networks or individual workstations through the ISDN, or may want to interwork with the ISDN. The first case implies that the users want to use only the bearer service of the ISDN as a 'raw carrier'; the second case implies that the users want to access the teleservices as well as the bearer services. These two options present different problems for interconnection and necessitate the DCO and TCO interworking, respectively.

Most of today's local data networks can be modelled as multiple hosts, workstations, personal computers and terminals interconnected through a local area network. The need to interconnect these LANs with other LANs at remote sites has already been discussed. In the ISDN era, DCO or TCO interworking through public or private ISDNs is possible.

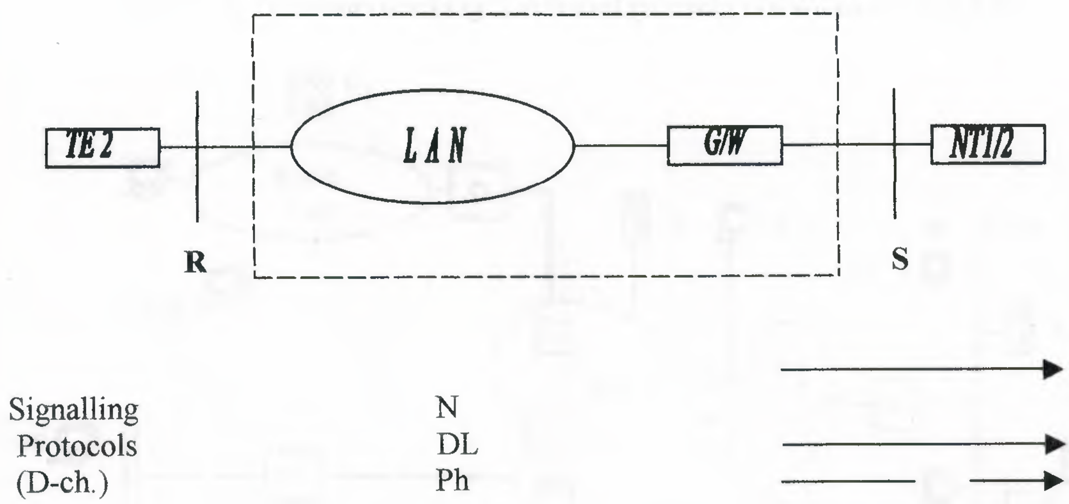


Figure 1.2 DCO interworking : LAN and gateway (G/W) as a TA

A private ISDN network may be a local integrated services private branch exehang (ISPBX) or multiple ISPBXs interconnected by leased lines to which multiple LANs can be attached. Hence, the two scenarios of interworking needs to be investigated. Figure 1.2 shows the DCO interworking scenario, while Fig. 1.3 shows the TCO interworking scenario fo LAN-ISDN interconnection. The main difference between the two is in the scope of the signalling protocols. In the DCO interworking, the ISDN is made transparent to the LAN hosts. It is this mode that applies to the LAN-ISDN-LAN working since traditional LANs are data-communications-oriented. In the TCO interworking, the signalling protocols need to be terminated in the LAN hosts, making the LAN transparent to ISDN-compatible terminals an ISDN services.

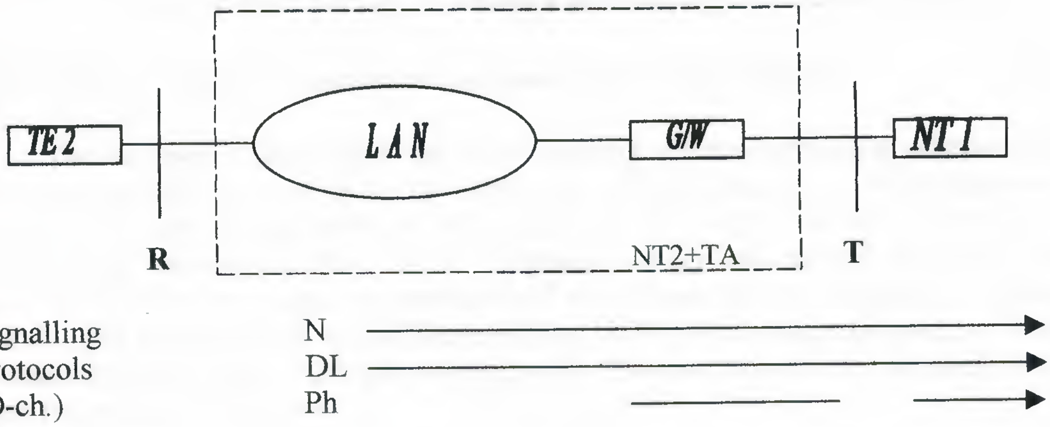
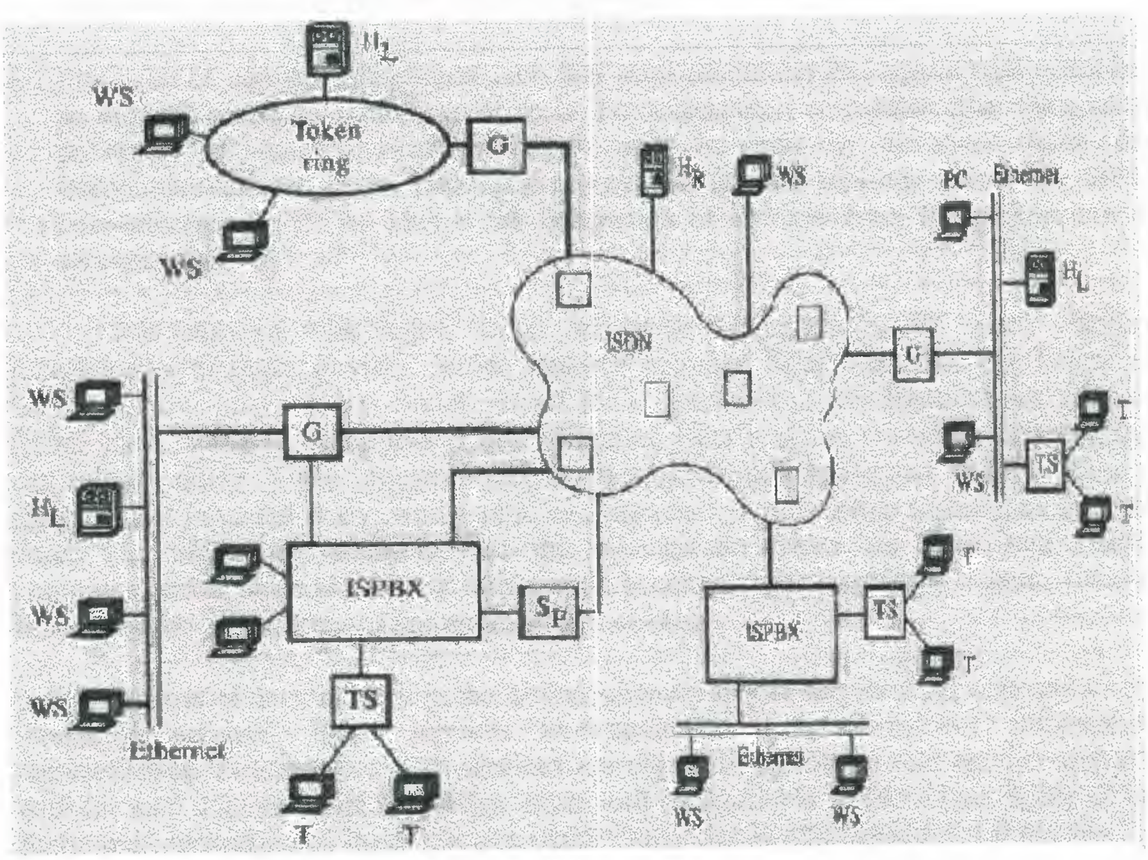


Figure 1.3 TCO interworking: LAN and gareway (G/W) as a NT2+TA



Sp: primary-rate server; T: terminal; TS: terminal server; WS: workstation;
PC: personal computer H_L: local host; H_R: remote host

Figure 1.4 An interworking reference configuration

The issues are further discussed in Figure 1.4 shows a reference configuration for LAN-ISDN and LAN-ISPBX-ISDN as wellas a workstation-ISDN interconnection.

1.3.5 Future trends in network services and networking

The common underlying trend in the network services provision, whether at the local, metropolitan or wide area, the public or private domain, is the integration of services. This implies the provision of voice, data and video services within an all-encompassing network resulting in the integration of services as seen by users at the access node. In earlier stages, the provision of actual services may be done by different networks, but the user need not be aware of this. ISDN is following this route as it is an evolutionary rather than a revolutionary network. The concept of services integration is driven by two main objectives:

1. Provision of a simplified access to a multitude of services through a single interface-integration of services from the user perspective.
2. Provision of network integration such that implementation and operational costs can be reduced owing to economies of scale. For example, it is expected that the cost of provision of data services in ISDN will be met by revenues from the telecommunications users, making the provision of data services within the ISDN cost-effective for PTTs. This is the integration of services from the perspective of service providers.

The problem with voice, video and data integration is the vastly varying requirements of these services. Voice requires bounded delay with low coefficient of variation (low jitter) and is better served by a synchronous communications channel (Hilal and Liu 1984). Some loss is also tolerated. Data requires error-free delivery, but can tolerate delay. Video requires much greater bandwidth than either voice or data; it also requires bounded delay, while some loss tolerated. Compression techniques for both voice and video are available, but this necessitates better bit error rate (BER) communications, since any loss of information becomes more prominent. Again, video is best served by a synchronous communications channel.

A parallel development is the arrival of multi-media services. As opposed to the integrated services, these services incorporate multiple forms of information representation. Examples of such services are the voice-annotated text service and text with bit map diagrams/pictures. Many more will be available in the future. Most of the documents exchanged by these services require huge bandwidth capacities for transfer.

Although no international standards exist for services integration at the local and metropolitan area networks, work is carried out by various national and regional institutions for services integration. An example of this is the integrated voice and data (IVD) architecture study by the IEEE (1988a). Services integration can be further studied at the local metropolitan and wide area networking levels, as it affects all three of them.

Local area networking The controversy of LAN versus private branch exchange (PABX or PBX) in the provision of local area networking has been going on for years. It seems that both are going through an evolution and will coexist together, filling similar roles and interworking. Integrated-services LANs (ISLANs or ISLNs), as well as integrated-services PABXs (ISPBXs), have so far concentrated on the integration of voice and data. Traditionally, LANs have been better at dealing with data, while the PABXs are better at dealing with voice.

Various proposals exist for ISLANs. These either involve modifications to the existing media access protocols, so as to provide the service requirements of different services, or propose new technologies. Examples of the first type are the Orwell ring (Adams and Falconer 1984; Falconer and Adams 1985) (based on sloned ring), the modified Ethernet (Gonsalves 1983; Nun and Bayer 1982; Tobagi and Cawley 1982) or token rings (Ibe and Gibson 1986; Wong and Gopal 1984), while FDDI-II is of the latter type and is based on fibre optics.

ISPBXs are already available and implement ISDN access protocols for both the user and network interfaces for compatibility. In the United Kingdom a similar protocol for ISPBX-ISDN access exists and is called the DASS-2 protocol (British Telecom 1985). However, for the ISPBX-ISPBX interconnection there are as yet no international protocols. In the United Kingdom a protocol called the digital private network signalling system (DPNSS) (British Telecom 1989) exists and is based on the common channel signalling (CCS) principles. In Europe there are moves by France and Germany to produce an alternative protocol. The interconnection of data processing equipment and PABX is covered by a technical report (TR-24) produced by the European Computer Manufacturers Association (ECMA) (Leiner et al. 1985).

LAN (or ISLAN) and PABX (or ISPBX) interconnection is another issue where no international standards exist. A study by IEEE (1988a) on the LAN-ISDN interconnection proposes the use of frame relay.

Metropolitan area networking (MAN) Integrated services MAN is now becoming feasible. An example is the distributed queue dual bus (DQDB), which is a draft standard in the form of IEEE 802.6 (IEEE 1988c). These will provide access to synchronous and asynchronous services and hence provide voice, video and data integration at the metropolitan area.

Wide area networking (WAN) ISDN is a new concept that is providing a useful framework for the development of future telecommunications networks and services. The natural extension to ISDN is the broadband ISDN (B-ISDN). CCITT specifies the asynchronous transfer mode (ATM) as the technology on which the B-ISDN will be based.

ATM technique will provide synchronous as well as asynchronous services. Access to ATM networks will be through fibre optic links, and so far 150 Mbps and 600 Mbps access rates have been defined (CCITT 1988a).

1.4 DYNAMIC CHANNEL MANAGEMENT

Resource management is a well-known concept in data communications and computer networks. It enables users or applications to manage the scarce and expensive resoures in communications, such as the processing capacity of nodes, the bandwidth capacity of transmission lines and buffers at the nodes. All these resources and their management are also valid in communications over the ISDN.

As pointed out above, one of the most important features of ISDN is the provision of multiple channels at the user-network access interface (UNI) and its flexible control by the use of common channel signalling (CCS). It is these two features that are concentrated, i.e. the use of CCS to control channel access, and dynamic bandwidth variation the UNI. In this text, the phrase 'channel management is used to represent a group of related activities and policies relevant to the interface bandwidth resource management. These include bandwidth allocation, bandwidth management and channel assignment and transmission control activities within the UNI. These activities are described by specific policies for the system. The following distinctions are made between them in the ISDN context:

- *Bandwidth aflocation* Describes how the total bandwidth of a communications facility is distributed (allocated) among different contending users. It is assumed that the bandwith applies to the whole communications interface.

- *Bandwidth management* Describes the means (or procedures) by which the bandwidth of a communications facility is managed. It works in collaboration with, and within the confines of, a bandwidth allocation policy. At the microscopic level, it is assumed to apply to the bandwidth of a single channel of variable capacity.

- *Channel assignment and transmission control* Describes the procedures for channel assignment to incoming requests and de-assignment for cost effectiveness, transmission control for data packet forwarding, and receiving and initiating signalling for link establishment and removal.

- *Channel management* Applies to multiple distinct channels at a communications facility and describes their management. A channel management strategy comprises policies regarding bandwidth allocation, bandwidth management and channel assignment and transmission control operations.

We shall now consider these activities in a little more detail.

A bandwidth allocation policy provides access control to new customers (e.g. users, packets, protocol data units-PDUs) for sharing the interface bandwidth. It also regulates changes in the bandwidth allocation to existing channels. For example, a class of users may not be allowed to access more than a certain share in the link bandwidth.

A bandwidth management policy specifies the method and the algorithm by which the bandwidth of a channel is to be increased or decreased. For example, for a given facility, a hysteresis threshold control may be designed for the service capacity (or bandwidth) control of its channels.

A channel assignment and transmission control policy specifies the conditions, i.e. when to set up a new channel and when to remove an existing one. For example, in the case of a connectiontess network layer packet, the policy may specify the setting up of a new channel to a hitherto unconnected destination. Similarly, a channel may be totally removed if it is not used for τ seconds. It will deal with the packet forwarding to channel queues. Initiation of D-channel signalling activity and initiation and ending of packet transmission on any channel is also defined by this policy unit. Lower-layer functions of time slot to channel mapping and free-titne slot hunting are also carried out under this policy directive.

Channel management encompasses policies for the above activities. Hence, it includes policies on how a channel or a group of channels is to be used, e.g. separately or aggregated together to form a larger capacity channel (i.e. a superchannel); when to set up new links and remove existing links; when and how to increase/decrease the existing channel capacity to a destination. it may also include a scheduling (routing) policy if multiple channels with individual queues exist to a given destination. A congestion control policy may also be implemented (e.g., throw packets away if the transmission queue gets longer than a certain level). Finally, it may involve tralfic monitoring and statistics gathering operations.

1.4.1 Dynamic channel management architecture (DCMA)

In order to achieve dynamic channel management, a generalized approach is needed to identify the necessary modules and units of a software architecture such that it could be applied to different types of ISDN user-network interfaces. Such an architecture would also include events and messages that will be encountered at a UNI. In the absence of such an architecture. Its main features are described below.

An access node interconnected to ISDN will have a physical interface as well as a software interface. The distribution of functionality within this access node can be various for different nodal architectures. In general, this interface can be represented as shown in Fig. 1.5. The dynamic channel management (DCM) module (composed of one or more processes) is shown to have interaction with the interface access and control process. This module needs to have regular access to the status of the particular ISDN interface it is supposed to manage. Figure 1.6 shows the relationship between the DCM and associated parameters that affect it.

The DCM monitors the ISDN interface status continuously by a report sent to it by each relevant event across the interface as well as within the ISDN interface. These events include:

- *Packet sent* A packet has been sent to the interface to be queued to a channel queue.
- *Packet received* A packet has arrived on any one of the channels.
- *Set-up channel* Set up a new channel to the destination or set-up requested by remote destination.
- *Disconnect channel* Disconnect a channel to the destination or disconnect requested by remote destination.
- *Vary channel bandwidth* Increase/decrease channel bandwidth to a given destination.

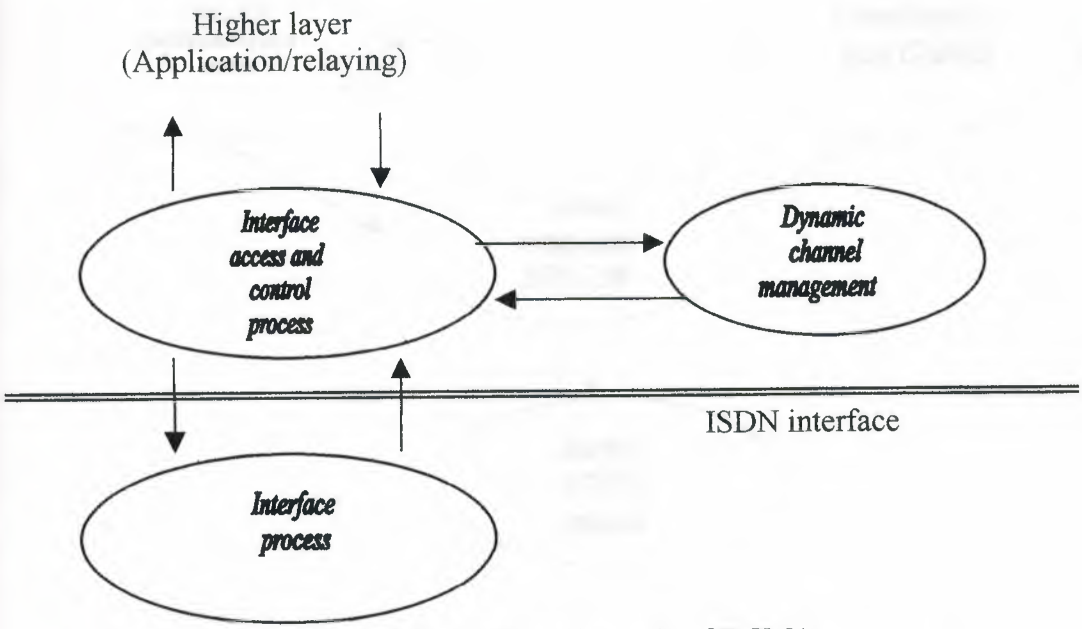


Figure 1.5 a simple schematic of DCMA

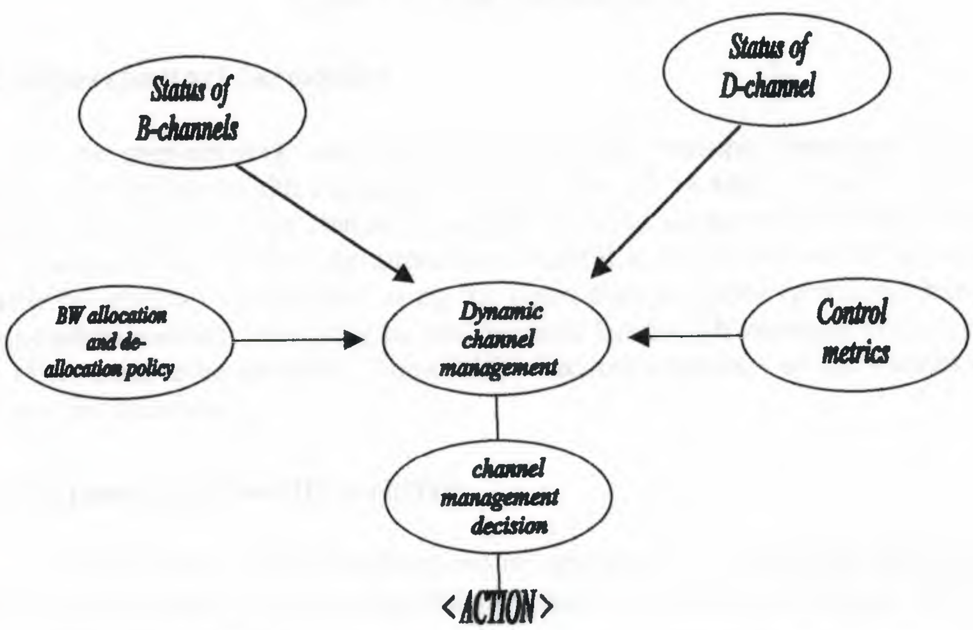


Figure 1.6 Relationship between DCM and associated parameters

Each of these events generates a change in the status of the interface and hence causes an update of status information by the DCM module. Figure 1.7 shows the relation ship of the DCM and events sequence within the architecture. As a result of this event, an action command may be the DCM module and sent to the interface process.

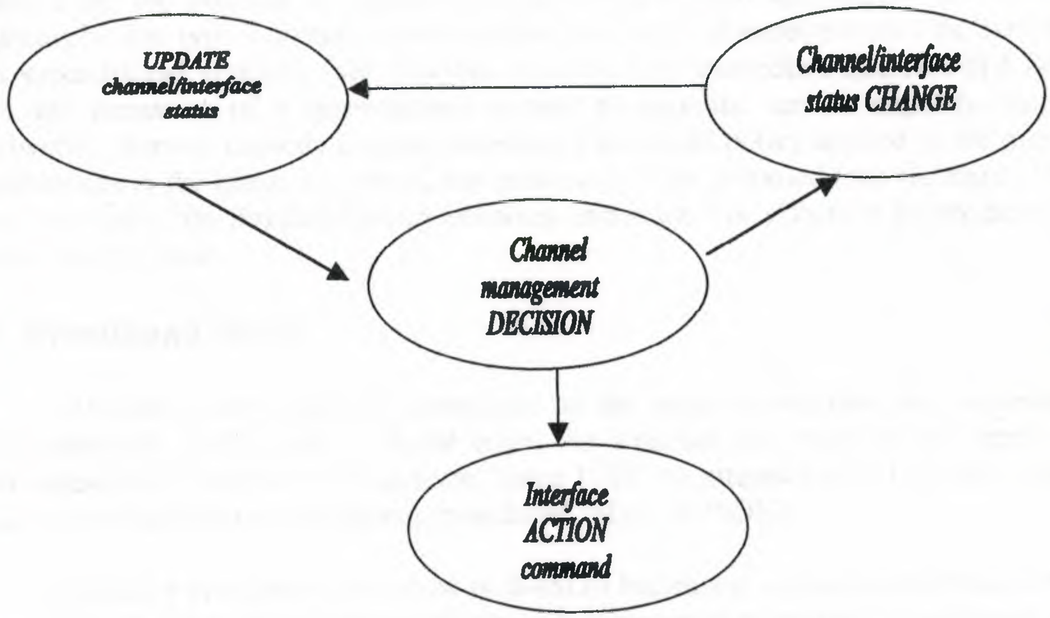


Figure 1.7 DCM events sequence

1.4.2 Superchannel formation

At the user-network interface, ISDN provides multiple fixed-size channels of possibly differing bandwidth capacities (in multiples of 64 kbps). Two problems exist: the provision of n X 64 kbps channels, and the dynamic variation of channel bandwidth. In the absence of the former, an alternative method is the formation of superchannels (channels of arbitrary bandwidth) using the basic channel types (physical channels) by the aggregation method. Identification and dynamic bandwidth variation of such channels at the UNI needs to be provided. The CCITT Recommendations of the I-series have no provisions for the above.

1.4.3 Dynamic bandwidth control

A multi-channel ISDN interface can be organized in a variety of ways, leading to different queuing models. Assuming that no quality-of-service queuing is incorporated, these can be listed as follows:

1. Multiple parallel servers with their individual queues: n X A/B/1
2. Multiple parallel server groups, each with a single queue: m X A/B/c
3. Single server groups, each with a single queue but variable service rate: k x A/B/1
4. A mixture of the above

In queuing models 1 and 2, the variation in the logical channel (a channel formed by the association of several physical channels) bandwidth to a given destination is achieved by the addition or deletion of servers and their queues, or just servers, respectively. The type 3 queuing model applied to a single channel assumes the existence of a superchannel structure (see previous section). One immediate question that arises from the formation of a superchannel is how to vary the service capacity (rate or bandwidth). Service capacity control, based on a threshold policy applied to the number of customers in the queue or system, has previously been proposed (see Gebhard 1967). Here, the type of the threshold policy becomes important. The effects of policy decisions need to be evaluated.

