NEAR EAST UNIVERSITY

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BROADBAND ISDN (B-ISDN)

Graduation Project
EE 400

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LIST OF ABBREVIATIONS

AAL	ATM Adaptation Layer
ANSI	American National Standards Institute
ATM	Asynchronous transfer mode
B-ISDN	Broadband ISDN
Bellcore	Bell Communication Research
BRI	Basic rate interface
CCITT	International Telegraph and Telephone Consultative Committee [now Known as the ITU-T]
C.O.	Central office
CPE	Customer premises (or provided) equipment
CS	Convergence Sublayer (ATM)
DS-n	Digital Signal level n
DTE	Data terminal equipment
ET	Exchange termination
FCC	Federal Communications commission
HEC	Header Error Control field (ATM)
IDN	Integrated digital network
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
ITU	International Telecommunication Union
ITU-T	International Telecommunication Union-Telecommunication Standardization Sector [formerly the CCITT]
LAN	Local area network
LAPB	Link Access Procedures Balanced (X.25)
LAPD	Link Access Procedures on the D-channel (Q.920/I.440)
LE	Local exchange
LT	Local termination
MAN	Metropolitan area network
MPEG	Motion (or Moving) Pictures Experts Group
MSVC	Meta-signaling virtual channel (ATM)
N-ISDN	Narrowband ISDN

NT	Network termination
NT1	Network termination type1
NT2	Network termination type2
OAM	Operations, administration, and maintenance
OC-n	Optical Carrier level n (SONET)
OSI	Open Systems Interconnection reference model
PBX	Private branch exchange
PC	Personal computer
PCM	Pulse code modulation
PDU	Protocol data unit
PRI	Primary rate interface
PRM	Protocol Reference Model
PSPDN	Packet switched public data network
PSTN	Public switched telephone network
QoS	Quality of Service
s	Second
SAPI	Service Access Point Identifier (LAPD)
SAR	Segmentation and Reassembly Sublayer (ATM)
SDH	Synchronous Digital Hierarchy (ITU-T)
SONET	Synchronous Optical Network (ANSI/Bellcore)
SS7	Signaling System No.7
STM-n	Synchronous Transport Module level n (SDH)
SVC	Signaling virtual channel (ATM)
TA	Technical Advisory (Bellcore)
TDM	Time division multiplexing
UNI	User-Network Interface (ATM, FR)
VC	Virtual channel (ATM)
VCI	Virtual Channel Identifier (ATM)
VLSI	Very Large scale integration
VP	Virtual path (ATM)
VPI	Virtual Path Identifier (ATM)
WAN	Wide area network

ABSTRACT

An evolution is currently taking place in our telecommunication networks: the design development and implementation of ISDN. It is by no means a coincidence that the recent advances in electronics, communications and computer technologies have brought the telecommunications 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 successors, the Broadband ISDN (B-ISDN), will play a pivotal role in the achievement of this goal.

The concept of B-ISDN was originally defined in the late 1980s. It is a collection of technologies with ATM as the "cornerstone" which is expected to form a universal network. The B-ISDN is essentially characterized by the ability to convey all present and future types of information, at very high speeds, in a cost efficient manner. This is a contrast to the present situation, where a multitude of different networks coexists to provide services of different kinds.

So the aim of this project is the analysis, interpretation and clearly defines the conception and realization of B-ISDN, which can handle higher transmission speeds, can easily carry digitized video transmission along with the digitized voice and data in a good resolution.

CONTENTS

INTRODUCTION

B-ISDN is a service requiring transmission channels capable of supporting rates greater than the primary rate. Behind this statement lies the plane for a network and services that will have for impact on the world we know today, than ISDN ever world.

B-ISDN development can be justified and will be successful if it meets the needs of potential future customers. Therefore, a brief outline of foreseeable broadband applications will be given before entering into a discussion of network aspects.

So, this project is divided into five main chapters, every chapter is related to specific topic.

In the first chapter we will take a look on Integrated Service Digital Network (ISDN), about its principles, benefits, services, standards, term, definition and protocol architecture.

In the next chapter, an introduction to Broadband ISDN with its historical and background are provided.

In the subsequent chapter, the principles and building blocks of Broadband ISDN are described. In principle, B-ISDN should be suitable for both business and residential customers, so besides all sorts of data communication, TV program distribution and the provision of other entertainment facilities have to be considered.

In the fourth chapter, the concept of Broadband ISDN, networking techniques, signaling principles and its network performance are clarified.

In the last chapter, the Broadband ISDN user-network interfaces and protocols are described with the details explanations of the different layers that provided in Protocol Reference Model by CCITT recommendation, also this chapter deals with the two broad categories which are: interactive and distribution services.

Finally, this project will be going in a smooth manner, step by step, in order to give the reader a good idea about one of the powerful technologies and for reaching the purpose of this project.

1. INTEGRATED SERVICE DIGITAL NETWORK (ISDN)

1.1 INTRODUCTION

While you have heard of ISDN, there is a good chance you are unsure whether you need it or even what exactly it is. Even though ISDN is globally available, it is so new that understanding it may require a little investigation.