1.5 Broadband ISDN

Although some work still continues on the recommendations for narrowband ISDN especially in the area of frame relay, the structure and most of the details for narrowband ISDN are now in final form. Since 1988, the attention of ITU-T has focused on a far more ambitious undertaking, broadband ISDN (B-ISDN).

Chapter 4 provides an overview of B-ISDN beginning with an examination of the variety of services that this high-speed network is designed to support. The chapter also discusses the requirements at the user-network interface and the functional architecture at that interface.

Chapter 5 surveys the protocols associated with the B-ISDN user-network interface. Following a discussion of the overall protocol reference model, the chapter focuses on the physical layer aspects. The chapter also discusses SONET/SDH, which is a separate set of standards that are also used at the B-ISDN physical layer.

CHAPTER
TWO

THE INTEGRATED SERVICES DIGITAL NETWORK

This chapter highlights the most relevant features of the integrated services digital network (ISDN) in its application to data communications and the interconnection of local area networks using the ISDN. It also provides a general background to the ISDN and its current development status.

The ISDN has evolved from a digital network concept, and this evolution is expected to continue for years to come (one or more decades). In this respect, the features of ISDN can be discussed meaningfully only with reference to the global principles, concepts and features of the network and its services, or to its current consolidated and standardized features, or to proposals for the forthcoming CCITT study period of four years. Beyond that time scale, concrete evaluation can not be made easily owing to the evolutionary process; only migratory paths could be indicated. Here, we shall concentrate mainly on the first two cases, with some reference to the immediate proposals expected for the next study period. Some possible future trends will be indicated.

Since its conception, the ISDN has diversified into two main streams: ISDN (also termed norrowband or N-ISDN in text) and broadband ISDN (B-ISDN). N-ISDN refers to network access at bit rates up to and including 2 megabits per second (Mbps), while B-ISDN refers to network access at bit rates (up to and) greater than 2 Mbps, usually in tens or hundreds of megabits per second. It also concentrates on the circuit mode bearer service, because of its wider and earlier availability in Europe. N-ISDN as well as at the current and expected developments in B-ISDN.

2.1.1 Principles of ISDN

An ISDN can be characterized by its three essential features:

- End-to-end digital connectivity
- Multi-service capability (voice, data, video, and multi-media)
- Standard terminal interfaces

The ISDN concept includes the support of a wide range of voice and non-voice applications in the same network. The service integration for an ISDN will be provided by a range of services using a limited set of connection types and multi-purpose user-network interface arrangements. ISDNs will support a variety of applications including both switche (circuit- or packet-switched) and non-switched connections. They will contain intelligence for the provision of service features, maintenance and network management functions. The specification of access to an ISDN should be by a layered protocol structure. ISDN may be implemented in a variety of configurations to be determined by the national service providers. Hence the details of the underlying network will not be important for the users, since they will see a common service across ISDNs.

2.1.2 Evolution of ISDN

ISDNs will be based on the concepts developed for the integrated digital network IDN and will progressively incorporate additional functions and features at present provided by separate networks, as well as other new ISDN-specific features and services. During the transition period, arrangements will be developed for the interworking of services on ISDNs and services on other networks.

2.2 TECHNICAL FEATURES

Three key ISDN communication capabilities could be used to define the user's perception of an 'ISDN service': the provision of end-to-end digital connectivity between end users, the provision of multiple-access channels; and intelligent out-band (common channel) signalling and user control. The end-to-end digital connectivity will provide larger bandwidths, better signal qualities and better error rates than most of the present networks. Multiple access channels will provide more flexibility in the use of the total bandwidth available at the user-network interfaces; to this end the CCITT has defined different channel types and interface structures. The new common channel signalling scheme has been chosen so as to allow the user to control both the network connections and the delivery of user services and applications independently of the user information paths in an effective manner.

The basic architectural model of an ISDN as describe in Rec. I.324, the ISDN Network Architecture (CCITT 1988a), includes the following main switching and signalling functional capabilities: ISDN local functional capabilities (e.g. user-user and user-network signalling, charging); 64 kbps circuit switched and non-switched capabilities; rates greater than 64 kbps switched and non-switched capabilities; packet-switched and non-switched functional capabilities; and common channel signalling (user-exchange and inter-exchange) functional capabilities. For the circuit-switched connections, user-bit rates less than 64 kbps are rate-adapted as describe in Rec. I.460 before any switching can take place in the ISDN. Multiple information streams from a given user may be multiplexed together in the same B-channel, but for circuit switching an entire B-channel will be switched to a single usernetwork interface. Packet-switching capabilities are formed by two functional groupings; packet handling functional grouping and interworking functional grouping. The first grouping contains functions relating to the handling of packet calls within the ISDN, while the latter ensures interworking between ISDN and packet-switched data networks (PSDNs). Another feature of the ISDNs will be its fast switching ability, made possible by digital switching techniques. Although the performance issues relating to this have not been fully defined, average national circuit switching speeds are expected to be below 1 s while for international calls the aim is for a speed below 5 s.

2.2.1 Service aspects

Services provided by ISDNs have been divided into two broad categories: bearer services and teleservices. The bearer service is a type of telecommunications service that provides the capability for the transmission of signals between user-network interfaces and as such conveys information between users in real-time and without alteration to the information 'message'. The teleservice is a type of telecommunication service that provides the complete capability, including terminal equipment functions, for communication between users according to protocols established by agreement between administrations.

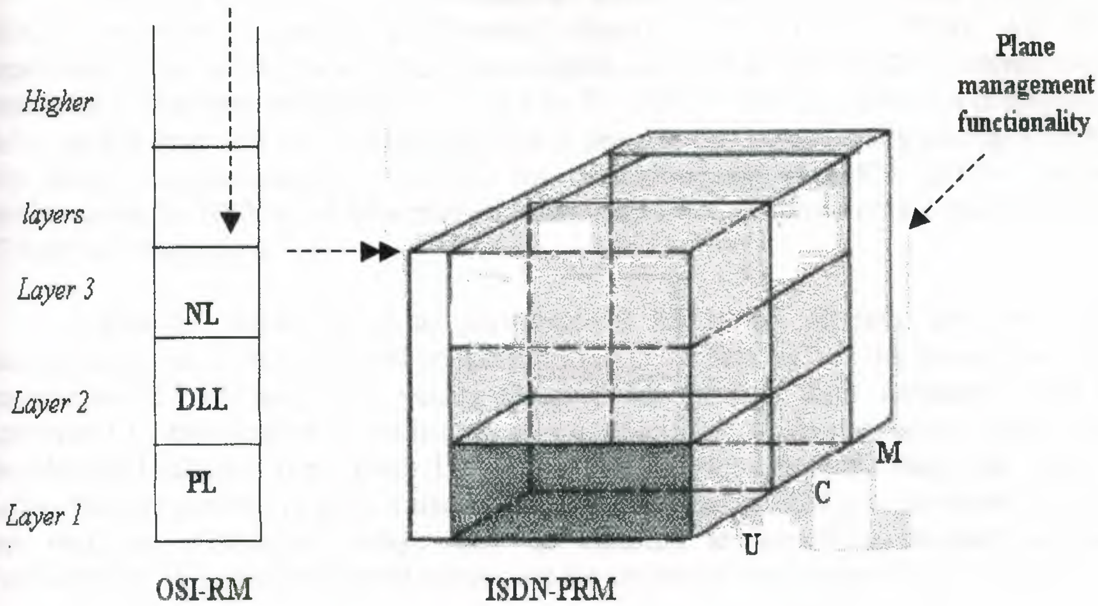
Bearer services Two types of bearer services have been defined: circuit and packet modes. The circuit mode bearer service has been defined for 64 kbps, 384 kbps, 1536 kbps and 1920 kbps rates. In circuit mode, the 'unrestricted information transfer' with '8 kHz structural integrity' capability is of interest for data applications since it provides switched 'bit pipes' over which transfer of user information can be achieved without alteration (within the quality-of-service (QoS) limitations).

The packet mode bearer service involves packet handling functions. The following service categories identified in Rec. I.230 virtual call and permanent virtual circuit (connection-oriented (CO) mode connectionless (CL) and user signalling packet mode bearer services. In the CO mode of operation, 'unrestricted information transfer capability' and 'service data unit structural integrity' are supported. User information is conveyed over a virtual circuit (VC) within a B- or D-channel. Signalling may be provided via D-channel and/or VC within B-channel. Access protocols are as specified in Rec. I.440, I.450/1, I.462 (X.31) and X.25 (layers 2 and 3) (CCITT 1988a).

Teleservices Teleservices use bearer services to move information around, and in addition employ 'higher-layer functions' corresponding to layers 4-7 of OSI-RM.

2.2.2 Network aspects

These cover the network functional principles, the ISDN Protocol Reference Model (PRM), numbering, addressing and routing principles, connection types and performance objectives. The ISDN-PRM, which is based on the principles of OSI-RM, allocates functions in a modular fashion that facilitates the definition of telecommunications protocols and standards. The ISDN-PRM extends the OSI model beyond the traditional point-to-point user-network-user, in-band signalling, data-only communications. This extension includes the separation of signalling and management operations from the flow of application information within a piece of equipment; definition of communication contexts which may operate independently from each other; and the application of the above to internal network components. This separation leads to the definition of independent communications contex Each context can be modelled individually and use independent protocols.



NL: network layer; DLL: data link layer; PL: physical layer
U: user plane; C: control plane; M: management plane

Figure 2.1 OSI reference model (OSI-RM) and ISDN protocol reference model (ISDN-PRM)

The ISDN-PRM refers to two distinct logical planes: user (U) and control (C) planes. The layering principles apply to each of these planes; each one can potentially accommodate a seven-layer protocol stack. A plane management function is required to allow co-ordination between the activities in different planes. Further study is needed to specify the types of layer services required to describe a telecommunications service, data flow modelling and ISDN management. The relationship between the OSI-RM and the ISDN-PRM is shown in Fig. 2.1

Numbering principles within the ISDN will be based on the expansion of the international PSTN numbering plan. An ISDN address is composed of an international ISDN number and an ISDN subaddress of up to 15 decimal digits and 40 decimal digits (20 octets) respectively (CCITT 1988a). The ISDN address may be of variable length, and all ISDNs will be capable of conveying the ISDN subaddress transparently. This subaddress may be used by private communications facilities such as LANs and PABXs or by other private networking arrangements. In order to identify different OSI network layer service access points (NSAPs), methods have been defined in the (CCITT 1 988a) to relate the ISDN number to the OSI network layer address.

The performance objectives regarding propagation delays, availability and errors were not dealt with in full during the 1980-4 period. Currently, provisional performance values are quoted, while the actual target values are left for further study. The network performance objectives for connection processing delays in an ISDN.

The CCITT G-series recommendations define hypothetical reference connections (HIOC) in order to develop performance objectives for different HRXs. An HRX represents a typical worst-case end-to-end digital connection. The longest (international) terrestrial connection envisaged by CCITT is 27 500 km. This represents a propagation delay of less than 100 ms. If a satellite link is present, this would easily add up a round-trip delay of approximately 520-560 ms. Recommendation G.821 defines overall performance for HRX at 64 kbps and an end-to-end BER of 10E-6 on a circuit-switched 27 500 km connection.

Table 2.1 shows the delay performances for set-up, alerting, disconnect and release delays in circuit-switched connections (voice or data) across the worst-case HRX connection (27 500 km). The values observed for the first three parameters will be dominated by the number of exchanges in a connection. For shorter-length connections the observed values will be lower. Delays are specified for a nominal busy hour, and the delays that are dependent upon a user equipment (or network) and user response time are not included. Additional delays may be incurred at signalling message queues. Furthermore, the specified performances are for connections exclusively over ISDNs.

Statistic	Delay (ms)			
	Set-up	**Alening**	**Disconnect**	**Release**
Mean	4500	4500	2700	300
95%	8350	8350	4700	850

Table 2.1 Objectives for connection processing delays in an ISDN (worst-case HRX connection)

2.2.3 User-network interfaces

An important aspect of service integration for an ISDN is the provision of a limited set of standard multi-purpose user-network interfaces (UNIs). An ISDN is recognized by the service characteristics available through user-network interfaces, rather than by its internal architecture, configuration or technology. Hence the CCITT has put most of its initial effort into the specification of this interface to cover both the existing terminal/user base and future ISDN terminals/users.

The I.400 series of recommendations (CCITT 1988a) describe the interface between user equipment and ISDNs. They include a reference configuration, giving the functional model for the subscriber, a definition of interface structures and access capabilities, and detailed specifications of layers 1-3 for the basic and primary-rate interface structures. Several of recommendations in the series provide standardized methods for rate-adapting classical X.1 and V.5 data rates into B-channels, for submultiplexing B-channels and corresponding circuit-mode bearer services, and for interworking with digital network facilities providing only restricted 64 kbps information transfer rates.

Reference configurations The user-network interface lies within the customer premises. The reference configurations include reference points which are the conceptual points dividing flinctional groups. These functional groups include the termination (network termination-NTl), distribution and switching (NT2), terminal equipment with ISDN user-network interfaces (TE1), and terminal equipment with other interfaces (TE2) and associated terminal adaptors (TA). Figure 2.2 shows the reference configurations for the ISDN UNI. The use of S and T reference points will be discussed.

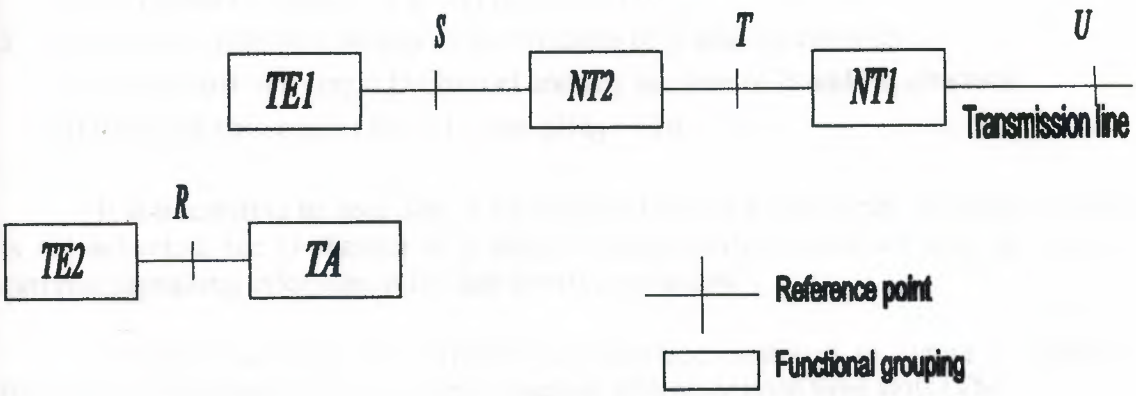


Figure 2.2 Reference configurations for ISDN user-network Interfaces

Channel types A limited set of channel types is defined, including B, D and H channels. The B-channel (64 kbps) carries user information. The D-channel (16 or 64 kbps for basic and primary rate, respectively) carries packetized signalling (s-data) information to control the set-up, modification and clearing of calls and services. Surplus bandwidth capacity on this channel may also be used for packet mode user data (p-data) and telemetry (t-data). The H-channels-384 (H_0), 1536 (H_{11}) or 1920 (H_{12}) kbps-carry circuit or packet mode user information.

Interface structures Only two general (narrowband) ISDN user-network interfaces are described. These are the basic rate and the primary rate interface structures.

2.2.4 Basic-rate access (BRA)

This interface has an information-carrying capacity of 144 kbps. It is organized as (2B + D) channel types. With the framing, synchronization and D-channel echo bits, the aggregate transmission rate is 192 kbps. This interface is mainly intended for the connecfion of ISDN terminals or other individual terminals/workstations which will not need very high bandwidths. At this interface both the point-to-point and bus (S-interface bus, or S-bus) distribution types are available. In the S-bus configuration, up to eight terminals can be connected to the NT2, all sharing the same D-channel.

2.2.5 Primary-rate access (PRA)

This interface has two subdivisions with differing information-carrying capacities. These are 1536 and 1984 kbps, and they represent requirements of US and European networks. Their aggregate transmission rates are 1544 and 2048 kbps, respectively. This interface can 1 organized in several ways:

1. Primary-rate B-channel interface structures (23B + D) and (30B + D)
2. Primary4ate H-channel interface structures:
   (a) H_0 channel structures, e.g.: $4H_0$, $(3H_0 + D)$, $(5H_0 + D)$
   (b) H_1 channel structures, e.g.: H_{11}, $(H_{12} + D)$
3. Primary-rate interface structures for mixtures of B and H_0-channels:
   (a) Can consist of a single D-channel and any mixture of B and H_0-channels
   (b) Example structures: $(5H_0 + D)$ and $(2H_0 + 11B + D)$

It is interesting to note that, if a D-channel in one primary-rate interface structure is not activated, the D-channel of a neighbouring interface structure may be used for carrying signalling information for that interface structure.

The physical layer of a primary-rate interface conforms to Figure 2.3 shows a time division multiplex (TDM) frame structure with associated time slots (TSs).

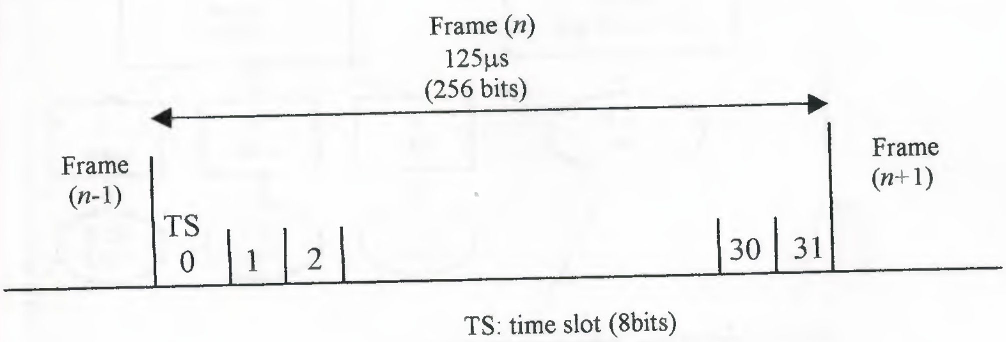
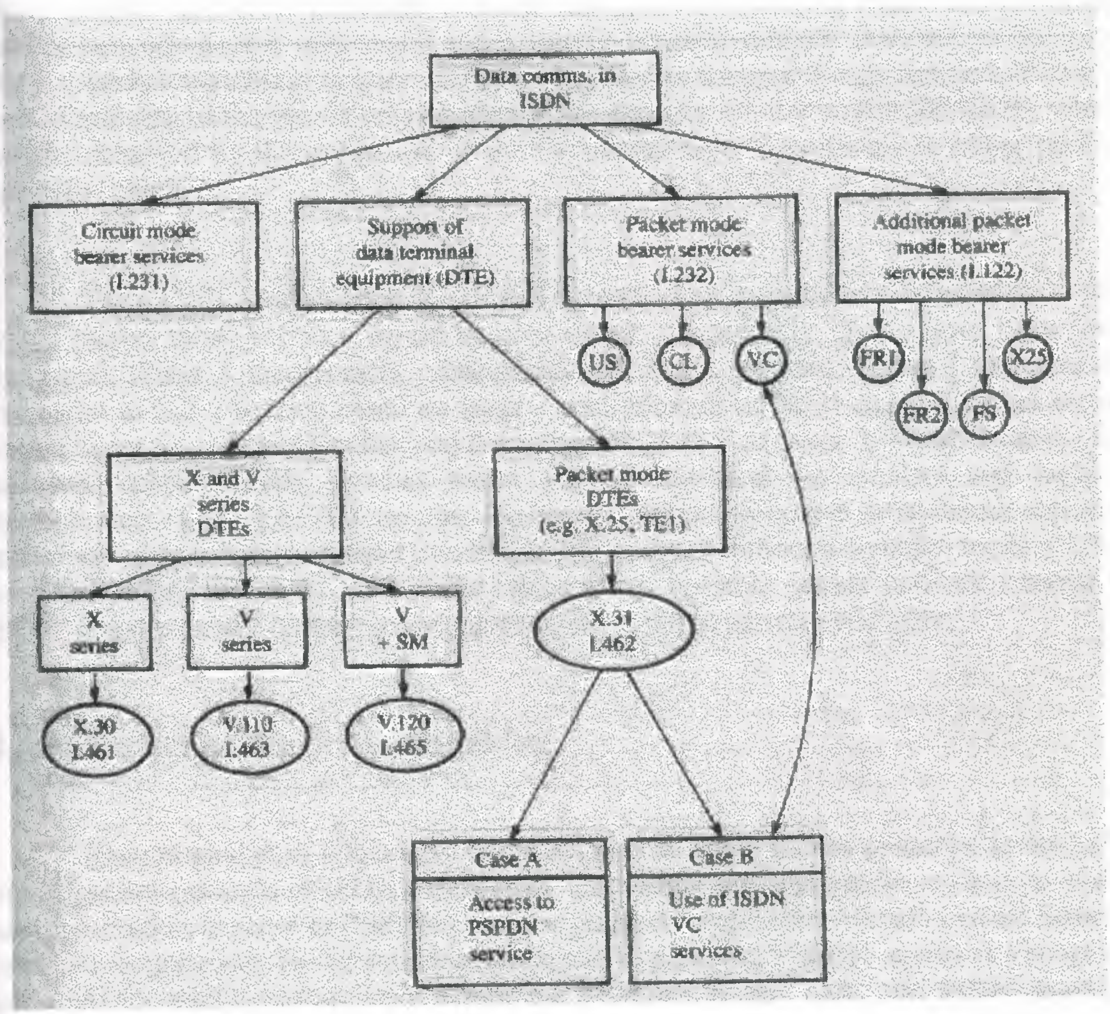


Figure 2.3 TDM frame structure used at PRA physical layer (Europe)

2.3 DATA COMMUNICATION IN ISDN

Data communication in ISDN can be achieved by using either the circuit- or packet-switched and/or non-switched bearer services. The current alternatives for data communication in ISDN are summarized in Fig. 2.4. The circuit mode in ISDN . This service provides a digital bit pipe where the user channels are presented to the users at the physical layer. A channel occupies an integer number of time slots (TSs) and the same time slot positions in every frame. A circuit is formed by the allocation of TSs to a channel in consecutive TDM frames available at the interface and connecting this to the destination by similar allocation of TSs in TDM trunks en route. The type of protocols to be used is left to the users. This provides a challenge to users as to how best to utilize this flexibility. The good BER of ISDNs means that light-weight protocols could be used at the data link and the network layers, hence reducing communications overhead. The packet modes in ISDN are described in the following section.



US: user signalling; CL: connectionless; VC: virtual circuit;
FR ½ :frame relay ½ ; FS: frame switching; SM: ststistical multiplexing

Figure 2.4 Summary of data communication alternatives in ISDN

2.4 PACKET MODES IN ISDN

ISDN is principally a circuit-switch network which can be used for packet network interworking. The definition of a framework for providing additional packet mode services has improved the data communications aspects of ISDNs. CCITT describes how an ISDN may offer access to an existing PSPDN from X.25 terminals connected to the ISDN via a terminal adaptor. It also describes how an X.25-like service may be supported wholly within an ISDN to offer a virtual circuit bearer service; however, this requires a two-stage call set-up and as such is awkward. The recent developments and draft proposals indicate that a move is being made to incorporate packet network access in a much more tightly coupled manner than access to some distinct packet-switching function or packet handler as was previously defined. This will be a closer step to the provision of packet mode services wholly within the ISDN, which will be achieved by the expansion of the D-channel layer 3 protocols to cover packet-switching cases.

The CCITT Study Group XVIII has agreed on an evolutionary framework within which packet mode services would be considered. Accordingly, four phases have been described. Phase 1 incorporates enhancement of X.3 1 services. Phase 2 includes the extension to X.3 1 service based on layer 2 multiplexing in the B-channel for an access arrangement to a packet handler and the use of X.25 PLP at layer 3. Phase 3 covers the additional packet mode services based on full out-band call control and layer 2 multiplexing (I.441-LAP-D) on the B-channel. Phase 4 covers broadband services, including asynchronous transfer mode (ATM) and synchronous transfer mode (STM) services. Although Rec. X.31 (1984) describes a possible packet network internal to ISDN, it concentrates on the provision of interworking to existing PSPDNs.

2.4.1 Packet network interworking

Recommendation I.462/X.31 describes two different access scenarios to an X.25. based packet network (PSPDN): minimum and maximum integration scenarios. These are classified as 'Access to PSPDN Services' (case A) and 'ISDN Virtual Circuit Service' (case B) respectively. In the minimum integration scenario, PSPDN access is via access units (AUs), which are situated within the PSPDN. In this case, the ISDN provides transparent, or rate-adapted connection, for an X.25 terminal to/from a PSPDN port (AU). Therefore, as such it offers access to non-ISDN packet mode services. This access could be semi-permanent or switched. For switched access, a two-stage call set-up procedure is needed. In the first stage, ISDN D-channel signalling procedures (1.451) are used to establish a connection to/from the AU. Then X.25 call set-up procedures are used over the circuit-switched connection to complete an X.25 call over the PSPDN. The AU will be allocated an ISDN address. The user data access will necessarily be over the B-channels.

2.4.2 ISDN virtual circuit bearer service

This service is defined in Rec.I.232 .It was named the 'maximum integration scenario' in Rec. I.462/X.31. This provides an X.25-like service within an ISDN from the user's point of view.. Packet terminals using the ISDN numbering plan will have their protocols terminated by an ISDN packet handler (PH) within the ISDN rather than the PSPDN access unit. Access to the PH may be via the B- or D-channel.

In access via the B-channel, a two-stage call set-up is needed. The user will not be aware of this because of the inlfial 'packet transfer mode' requested using the I.451 signalling protocol. The ISDN will then establish a circuit-switched connection to a PH. For access using the D-channel, LAP-D frames identifying packet data are interleaved with the signalling information. The distinction is done using a service access point identifier (SAPI) within the frame header. The network will route packet frames to/from the PH. Signalling frames are given priority over packet frames. An X.25 terminal uses a terminal adaptor (TA) to interface to the network terminafion. Throughput of data over D-channel is limited by the 16 kbps data rate, and additional delays may be incurred in the TA. However, it can be used in parallel with the circuit-switched B-channels.

24.3 Additional packet modes

The signalling the D-channel is for controlling circuit-switched user traffic channels and non-connection-related applications. The new (CCITT 1988a) aims to use the enriched call control technique in controlling packet-switched virtual circuits. Recommendation I.122 describes only the architectural framework and service descriptions of the associated bearer services. It will apply to data communicafions at bit rates up to 2 Mbps. The reasoning behind the additional packet modes include the following: the provision of packet mode bearer services, which would be accessible using clearly separate control and user planes employing the same signalling protocols as other ISDN bearer services; and fast data transfer (with reduced delay and high throughput), by avoidance of full three-layer termination at each node in the network.

The method involves the use of outslot signalling with single-step call establishment in accordance with I.451, rather than the X.25 PLP call control procedure. Also, the multiplexing and switching of virtual connections takes place in layer 2 (LAP-D over B-channels) rather than the X.25 PLP. In the control plane, information elements specific to packet switching have to be added to existing I.451 signalling messages. In the user plane, the LAP-D flinctionality which will be terminated in every exchange may be restricted to a core subset including the frame delimiting, alignment and transparency; frame multiplexing and demultiplexing using the address field; and detection of transmission errors. These core flinctions result in a low-cost service, independent frame-relaying mechanism on a link-by-link basis which will result in low overheads and could be used in various applications.

Recommendation I.122 (CCITT I 988a) specifies four potential bearer services: frame relaying types 1 and 2, frame switching, and X.25-based additional packet mode.

- Frame relaying involves establishing a transparent network path for a call at call set-up time and then conveying subsequent frames along that path checking only the validity of frame format. Frame order is preserved, but frame acknowledgement within the network is not undertaken. Additional network functions to monitor and enforce throughput and achieve congestion control as well as frame error detection and QoS parameters are left for future study. The difference between the types of frame relaying is that type 1 implements only the core functions of Rec. I.441 (layer 2), whereas type 2 implements all the extended I.441 functions within the user terminals. In both cases, the network implements only the core layer 2 functions.

- Frame switching is similar except that the network passes on frames which corerctly observe the layer 2 protocols. Additionally, it provides frame acknowledgement, error detection and recovery, and provides flow control. It necessitates the full implementation of layer 2 protocol (I.441 with extensions if necessary) both in the user terminal and in the network.

- X.25-based service adds to this the network support for X.25 PLP data transfer part.

Many important issues in the provision of additional packet modes still remain for future studies, including throughput enforcement, flow and congestion control (due to lack of layer 3 congestion and flow control mechanisms at layer 2), signaling enhancements to I.451, application categories (to determine type of bearer service), charging (frame types need to be distinguished to enable charging).

2.5 PROTOCOL CONSIDERATIONS AND STANDARDS

With the introduction of distinct user and control planes in the ISDN reference model, functionally separate interactions associated with the control and signalling functions and transferring data are divorced, leading to separate and parallel developments of their functionalities and protocols. Within the CCITT, the protocols for the D-channel have been defined for the layers 1-3. For the B-channel, in the case of circuit mode services only layer 1 has been defined, while for the packet mode DTEs layers 1-3 based on the X.25 model are proposed. Additional packet modes incorporate layers 1-2 and 1-3 depending on the type of service, with LAP-D in layer 2 and X.25 PLP in layer 3 (when used). In the circuit-switched ISDN case, the user is left free to decide which particular protocol stacks to use on the B-channels for data communications over the links established. The D-channel signalling protocol is message/frame-structured and layered according to the OSI seven-layer model. Basic and primary-rate interface layer 1 specifications are necessarily different, but are common for layers 2 and 3. Table 2.2 shows protocol stacks on the D-channel for both BRA and PRA.

Protocol Layer	Signalling protocols	
	BRA	PRA
Layer 3	I.450/I.451	I.450/1 (Q.930/1)
Layer 2	I.440/I.441	I.440/1 (Q.920/1)
Layer 1	I.430	I.431

Table 2.2 Protocol stacks for the D-channel

Recommendations I.450/1 (alias Q.930/l) define the network layer features and protocol. This has 'broad' similarities to the X.25 PLP functionality (e.g. frame formats), but is much more complex. It has a sophisticated message set in order to achieve call control for different types of services (bearer and teleservices, e.g. circuit- and packet-switched; additional packet mode services) and telephony functions.. However, the protocol is easily expandable to support more complex calls, standardized supplementary services and network specific services. Furthermore, these signalling procedures may also be used within private networking arrangements (e.g. between two PABXs).

Recommendations I.440/1 (Q.920/l) define the data link layer procedures for the ISDN D-channel (LAP-D). This protocol extends the X.25 LAP-B protocol. The main difference is that it allows multiple data links by virtue of an extended address field (two octets). It also uses several additional HDLC commands and responses.

Recommendations I.430 and I.431 define the physical characteristics of the basic and primary-rate user-network interfaces, respectively. The basic rate interface supports point-to-point as well as passive bus (S-bus) arrangements (including collision detection and contention resolution) and it has a four-wire 'S' interface. The primary-rate interface specifies coaxial wires for receive and transmit paths, and only the point-to-point configuration is supported according to CCITT Rec. G.703 (CCITT 1988a).

2.6 CURRENT STATUS AND FUTURE TRENDS

2.6.1 Current status

The Recommendations developed during the CCITT study period 198Ck4 concentrated on general principles and on a definition of ISDN services as well as the definition of D-channel protocol specifications. During the CCITT study period 1984-8 much effort was put into further extensions. These included the extension of D-channel signalling protocols, the development of further network standards for ISDNs (numbering and addressing, network and terminal identification, network interworking and routing), the ISDN protocol reference model and consolidation with the OSI-RM, definition of additional packet modes, and the work on the definition of the B-ISDN principles.

One of the work areas that has progressed during the second study period has been the Q.931 expansion for layer 3 specification. This includes the essential features, procedures and messages required for call control (CS, user-user, PS) in the D-channel. However, some procedural details have not yet been specified and have been left for further study (e.g. transport or other message-based information flows, and the alignment of the functions and protocol with those of OSI NL). Further developments have been achieved in the CCITT Study Group regarding the subaddressing and NSAP addressing issues. Rec. I.334 and propose, among other things, the conveyance of NSAPs in the Q.931 subaddress field. ISDN routing principles are detailed in Rec. 1.335. Results of the work on the Q.93 1 and SSN.7 alignment (ISUP-ISDN User Part) as well as new interworking arrangements with existing networks.

During the period 1984-8, (CCITT 1984) provided enough impetus and reasonably firm standards for integrated circuit manufacturers to start work on new ISDN VLSI chips. Several manufacturers have developed and introduced ISDN chip families, board-level products and test instruments for the basic and primary-rate interface structures.

Recommendation I.122, providing a framework for the additional packet modes (APMBS). Recommendation I.232 for packet mode bearer services, details three further bearer service categories: virtual call and PVC, connectionless, and user signalling. (Deletion of the last two services has been proposed to the CCITT Study Group XVIII.) These will add to the existing X.31 option for data transmissions within ISDNs and should prove that the common channel signalling on the D-channel can be used for all types of connections within the ISDNs. Its implications for hardware and software need to be evaluated. Several studies have so far been carried out for the use of APMBS in LAN interconnection. These studies include a Temporary Document from British Telecom (TDl7 : BT to CEPT/NA1-WP3 Report) and the IEEE IVD-LAN Interface Working Group (IEEE 1988a).

Recommendation I.121 on the broadband aspects of ISDNis intended to provide a framework for the service definition, but there still is a lot of confusion regarding the technical implementation details and B-ISDN applications despite the European Commission's aim to hold field trials during the 1991-5 period. However, we cannot expect to see much proliferation in the equipment or services available to customers before 1995. During the third CCITT study period (1988-92) the consolidation of the technical aspects of ATM and B-ISDN are expected. Without these, it is difficult to see manufacturers committing themselves to interim standards.

The CCITT Study Group XVIII prepared a new list of issues to be pursued during the 1989-92 period. These included the ATM; performance aspects; the interworking of ISDN and PSIN, PSPDN, CSPDN, ISDN; and private networks including LANs and user-Network interfaces; layer 1 characteristics of B-ISDN; layer 1 characteristics of 64 kbps ISDN including the updating/completion of Rec. I.430/431.

The earliest option available for data transmission over (narrowband) ISDNs in europe will be the circuit-switched access (as this is 'inherent' to the system). The second option will be packet-switched (X.31-based) access (though this will depend on the carriers' implementation policies). It seems that, for the X.25-based applications, the X.31- based implementations will be the norm for the immediate future. This protocol is now quite mature, although further evolution may be expected. However, some early implementations are available in the United States as frame-relaying 'islands'. Further clarity is needed before field trials of such a service can be held. Earliest B-ISDN field trials will be in the 1991-5 period. Again, this will depend on the agreements on the technical issues during the 198892 period.

2.6.2 Future trends

Customer applications will probably determine and justify the selection of bearer services, in which case some of the existing Recommendations may or may not be implemented by all carriers. The degree of acceptance of Rec. I.462/X.3 1 will depend on the success of the additional packet modes, since the frame-relaying/switching may be preferred for some applications and the X.25-based approach for others where a common call control procedure will be advantageous to the X.3 I methods. The X.3 1 methods provide an early solution to the packet modes in ISDNs, while the use of X.25 over highly reliable (good BER) ISDN lines seems wasteful. Hence light-weight protocols for data transfers are needed. Additional packet modes. However, it is still by no means certain that all the bearer services proposed in the additional packet modes will mature to be implemented. X.31 is still evolving, and ISDNs capable of supporting X.3I are currenfly being implemented.

The future of circuit-switched services within the ISDNs seems to be guaranteed (essential for telephony, fax and video), and they may be incorporated into the ATM-based ISDNs as well. However, it is interesting to note that the connectionless packet mode of working within the ISDN is not available. The alternative seems to be a move towards an all-CO mode of communications, both at the local networks and at the public networks, or the provision of a CL mode of operation on top of circuit-switched or semi-permanent lines or within some frame-relaying/switching or X.25-based 'tunnel'. Another solution may be the CL and CO interworking arrangement, as indicated with the recent work by the ISO (1989).

Another issue is the recent and future developments regarding the ATM and B-ISDN. Coordinated B-ISDN field trials in Europe are expected during the 1991-5 period; an earlier start apparently could not be made because of the difficulty of deciding on the right multiplexing technology to be used. No one yet has a clear idea of how broadband will be used in the near future; the only existing demand is for high-speed data (and to some extent for video). One of the main problems the B-ISDN activists have been facing is finding real applications for B-ISDNs (e.g. motion video, medical applications, etc.). The ATM is a statistical technique and as such its capability to provide circuit-switched (CS) services are questioned. It is expected that it will eventually be able to replace CS services, even for voice. However, the costs involved are prohibitive for now. Another problem of the ATM technique is not so much the speed, but the handling of a large number of basic channels like the 64 kbps narrowband ISDN channels.

Value-added services (VASs) depend on the provision of higher-layer functions associated with the OSI layers 4-7 and are provided on top of basic services by value added carriers. The VAS service modules or servers can be accessed from a number of different networks, including the ISDNs. These services will include database access, store-and-forward communications, communications suppon services and compatibility services. The enhanced signalling capabilities of an ISDN is seen as a useful method for allowing signalling messages to be exchanged between a VAS user and server in parallel with, or in the absence of an established network connection. It is thought that ISDNs will provide an optimum framework for VAS. Hence, widespread implementations of VASs are expected in the ISDNs in future.

2.7 RELEVANT FEATURES OF ISDN IN LAN-ISDN INTERCONNECTION

In the design of data-oriented LAN-ISDN relays, the following features of the ISDN are most relevant:

- Multiple channel access structures
- Common channel signalling (CCS) using the D-channel
- Switched and non-switched capabilities
- Circuit and packet-switching capabilities

Multiple channels within one interface, which are user-controlled with regards to the way they are used and the type of ISDN services selected, are available in the ISDN era through the use of a CCS system. This is a completely new development in the field of data communications, where most networks still use leased lines for interconnection. Packet data is by nature bursty and the bandwidth requirements of data networks connected to ISDNs may vary during a given time duration. Hence one could conclude that the channels at the UNI could best be utilized by dynamically controlling their total bandwidth. This leads us to the idea of superchannels and dynamic channel (bandwidth) management. Naturally, the integration of services within the ISDN also has implications for the integrated services LANs (ISLANs) and integrated services PABXs.

2.8 SUPERCHANNELS IN ISDN

Channels of arbitrary bandwidth size (in units of 64 kbps) are termed 'superchannels'. Current ISDN recommendations do not specify such a facility, although channels at predetermined higher bandwidth values are defined. However, there is a need in many applications to have channel capacities that are not limited by the basic channel types. Hence formation of superchannels by suitable aggregation of basic channel types is desirable. However, identification of such channels on an end-to-end basis, as well as provision of dynamic variation of their allocated bandwidth, is not yet available within the CCITT recommendation.

2.9 CONCLUSION

This issue has not been completely addressed so far by the parties involved. However, the early indications show that, for data communications using the circuit-switched ISDN, a tariff structure similar to that of telephony will be applied. This means that each call is charged according to the charge band applicable (depending on the time of day) and distance. Each unit is charged to the customer at the beginning of the charge period. In some countries the charge period (or the charge applied to each charge period) is not linear, the first charge period being shorter (or the first charge unit being higher), so that a type of 'connection cost' is incurred by the users. In the rest of this book we will assume a linear charge period.

This chapter provides a background to the ISDN by first discussing its general principles and important technical features and then presenting a short summary of the CCITT Recommendations pertaining to the salient features of ISDNs. The section on the network performance objectives for call processing delays for circuit-switched connections indicates the type of performances to be expected from ISDNs. The ISDN Protocol Reference Model includes the logical user and control planes and proposes a plane management function for co-ordinating their activities. The relevant features of ISDN for LAN-ISDN-LAN interconnections are also presented, forming the basis for our discussions in Chapters 3. Here, it is noted that bandwidth management is not included in the current ISDN t Protocol for Management (Q.940).

CHAPTER
THREE

INTERCONNECTING LANs AND ISDN

Developments in the local and wide area carrier technologies, and the need for new applications with large bandwidth requirements, running on very fast processors, mean that the methods of interconnection of these devices will be the crucial issue in their collective performance. Today, in the local area, the workstation/server model with fast local area network (LAN) interconnection has become the norm in data communications and local networking. In the wider area, private and public networks with ever increasing capabilities are providing better facilities for the interconnection of local networks, servers and workstations.

In data communications, the interconnection of LANs using ISDN has become an issue of great importance because of the ISDN capabilities described in Chapter 2. The ISDN, apart from integrating services and providing common user interfaces, will facilitate fast switching via end-to-end digital connectivity as well as multiple channels at various transmission capacities. The use of common channel signalling (CCS) will mean that control of these channels can be made in an outband mode concurrent with the user data transmission over the user channels. To date, little has been reported about how these facilities may be used in LAN-LAN interconnections using the ISDN. Hence our interest in LAN-ISDN-LAN interconnection arises from two ambitions: to investigate the issues involved in the LAN-ISDN interconnection, and to study the channel management issue at the boundary of the packet switching-circuit switching network interconnection. The LAN-ISDN interconnection will be a common source of PS-CS network traffic.

3.1 PACKET NETWORK INTERCONNECTION ISSUES

For a multitude of reasons which have already been discussed above, computer networks need to be interconnected (see Fig. 3.1). The common objective of all interconnection methods is to allow all subscribers a transparent means of accessing a host or service on any of the interconnected networks.

To achieve this objective, data produced at a source in one network must be able to be delivered and correctly interpreted at the destination in another network. This necessitates the provision of inter-process communication across the network boundaries In order to achieve this, some sort of 'commonality' is required across the interconnected networks. This can be achieved by two general approaches:

1. Translation of one protocol into another, when different protocols operate on separate networks.

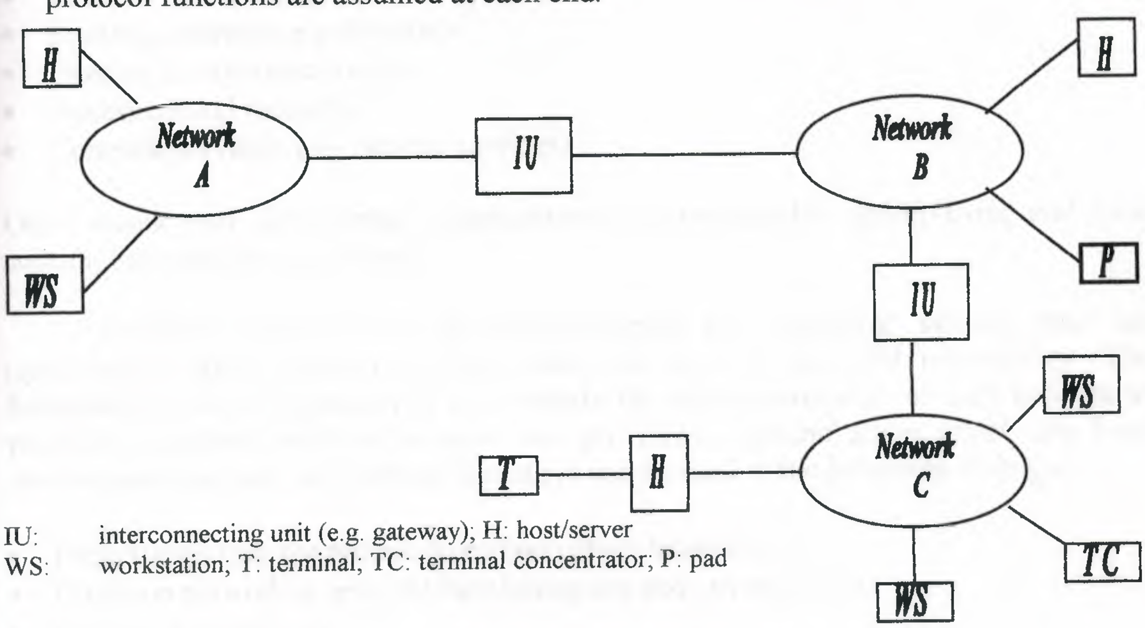
2. Using protocols common among the communicating parties.

Also, a strategy combining the two approaches may be employed (e.g. using some common protocol at a given layer and translating protocols at one or more layers to the interworking protocols). In order to provide a common model for data communications, ISO has developed the Reference Model for Open Systems Interconnection (OSI-RM) This model provides the basis for development of common protocols as well as for interworking between heterogeneous environments.

3.1.1 Network interconnection approaches

From the point of view of the desired functionality, three general approaches to network interconnection can be described :

1. **Network access** Achieves physical access and protocol compatibility in the lower layers of the OSI model (e.g. physical, data link and network layers of X.25). This methot is used when the networks (e.g. LANs and the long-distance network) already exist with their own established protocol structures.
2. **Network services** Obtains the use of specific types of services (e.g. virtual circuit service) to satisfy user needs. This method is used for resource sharing or value added networks. It stresses obtaining network services for the user (e.g. provision of remote interactive processing involving session control and sequenced error-free message delivery).
3. **Protocol functions** Matches the number and types of protocols on each type of network. Protocol conversion is necessary for this method, since different sets of protocol functions are assumed at each end.



IU: interconnecting unit (e.g. gateway); H: host/server
WS: workstation; T: terminal; TC: terminal concentrator; P: pad

Figure 3.1 Multiple network interconnection

Two similar terms are usually used in describing the interaction between two or more networks:

- Network interconnection
- Interworking (or internetworking)

In this text we define the network interconnection issues as those relating to problems and general methods of interconnecting different types of networks without necessarily achieving interworking. Interworking issues are defined as those issues relating to the provision of services and facilities available on one network to the users on another network or to single users accessing that network using isolated terminals or workstations.

The network access approach falls into the interconnection classification, while the network services fails into the interworking classification described above. In a layered communications architecture, the protocols used in each layer provide a service to the layer above. Hence the protocol functions approach falls somewhere between the two. In this text we are interested in network access as far as the LAN-ISDN interconnection is concerned. For the LAN-ISDN-LAN interconnection, however, we are interested in the LAN-LAN interworking. Hence the use of ISDN to interconnect LANs and isolated individual hosts/workstations.

3.1.2 Technical issues in interconnection

The following issues need to be resolved for a coherent network interconnection:

- Level of interconnection
- Naming, addressing and routing
- Flow and congestion control
- Access control (security)
- Common services (e.g. internet services)

Other issues such as buffering, fragmentation and re-assembly, multiplexing and error control, must also be considered.

Different networks can be interconnected by 'mediating' systems that are (generically) called gateways, corresponding to relays in the OSI terminology. The fundamental role of a gateway is to terminate the internal protocols of each network to which it is attached, while at the same time providing a 'ground' across which data from one network can pass into another. Gateways can be used in the following strategies.

- Packet-level interconnection (common subnet technology)
- Common network access interface (datagram and virtual circuit)
- General host gateways
- Protocol translation gateways

In general, when different protocols operate on separate networks, two approaches can be achieved for interconnection:

1. **Media conversion** A media conversion gateway bridges the gap between differing data link and physical layer protocols; messages from one network are read by unwrapping their network packaging, the necessary routing is computed, and messages are sent to another network by wrapping them into that network's packaging. Examples of these are repeaters and bridges operating at the physical and data link layers, respectively.

2. **Protocol conversion** A protocol conversion gateway bridges the gap between differing network and higher-layer protocols; messages received from one network are replaced by different messages with the same protocol semantics and sent into another network. Examples of these are network or transport layer relays.

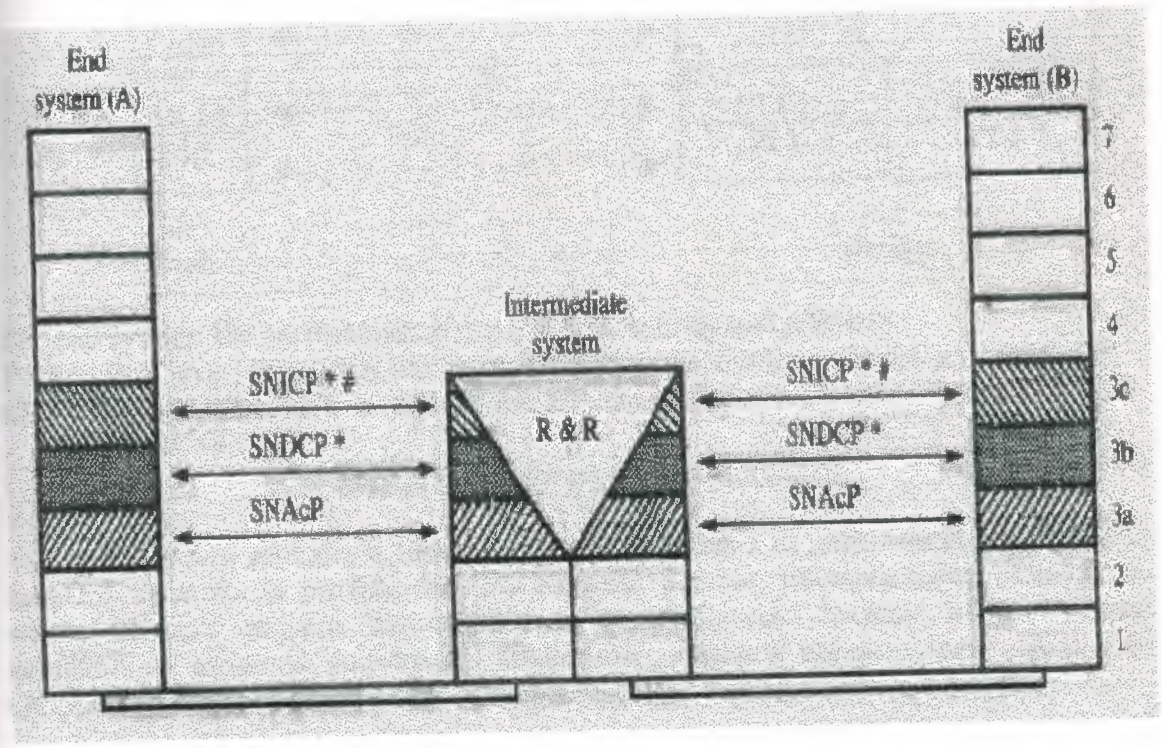
3.1.3 The OSI model for interconnection

The OSI-RM refers to a seven-layer architecture. The top three layers (layers 5-7) are responsible for the processing of information, while the bottom four layers (layers 1-4) are responsible for moving information units a co-operation between heterogeneous networks at layers 1-4 provides interconnection, while the full 1-7 layer co-operation provides interworking between end systems and processes. It is the heterogeneity of networking technologies at both the local and wide areas that causes the interconnection problems, since information units must be transported across these networks securely. Interworking necessitates interconnection, but not vice versa. Heterogeneous networks can be interconnected by intermediaries. A relay described by the OSI-RM is such an intermediary. Its function is to facilitate communications between peers in the protocol hierarchy. A relay implements a set of procedures by which data from one system is forwarded to another. This is called a relaying function. A relay sharing a common protocol at layer **n** with other systems but not participating in a layer **n+1** protocol in implementing its relaying function is called a layer n relay in OSI terminology.