In simple terms, ISDN is a replacement for plain old telephone service, which was never designed to meet the needs of the information age. ISDN uses the same wiring that currently serves homes and businesses. You get ISDN service from the same companies who provide telephone service, and you use it to connect telephones, computers, and fax machines. The difference is that you get much faster, much more dependable connections for voice, data, fax, and even video- all through a single line. There is no other technology that comes close to delivering such communications benefits today.

International ISDN standards were established about 10 days years ago. Since then, telephone companies throughout the world have raced to upgrade their equipment to ISDN standards. As ISDN service available has spread, many millions of computer users have to turn to ISDN, and new users are coming on board even faster.

1.2 The Meaning of ISDN

ISDN stands for Integrated Services Digital Network.

"Integrated Services" refers to ISDN's ability to deliver two simultaneous connections, in any combination of data, voice, and fax, over a single line. Multiple devices can be attached to the line, and used as needed. That means an ISDN line can take care of most people's complete communications needs, without forcing the purchase of multiple analog phone lines at a much higher transmission rate.

The "Digital" in ISDN refers to its purely digital transmission, as opposed to the analog transmission of plain old telephone service. If you are using a modem for internet access at this moment, your internet service provider's modem has converted this site's digital content to analog signals before sending it to you, and your modem converts those signals back to digital when receiving(the same thing happens with every keystroke and mouse click you transmit). When you connect with ISDN, there is no analog conversion. ISDN transmits data digitally, resulting in a very clear transmission quality.

There is none of the static and noise of analog transmissions that can slow transmission speed.

"Network" refers to the fact that ISDN is not simply a point-to-point solution like a leased line.ISDN networks extend from the local telephone exchange to the remote user and include all of the telecommunications throughout the world to other ISDN equipment. If your ISDN equipment includes analog capabilities, you can also connect to analog modems, fax machines, and telephones, even though they may be connected to plain old telephone service.

1.3 Principles of ISDN

Standard for ISDN have been defined by ITU-T a topic that we explore later in this chapter. Let us look at each of these points in turn.

1. **Support of voice and non-voice applications using a limited set of standardized facilities:** This principle defines both the purpose of ISDN and the means of achieving it. The ISDN will support a variety of services related to voice communications (telephone calls) and non-voice communications (digital data exchange). These services are to be provided in conformance with standards (ITU-T recommendations) that specify a small number of interfaces and data transmission facilities. The benefit of standards will be explored later in this chapter. For now, we simply state that without such a limitation, a global interconnected ISDN is virtually impossible.
2. **Support for switched and non-switched applications:** ISDN will support both circuit switching and packet switching. As we discussed in part one, there is a place for both technologies. In addition, ISDN will support non-switched services in the form of dedicated lines.
3. **Reliance on 64-kbps connections:** ISDN is intended to provide circuit-switched and packet-switched connections at 64kbps. This is the fundamental building block of ISDN. This rate was chosen because at the time it was the standard rate for digitized voice and hence was being introduced into the evolving IDNs. Although this data rate is useful, it is unfortunately restrictive to rely solely on it. Future developments in ISDN will permit grater flexibility
4. **Intelligence in the network:** An ISDN is expected to be able to provide sophisticated services beyond the simple setup of a circuit-switched call. In

addition, network management and maintenance capabilities need to be more sophisticated than in the past. All of this is to be achieved by the use of Signaling System Number 7 and by the use of intelligent switching nodes in the network.

5. **Layered protocol architecture:** The protocol being developed for user access to ISDN exhibit a layered architecture and can be mapped into the OSI model. This has a number of advantages:

- Standards already developed for OSI-related applications may be used on ISDN. An example is X.25 level 3 for access to packet-switching services in ISDN.
- New ISDN-related standards can be based on existing standards, reducing the cost of new implementations. An example is LAPD. This is based on LAPB.
- Standards can be developed and implementation independently for various layers and for various functions within a layer. This allows for the gradual implementation of ISDN services at a pace appropriate for a given provider or a given customer base.

6. **Variety of configurations:** More than one physical configuration is possible for implementing ISDN. This allows for differences in national policy (single-source versus competition), in the state of technology, and in the needs and existing equipment of the customer base.

1.4 Benefits

The principal benefits of ISDN to the customer can be expressed in terms of cost savings and flexibility. The integration of voice and a variety of data on a single transport system means that the user does not have to buy multiple services to meet multiple needs. The efficiencies and economies of scale of an integrated network allow these services to be offered at lower cost than if they were provided separately. Further, the user needs to bear the expense of just a single access line lo these multiple services. The requirements of various users can differ greatly in a number of ways. For example, information volume, traffic pattern, response time, and interface types. The ISDN will allow the user to tailor the service purchased to actual needs to a degree not possible at present. In addition customers enjoy the advantages of competition among equipment vendors. These advantages include product diversity low price, and wide availability of services. Interface standards permit selection of terminal equipment and transport and other services from a range of competitors without changes in equipment or use of special adapters. Finally because the offerings to the customer are based on the ISDN recommendations, which of necessity are slow to change, the risk of obsolescence is reduced.

Network providers. On a larger scale but in a similar way, profit from the advantages of competition including the areas of digital switches and digital transmission equipment. Also standards support universality and larger potential market for services. Interface standards permit flexibility in selection of suppliers, consistent control signaling procedures and technical innovation and evolution within the network without customer involvement.

Manufacturers can focus research and development on technical applications and be assured that a broad potential demand exists. In particular, the cost of developing VLSI implementations is justified by the potential market. Specialized niches in the market create opportunities for competitive, smaller manufacturers. Significant economies of scale can be realized by manufacturers of all sizes. Interface standards assure that the manufacturer's equipment will be compatible with the equipment across the interface

Finally, enhanced service providers of, for instance, information retrieval or transaction-based services, will benefit from simplified user access. End users will not be required to buy special arrangements or terminal devices to gain access to particular services.

Of course, any technical innovation comes with penalties as well as benefits. The main penalty here is the cost of migration. This cost, however, must be seen in the context of evolving customer needs. There will be changes in the telecommunications offerings available to customers, with or without ISDN. It is hoped that the ISDN framework will at least control the cost and reduce the confusion of migration. Another potential penalty of ISDN is that it will retard technical innovation. The process of adopting a standard is a long and complex one. The result is that by the time a standard is adopted and products are available, more advanced technical solutions have appeared. This is always a problem with standards. By and large, the benefits of standards outweigh the fact that they are always at least a little way behind the state of the art.

1.5 Services

The ISDN will provide a variety of services, supporting existing voice and data applications as well as providing for applications now being developed. Some of the most important applications are as follows:

- **Facsimile:** Service for the transmission and reproduction of graphics and hand-written and printed material. This type of service has been available for many years but has suffered from a lack of standardization and the limitations of the analog telephone network. Digital facsimile standards are now available and can be used to transmit a page of data at 64 kbps in 5 seconds.
- **Teletex:** Service that enables subscriber terminals to exchange correspondence. Communicating terminals are used to prepare, edit, transmit, and print messages. Transmission is at a rate of one page in 2 seconds at 9.6 kbps.
- **Videotext:** An interactive information retrieval service. A page of data can be transmitted in 1 second at 9.6 kbps.

These services fall into the broad categories of voice, digital data, text, and image. Most of these services can be provided with a transmission capacity of 64 kbps or less. This rate, as we have mentioned, is the standard rate offered to the user. Some services require considerably higher data rates and may be provided by high-speed facilities outside the ISDN (e.g., cable TV distribution plants) or in future enhancements to ISDN (see Part two on broadband ISDN).

One of the key aspects of' the ISDN will be that it is an "intelligent network" By use of a flexible signaling protocol; the ISDN will provide a variety of network facilities for each service.

1.6 ISDN STANDARDS

Although a number of standards organizations are involved in various aspects of ISDN, the controlling body is the ITU-T. In this section, we first look at the rationale for standards and then examine the ISDN-related standards from ITU-T.

1.6.1 THE IMPORTANT OF STANDARDS

It has long been accepted in the telecommunications industry that standards are required to govern the physical, electrical and procedural characteristics of com-munication equipment. With the increasingly digital character of telecommunication networks and with the increasing prevalence of digital transmission and processing services, the scope of what should be standardized has broadened. As we shall see the functions interfaces, and services embodied in ISDN that are subject to standardization cover an extremely broad range.

Although there is no widely accepted and quoted definition of the term standard, the following definition from the 1979 National Policy on Standards for the United States encompasses the essential concept (NSPA79)

A prescribed set of rules conditions, or requirements concerning definition of terms; classification of components: specification of materials, performance, or operation: delineation of procedures: or measurement of quantity and quality in describing materials, product, systems, services, or practices.

[CERN84] lists the following advantages of standards:

- Increased productivity and efficiency in industry because of larger-scale, lower-cost production
- Increased competition by allowing smaller firms 10 market products readily acceptable by the consumer, without the need for a massive advertising budget
- Dissemination of information and the transfer of technology
- Expansion of international trade because of the feasibility of exchange of products among countries
- Conservation of resources
- Increased opportunity for worldwide exchange of information both voice and data.

Because of the complexity of ISDN, and because its success depends on the capability of providing true interconnectivity and inter-operability, standards are not only advantageous but also essential in the introduction of such a network.

1.6.2 Historical Background

The development of ISDN is governed by a set of recommendations issued by ITU-T, called the I-series of recommendations. These recommendations or standards were first issued in 1984. A more complete set has since been issued.