In the OSI-RM, layers 4 and above operate on an end-to-end basis. Furthermore, OSI principles state that interconnection of data networks (subnetworks in OSI terminology) must be achieved at layer 3, the network layer, since this layer provides global network addressing and provides routing and switching as well as relaying functions, among others. Network interconnection can also be achieved at layers 1 and 2; however, as these result in extended subnetworks, they do not contravene the OSI principles.

The OSI-RM specifies that layer **n+1** makes use of the layer **n** service in performing its own layer service. This leads to the n-layer Service inteiface and the service relay concept for network interconnection. This assumes that the services operating on either side of a relay are identical (e.g. connection mode network service-CONS). In this case, the relaying function consists of a simple mapping of indications and confirmations arriving through one service interface onto requests and responses sent through the other. Provision of different services on either side causes incompatibilities. In practice, the services offered by real subnetworks (e.g. LANs and X.25 PSPDNs) are rarely identical and usually they do not provide a true OSI network service. A further complication is that the OSI Network Service (OSI-NS) can have two guises: the connection mode (CO) and connectionless (CL) network services. If these are operated on either side of a relay, a CO/CL interworking arrangement is needed (ISO 1989). This is often the case when LANs (usually CL) and WANs (usually CO) are interconnected.

According to the OSI principles, service incompatibilities on either side of a relay can be remedied by modifying the service on one or both sides such that a common service is achieved. This aim is made easier to achieve since the OSI network layer functions are divided into three sublayers: two convergence protocols and a subnetworking access protocol (SNAcP). The convergence protocols are referred to as the subnetwork independent and dependent convergence protocols, (SNICP and SNDCP) respectively (see Figs. 3.2 and 3.3).

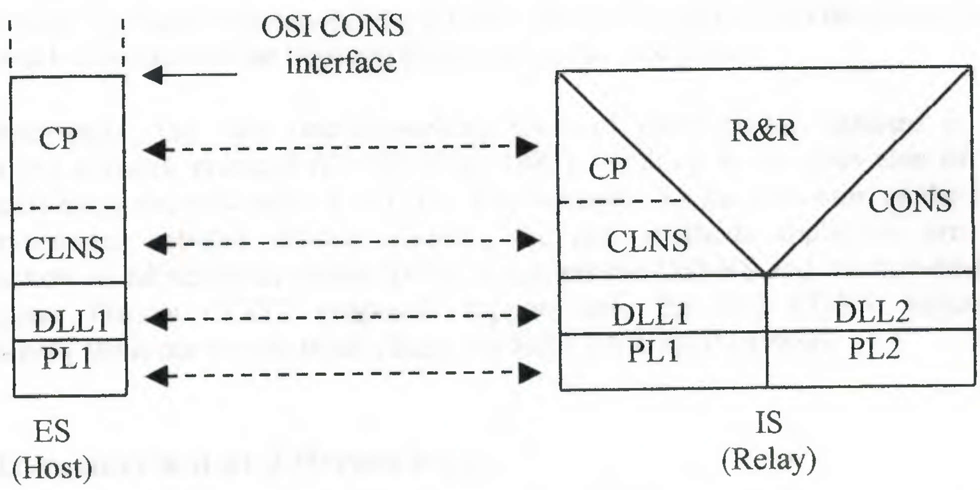


R & R: routing and relaying; SNICP: subnetwork independent convergence protocol
SNDCP:subnetwork dependent convergence protocol;
SNAcP: subnetwork access protocol

*May not be needed in all instances.
These protocols may be identical.

Figure 3.2 Partitioning of network layer

The roles assigned to different sublayers can be provided by a single protocol (e.g. the X.25 Packet Level Protocol (PLP)-as well as by a set of protocols. The role of the convergence protocols is to enhance or de-enhance an existing service to provide the OSI Network Service at the service interface to the transport layer. This extra layer of protocol needs to be added to every network node wishing to communicate with a NL relay configured in this fashion. A practical way to avoid the large number of modifications the above scheme implies is to implement relaying at the transport layer, where a commonality can be achieved (using either CO or CL network service modes). However, this compromises the end-to-end nature of the transport service and hence violates the OSI-RM.



ES: end system; IS: intermediate system; R & R: routing and relaying
PL: physical layer; DLL: data link layer; CLNS: connectionless network service
CONS: connection mode network service; CP: convergence protocol

Figure 3.3 Use of a convergence protocol

ISO work provides a framework that can be used to interconnect both OSI and non-OSI networks to provide the OSI Network Service. Interconnection of networks whose SNAcPs provide the OSI-NS is straightforward because of the service compatibility across all participants. When interconnecting networks that include non-OSI networks, two approaches are available under the common service concept:

- Hop-by-hop harmonisation
- Internetworking protocol

The hop-by-hop harmonization approach prescribes the 'harmonization' of the subnetwork service available on each non-OSI network to that of the OSI-NS. The harmonization hinctions reside in the SNICP sublayer and possibly, when (de-) enhancement is necessary, the SNDCP sublayer. Routing and relaying functions are employed to interconnect the harmonized subnetwork services to provide the OSl-NS end-to-end. With this approach, all end and intermediate systems attached to a given subnetwork have to support the same sublayer protocol(s) to enable communication between all end system in this subnetwork.

In the internetworking protocol approach, an internet protocol (operating in the SNICP role) runs over the interconnected series of networks, which may be of different types, providing the OSI-NS across these networks and intermediate systems. An internetworking protocol is based on a predefined set of capabilities over which it is to operate. If a network participating in the interconnection cannot provide a subnetwork service adequate for the capabilities required by the internetworking protocol, a sublayer SNDCP protocol has to be used to enhance its subnetwork service to the level of that required by the internetworking protocol. When this approach is used for network interconnection, the same intemetworking protocol has to be used in all end-systems and relays to enable communication between these systems to take place.

Interestingly, the only internetworking protocol international standard is the connectionless network protocol (CLNP) (ISO 1988), resulting in the provision of the OSI connectionless network service (CLNS). Furthermore, for the provision of the OSI connection-oriented network service (CONS), the only methods applicable are the interconnection of subnetworks whose SNAcPs support the OSI-NS and the hop-by-hop harmonization. Present CCITT proposals support only the OSI CONS; hence it recognizes only the latter two methods (Burg and loflo 1989; CCIU 198Sf).

3.1.4 Interconnection at different layers

As mentioned earlier, interconnection of networks at layers other than the network layer is possible. Here, these are mentioned briefly. It is interesting to note that session or presentation layer relays have so far not been developed.

Data link layer relay The MAC bridge is a widely used example of such interconnection. It achieves relaying within layer 2 and interconnects LANs. Local and remote bridging techniques are available. More than two LANs can be connected via a single bridge. However, MAC layer bridges present problems in areas of address management, security broadcast control, resilience, load balancing and upgradability. Further problems arise in (global) addressing and protocol compatibility when LAN services are to be accessed by remote terminals or workstations.

Transport layer relay The CO/CL network service interworking without modifications at the hosts, can be established by using a transport layer relay. An ISO Technical Report proposes passive and active types of transport layer relays (TLRs). A TLR is called an interworking functional unit (IFU) and achieves interworking between CO and CL network services by relaying and/or conversion of protocol data units (PDUs) from one network type to another. This method assumes the use of a connection oriented transport service on botti networks in order for them to be interconnected. However, these modes are outside the OSI architecture, and hence this solution is not an International Standard but a Technical Report.

Application layer relay Application layer relays are used for mapping largely incompatible (and often proprietary) protocol stacks, masking incompatibilities at lower layers. Examples are terminal and mail gateways. They may also be used for administrative reasons, e.g. to restrict inter-domain traffic to certain applications. Their major disadvantages are the need to develop new gateway modules for each application and set of protocol stacks, and slower performance.

3.2 INTERCONNECTING WITH ISDN

Two issues determine the level of interworking between an ISDN and an external user:

- Type of user interface (or user interface capabilities)
- ISDN services needed, le. bearer and/or teleservices

The type of user interface determines the level of services that can be obtained from the ISDN. For example, a terminal or host supporting only traditional data interfaces. which are non-ISDN-compatible, needs to be connected through a terminal adaptor to the ISDN. This means that it cannot request the full range of services offered through an ISDN-compatible interface. Since teleservices require layers 4-7 compatibility with ISDN, these services are offered only to equipment supporting ISDN interfaces (compatible with S or T reference interworking). when interconnecting LANs and terminal or workstations to ISDN, four cases can be described:

1. Provision of all ISDN services to LAN users
2. Provision of LAN services to ISDN terminals/workstations
3. Provision of LAN services to non-ISDN terminals/workstations
4. LAN-LAN interworking across ISDN

The first case necessitates the provision of ISDN-compatible interfaces to the LAN users capable of interworking at the S reference point. This necessitates the support of the S-interface over the LAN and cannot be easily implemented over the existing data-only LANs. With such a functionality the LAN becomes more like an ISPBX. We shall call such a LAN an ISDN-compatible LAN (IcLAN). Also, a LAN may be modified to support integrated services, in which case it is called an integrated services LAN (ISLAN). However, an ISLAN does not necessarily need to support the S-interface.

The second case can easily be supported if the LAN is connected to the ISDN via a network layer relay. The third case necessitates the use of either the circuit or packet mode bearer services by both the LAN and the non-ISDN terminal/workstation for data transfer. Finally, the fourth case necessitates the access of ISDN switched or non-switched bearer services for interconnection and can be implemented to operate at the R, S or T reference point. Table 3.1 summarizes the ISDN services needed and or usable in each case. Here, the type of bearer service to be used and the layer of interconnection need to be darified. These also have an effect on the protocol stacks to be used on the LAN/workstation as well as the ISDN. Furthermore, the way in which LAN is to be interconnected to the ISDN needs to be specified.

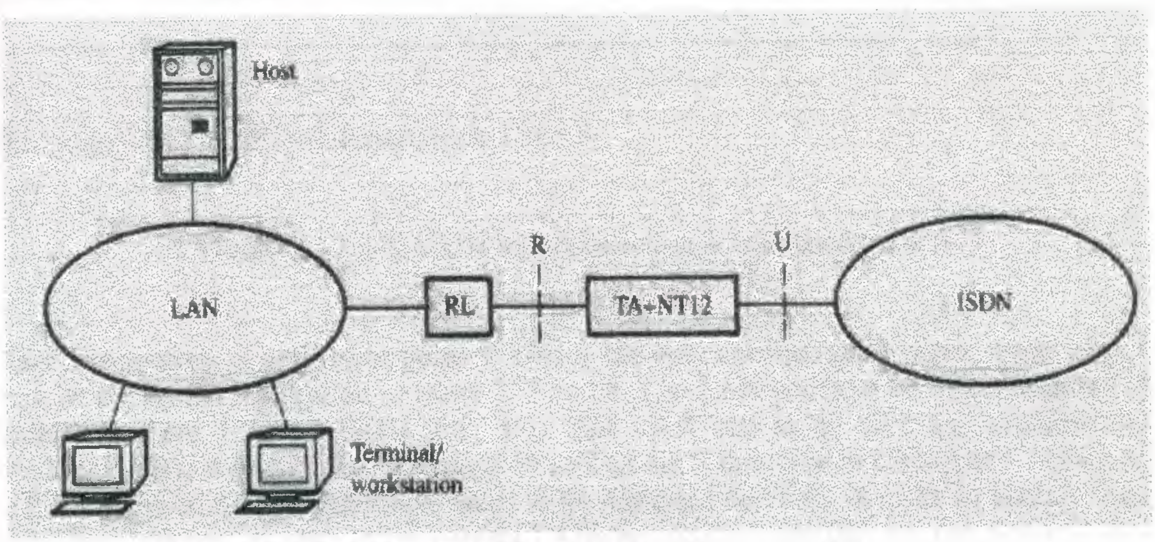
3.3 INTERCONNECTION OF LANs AND ISDN

The choice of reference points with regard to the usage scenarios described in the previous section are given in the following subsections. In all of these scenarios, we assume that the LAN is connected to the ISDN via a relay, as opposed to individual LAN hosts having direct access to the ISDN.

Interconnection type	ISDN services	
	Bearer service	Teleservices
T/WS-ISDN-Host/Server	□	-
T/WS-ISDN-LAN	□	-
LAN-ISDN-LAN	□	-
LAN-ISDN	□	-
IcLAN-ISDN	□	□
IWS-ISDN	□	□
IWS-ISDN-IcLAN	□	□

Table 3.1 Services in LAN/workstation-ISDN interconnection

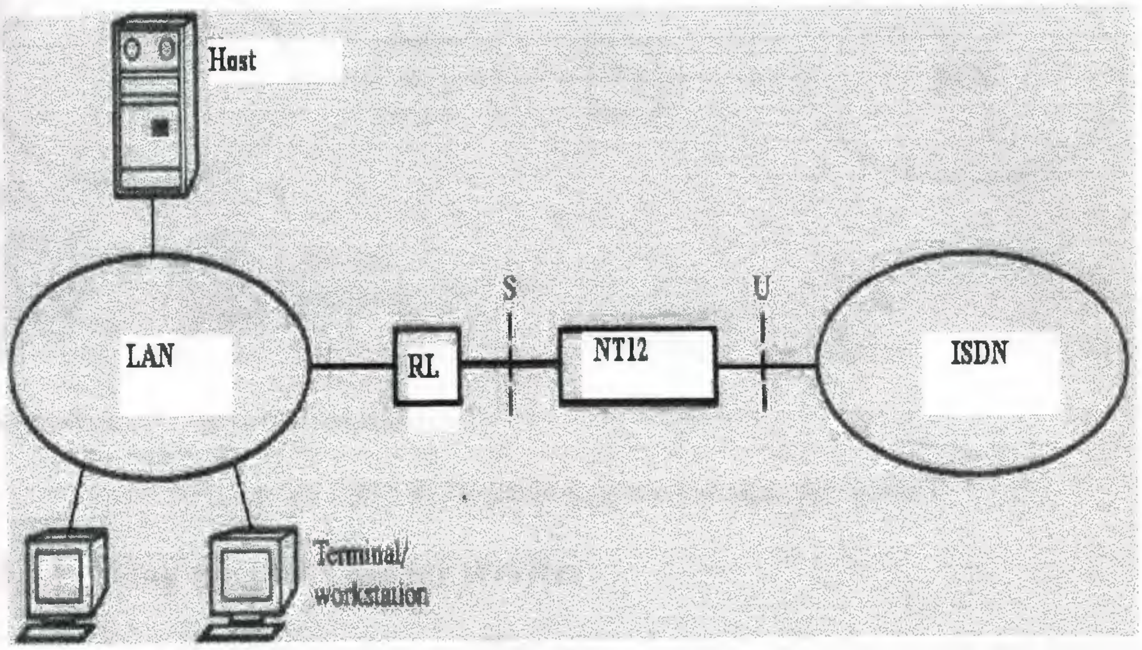
Interconnection at reference point R Figure 3.4 shows the LAN-ISDN interconnection at reference point R. The LAN-ISDN relay can have two types of interfaces: circuit or packet mode, hence acting as a circuit or packet mode DTE, respectively. In either case, a compatible terminal adaptor is used to interwork with the S-interface. Thus, usage cases 2, 3 and 4 can he supported with this configuration. Ordinarily TAs will support only one B- or H-channel at the ISDN side, thereby limiting the internet traffic that can be handled. However, intelligent TAs which can aggregate B- or H-channels in ISDN are also possible, and these could support larger-capacity connections.



RL:relay; TA: terminal adaptor; NT12: network termination 1 and 2

Figure 3.4 LAN-ISDN interconnection at reference point R

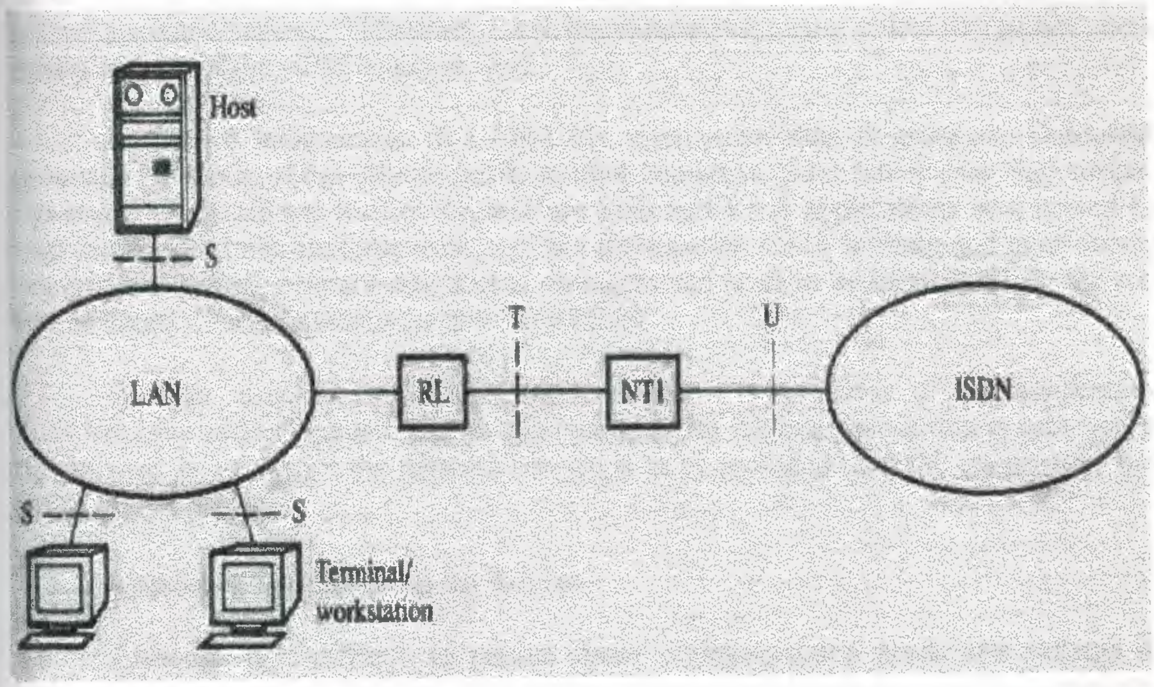
Interconnection at reference point S This configuration, shown in Fig. 3.5, can be used to support usage cases 2, 3 and 4. The advantage of this configuration is that it provides direct access to the S-interface by the LAN-ISDN relay, which can use the flexibility of the control of that interface by ISDN signalling procedures. In this mode, LAN-relay combination acts as an intelligent terminal adaptor.



RL: relay; NT12: network termination 1 and 2

Figure 3.5 LAN-ISDN interconnection at reference point S

Interconnection at reference point T This is the only configuration where usage case 1 can be supported in addition to cases 2, 3 and 4. The LAN needs to be interconnected at reference point T to the ISDN (Fig. 3.6). The LAN acts as an NT2 and provides the multiplexing and distribution functions as well as the S-interface to LAN users. However, a LAN supporting the S-interface needs to be designed carefully in order to benefit from this configuration, as none of the current LANs provide this facility, nor can normal LAN hosts exploit it.



RL: relay; NTI: network termination I

Figure 3.6 LAN-ISDN interconnection at reference point T

3.3.1 Using the ISDN bearer services

The data communications in ISDN were classified under the circuit- and packet-switched bearer services and the additional packet mode bearer services (APMBS). The packet-switched bearer service is currently available only using the X.25 protocol suite, and the APMBS is not expected to be available in Europe in the immediate future.

The frame-relaying type 1 (Lai 1989a, 1989b, 1989c) implies a core layer 2 service on the B-channels and is found to offer significant benefits for the interconnection of LANs by remote bridges. Indeed, its trade-off between functionality and speed appears to suit LAN-LAN interconnection better than either of the other alternatives, i.e. circuit-switched channels or X.25 packet switching. This is because the simple access interface, relatively high access speed and statistical multiplexing capability (in layer 2) of frame relaying is ideally suited to LAN interconnection. The remote bridge solution using frame relaying suggests the encapsulation of LAN MAC layer frames in the LAP-D frames. High-speed operation is possible by transparent operation because of the non-termination of higher-layer protocols and the use of core layer 2 functions only (e.g. no frame acknowledgement). Owing to layer 2 multiplexing, high-speed access is more cost-effective, especially to multiple destinations. This facility is similar to the multiple virtual circuits in X.25 networks but at reduced protocol overhead and associated speed/cost penalty of layer 3 multiplexing.

However, because of the additional requirement of enabling isolated workstations to be able to access the LAN services and the earlier availability and ubiquity of the circuit-switched service. Therefore, LAN interconnection using either the packet mode bearer service or the APM bearer service.

A further requirement in LAN-LAN interconnections is adequate bandwidth provision. In cases where off-site traffic is light enough, a basic-rate access may suffice. However, when off-site traffic volumes are high and LAN applications best served by high-bandwidth links are to be used (e.g. fast file transfer, CAD, bit-map and multi-media document transfer), primary-rate access arrangements need to be considered. In the rest of this book, we shall assume the use of PRISDN.

Another issue in LAN-ISDN interconnection is the layer of interconnection. Following the earlier discussions, we shall assume that the interconnection is achieved at the network layer. Hence the network service is to be provided over the circuit-switched ISDN digital bit pipes.

3.3.2 Appikations running on LANs

Although it is difficult to predict future communication needs and patterns of various user groups, all existing data communication applications could be supported over the ISDN. Furthermore, it is expected that remote terminal, file and database accesses, fast file transfer, distributed databases, CAD applications, electronic mail, multi-media document services and telematic services applications will be prominent in the immediate future. It is obvious that some of these applications will not be able to use the full 64 kbps channel capacity when offered, for example, a remote terminal access session. Several such sessions can therefore be multiplexed onto a single channel if they pass through the same pair of ISDN stations (access nodes). Also, interactive applications such as terminal access and file access need 'real-time' responses in order to be usable. Delay becomes more important than throughput in these cases.

3.3.3 Interconnection scenarios

The following LAN-ISDN-LAN interconnection scenarios can be visualized:

- **Scenario 1** A fixed number of LAN sites communicate with each other on a regular basis (e.g. branches of a corporation) and have regularly distributed traffic.
- **Scenario 2** Users on a large number of LANs want to communicate with each other on an irregular basis.

In scenario 1, a leased-line or semi-permanent line solution may be more cost-effective than a circuit-switched solution, as the advantages of ISDN will not be evident if the tariffing structure is not favourable to switched connections. However, the ISDN could provide added bandwidth on demand or act as an emergency backup facility.

In scenario 2, a circuit-switched solution will be more cost-effective. Hence a judicious management of the circuit-switched connections under different tariff structures, user demand (traffic volume) and service/user priority constraints will bring about cost-effective utilization of the local ISDN bandwidth. It seems more likely that an advanced automated office environment will need the flexibility of scenario 2 for its applications.

3.3.4 The LAN-ISDN relay

The LAN-ISDN relay is a specialized relay, which must overcome several technical problems. It differs from most other relays in that:

- It is multichannel.
- It must manage many switched connections simultaneously.
- It has common channel signalling for outband control of circuits.
- It connects to a network (the ISDN) which imposes no restrictions on the protocols to be used-the B-channels appearing merely as bit pipes (assuming circuit-switched bearer service).

These properties present the following problems:

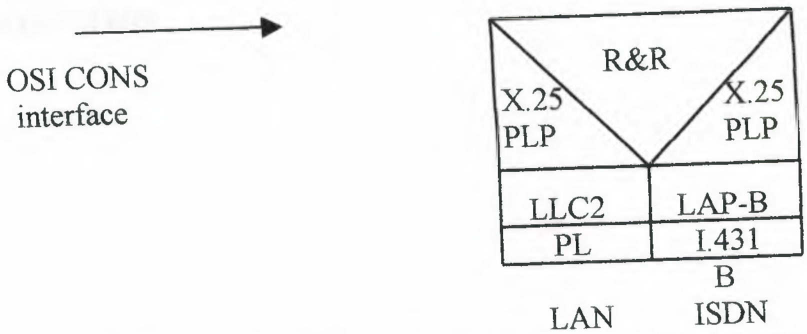
1. Intelligent management of multiple channels for switched connections; circuit set-up and removal actions as well as dynamic bandwidth control.
2. Efficient queue management for channels.
3. Conversion of inband data signalling (e.g. addressing, routing and other packet information) on the LAN to outband control signals for circuit-switched connection set-up on the ISDN. This is basically a way of protocol conversion from the single-plane format of the OSI-RM to the two-plane format of the ISDN-PRM.
4. Choice of protocol stacks to be used over bit pipes.

In the local area, the workstation/server/LAN system model has become the most popular environment, and this must he interfaced to other LANs via the ISDN. A LAN-ISDN relay with a LAN interface on one side and a PRISDN interface on the other is needed. The capabilities required from this relay must reflect service requirements as well as the underlying communications requirements. The LAN-ISDN relay must be able to manage multiple channels which may be switched individually or in bundles, depending on user/network requirements. Procedures need to be defined to manage a variable number of B-channel connections depending on system status and traffic variations.

3.3.5 Protocols over the ISDN bit pipes

Another issue in the LAN-ISDN relay is the type of protocols to he supported. Both the CO and CL network services can be provided over the digital bit pipes provided by the ISDN circuit-switched bearer service. This leads to different protocol stacks in the LAN-ISDN network layer relay. For simplicity, the same type of network service is ssumed in each of the scenarios described below. Here, we note that other possible cenarios exist (e.g. X.25 tunnelling, where connectionless packets could be carried vithin connection mode packets, etc.).

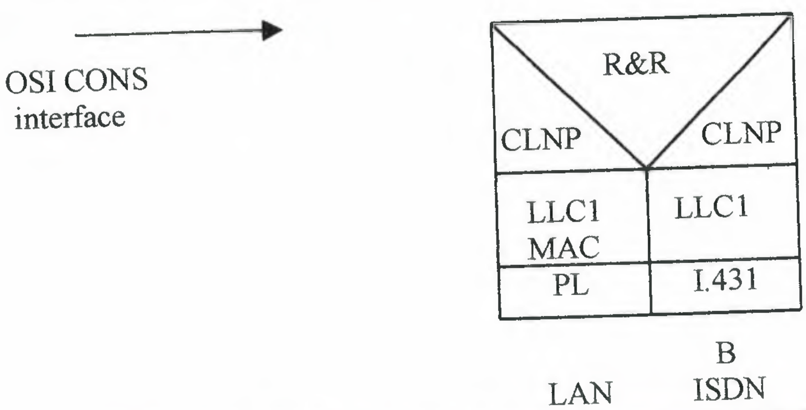
CONS across ISDN Figure 3.7 shows a NL relay protocol stack where the CONS is provided across both the LAN and the ISDN. At the network layer both the LAN and the SDN are assumed to have the X.25 packet layer protocol (PLP). The lower layers are necessarily different. when a new B-channel is set up, the data link must be established over it.



PLP: packet level protocol (IS 8208); LLC2: logical link control type 2 (IS 8802-2)
LAP-B: link access protocol-balanced (IS 7776); PL: physical layer;
R & R: routing and relaying

Figure 3.7 A connection oriented LAN-ISDN network layer relay

CLNS across ISDN Figure 3.8 shows a NL relay protocol stack where the CLNS is provided across both the LAN and the ISDN. At the network layer both the LAN and ISDN are assumed to have the CL network protocol (ISO internet protocol). At the data link layer, the ISDN need not have the MAC-level protocol. Indeed, HDLC core protocol could also he used instead of the LLC1. If LLC 1 is used, no data link needs to be established after a circuit set-up since this is a CL mode layer 2 protocol. If HDLC is used, however, the data link needs to be established anew with every new circuit set-up. The interaction of CLNP and the channel management.



R & R: routing and relaying; CLNP:connectionless network protocol (IS 8473);
LLC1: logical link control type I (IS 8802-2);MAC: medium access control protocol;
PL: physical layer; 1.431: ISDN physical layer

Figure 3.8 A connectionless LAN-ISDN network layer relay

3.4 CONCLUSION

Circuit-switched ISDN, providing fast switching, multiple channels, common channel signalling and digital bit pipes, presents a flexible wide area network for LAN-ISDN and LAN-ISDN-LAN interconnection. The user flexibility to choose suitable protocols over raw bit pipes presents a challenge. These protocols do not need to be heavy-weight, owing to ISDN's good bit error rate performance. Network layer interconnection has its advantages in conforming with the OSI-RM and eases the problem of global addressing.

CHAPTER
FOUR

BROADBAND ISDN ARCHITECTURE

The planning for ISDN began as far back as 1976 and has only in recent years moved from the planning stage to prototypes and actual implementations. It will be a number of years before the full spectrum of ISDN services is widely available, and there will continue to be reflinements of and improvements to ISDN services and net-work facilities. Nevertheless, with the publication of the 1988 set of recommendations from CCITT. the bulk of the work on ISDN is complete. To be sure, future versions of the standards will provide refinements and enhancements to ISDN. But since 1988, much of the planning and design effort has become directed toward a network concept that is more revolutionary than ISDN itself. This new concept is broadband ISDN (B-ISDN).

ITU-T modestlv defines B-ISDN as "a service requiring transmission channels capable of supporting rates greater than the primary rate." Behind this innocuous statement lie plans for a network and set of services that will have far more impact on business and residential customers than ISDN. With B-ISDN, services, especially video services, requiring data rates orders of magnitudes beyond those that can be delivered by ISDN will become available. These include support for image processing. video. and high-capacity workstations and local area networks (LANs). To contrast this new network and these new services to the original concept of ISDN, that original concept is now referred to as narrowband ISDN.

The primary triggers for evolving toward the B-ISDN include an increasing demand for high-bit-rate services, especially image and video services, and the evolution of technology to support those services. The key developments in technology are as follows:

- Optical fiber transmission systems that can offer low-cost, high-data-rate transmission channels for network trunks and for subscriber lines
- Microelectronic cirrcuits that can offer high-speed, low-cost building blocks for switching, transmission, and subscriber equipment
- High-quality video monitors and cameras that can, with stifficient production quantities, be offered at low cost

These advances in technology will result in the integration of a wide range of communications facilities and the support of, in effect, universal communication with the following key characteristics:

- Worldwide exchange between any two subscribers in any medium or combination of media
- Retrieval and sharing of massive amounts of information from multiple sources, in multiple media, among people in a shared electronic environment
- Distribution, including switched distribution, of a wide variety of cultural, entertainment, and educational materials to home or office, virtually on demand

4.1 B-ISDN STANDARDS

Since 1988, the work within CCITT (now ITU-T) has been guided by the concepts outlined in Tables 4.1 and 4.2. The result, so far, has been the publication of a number of recommendations in the I-series that specifically relate to B-ISDN. These are listed in Table 4.3.

Mention should be made at this point of the ATM Forum, which is playing a crucial role in the development of ISDN standards. In the ITU and the constituent member bodies from the participating countries, the process of developing standards is characterized by wide participation by government, users, and industry representatives and by consensus decision making. This process can be quite time-consuming. While ITU-T has streamlined its efforts, the delays involved in developing standards are particularly significant in the area of B-ISDN, which is dominated by the rapidly evolving asynchronous transfer mode (ATM) technology. Because of the strong level of interest in ATM technology, the ATM Forum was created with the goal of accelerating

Broadband: A service or a system requiring transmission channels capable of supporting rates greater than the primary rate.
The term B-ISDN is used for convenience in order to refer to and emphasize the broadband aspects of ISDN. The intent, however. is that there be one comprehensive notion of an ISDN that provides broadband and other ISDN services.
Asynchronous transfer mode (ATM) is the transfer mode for implementing B-ISDN and is independent of the means of transport at the physical layer.
B-ISDN will be based on the concepts developed for ISDN and may evolve by progressively incorporating directly into the network additional B-ISDN functions enabling new and advanced services.
Since the B-ISDN is based on overall ISDN concepts, the ISDN access reference configuration is also the basis for the B-ISDN reference configuration.

Table 4.1 Noteworthy Statements in I.113 and I.121

The emerging demand for broadband services
The availability of high-speed transmission, switching, and signal-processing technologies
The improved data- and image-processing capabilities available to the user
The advances in software application processing in the computer and telecommunications industries
The need to integrate both interactive and distribution services
The need to integrate both circuit- and packet-transfer mode into one universal broadband network
The need to provide flexibility in satisfying the requirements of both user and operator
The need to cover broadband aspects of ISDN in ITU-T recommendations

Table 4.2 Factors Guiding ITU-T Work on B-ISDN (I.121)

the development of ATM standards. The ATM Forum has seen more active participation from computing vendors than has been the case in ITU-T. Because the forum works on the basis of majority rule rather than consensus, it has been able to move rapidly to define some of the needed details for the implementation of ATM [PRAS93]. This effort, in turn, has fed into ITU-T standardization effort.

4.2 BROADBAND SERVICES

When the capacity available to the ISDN user is increased substantially, the range of services that ISDN can support also increases substantially. ITU-T classifies services that could be provided by a B-ISDN into interactive services and distribution services (Figure 4.1). Interactive services are those in which there is a two-way exchange of information (other than control-signalling information) between two subscribers or between a subscriber and a service provider. These include conver-sational services, messaging services, and retrieval services. Distribution services are those in which the information transfer is primarily one way. from service provider to B-ISDN subscriber. These include broadcast services, for which the user has no control over the presentation of the information, and cyclical services (explained subsequently), which allow the user some measure of presentation control.

Number	Title	Date
I.113	Vocabulary of Terms for Broadband Aspects of ISDN	1997
I.121	Broadband Aspects of ISDN	1991
I.150	B-ISDN ATM Functional Characteristics	1995
I.211	B-ISDN Service Aspects	1993
I.311	B-ISDN General Network Aspects	1996
I.321	BASDN Protocol Reference Model and Its Application	1991
I.327	B-ISDN Functional Architecture	1993
I.356	B-ISDN ATM flayer Cell Transfer Performance	1993
I.357	B-ISDN Semipermanent Connection Availability	1996
I.361	B-ISDN ATM Layer Specification	1995
I.363	B-ISDN ATM Adaptation Layer (AAL) Specification	1993
I.363.1	B-ISDN ATM Adaptation Layer Specification: Type 1 AAL	1996
I.363.3	B-ISDN ATM Adaptation Layer Specification: Type 314 AAL	1996
I.363.5	B-ISDN ATM Adaptation Layer Specification: Type 5 AAL	1996
I.364	Support of Broadband Connectionless Data Service on B-ISDN	1995
I.371	Traffic Control and Congestion Control in B-ISDN	1996
I.413	B-ISDN User-Network Interface	1993
I.414	Overview of Recommendations on Layer 1 for ISDN and B-ISDN Customer Access	1993
I.432.1	B-ISDN UNI Physical Layer Specification:General Characteristics	1996
I.432.2	B-ISDN UNI Physical Layer Specification: 155.520 Mbps and 622.080 Mbps Operation	1996
I.432.3	B-ISDN UNI Physical Layer Specification:1.544Mbps and 2.048 Mbps Operation	1996
I.432.4	B-ISDN UNI Physical Layer Specification:51.840Mbps Operation	1996
I.432.5	B-ISDN UNI Physical Layer Specification:25.600 Mbps Operation	1997
1.580	General Arrangements for Interworking Between B-ISDN and 64 kbitls Based ISDN	1995
I.610	B-ISDN Operation and Maintenance Principles and Functions	1995
I.731	Types and General Characteristics of ATM Equipment	1996
I.732	Functional Characteristics of ATM Equipment	1996
I.751	ATM Management of the Network Element View	1996

Table 4.3 ITU-T Recommendations on Broadband ISDN

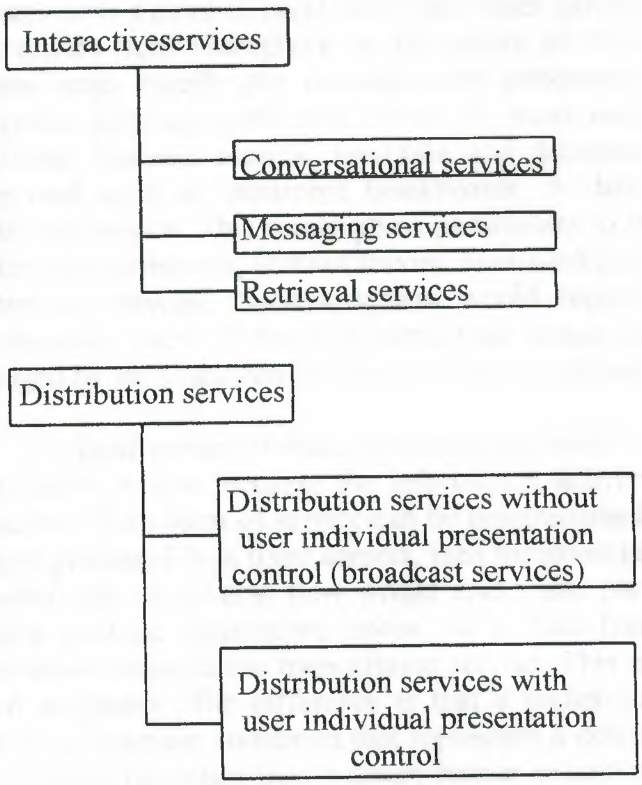


Figure 4.1 Broadband Services.

Conversational Services

Conversational services provide the means for bidirectional dialogue communication with bidirectional. real-time (not store-and-forward), end-to-end information transfer between two users or between a user and a service provider host. These services support the general transfer of data specific to a given user application. That is, the information is generated by and exchanged between users; it is not "public" information.

This category encompasses a wide range of applications and data types. including moving pictures (video), data, and document. In the long run, perhaps the most important category of B-ISDN service is video conversational services, and perhaps the most important of these services is video telephony. Video telephony simply means that the telephone instrument includes a video transmit and receive/display capability so that dial-up calls include both voice and live picture. The first use of this service is likely to be the office environment. It can be used in any situation where the visual component of a call is advantageous, including sales, consulting, instruction, negotiation. and the discussion of visual information, such as reports, charts, advertising layouts, and so on. As the cost of videophone terminals declines, it is likely that this will be a popular residential service as well.

Another video conversational service is videoconference. The simplest form of this service is a point-to-point capability which can be used to connect conference rooms. This differs from videophone in the nature of the equipment used. Accordingly, the service must specify the interface and protocols to be used to assure compatible equipment between conference rooms. A point-to-point videoconference would specify additional features, such as facsimile and document transfer and the use of special equipment such as electronic blackboards. A different sortof videoconference is a multipoint service. This would allow participants to the together single videophones in a conference connection, without leaving their workplaces, using a video conference server within the network. Such a system would support a small number (e.g., five) of simultaneous users. Either one participant would appear on all screens at a time, as managed by the video conference or a split-screen technique could be used.

A third variant of video conversational service is video surveillance. This is not a distribution service, because the information delivery is limited to a specific intended subscriber. This form of service can be unidirectional; if the information is simple video images generated by a fixed camera, then the information flow is only from video source to subscriber. A reverse flow would come into play if the user had control over the camera (change orientation, zoom, etc.). The final example listed in the table is video/audio information transmission service. This is essentially the same capability as video telephony. The difference is that a higher-quality image may be required. For example, computer animation that represents a detailed engineering design may require much higher resolution than ordinary human-to human conversation.

Another type of conversational service is for data. In this context, the term data means arbitrary information whose structure is not visible to ISDN. Example of applications that would use this service include the following:

- File transfer in a distributed architecture of computer and storage systems (load sharing, back-up systems, decentralized databases, etc.)
- Large-volume or high-speed transmission of measured values or control information
- Program downloading
- Computer-aided design and manufacturing (CAD/CAM)
- Connection of local area networks (LANs) at different locations

Finally, there is a conversational transfer of documents. This could include very high resolution facsimile or the transfer of mixed documents that might include text, facsimile images, voice annotation, and/or a video component. Two types applications are likely here: a document-transfer service for the exchange of documents between users at workstations and a document storage system, based on the document-transfer service, which provides document servers for the filing, update and access of documents by a community of users.

Messaging Services

Messaging services offer user-to-user communication between individual users via storage units with store-and-forward, mailbox, and/or message-handling (e.g., information editing, processing, and conversion) functions. In contrast to conversational services, messaging services are not in real time. Hence, they place lesser demands on the network and do not require that both users be available at the same time. Analogous narrowband services are X.400 and teletex.

One new form of messaging service that could be supported by ISDN is video mail, analogous to today's electronic mail (text/graphic mail), and voice mail. Just as electronic mail replaces the mailing of a letter, so video mail replaces mailing a video cassette. This may become one of the most powerful and useful forms of message communication. Similarly, a document mail service allows the transmission of mixed documents, containing text, graphics, voice, and/or video components.

Retrieval Services

Retrieval services provide the user with the capability to retrieve information stored in information centers that is, in general. available for public use. This information is sent to the user on demand only. The information can be retrieved on an individual basis; that is, the time at which an information sequence is to start is under the control of the user.

An analogous narrowband service is Videotex. This is an interactive system designed to service both home and business needs. It is a general-purpose database retrieval system that can use the public switched telephone network or an interactive metropolitan cable TV system. Figure 4.2 depicts a typical system. The Video-tex provider maintains a variety of databases on a central computer. Some of these are public databases provided by the Videotex system. Others are vendor-supplied services, such as a stock market advisory. Information is provided in the form of pages of text and simple graphics.

Broadband videotex is an enhancement of the existing Videotex system [SUGI88]. The user would be able to select sound passages, high-resolution images of TV standard, and short video scenes, in addition to the current text and simplified graphics. Examples of broadband videotex services include the following:

- Retrieval of encyclopedia entries
- Results of quality tests on consumer goods
- Computer-supported audiovisual entries
- Electronic mail-order catalogs and travel brochures with the option of placing a direct order or making

Another retrieval service is video retrieval. With this service, a user could order full-length films or videos from a film/video library facility. Because the provider may have to satisfy many requests, bandwidth considerations dictate that only a small number of different video transmissions can be supported at any one time. A realistic service would offer perhaps 500 movies/videos for each two-hour period. Using a 50-Mbps video channel, this would require a manageable 25-Gbps transmission capacity from video suppliers to distribution points. The user would be informed by the provider at what time the film will be available to be viewed or transmitted to the subscriber's video recorder.

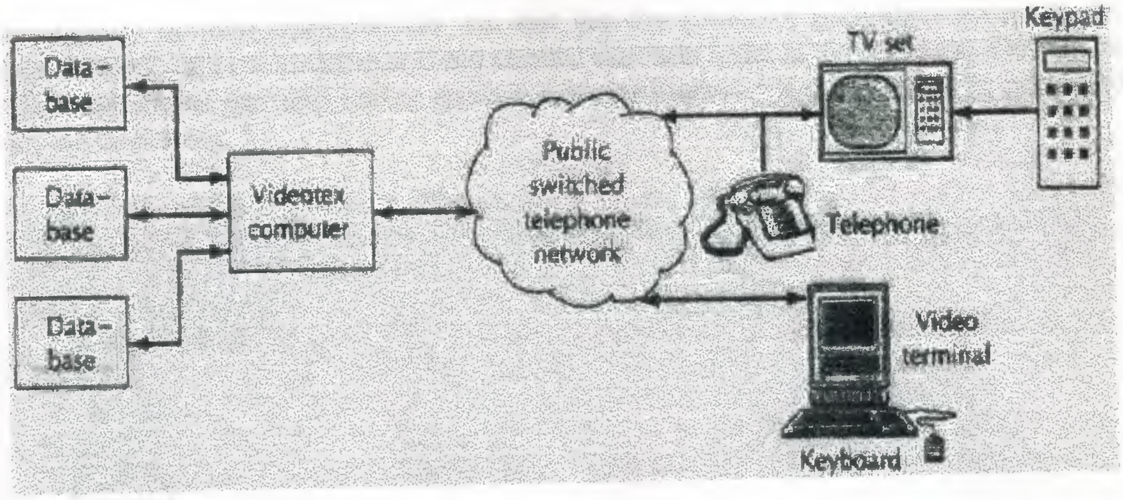


Figure 4.2 A Typical Videotex System.

Of greater interest to business, educational, and medical organizations, the envisioned broadband retrieval service would also allow the retrieval of high-resolution images such as X-ray or computerized axial tomography (CAT) scans, mixed-media documents, and large data files. This service could also be used for remote education and training.

Distribution Services without User Presentation Control

Services in this category are also referred to as broadcast services. They provide a continuous flow of information, which is distributed from a central source to an unlimited number of authorized receivers connected to the network. Each user can access this flow of information but has no control over it. In particular, the user cannot control the starting time or order of the presentation of the broadcasted information. All users simply tap into the flow of information.

The most common example of this service is broadcast television. Currently, broadcast television is available from network broadcast via radio waves and through cable television distribution systems. With the capacities planned for B-ISDN this service can be integrated with the other telecommunications services. In addition, higher resolutions can now be achieved, and it is anticipated that these higher-quality services will also be available via B-ISDN.

An example of a nonvideo service is an electronic newspaper broadcast service. This would permit the transmission of facsimile images of newspaper pages to subscribers who had paid for the service.

Distribution Services with User Presentation Control

Services in this class also distribute information from a central source to a large number of users. However, the inforrnation is provided as a sequence of information entities (e.g., frames) with cyclical repetition. So the user has the ability of individual access to the cyclical distributed information and can control start and order of presentation. Due to the cyclical repetition, the information entities, selected by the user, will always be presented from the beginning.

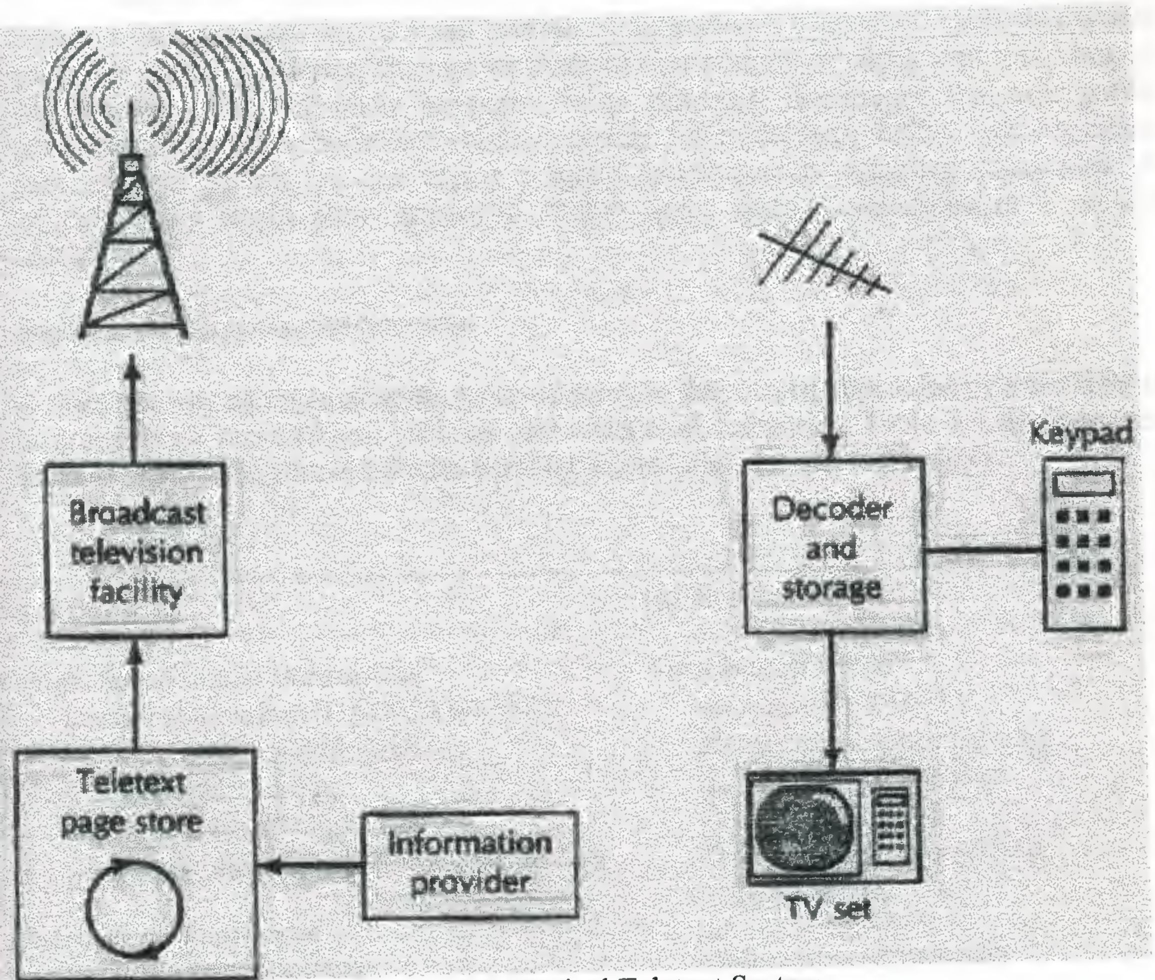


Figure 4.3 A Typical Teletext System.