It is enlightening to look at the history of ITU-T/ CCITTs interest in ISDN. In 1968, CCITT established Special Study Group 9 (forerunner of today's Study Group XVIII, which has ISDN responsibility within CCITT) to look at a variety of issues related to the use of digital technology in the telephone network. At each plenary assembly, the study group was given assignments for the next four-v ear study period. The first and principal question assigned over this period is shown in Table 1.1. The titles of the first question reflect the evolution of CCITT interest. The focus shifts from digital technology to integrated digital networks (IDNs), to ISDN.

Table 1.1 Questions I As Assigned to Special Study Group D (1969-1976) and to Study Group XVIII (1977-1992)

Study Period	Title of Question I
1969- 1972	Planning of digital systems
1973-1976	Planning of digital Systems and integration of services
1977- 1980	Overall aspects of an ISDN
1981-1984	General network aspects of an ISDN
1985-1988	General question on ISDN
1989- 1992	General aspects of ISDN

In 1968, Study Group D was set up to study all questions related to the standardization of transmission of pulse-code modulated (PCM) voice and to coordinate work going on in other groups relating to digital networking. Even at this early stage, there was a vision of an ISDN. Recommendation G.702, issued in 1972, contained the following definition of an integrated services digital network:

- An integrated digital network in which the same digital switches and digital paths are used to establish connections for different services, for example, telephony, data.

At this point, there was no information on the type of network that could integrate digital switches and paths, or how the network could integrate various services. Nevertheless, it was recognition of the path that could be followed with digital technology.

During the next study period (1973-1976), there were continuing advances in digital transmission technology. In addition, digital switching equipment began to emerge from the laboratory. Thus, the construction of integrated digital networks became a real possibility. Accordingly, the 1976 set of recommendations included specifications dealing with digital switching as well as the specification of a new signaling system (Number 7) designed for use in the forthcoming digital networks. The first question for this period also specifically deals with the integration of services.

In planning for the 1977-1980-study period, CCITT recognized that the evolution toward a digital network was under way and was more important than the standardization of individual digital systems and equipment. Thus, the focus was on the integration aspects of the digital network and on the integration of services on an IDN. Two key developments that emerged during this study period were the following:

- The integration of services is based on providing a standardized user-network interface that allows the user to request various services through a uniform set of protocols.
- ISDN will evolve from the digital telephone network.

At the end of this period, the first ISDN standard emerged, entitled Integrated Services Digital Network (ISDN), G.705 (Table 1.2). No other standards on ISDN were issued in 1980; at this point, only the general concept of an ISDN had been developed.

As the next period began (1981-1984), ISDN was declared the major concern of CCITT for the upcoming study period. A set of recommendations called the I-series, was published at the end of this period. This initial set of specifications was incomplete and, in some cases internally inconsistent. Nevertheless the specification) of ISDN by 1984 was sufficient for manufacturers and service providers to be am to develop ISDN -related equipment and to demonstrate ISDN-related services and networking configurations. The 1984 series included this definition of ISDN, retained in the 1988 documents:

- An ISDN is a network, in general evolving from telephony IDN that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services to which users have access by a limited set of standard multi-purpose user-network interfaces.

Work on the I-series and related recommendations continued in the 1985- 1988 period. At the beginning of this period. CCITT was significantly restructured to give a number of its study groups a part of future ISDN work. The dominant function of CCITT became the study of ISDN matters.

INTEGRATED SERVICES DIGITAL NETWORKS (ISDN)

The CCITT

Considering

The measure of agreement that has so far been reached in the studies of integrated

a) Digital Networks (ISDNs) dedicated to specific services such as telephony data and also of an Integrated Services Digital Network (ISDN).
b) The need for a common basis for the future studies necessary for the evolution toward an ISDN.

Recommends

That the ISDN should be based on the following conceptual principles:

1) The ISDN will be based on and evolve from the telephony IDN by progressively incorporating additional functions and network features including those of any other dedicated networks so as to provide for existing and new services.
2) New services introduced into the ISDN should be arranged to be compatible with 64-kbit.5 switched digital connections.
3) The transition from the existing networks to a comprehensive ISDN may require a period of time extending over one or two decades.
4) During the transition period arrangements must be developed for the interworking of services on ISDNs and services on other networks.
5) The ISDN will contain intelligence for the purpose of providing service features, maintenance and network management functions. This intelligence may not be sufficient for some new services and may have to be supplemented by either additional within the network, or possibly compatible intelligence in the customer terminals..
6) A layered functional set of protocols appears desirable for the various access arrangements to the ISDN. Access from the customer to ISDN resources may vary depending upon the service required and on the status of evolution of national ISDN

Table 1.2 CCITT Recommendations G.705 (1980)

The 1988 version of the I-series recommendations was sufficiently detailed to make preliminary ISDN implementations possible in the late 1980s.

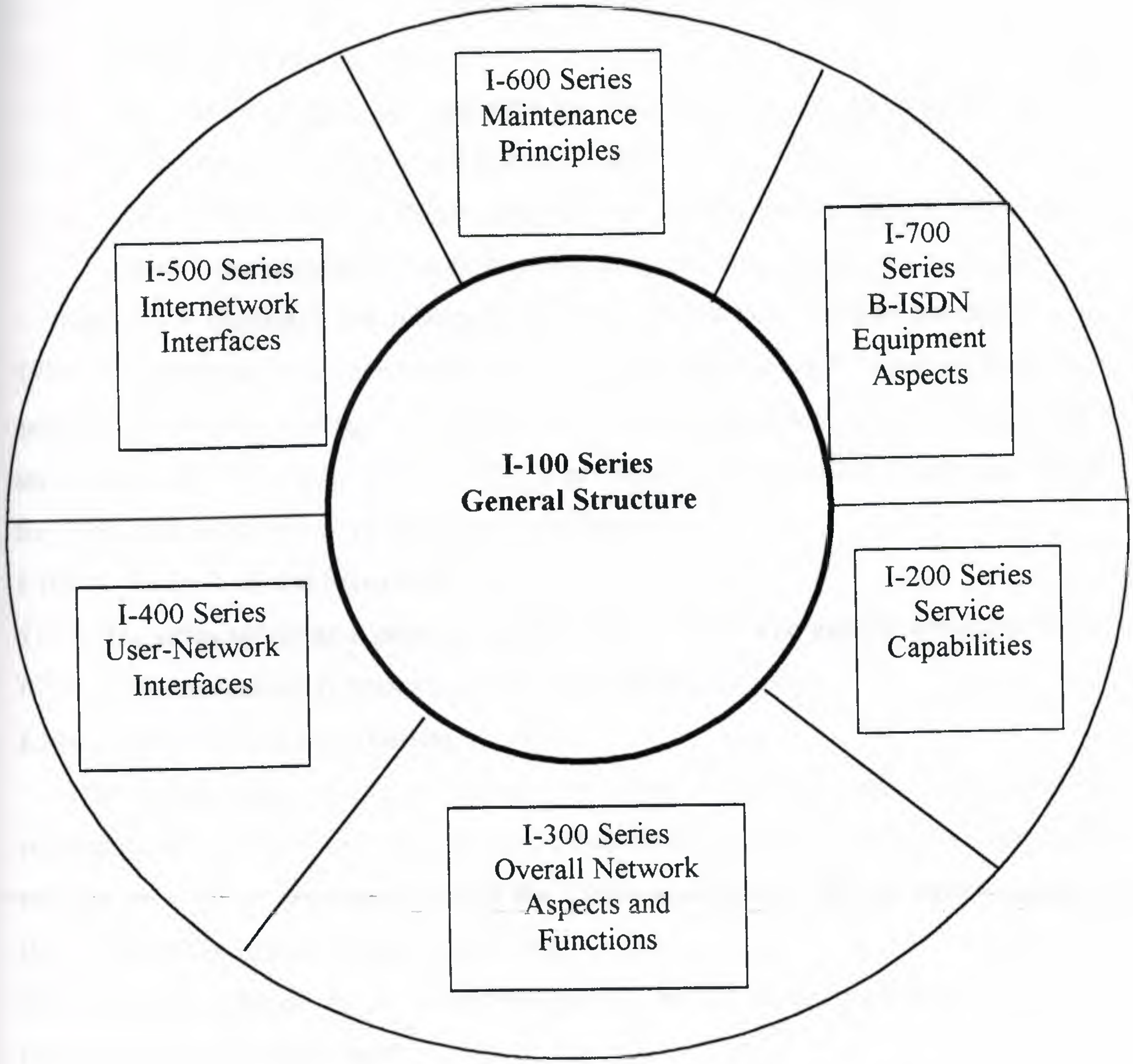


Figure 1.1 Structures of the I-Series Recommendations

1.6.3 The I-Series Recommendations.

The bulk of the description of ISDN is contained in the I-series of recommendations, with some related topics covered in other recommendations. The characterization of ISDN contained in these recommendations is centered on three main areas:

1. The standardization of services offered to users, so as to enable services to be internationally compatible.
2. The standardization of user-network interfaces, so as to enable terminal equipment to be portable, and to assist in (1)
3. The standardization of ISDN capabilities to the degree necessary to allow user-network and network-network inter-working, and thus to achieve (1) and (2).

Figure 1.1 illustrates the relationship among the various. I-series standards. The 1984 set contained recommendations in series I.100 through I.400. Some updates and expansions occurred in these series in the 1985-1988-study period. The I.500 and I.600 series were left for further study in1984, a preliminary set of specifications was ready for 1988, and additional work has been done since then.

I.100 Series-General Structure

The I.100 series serves as a general introduction to ISDN. The general structure of the ISDN recommendations is presented as well as a glossary of terms.

I.200 Series-Service Capabilities

The I.200 series is, in a sense, the most important part of the ISDN recommendations. Here, the services to be provided to users are specified. We may look on this as a set of requirements that the ISDN must satisfy. In the ISDN glossary (I.112), the term service is defined as follows:

That which is offered by an Administration to its customers to satisfy a specific telecommunication requirement.