An analogous narrowband service is Teletext, which is depicted in Figure 4.3 Teletext is a simple one-way system that uses unallocated portions of the bandwidth of a broadcast TV signal. At the transmission end, a fixed set of pages of text is sent repeatedly in round-robin fashion. The receiver consists of a special decoder and storage unit, a keypad for user entry, and an ordinary TV set. The user keys in the number of the page desired. The decoder reads that page from the incoming signal. stores it, and displays it continuously until instructed to do otherwise. Typically, pages of Teletext form a tree pattern, with higher-level pages containing menus that guide the selection of lower-level pages. Thus, although the system appears interactive to the user, it is actually a one-way broadcast of information. Because only a small portion of the TV' signal bandwidth is used for this purpose, the number of pages is limited by a desire to reduce access time. A typical system will support a few hundred pages with a cycle time of a few tens of seconds.

Teletext is oriented primarily to the home market, with different sets of pages offered on different channels. Examples of information presented by such a system are stock market reports, weather reports, news, leisure information, and recipes.

With B-ISDN, an enhancement to Teletext known as cabletext can be provided. Whereas Teletext uses only a small portion of an analog TV channel. cable-text would use a full digital broadband channel for cyclical transmission of pages with text, images, and possible video and audio passages. As an electronic newspa-per that uses public networks, or as an in-house information system for trade fairs, hotels, and hospitals, cabletext will provide low-cost access to timely and frequently requested information. A typical system might allow access to 10,000 pages with a cycle time of 1 second [ARMB87].

Business and Residential Services

A different way of organizing the types of services that can be supported by a B-ISDN is to group those services into business and residential categories. Table 4.4 lists services that are likely to be supported with B-ISDN and its related ATM teclmology.

(a) Business	(b) Residential
High-Speed Image Networking	Distribution Video
-Design automation (CAD/CAM/CAE)	-Broadcast TV/HDTV
-Medical imaging/consultation	-Broadcast distance learning
-Photographic editing	-Enhanced pay-per-view
-Scientific visualization	-Video-on-demand
-High-resolution graphics/image rendering	-Video catalog/advertising
	-Teleshopping
Interactive Multimedia	
-Interactive teletraining	Interactive Multimedia
-Work-at-home/telecommuting	-Multimedia electronic mail
-Executive (desktop) teleconferencing	-Multimedia 700,800& 900 services
-Print/publishing collaboration	-Sports event simulcasting/telewagering
-Subject-matter-expert consultation	-Interactive distance learning
-Virtual reality	-Multimedia videotext/"Yellow Pages"
-Multimedia telephony	-Interactive TV/games
	-Multimedia telephony & virtual reality
Wide Area Network Distributed Computing	
-LAN backbone/interconnect	
-Host-to-host channel networking	
-Disaster recovery/information vaulting	
-Load sharing	

Table 4.4 Applications Having Good Prospects for Broadband ATM-Based Services [DEMA93]

In the business world, the changes both in organizational structure and in the degree of reliance on high-capacity, high-speed networked computing sugges an increasing demand for high-capacity broadband communications. In particular, in many organizations, some or all of the following factors will come into play:

- Increasing use of applications involving high volumes of data, including high-resolution graphics and image processing
- A distributed client/server architecture, with communication across an internet
- Increasing reliance on multiple-LAN, multiple-site configuration

In the residential category, nonbusiness consumers want more advanced telecommunications services that build on their familiarity with telephone and cable TV services. Entertainment and "useful" applications, at the right price, will dominate this market.

4.3 REQUIREMENT

To get some sense of what is required for a broadband ISDN, we need to look at the requirements it must satisfy. As a first step, the B-ISDN services presented in Section 4.2 provide a qualitative description of requirements. To decide on the transmission structure, we need some ideas of the data rate requirements of the subscriber. Figure 4.4 provides an estimate. As can be seen, the potential range of data rates is wide. The figure also gives estimated durations of calls. which is also a factor in network design.

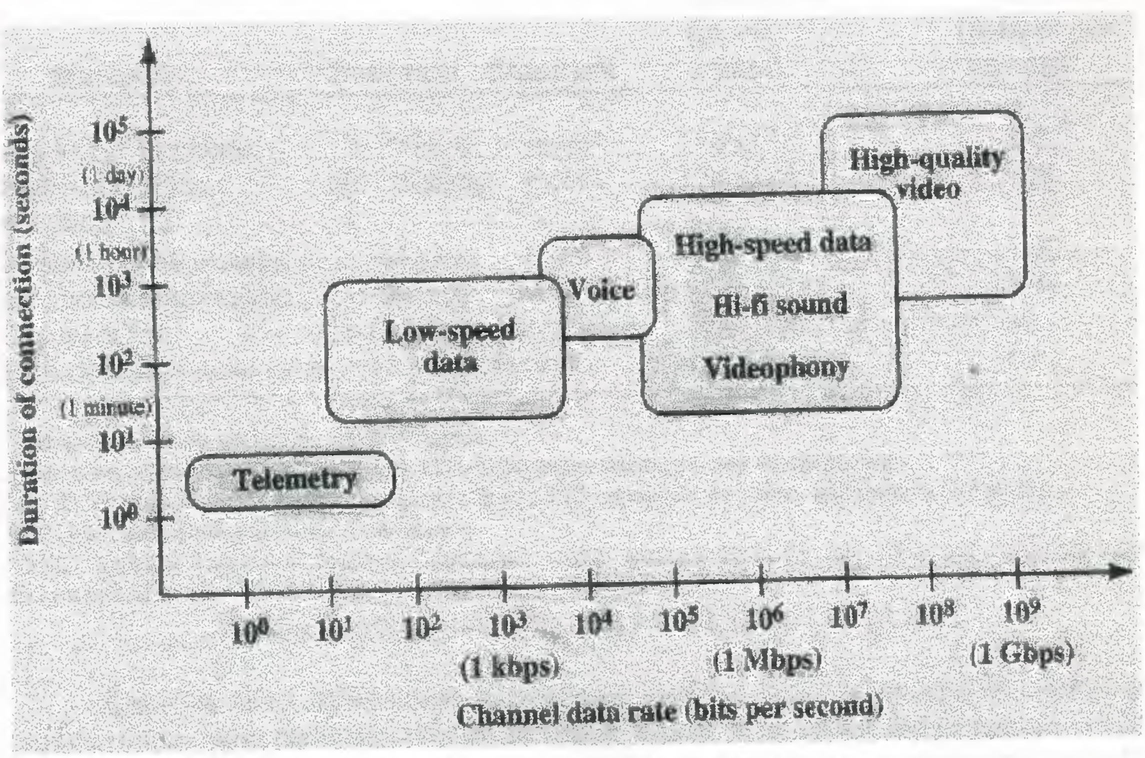


Figure 4.4 Data Rate and Duration of Potential B-ISDN Services [PRYC93b].

Another estimate of data rate requirements is shown in Table 4.5. Note that the values here differ from those in Figure 4.4. In both cases, the numbers can only be estimates for the projected services, and the differences point out the uncertainty in planning that will face B-ISDN designers. The column labeled CBR/VBR refers to whether support for this service requires a constant-bit-rate or a variable-bit-rate transmission facility. The table also includes the useful parameter of burst ratio, the ratio of the time for which the channel is occupied to the time during which information is sent. This quantity provides guidance on the type of switching technology (circuit switching versus packet switching) appropriate for B-ISDN. The last two columns in the table deal with error and delay characteristics when ATVM cell transmission is used.

It is worth elaborating briefly on the data rate requirements for video transmission, because it is video that will drive the overall data rate requirement. The transmission of an analog video signal requires on the order of 6 MHz bandwidth. Using straightforward digitization techniques, the data rate required for diaital video transmission can be as much as 1 Gbps. This is clearly too high even for a network based on optical fiber and high-speed switches. Two complementary approaches are used to reduce bit rate requirements:

- Use data-compression techniques that remove redundancy or unnecessary information.
- Allow for distortions that are least objectionable to the human eye.

Market	Data rate	Standard	Resolution (pixels x lines)	Frame rate (frames per second)
Analog videophone	5-10 kbps	none*	170 x128	2-5
Basic-rate video telephony	56-128 kbps	Px64	176 x144	5-10
Business conferencing	≥ 384 kbps	Px64	352 x 288	15-30
Interactive multimedia	1-2Mbps	MPEG	up to 352x288	15-30
Digital NTSC	3-10 Mbps	NTSC	720 x 480	30
Hith-definition television	> 15 Mbps	FCC	1200 x 800	60

* Several standards initiatives are in progress.
Px64: a set of standards established by ITU-T for video telephony and conferencing
MPEG: Motion Picture Experts Group. which sets ISO standards for video, particularly CD-ROM
FCC: Federal Communications Commission
NTSC: National Television Svstems Committee, which sets standards for television and video playback and recording in the United States.

Table 4.6 Applications of Compressed Video [ACKL93]

Knowing what information is necessary and the types of acceptable distortion requires an in-depth understanding of the image source to be coded and of human vision. With this knowledge, one can apply various coding techniques and engineering tradeoffs to achieve the best image possible.

Service Type	Service Category	Bandwidth Range	CBR/ VBR	Burst Lengths	Burst Ratio	Cell Loss Tolerance	Cell Delay Tolerance
Voice	PCM voice	64 kbps	CBR	1	N/A	10□□ to 10□□	10-150 ms
	ADPCM voice	32 kbps	CBR	1	N/A	10□□ to 10□□	10-150 ms
	Predictive coding	16 kbps	VBR	5-15	2-3 KB	10□□ to10□□	10-150 ms
	High-quality voice	192-384 kbps	CBR	1	N/A	10□□ to 10□□	10-150 ms
	Voice mail	16-64 kbps	CBR/ VBR	1-3	N/A	10□□	500 ms-5s
	CD-quality voice	1.4 Mbps	CBR	1	N/A	10□□	500 ms-25s
	Video telecon-ferencing/voice part	64-192 kbps	CBR	1	N/A	10□□ to 10□□	10-150 ms
Data	LAN interconnection	1.5-100Mbps	BR	vary	100-1000B	10□¹²	10-100 ms
	Host-host file transfer	64kbps-1.5mbps	VBR	1	12KB-10MB	10□¹²	1-500 s
	PC file transfer	9.6-64 kbps	VBR	1	1KB-1MB	10□□	10-100s
	Client/server system	10-100Mbps	VBR	1000	1-500KB	10□□	10-500ms
	Remote database access	1-10Mbps	VBR	1000	100B-100KB	10□□	1m-10s
	Remote procedure call	6-60Mbps	VBR	15-20	60-1000 B	10□□	100µs-100ms
	Electronic mail	9.6kbps-1.5Mbps	CBR	1	50-5000B	10□□	1-10s
	Workstation CAD/CAM	64kbps-1.5Mbps	VBR	5	40-100KB	10□□	1-10s
	Mainframe CAD/CAM	1.5-36Mbps	VBR	10-100	100KB-1MB	10□□	10-60 s
	Transaction processing	64kbps-5Mbps	VBR	40	100-300B	10□□	1.3 s
	Time sharing	2.4-64kbps	VBR	30-100	20-4000 B	10□□	100ms-10s
Video	Video telephony	64 kbps-2Mbps	CBR/VBR	2-5	2-10 KB	10□□	150-350ms
	Videoconferencing	128 kbps-14Mbps	CBR/VBR	2-5	1.6-40 KB	10□□	150-350 ms
	Video/image mail	1-4 Mbps	CBR	1	64 KB-1 MB	10□¹□	1-5 s
	Broadband videotex	64 kbps-10Mbps	VBR	10	>1MB	10□□to10□¹□	0.1-2s
	NTSC-quality TV	15-44 Mbps	VBR	2-5	0.5-1.3 MB	10□¹□	40 ms
	HDTV-quality TV	150 Mbps	VBR	2-5	5-14MB	10□¹²	40 ms
	Video browsing	2-40 Mbps	CBR	1	0.5-40 MB	10□□	0.1-2 s
	Group 4 fax (400 x 400)	64kbps	CBR	1	256-640KB	10□□	4-10 s
	Medical X-ray (14 x 17 in)	1.5-10 Mbps	CBR/ VBR	25	5-8 MB	10□¹²	2s
	Medical MRI/ CAT scan	10-200Mbps	CBR/ VBR	25	250kb-3 MB	10□¹²	2s
	High-resolution Graphics	100 Mbps-10Gbps	VBR	25	1-100 MB	10□¹²	10-500 ms

Table 4.5 Characteristics of Various Traffic Types [DUBO92]

What is acceptable image quality and data rate is a function of application. For example, videophone and videoconferencing require both transmission and reception. To limit the engineering requirements at the subscriber site, we would like to limit drastically the video transmission data rate. Fortunately, in the case of video-phone, the resolution required, especially for residential applications, is modest, and in the case of both videoconference and videophone, the rate of change of the picture is generally low. This latter property can be exploited with interframe redundancy-compression techniques, as opposed to merely intraframe compression techniques used in systems such as facsimile.

Table 4.6 indicates the relationship between the quality of the video image and the data rate required. At the low end of the spectrum is the use of ordinary analog telephone lines to support video transmission. The compressed-video data rate is limited to about 10 kbps in turn limiting picture resolution and frame rate, thereby limiting picture quality.

The first four categories are often referred to as low-bit-rate encoding systems, which are defined as systems that transmit at data rates of about 2 Mbps or less [HASK87]. For business conferencing and interactive multimedia, there is reduced resolution compared with broadcast television and reduced ability to track movement: In general. this produces acceptable quality. However, if there is rapid movement in the scene being televised. this will appear as jerky, discontinuous movement on the viewer's screen. Furthermore, if there is a desire to transmit a high-resolution graphics image (e.g., during a presentation at a videoconference), then the resolution on the screen may be inadequate. To overcome this latter problem. the transmitter should be capable of switching between a full-motion, lower-resolution transmission and a freeze-frame, higher-resolution transmission at the same data rate.

At present, a data rate of 64 kbps produces a noticeably inferior picture. This data rate may be acceptable for videophone. However, the distinction among the first four categories may disappear as advances in coding technology continue. Digital NTSC coding corresponds to quality of analog broadcast television today.

Finally, the highest-quality standard is known as high-definition television (HDTV). This system is comparable in resolution with 35-mm film projection and will put the quality of TV reception in the home and office at the level of the cinema. With HDTV, not only is the resolution greater, but the system will suppon wider screens, more along the lines of cinema screens in height-width ratio.

Table 4.6 provides a rather large range of data rates within most of the cate-gories. This is for two reasons. First, the technology of digital video coding is evolving rapidly, and this table attempts to predict the rates needed. Second, a distinction is made between two types of signals:

- Contribution, where the signal is transferred between studios and is subject to postproduction studio processing.
- Distribution, where the signal is distributed for viewing and is not subject to such processing.

Generally, a higher degree of compression can be applied for distribution than for contribution signals.

The estimates in Figure 4.4 show that broadband services require the network to handle a wide range of call types, from those with short holding times (e.g., file transfer) to those with long holding times (e.g., distributive services), at a wide range of data rates. Also, it is to be expected that many of these services will show the same busy-hour characteristics of narrowband ISDN services, with peaks during business hours.

4.4 ARCHITECTURE

The B-ISDN will differ from a narrowband ISDN in a number of ways. To meet the requirements for high-resolution video, an upper channel rate of about 150 Mbps will be needed. To support one or more interactive and distributive services simultaneously, a total subscriber line rate of about 600 Mbps is needed. In terms of today's installed telephone plant, this is a stupendous data rate to sustain. The most appropriate technology for widespread support of such data rates is optical fiber Hence, the introduction of B-ISDN depends on the pace of introduction of fiber subscriber loops.

1. Asynchronous transfer mode (ATM) is the transfer mode for implementing B-ISDN and is independent of the means of transport at the physical layer.
2. B-ISDN supports switched, semipermanent, and permanent point-to-point and point-to-multipoint connections, and provides on demand reserved and permanent services. Connections in B-ISDN support both circuit-mode and packet-mode services of a mono- and/or multimedia type and of a connectionless or connection-oriented nature and in a bidirectional or unidirectional configuration.
3. The B-ISDN architecture is detailed in functional terms and is therefore. technology- and implementation-independent.
4. A B-ISDN will contain intelligent capabilities for the purpose of providing advanced service characteristics and supporting powefful operation and maintenance tools, network control. and management. Further inclusion of additional intelligent features has to be considered in an overall context and may be allocated to different network/terminal elements.
5. Since the B-ISDN is based on overall ISDN concepts, the ISDN access reference configuration is also the basis for the B-ISDN access reference configuration.
6. A layered structure approach. as used in established ISDN protocols. is also appropriate for similar studies in B-ISDN. This approach should be used for studies on other overall aspects of B-ISDN, including information transfer, control, intelligence. and management.
7. Any expression of network capabilities or change in network performance parameters will not degrade the quality of service of existing services.
8. The evolution of B-ISDN should ensure the continued support of existing interfaces and services.
9. New network capabilities will be incorporated into B-ISDN in evolutionary steps to meet new user requirements and accommodate advances in network developments and progress in technology.
10. It is recognised that B-ISDN may be implemented in a variety of ways according to specific national situations.

Table 4.7 Principles of B-ISDN (I.121)

Table 4.7, taken from recommendation I.121, lists the principles of B-ISDN and is suggestive of its architecture.

Internal to the network, there is the issue of the switching technique to be used. The switching facility will have to be capable of handling a wide range of different bit rates and traffic parameters (e.g., burstiness). Despite the increasing power of digital circuit-switching hardware and the increasing use of optical fiber trunking, it may be difficult to handle the large and diverse requirements of B-ISDN with circuit-switching technology. For this reason, there is increasing interest in fast packet switching as the basic switching technique for B-ISDN. This form of switching readily supports the user-network interface protocol known as asynchronous transfer mode (ATM).

Functional Architecture

Figure 4.5 depicts the functional architecture of B-ISDN. As with narrowband ISDN. control of B-ISDN is based on common-channel signaling. Within the network, an SS7, enhanced to support the expanded capabilities of a higher-speed network, will be used. Similarly, the user-network control signaling protocol will be an enhanced version of Q.931.

B-ISDN must of course support all of the 64-kbps transmission services, both circuit switching and packet switching, that are supported by narrowband ISDN. This protects the user's investment and facilitates migration from narrowband to broadband IS DN. In addition, broadband capabilities are provided for higher-data-rate transmission services. At the user-network interface, these capabilities will be provided with the connection-oriented asynchronous transfer mode (ATM) facility.

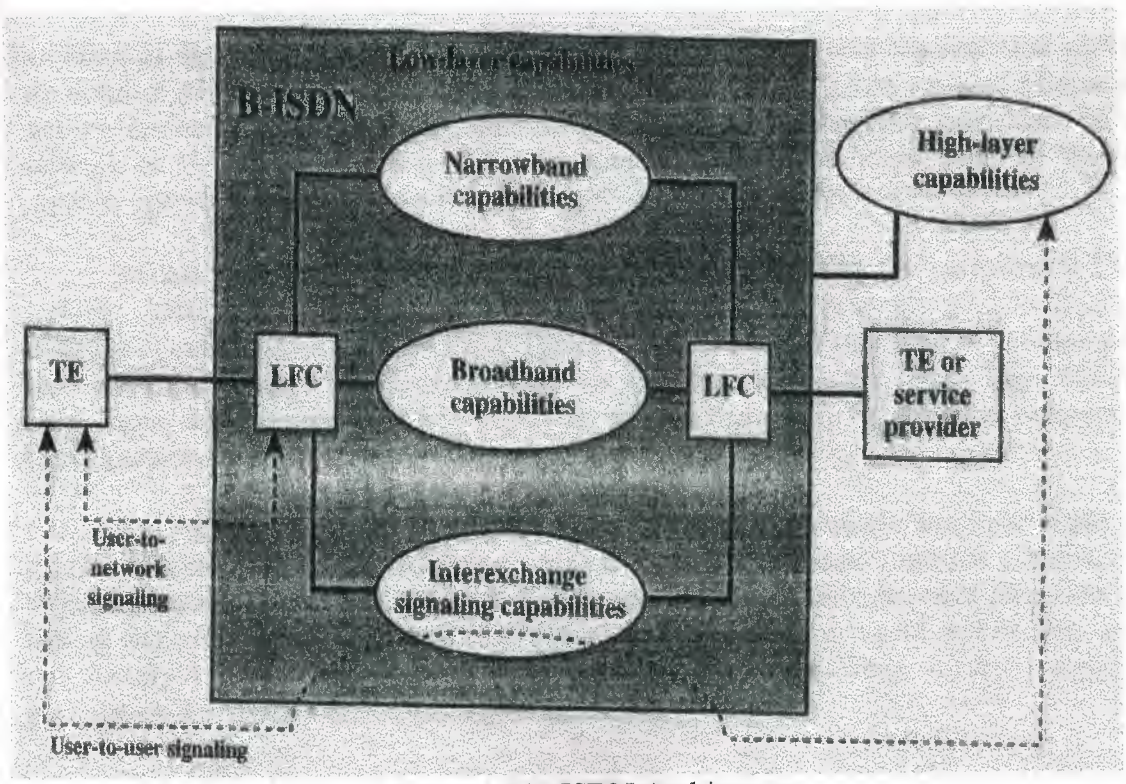


Figure 4.5 B-ISDN Architecture

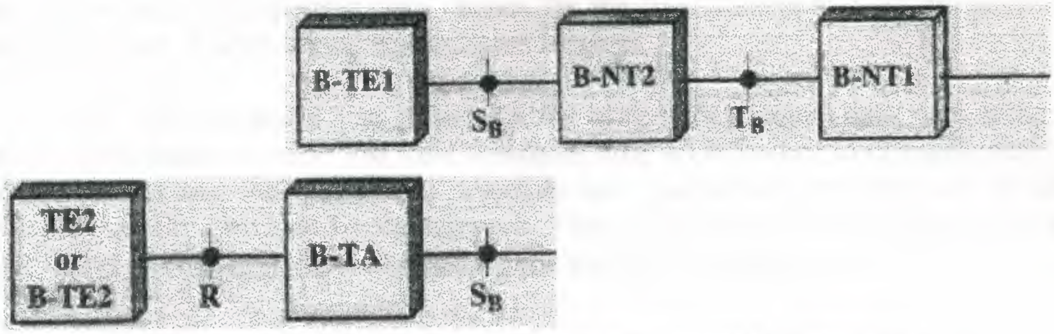


Figure 4.6 B-ISDN Reference Points and Functional Groupings.

User-Network Interface

Figure 4.7 is a general depiction of the B-ISDN user-access architecture. The local exchange to which subscribers attach must be able to handle both B-ISDN and ISDN subscribers. ISDN subscribers can be supported with twisted pair at the basic and primary access rates. For B-ISDN subscribers, optical fiber will be used. The data rate from network to subscriber will need to be on the order of 600 Mbps to handle multiple video distributions, such as might be required in an office environment. The data rate from subscriber to network would normally need to be much less, because the typical subscriber does not initiate distribution services. A rate of about 150 Mbps or less is probably adequate.

Transmission Structure

In terms of data rates available to B-ISDN subscribers, three new transmission services are defined. The first of these consists of a full-duplex 155.52-Mbps service. The second service defined is asymmetrical, providing transmission from the subscriber to the network at 155.52 Mbps and in the other direction at 622.08 Mbps. And the highest-capacity service yet defined is a full-duplex 622.08-Mbps service.

A data rate of 155.52 Mbps can certainly support all of the narrowband ISDN services. That is, it readily supports one or more basic or primary-rate interfaces. In addition, it can support most of the B-ISDN services. At that rate, one or several video channels can be supported, depending on the video resolution and the coding technique used. Thus, the full-duplex 155.52-Mbps service will probably be the most common B-ISDN service.

The higher data rate of 622.08 Mbps is needed to handle multiple video distribution, such as might be required when a business conducts multiple simultaneous videoconferences. This data rate makes sense in the network-to-subscriber direction. The typical subscriber will not initiate distribution services and thus would still be able to use the lower, 155.52-Mbps service. The full-duplex 622.08-Mbps service would be appropriate for a video distribution provider.

The 1988 document (1.121) discussed the need for a 150-Mbps and 600-Mbps data rate service. The specific rates chosen for the final standards were designed to be compatible with defined digital transmission services.

The 1988 document also included a list of specific channel data rates to be supported within these services. The final standards drop all reference to channel rates. This allows the user and the network to negotiate any channel capacity that can fit in the available capacity provided by the network. Thus, B-ISDN becomes considerably more flexible and can be tailored precisely to a wide variety of applications.