Although this is a very general definition, the term service has come to have a very specific meaning in ITU-T, a meaning that is somewhat different from the use of that term in an OSI context. For ITU-T, a standardized service is characterized:

- Complete, guaranteed end-to-end comparability
- ITU-T-standardized terminals, including procedures
- Listing of the service subscribers in an international director
- ITU-T-standardized testing and maintenance procedures

- Charging and accounting rules

There are three simple ITU-T services: telegraphy, telephony and data. There are four newer ITU-T telemetric services: teletex, facsimile, videotext, and message handling. The goal with all of these services is to ensure high-quality international telecommunications for the end user, regardless of the make of the terminal equipment and the type of network used nationally to support the service.

The I.200 series classifies services into lower-level bearer services and higher-level teleservices. For each service, various attributes are defined, constituting a "laundry list" that is configured by agreement between the subscriber and the provider.

I.300 Series -Overall Network Aspects and Functions

Whereas the I.200 series focuses on the user, in terms of the services provided to the user, the I.300 series focuses on the network, in terms of how the network goes about providing those services. A protocol reference model is presented that, while based on the seven-layer OSI model, attempts to account for the complexity of a connection that may involve two or more users (e.g., a conference call) plus a related common-channel signaling dialogue. Issues such as numbering and addressing are addressed. There is also a discussion of ISDN connection types.

I.400 Series-user-Network Interfaces

The I.400 series deals with the interface between the user and the network. Three major topics are addressed:

- **Physical configurations**: The issues of how ISDN functions are configured into equipment. The standards specify functional groupings and define reference points between those groupings.
- **Transmission rates**: The data rates and combinations of data rates to be offered to the user.
- **Protocol specifications**: The protocols at OSI layers 1 through 3 that specify the user-network interaction.

I.500 Series-Internetwork Interfaces

ISDN supports services that are also provided on older circuit-switched and packet-switched networks. Thus, it is necessary to provide inter-working between an ISDN and other types of networks to allow communications between terminals belonging to equivalent services offered through different networks. The I.500 series deals with the various network issues that arise in attempting to define interfaces between ISDN and other types of networks.

I.600 Series-Maintenance Principles

This series provides guidance for maintenance of the ISDN subscriber installation, the network portion of the ISDN basic access, primary access, and higher-data-rate services. Maintenance principles and functions are related to the reference configuration and general architecture of ISDN. A key function that is identified in the series is loop back. In general, loop back testing is used for failure localization and verification.

I.700 Series B-ISDN Equipment Aspects

This series was first introduced in 1996. It covers functional and characteristics of ATM equipment and various management aspects.

1.7 ISDN Terms and Definitions

An ISDN is a digital network that can provide many types of services to a user. The real thrust of the ISDN standards is not how the network operates but how the user communicates with the network and accesses network services. ISDN standards, then define the interface between the user and the network. This interface is in the form of a set of protocol, including a message set used to request services.

Most people have heard many of the terms commonly associated with ISDN, such as D-channel, 2B+D, 23B+D, basic rate, primary rate, NT1, TA, bearer services, ITU-T, ANSI, etc. This section will introduce and define many of the terms used in the standards.

1.7.1 ISDN Channels

In data communications, a channel is a unidirectional conduit through which information flows. A channel can carry digital or analog signals comprising user data or network signaling information. In ISDN and other digital TDM environments, a channel generally refers to a time slot on a transmission facility and is full-duplex (bidirectional).

In today's telephone network, the local loop connection between the user and C.O provides a single analog channel, used for different types of information. First, the loop is used to carry signals between the user's equipment and the network. The telephone, for example, places a short circuit on the line to indicate that the handset has been taken off-hook. A dial tone from the network signals the user to enter the telephone number.

Pulses or tones representing the dialed digits, busy signals, ringing signals also appear over the local loop. Second, after the call is established, the loop carries user information, which may be voice, audio, video, data, depending upon the application. These two types of usage could be said to represent two logical channels, one for signaling and one for user services.

In an ISDN, the local loop carries only digital signals and comprises several channels used for signaling and user data. The different channels coexist on the local loop using TDM. There are three basic types of channels defined for user communications in an ISDN, differentiated by their function and bit rate (Table 1.3):

Table 1.3 ISDN channel types

Channel	Function	Bit rate
B	Bearer services	64 kbps
D	Signaling and packet-mode data	16 kbps (BRI) 64 kbps (PRI)
H_0	Wideband bearer service	384 kbps
H_1	Wideband bearer service	
	H_{10} (23B)*	1.472 Mbps
	H_{11} (24B)	1.536 Mbps
	H_{12} (30B)	1.920 Mbps
N x 64	Variable bandwidth bearer Services	64 kbps to 1.536Mbps in 64-kbps increments
B-ISDN	Nonchannelized DS-3	44.736 Mbps
	Nonchannelized STM-1/OC3	155.52 Mbps
	Nonchannelized STM-4/OC12	622.08 Mbps

*An H_{10} -channel is defined by ANSI but not by the ITU-T.