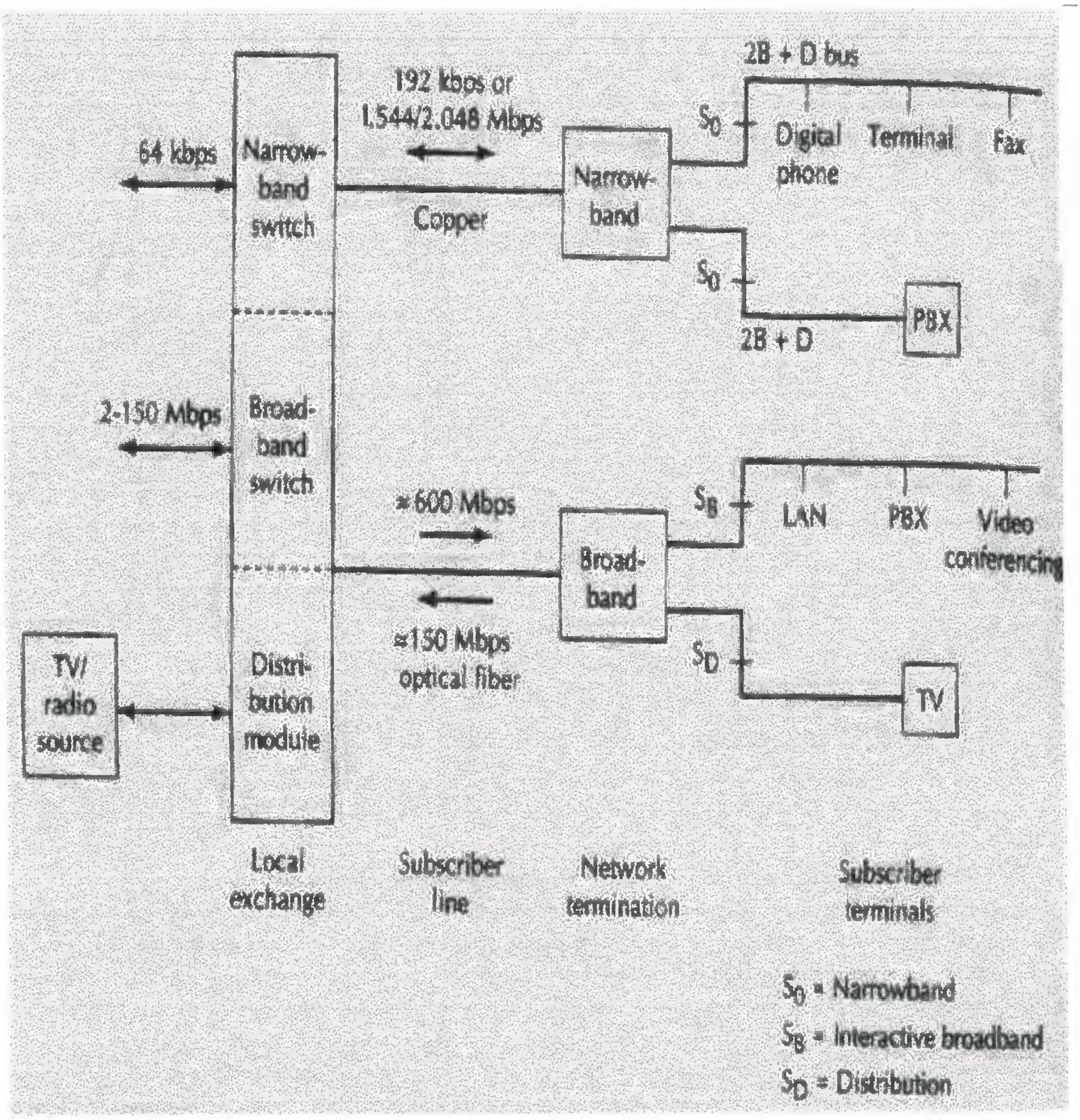


Figure 4.7 Block Diagram of B-ISDN User-Network Interface

.5 CONCLUSION

Although the development and deployment of ISDN is not yet complete, planners nd designers are already looking toward a much more revolutionary change in elecommunications: the broadband ISDN. Advances in terminal technology, optical fiber ransmission technology, and switching technology. together with a rising demand for nformation-rich services, are acceleratino the telecommunications environment through SDN to a B-ISDN before the end of the century. Just as the capacity of B-ISDN is everal orders of magnitude greater than ISDN, its impact will also be greater.

CHAPTER FIVE

BROADBAND PROTOCOLS

For B-ISDN, the transfer of information across the user-network inter-face uses asynchronous transfer mode (ATM). The ATM mechanism is embedded into a protocol reference model that defines the B-ISDN user-network interface. This chapter provides an overview of the BISDN protocol reference model and then looks at the underlying physical layer for B-ISDN, referred to as SONET (synchronous optical network) in the United States and as SDH (synchronous digital hierarchy) in ITU-T recommendations.

5.1 B-ISDN PROTOCOL REFERENCE MODEL

The protocol architecture for B-ISDN introduces some new elements not found in the ISDN architecture, as depicted in Figure 5.1. ATM is, in essence, a form of packet transmission across the user-network interface in the same way that X.25 is a form of packet transmission across the user-network interface. One difference between X.25 and ATM is that X.25 includes control signaling on the same channel as data transfer. whereas ATM makes use of common-channel signaling. Another difference is that X.25 packets may be of varying length, whereas ATM packets are of fixed size, referred to as cells.

The decision to use ATM for B-ISDN is a remarkable one. This implies that B-ISDN is a packet-based network, certainly at the interface and almost certainly in terms of its internal switching. Although the recommendation also states that B-ISDN will support circuit-mode applications, this is done over a packet-based transport mechanism. Thus, ISDN, which began as an evolution from the circuit-switching telephone networks, has transformed itself into a packet-switching network as it takes on broadband services.

Two layers of the B-ISDN protocol architecture relate to ATM functions. There is an ATM layer common to all services, which provides packet transfer capabilities, and an ATM adaptation layer (AAL), which is service dependent. The AAL maps higher-layer information into ATM cells to be transported over B-ISDN, and collects information from incoming ATM cells for delivery to higher layers. The use of ATM creates the need for an adaptation layer to support information-transfer protocols not based on ATM. Two examples listed in I.121 are PCM voice and LAPD. PCM voice is an application that produces a stream of bits. To employ this application over ATM, it is necessary to assemble PCM bits into cells for transmission and to read them out on reception in such a way as to produce a smooth, constant flow of bits to the receiver. For LAPD, it is necessary to map LAPD frames into ATM packets; this will probably mean segmenting one LAPD frame into a number of packets on transmission and reassembling the frame

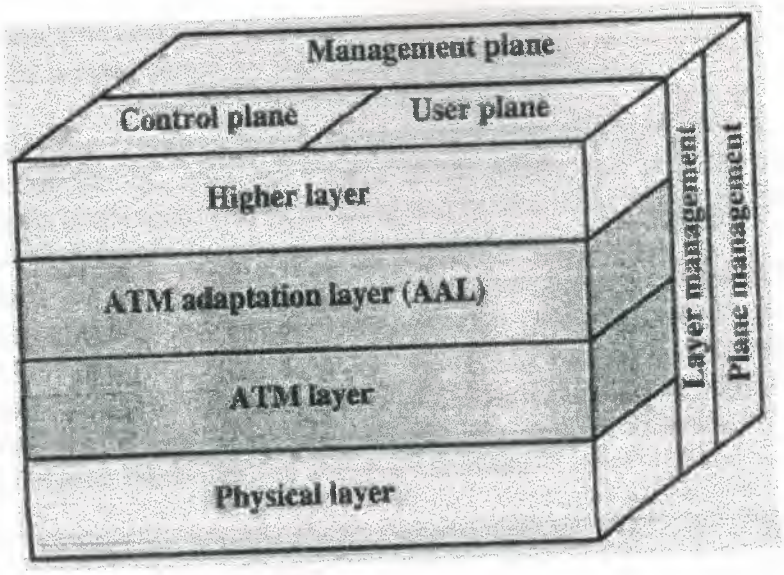


Figure 5.1 ATM PROTOCOL Architecture.

from packets on reception. By allowing the use of LAPD over ATM, all of the existing ISDN appli-cations and control-signaling protocols can be used on B-ISDN.

The protocol reference model makes reference to three separate planes:

- **User plane:** Provides for user information transfer, along with associated controls (e.g., flow control, error control).
- **Control plane:** Performs call control and connection control functions.
- **Management plane:** Includes plane management, which performs management functions related to a system as a whole and provides coordination between all the planes, and layer management, which performs management functions relating to resources and parameters residing in its protocol entities.

The B-ISDN standards include a description of functions to be performed, as illustrated in Table 5.1. Let us examine each of these briefly.

Physical Layer

The physical layer consists of two subtayers: the physical medium sublayer and the transmission convergence sublayer.

Physical Medium Sublayer

This sublayer includes only physical medium-dependent functions. Its specifi-cation will therefore depend on the medium used. One functon common to all medium types is bit timing. This sublayer is responsible for transmitting/receiving a continuous flowof bits with associated timing information to synchronize transmission and reception.

Transmission Convergence Sublayer

This sublayer is responsible for the following functions:

- **Transmission frame generation and recovery:** Transmission at the physical layer consists of frames, such as we saw in the basic- and primary-rate interfaces. This function is concerned with generating and maintaining the frame structure appropriate for a given data rate.
- **Transmission frame adaptation:** Information exchange at the ATM layer is a flow of ATM cells. This sublayer is responsible for packaging these cells into a frame. One option is to have no frame structure but simply to transmit and receive a flow of cells.
- **Cell delineation:** For transmission purposes, the bit flow may be scrambled. This sublayer is responsible for maintaining the cell boundaries so that cells may be recovered after descrambling at the destination.

<table>
<tr><td rowspan="6">Layer Management</td><td>Higher-Layer Functions</td><td colspan="2">Higher Layers</td></tr>
<tr><td>Convergence
Segmentation and reassembly</td><td>CS
SAR</td><td>AAL</td></tr>
<tr><td>Generic flow control
Cell header generation/extraction
Cell VPI/VCI translation
Cell multiplex and demultiplex</td><td colspan="2">ATM</td></tr>
<tr><td>Cell rate decoupling
HEC header sequence generation/verification
Cell delineation
Transmission frame adaptation
Transmission frame generation/recovery</td><td>TC</td><td rowspan="2">Physical layer</td></tr>
<tr><td>Bit timing
Physical medium</td><td>PM</td></tr>
</table>

CS = convergence sublayer
SAR = Segmentation and reassembly sublayer
AAL = ATM adaptation layer
ATM = Asynchronous transfer mode
TM = Transmission control sublayer
PM = Physical medium sublayer

Table 5.1 Functions of the B-ISDN Layers

- **HEC sequence generation and cell header verification:** Each cell header is protected by a header error-control (HEC) code. This sublayer is responsible for generating and checking this code.
- **Cell rate decotipling:** This includes insertion and suppression of idle cells to adapt the rate of valid ATM cells to the payload capacity of the transmission system.

ATM Layer

The ATM layer is independent of the physical medium. Here we give a brief description of its principal functions:

- **Cell multiltiplexing and demultiplexinig:** Multiple logical connections may be maintained across an interface, much like X.25 and frame relay.
- **Virtual path identifier (VPI) and virtual channel identifier (VCI) translation:**The VPI and VCI relate to logical connections and have local significance. Consequently, the values may need to be translated during switching.
- **Cell header generation/extraction:** In the transmit direction a call header is appended to user data from the AAL. All of the fields except the HEC code are generated. This function may also include translation from an address to a logical connection number (VPI and VCI).
- **Generic flow control:** This function generates flow-control information for placement in cell headers.

ATM Adaptation Layer

The ATM adaptation layer consists of two suplayer: the segmentation and reassembly sublayer. Here we give a brief description of its principal functions.

The segmentation and reassembly sublayer is responsible for the segmentation of higher-layer information intoa size suitable for the information field of an ATM cell on transmission and the reassembly of the contents of a sequence of ATMcell information fields into higher-layer information on reception.

The convergence sublayer is an interface specification. It defines the services that AAL provides to higher layers.

5.2 B-ISDN PHYSICAL LAYER

The B-ISDN physical layer is specified in I.432. The following options are provided in the standard:

- Full dublex at 155.52 Mbps in each direction
- Subscriber to network at 155.52 Mbps and network to subscriber at 622.08 Mbps
- Full dublex at 622.08 Mbps
- Full dublex at 51.84 Mbps
- Full dublex at 25.6 Mbps

In addition, the primary rates of 1.544 and 2.048 Mbps are supported.

A data rate of 155.52 Mbps can certainly support all of the narrowband ISDN services. That is, it readily supports one or more basic- or primary-rate interfaces. In addition, it can support most of the B-ISDN services. At that rate, one or several video channels can be supported, depending on the video resolution and the coding technique used. Thus, the full-duplex 155.52 Mbps service will probably be the most common B-ISDN service.

The higher data rate of 622.08 Mbps is needed to handle multiple video distribution, such as might be required when a business conducts multiple simultaneous videoconferences. This data rate makes sense in the network-to-subscriber direction. The typical subscriber will not initiate distribution services and thus would still be able to use the lower, 155.52-Mbps, service. The full-duplex 622.08-Mbps service would be appropriate for a video distribution provider.

The lower data rates of 51.84 and 25.6 Mbps were added in 1996 and 1997, respectively. These rates are intended to provide service for users who are not yet ready to move up to SDH data rates and/or do not require the higher speeds.

Table 5.2 summarizes some of the characteristics of the various options. Both electrical (copper) and optical fiber transmission media are considered. For the full-duplex 155.52-Mbps service, either coaxial cable or optical fiber may be used. The coaxial cable is to support connections up to a maximum distance of 100 to 200 m, using one cable for transmission in each direction.

Optical fiber for the full-duplex 155.52-Mbps service supports connections up to a maximum distance of 800 to 2000 m. The transmission medium consists of two single-mode fibers, one for each direction, according to Recommendation G.652.

For a service that includes the 622.08-Mbps rate in one or both directions, only the optical fiber medium has been specified, with the same characteristics as for the lower-speed interface. The use of coaxial cable is for further study.

Both the 51.98-Mbps and the 25.6-Mbps interfaces make use of twisted pair: unshielded twisted pair (UTP) for 51.84 Mbps and either UTP or shielded twisted pair (STP) for 25.6 Mbps. Thus, the interface may be able to take advantage of wiring already installed in the building.

Line Coding

1.432 includes a specification of the line coding technique to be used across the user-network interface for both the electrical and optical media. Keep in mind that this interface is on the customer premises. with relatively short distances between devices across the interface.

Electrical Interface

The line coding for the electrical interface at 155.52 Mbps is coded mark inversion (CMI). CMI uses two different voltage levels and obeys the following rules:

- For binary 0. there is always a positive transition at the midpoint of the binary unit time interval; thus, the signal is at the lower level for the first half of the bit time and at the higher level for the second half of the bit time.

UNI Data Rate	155.52 Mbps		622.08 Mbps*		51.84 Mbps	25.6 Mbps
Interface	Electrical	Optical interface	Electrical	Optical	Electrical	Electrical
Transmission Medium	Two coaxial cables	Two single-mode fibers	For further study	Two single-mode fibers	Two Category 3 UTP	Two Category 3 UTP or two STP
Line Coding	Coded mark inversion (CMI)	Nonreturn to zero (NRZ)	For further study	Nonreturn to zero (NRZ)	16-QAM	4B5B/NRZI
Maximum Distance	200 m	2 km	For further study	2 km	100 m	100 m
ATM Cell Transmission	Cell-based or SDH-based (STM-1)	Cell-based or SDH-based (STM-1)	For further study	Cell-based or SDH-based (STM-4)	Cell-based or SDH-based (STM-1)	Cell-based

*Includes asymmetrical interface with 622.08 Mbps in one direction and 155.52 Mbps in the other direction and symmetrical interface with 622.08 Mbps in both directions.

Table 5.2 B-ISDN Physical Layer Characteristics at User-Network Interface

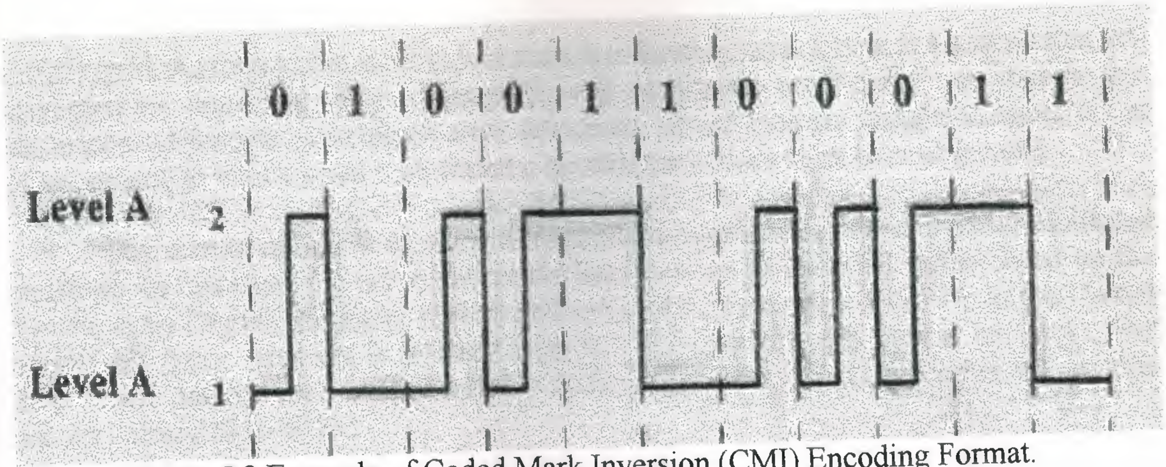


Figure 5.2 Example of Coded Mark Inversion (CMI) Encoding Format.

For binary 1, there is always a constant signal level for the duration of the bit time. This level alternates between high and low for successive binary is.

Figure 5.2 illustrates CMI. CMI has several advantages over a simple NRZ scheme.

1. If the high and low levels are positive and negative voltages of equal amplitude, then the signal has no DC component: Each 0 bit has both a high- and low-level portion, and 1 bits alternate between high and low levels. The lack of DC component improves spectrum characteristics and permits transformer coupling.
2. The frequent transitions make it easier to maintain synchronizanon between transmitter and receiver.

On the other hand, the signaling rate (baud rate) is higher than the bit rate, which requires greater bandwidth.

At 51.84 Mbps, the line coding scheme is 16-QAM; for a description of QAM. At 25.6 Mbps, the line coding scheme is 4BSB/NRZI.

Optical Interface

The line coding for the optical interface is referred to as nonreturn to zero (NRZ). In fact, it is a form of amplitude shift keying with the following rules:

- A binary l is represented by the emission of light.
- A binary 0 is represented by no emission of light.

Transniission Structure

A final important issue at the physical layer is the transmission structure to be used to multiplex ATM cells from various logical connections. 1.432 specifies two options.

The first of the two options is the use of a continuous stream of cells, with no multiplex frame structure imposed at the interface. Synchronization is on a cell-by-cell basis. That is, the receiver is responsible for assuring that it properly delineates cells on the 53-octet cell boundaries. This task is accomplished using the header error-control

(HEC) field. As long as the HEC calculation is indicating no errors, it is assumed that cell alignment is being properly maintained. An occasional error does not change this assumption. However, a string of error detections would indicate that the receiver is out of alignment, at which point it performs a hunting procedure to recover alignment.

The second option is to place the cells in a synchronous time-division multiplex envelope. In this case, the bit stream at the interface has an external frame based on the Synchronous Digital Hierarchy (SDH) defined in Recommendation G.707. In the United States, this frame structure is referred to as SONET (synchronous optical network). The SDH frame may be used exclusively for ATM cells or may also carry other bit streams not yet defined in B-ISDN.

5.3 SONET/SDH

SONET (synchronous optical network) is an optical transmission interface originally proposed by BellCore and standardized by ANSI. A compatible version, referred to as synchronous digital hierarchy (SDH), has been published by ITU-T in the 1996 Recommendation G.707.' SONET is intended to provide a specification for taking advantage of the high-speed digital transmission capability of optical fiber.

The SONET standard addresses the following specific issues:

1. Establishes a standard multiplexing format using any number of 51.84-Mbps signals as building blocks. Because each building block can carry a DS3 signal, a standard rate is defined for any high-bandwidth transmission system that might be developed.
2. Establishes an optical signal standard for interconnecting equipment from different suppliers.
3. Establishes extensive operations, administration, and maintenance (OAM) capabilities as part of the standard.
4. Defines a synchronous multiplexing format for carrying lower-level digital signals (DS1, DS2, ITU-T standards). The synchronous structure greatly simplifies the interface to digital switches, digital cross-connect switches, and add-drop multiplexers.
5. Establishes a flexible architecture capable of accommodating future applications, such as broadband ISDN, with a variety of transmission rates.

Three key requirements have driven the development of SONET. First was the need to push multiplexing standards beyond the existing DS-3 (44.736-MbPs) level. With the increasing use of optical transmission systems, a number of vendors have introduced their own proprietary schemes of combining anywhere from 2 to 12 DS-3s into an optical signal. In addition. the European schemes. based on the ITU-T hierarchy, are incompatible with North American schemes. SONET provides a standardized hierarchy of multiplexed digital transmission rates that accommodates existing North American and ITU-T rates.

A second requirement was to provide economic access to small amounts of traffic within the bulk payload of an optical signal. For this purpose. SONET introduces a new approach to time-division multiplexing. We address this issue subsequently when we examine the SONET frame format.

A third requirement is to prepare for future sophisticated service offerings, such as virtual private networking, time-of-day bandwidth allocation, and support of the broadband ISDN ATM transmission technique. To meet this requirement. a major increase in network management capabilities within the synchronous time-division signal was needed.

In this section, we provide an overview of SONET/SDH that shows how these requirements have been met.

Signal Hierarchy

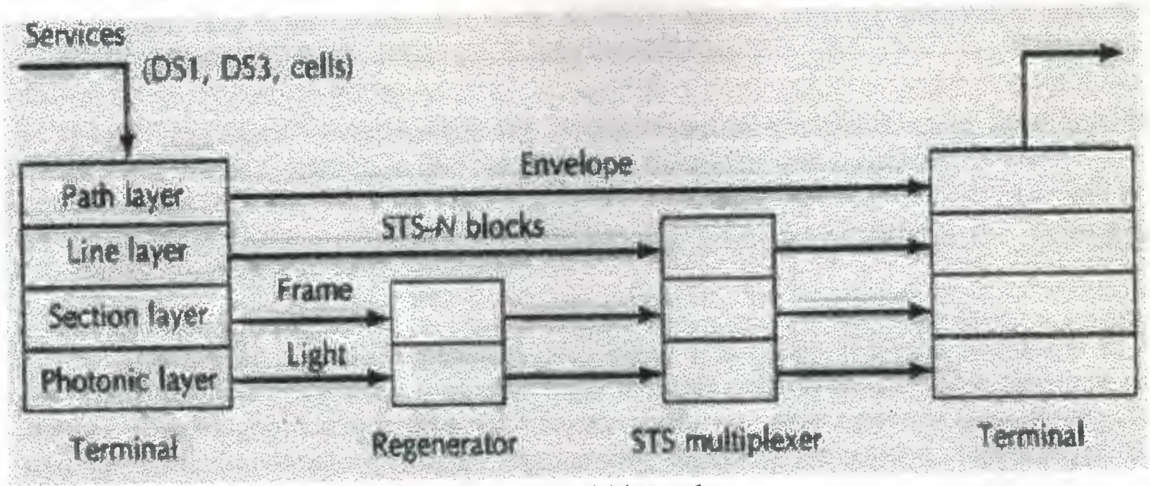
The SONET specification defines a hierarchy of standardized digital data rates (Table 5.3). The lowest level. referred to as STS-1 (synchronous transport signal level 1), is 51.84 Mbps. This rate can be used to carry a single DS-3 signal or a group of lower-rate signals, such as DS1, DS1 C, DS2, plus ITU-T rates (e.g., 2.048 Mbps).

Multiple STS-1 signals can be combined to form an STS-N signal. The signal is created by interleaving bytes from N STS-l signals that are mutually synchronized.