- D-channel: carries information between the user and the network; may also carry user data packets
- B-channel: carries information for user services, including voice, audio, video, and digital data; operates at the DS-0 rate (64 kbps)
- H-channel: same function as B-channels but operates at bit rates above DS-0

The sections below will describe these channels in more detail.

The D-Channel

All ISDN devices attach to the network using a standard physical connector and exchange a standard set of messages with the network to request services. The contents of the service-request messages will vary with the different services requested; an ISDN telephone, for example, will request different services from the network than will an ISDN television. All ISDN equipment, however, will use the same protocol and same set of messages. The network and user equipment exchange all services requests and other signaling messages over the ISDN D-channel. Typically a single D-channel will provide the signaling services for a single ISDN interface (access point). It is possible for a single ISDN device (e.g., a PBX) to be connected to the network with more than one ISDN interface. In this scenario, it is possible for the D-channel to provide signaling information for many ISDN interfaces. This capability saves channel and equipment resources by consolidating all signaling information on one channel; it is only available on the T-carrier ISDN interface, as discussed below.

Although the D-channel's primary function is for user-network signaling, the exchange of these signaling messages is unlikely to use all of the available bandwidth. Excess time on the D-channel is available for user's packet data and, indeed, the transport of packet-mode data is the secondary function of the D-channel. The excess time is deemed to be great enough to allow service providers to offer user data services at rates up to 9.6 kbps on the D-channel. This is a bargain for users because the full 16 kbps of the D-channel is typically available. User-network signaling messages always have priority over data packets.

The D-channel operates at either 16 or 64 kbps, depending upon the user's access interface, which is discussed later.

The B-Channel

Signals exchanged on the D-channel describe the characteristics of the service that the user is requesting. For example, an ISDN telephone may request a circuit-mode connection operating at 64 kbps for the support of a speech application. This profile of characteristics describes what is called a bearer service. Bearer services are granted by the network, allocating a circuit-mode bearer channel between the requesting device and the destination. At the local loop, the B-channels are designated to provide this type of service.

The primary purpose of the B-channel, then, is to carry the user's voice, audio, image, data, and video signals. No service requests from the user are sent on the B-channel. B-channels always operate at 64 kbps, the bit rate required for digital voice applications.

The B-channel can be used for both circuit switching and packet switching applications. A circuit-mode connection provides a transparent user-to-user connection, allowing the connection to be specifically suited to one type of service (e.g., television or music). In the circuit mode, no protocols above the Physical Layer (64 kbps) are defined for the B-channels; each user of a B-channel is responsible for defining the upper-layer protocols to be used over the connection. It is also the responsibility of the users to assure compatibility between devices connected by B-channels. Packet-mode connections support packet switching equipment using protocols such as X.25 or frame relay. The ISDN can provide either an internal packet-mode service or provide access to an existing PSPDN for packet service. In the latter case the protocols and procedures of PSPDN must be adhered to when requesting packet-mode service.

The most important point to remember with respect to the use of the B- and D-channels is that devices use the D-channel to exchange the signaling messages necessary to request services on the B-channel.

H-Channels

A user application requesting a bit rate higher than 64 kbps may be obtained by using wideband channels, or H-channels, which provide the bandwidth equivalent of a group of B-channels. Applications requiring bit rates above 64 kbps include LAN interconnection, high-speed data, high-quality audio, teleconferencing, and video services.

The first designated higher-rate channel is an H_0-channel, which has a data rate of 384 kbps. This is equivalent to logically grouping six B-channels together.

An H_1-channel comprises all available time slots at a single user interface employing a T1 or E1 carrier. An H_{11}-channel operates at 1.536 Mbps and is equivalent to 24 time slots (24 B-channels) for compatibility with the T1 carrier. An H_{12}-channel operates at 1.920 Mbps and is equivalent to 30 times slots (30 B-channels) for compatibility with the E1 carrier.

ANSI has designed an H_{10}-channel, operating at 1.472 Mbps and equivalent to 23 time slots on a T1 interface. This channel was defined by ANSI to support a single wideband channel and a D-channel on the same T1 access facility; with H_{11}-channel, a D-channel and wideband channel cannot coexist on the same T1 interface.

A relatively new set of ISDN channels has been defined for variable bit rate applications, called an $N \times 64$ channel. This channel is similar in the structure to the H-channels except it offers a range of bandwidth options from 64 kbps to 1.536 Mbps in increments of 64 kbps. When a user requests an $N \times 64$ channel for a given call, the service request contains the type of channel ($N \times 64$) and the value of N (1 to 24). A benefit to users of an $N \times 64$ channel is that they do not require inverse multiplexing equipment on the premises since the network maintains time slot sequence integrity between the N 64-kbps time slots. An advantage of the $N \times 64$ channel is the ability to customize the bandwidth requirements to the application.

1.7.2 Access Interfaces

An access interface is the physical connection between the user and the ISDN that allows the user to request and obtain services. The concept of an access interface is a familiar one to users of today's networks. Most residences, for example, have a single-line telephone and, accordingly, a single connection to the local C.O. This single local loop can be said to comprise two logical channels, as described earlier, one for user-network signals (on- and off-hook) and one for user data (voice and tones).