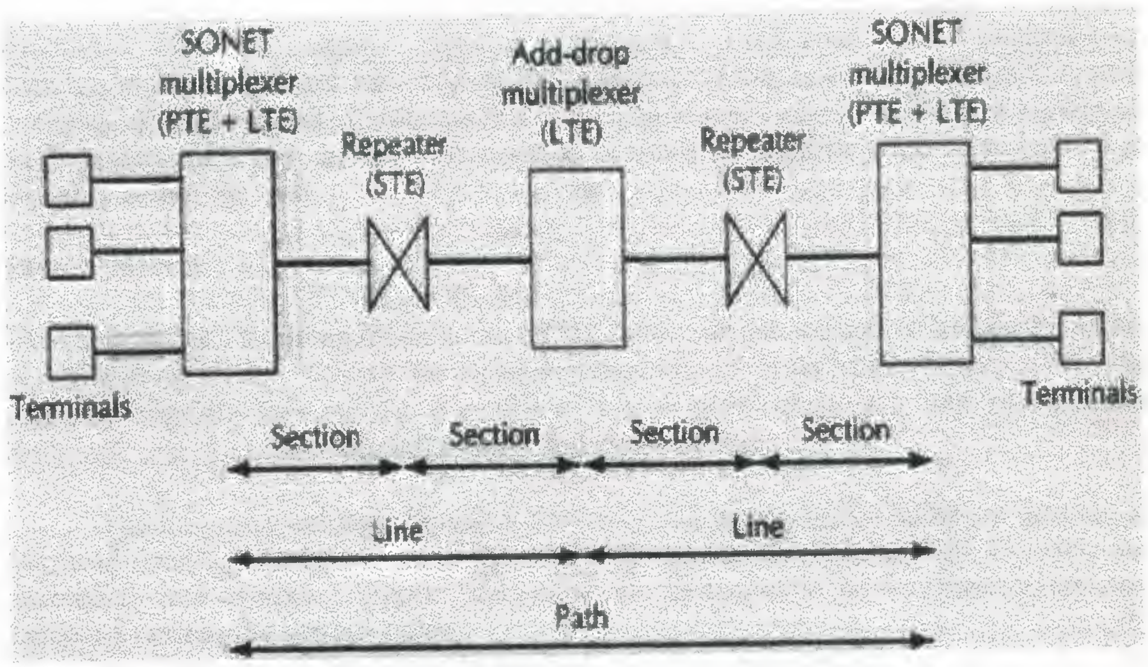
For the ITU-T synchronous digital hierarchy, the lowest rate is 155.52 Mbps. which is designated STM-1. This corresponds to SONET STS-3. The reason for the discrepancy is that STM-1 is the lowest-rate signal that can accommodate a ITU-T level 4 signal (139.264 Mbps).

SONET Designation	ITU-T Designation	Data Rate (Mbps)	Payload Rate (Mbps)
STS-1/OC-1		51.84	50.112
STS-3/OC-3	STM-1	155.52	150.336
STS-9/OC-9		466.56	451.008
STS-I2/OC-12	STM-4	622.08	601.344
STS-I8/OC-18		933.12	902.016
STS-24/OC-24		1244.16	1202.688
STS-36/0C-36		1866.24	1804.032
STS-48/O-C48	STM-16	2488.32	2405.376
STS-96/OC-96		4876.64	4810.752
STS-192/OC-192	STM-64	9953.28	9621.504

Table 5.3 SONETISDH Signal Hierarchy



(a)Logical hierarchy



(b) Physical hierarchy

Figure 5.3 SONET System Hierarchy.

System Hierarchy

SONET capabilities have been mapped into a four-layer hierarchy (Figure 5.3a):

- **Photonic:** This is the physical layer. It includes a specification of the type of optical fiber that may be used and details such as the required minimum powers and dispersion characteristics of the transmitting lasers and the required sensitivity of the receivers.

- **Section:** This layer creates the basic SONET frames, converts electronic signals to photonic ones, and has some monitoring capabilities.
- **Line:** This layer is responsible for synchronization, multiplexing of data onto the SONET frames, protection and maintenance functions, and switching.
- **Path:** This layer is responsible for end-to-end transport of data at the appropriate signaling speed.

Figure 5.3b shows the physical realization of the logical layers. A section is the basic physical building block and represents a single run of optical cable between two optical fiber transmitter/receivers. For shorter runs, the cable may run directly between two end units. For longer distances. regenerating repeaters are needed. The repeater is a simple device that accepts a digital stream of data on one side and regenerates and repeats each bit out the other side. Issues of synchronization and timing need to be addressed. A line is a sequence of one or more sections such that the internal signal or channel structure of the signal remains constant. Endpoints and intermediate switches/multiplexers that may add or drop channels terminate a line. Finally. a path connects to end terminals: it corresponds to an end-to-end circuit. Data are assembled at the beginning of a path and are not accessed or modified until they are disassembled at the other end of the path.

Frame Format

The basic SONET building block is the STS-1 frame, which consists of 810 octets and is transmitted once every 125 μ5, for an overall data rate of 51.84 Mbps (Figure 5.4a). The frame can logically be viewed as a matrtix of 9 rows of 90 octets each, with transmission being one row at a time, from left to right and top to bottom.

The first three columns (3 octets X 9 rows = 27 octets) of the frame are devoted to overhead octets. Nine octets are devoted to section-related overhead, and 18 octets are devoted to line overhead. Figure 5.5a shows the arrangement of overhead octets, and Table 5.4 defines the various fields.

The remainder of the frame is payload. which is provided by the path layer. The payload includes a column of path overhead. which is not necessarily in the first available column position; the line overhead contains a pointer that indicates where the path overhead starts. Figure 5.5b shows the arrangement of path overhead octets, and Table 5.4 defines these.

Figure 5.4b shows the general format for higher-rate frames, using the ITU-T designation.

Pointer Adjustment

In conventional circuit-switched networks, most multiplexers and telephone company channel banks require the demultiplexing and remultiplexing of the entire signal just to access a piece of information that is addressed to a node. For example, consider that T-1 multiplexer B receives data on a single T-1 circuit from T-1 multiplexer A and passes the data on to multiplexer C. In the signal received. a single DSO channel (64 kbps) is addressed to node B. The rest will pass on to node C and further on into the network. To remove that single DSO channel, B must demultiplex every bit of the 1.544-Mbps signal, remove the data, and remultiplex everv bit. A few proprietary T-1 multiplexers allow for drop-and-insert capability, meaning that only part of the signal has to be demultiplexed and remultiplexed. but this equipment will not communicate with that of other vendors.

SONET offers a standard drop-and-insert capability, and it applies not just to 64-kbps channels but to higher data rates as well. SONET makes use of a set of pointers that locate channels within a payload and the entire payload within a frame, so that information can be accessed, inserted, and removed with a simple adjustment of pointers. Pointer information is contained in the path overhead that refers to the multiplex structure

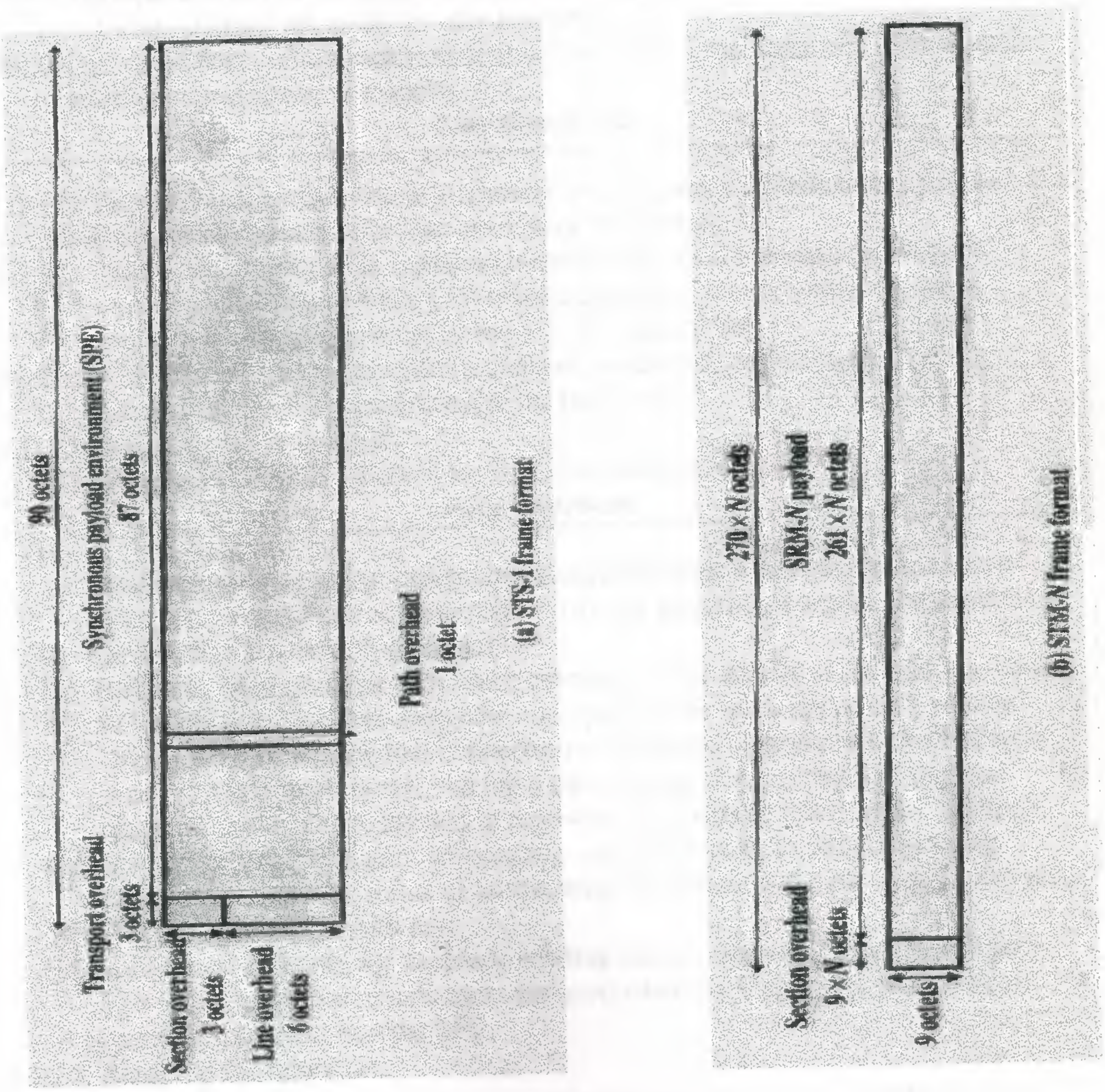


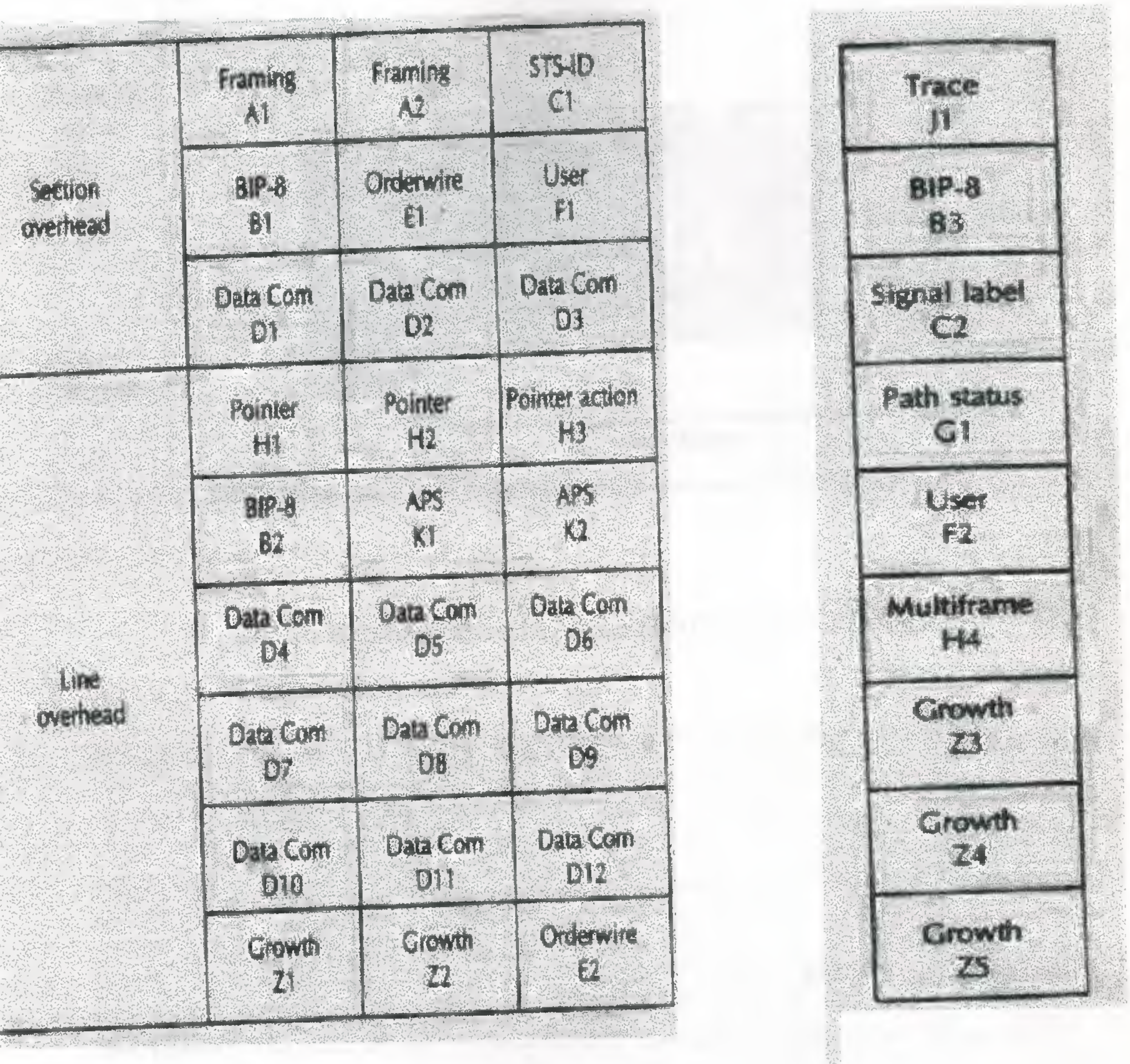
Figure 5.4 SONET/SDH Frame Formats.

of the channels contained within the payload. A pointer in the line overhead serves a similar function for the entire payload. We examine the use of this latter pointer in the remainder of this section.

Section Overhead	
A1, A2:	Framing bytes = F6.2S hex; used to synchronize the beginning of the frame.
C1:	STS-1 ID identifies the STS-1 number (1to N) for each STS-1 within an STS-N multiplex.
B1:	Bit-interleaved parity byte providing even parity over previous STS-N frame after scrambling; the *i*th bit of this octet contains the even parity value calculated from the *i*th bit position of all octets in the previous frame.
E1:	Section level 64-kbps PCM orderwire; optional 64 kbps voice channel to be used between section terminating equipment, hubs, and remote terminals.
F1:	64-kbps channel set aside for user purposes.
D1-D3:	192-kbps data communications channel for alarms, maintenance, control, and administration between sections.
Line Overhead	
H1-H3:	Pointer bytes used in frame alignment and frequency adjustment of payload data.
B2:	Bit-interleaved parity for line level error monitoring.
K1,K2:	Two bytes allocated for signaling between line level automatic protection switching equipment: uses a bit-oriented protocol that provides for error protection and management of the SONET optical link.
D4-D12:	576-kbps data communications channel for alarms, maintenance, control, Monitoring, and administration at the line level.
Z1, Z2:	Reserved for future use.
E2:	64-kbps PCM voice channel for line level orderwire.
Path Overhead	
J1:	64-kbps channel used to repetitively send a 64-octet fixed-length string so a receiving terminal can continuously verify the integrity of a path: the contents of the message are user programmable.
B3:	Bit-interleaved parity at path level, calculated over all bits of the previous SPE.
C2:	STS path signal label to designate equipped versus unequipped STS signals. Unequipped means the line connection is complete but there is no path data to send. For equipped signals, the label can indicate the specific STS payload mapping that might be needed in receiving terminals to interpret the payloads.
G1:	Status byte sent from path terminating equipment back to path originating equipment to convey status of terminating equipment and path error performance.
F2:	64-kbps channel for path user.
H4:	Multiframe indicator for payloads needing frames that are longer than a single STS frame: multiframe indicators are used when packing lower rate channels (virtual tributaries) into the SPE.
Z3-Z5:	Reserved for future use.

Table 5.4 STS-1 Overhead Bits

The synchronous payload environment (SPE) of an STS-1 frame can float with respect to the frame. The actual payload (87 columns x 9 rows) can straddle two frames (Figure 5.6). The HI and H2 octets in the line overhead indicate the start of the payload.



(a) Section overhead (b) Path overhead

Figure 5.5 SONET STS-1 Overhead Octets.

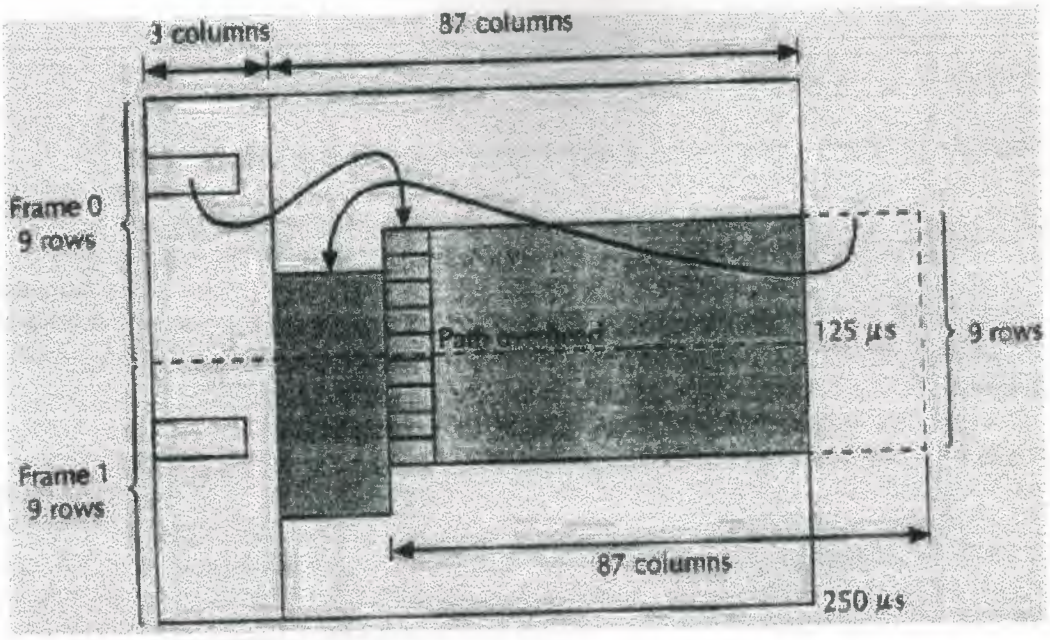
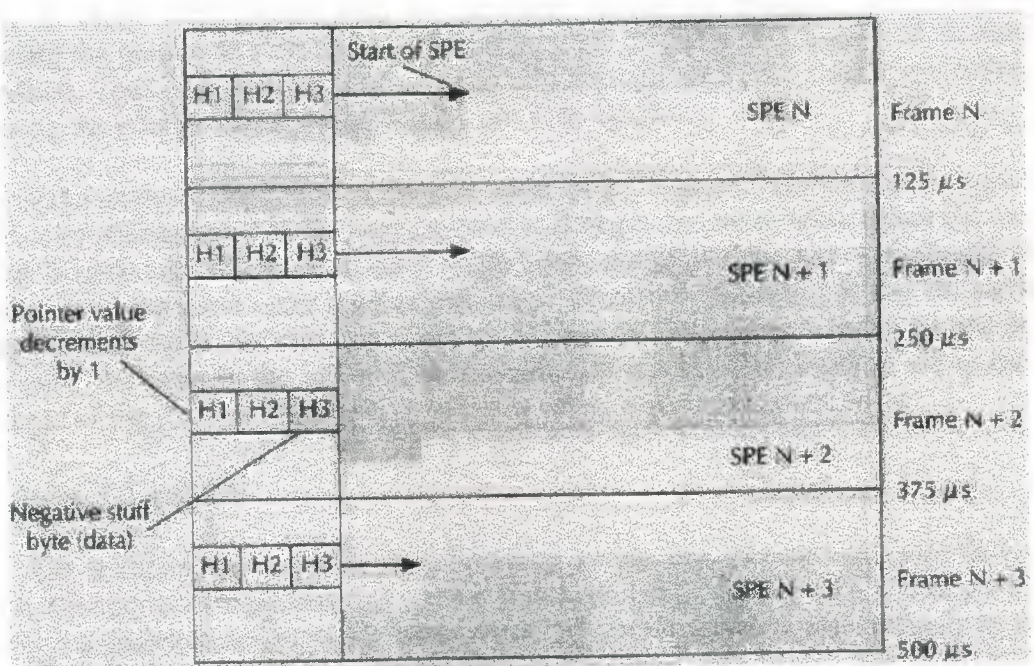
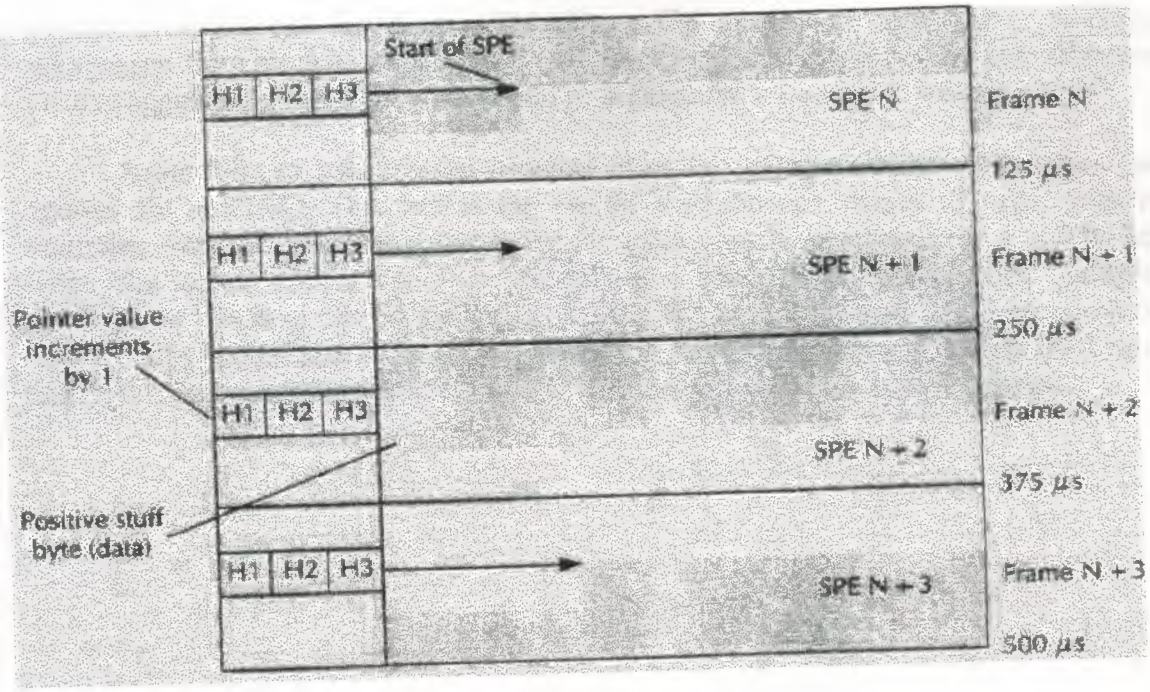


Figure 5.6 Representative Location of SPE in STS-1 Frame.



5.7 (a)Negative pointer adjustment



(b) Positive pointer adjustment
Figure 5.7 STS-1 Pointer Adjustment.

Because even the best atomic timing sources can differ by small amounts, SONET is faced with coping with the resulting timing differences. Each node must recalculate the pointer to alert the next receiving node of the exact location of the start of the payload. Thus, the payload is allowed to slip through an STS-1 frame, increasing or decreasing the pointer value at intervals by one byte position.

If the payload rate is higher than the local STS frame rate, the pointer is decreased by one octet position so that the next payload will begin one octet sooner than the earlier payload. To prevent the loss of an octet on the payload that is thus squeezed, the H3 octet is used to hold the extra octet for that one frame (Figure 5.7a). Similarly, if the payload rate lags behind the frame rate, the insertion of the next payload is delayed by one octet. In this case, the octet in the SPE that follows the H3 octet is left empty to allow for the movement of the payload (Figure 5.7b).

5.4 CONCLUSION

For B-ISDN, the transfer of information across the user-network interface uses what is referred to as asynchronous transfer mode (ATM). The use of ATM implies that B-ISDN is a packet-based network, certainly at the interface and almost certainly in terms of its internal switching. Although the recommendation also states that B-ISDN will support circuit-mode applications, this is done over a packet-based transport mechanism. Thus, ISDN, which began as an evolution from the circuit-switching telephone networks, has transformed itself into a packet-switching network as it takes on broadband services.

The use of ATM creates the need for an adaptation layer to support information transfer protocols not based on ATM. The ATM adaptation layer (AAL) packages information from the AAL user into 48-octet packages to fit into the ATM cell. This may involve aggregating bits from a bit stream or segmenting a frame into smaller pieces.

Some form of transmission structure must be used to transport ATM cells. Two options are specified. The first is the use of a continuous stream of cells, with no multiplex frame structure imposed at the interface. Synchronization is on a cell-by-cell basis. The second option is to place the cells in a synchronous time-division multiplex envelope. In this case, the bit stream at the interface has an external frame based on the Synchronous Digital Hierarchy (SDH) defined in Recommendation G.707. In the United States, this frame structure is referred to as SONET (synchronous optical network).

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