As the number of simultaneous users increases at a customer location, so does the requirement for the number of physical resources to handle those users. A second local loop, for example, can provide a second telephone line, while multiple trunk circuits can provide multiple lines between a customer's PBX and the C.O. Access to other networks and/or network services (e.g., a packet or telex network) can be provided by bringing additional lines to the customer's premises. It is not uncommon for a business location to have many individual lines connecting it to the C.O. for such services as telephony, fax, a point-of-scale terminal, and remote security.

ISDN access interface differ somewhat from today's telephone network access interface. First, one goal of ISDN is to provide all services over a single network access connection (physical resource), independent of the equipment or service type. Second, ISDN access interfaces comprise a D-channel for signaling TDM with some number of B-channel for user data. This design allows multiple information flows simultaneously on a single physical interface.

ISDN recommendations from ITU-T currently define two different access interfaces, called the basic rate interface (BRI) and primary rate interface (PRI). These access interfaces specify the rate at which the physical medium will operate and the number of available B-, D-, H-channels (Table 1.4).

Table 1.4 ISDN Access Interface Structures

Interface	Structure*	Total bit rate	User data rate
BRI	$2B+D_{16}$	192 kbps	144 kbps
PRI	$23B+D_{64}$	1.544 Mbps	1.536 Mbps
	$30B+D_{64}$	2.048 Mbps	1.984 Mbps

*The D-channel operates at 16 kbps in the BRI and at 64 kbps in the PRI.

+ This is one possible PRI configuration and the most common today. Other configurations are also possible, such as 24B.

Bellcore documents use a slightly different set of terms, namely, basic rate access (BRA) and primary rate access (PRA). The use of this terminology stems from the separation of the service access from the physical interface; a BRA, for example, could be physically delivered to a location in a form other than a single two-wire interface.

Basic Rate Interface

The BRI comprises two B-channels and one D-channel and is designated 2B+D. The BRI D-channel always operates at 16 kbps.

The BRI will typically be used in one of two ways. First, it can provide ISDN access between a residential or business customer and the ISDN LE. Alternatively, it can provide ISDN access between user equipment and an ISDN-compatible PBX in a business environment. As a tariff offering, the BRI can be ordered in configurations other than 2B+D, and other nomenclature may be encountered. If the BRI is to be used only for telephony and no data will be sent on the D-channel, the configuration is sometimes called 2B+S (the D-channel is for signaling only). If only a single B-channel is required, a1B+D or 1B+S arrangement may be ordered; packet data is allowed on the D-channel in the former and not in the latter. Finally, if only low-speed (9.6 kbps) packet data is required, a 0B+D configuration can be ordered. These configurations allow ISDN to be customized for customer applications and are priced differently based on the number of active channels. It should be noted that in all of these configurations, the interface's physical characteristics are the same; the only difference is in which channels have been activated by the LE and what type of traffic is allowed on the D-channel.

The user data rate on the BRI is 144 kbps (2 × 64 kbps + 16 kbps), although additional signaling for the physical connection requires that the BRI operate at a higher bit rate.

Primary Rate Interface

The PRI also has a number of possible configurations. The most common configuration in North America and Japan is designed 23B+D, meaning that the interface comprises 23 B-channels plus a single D-channel operating at 64 kbps. Optionally, the D-channel on a given PRI may not be activated, allowing that time slot to be used as another B-channel; this configuration is designed 24B. This PRI description is based on the T1 digital carrier. It operates at a bit rate of 1.544 Mbps, of which 1.536 Mbps are user data.

A 30B+D PRI is also defined that comprises 30 B-channels and one D-channel. Based on the E1 digital carrier, it operates at 2.048 Mbps, of which 1.984 Mbps are user data.

The PRI contains more channels than a typical end-user device will use. The PRI is, in fact, primarily intended to provide access to the network by some sort of customer premises switching equipment, such as a PBX, multiplexer, or host computer.

When a wideband application requires more throughput than that provided by a B-channel, the PRI can be configured to provide H-channel access. When this configuration is used, the number of available B-channels will decrease by the number of time slots used by the H-channel(s). An example would be a videoconferencing system needing 384 kbps (an H-channel) for a call. The supporting PRI would have extra bandwidth available for a D-channel and 17 B-channels. If the video system needed an H-channel, no B- or D-channel time slots would be available. This flexibility allows the PRI to act as wideband access system and a narrowband access system, depending on the application active at any time. The same bandwidth (time slots) can be configured for different types of channels on demand.

1.7.3 Functional Devices and Reference Points

Several different devices may be present in the connection between CPE and the network to which the CPE is attached. Consider the relatively simple example of a customer's connection to telephone network. All of the subscriber's telephones are connected with inside wiring to a junction box in the customer's building; the local loop provides the physical connection between the junction box and the LE. As far as the

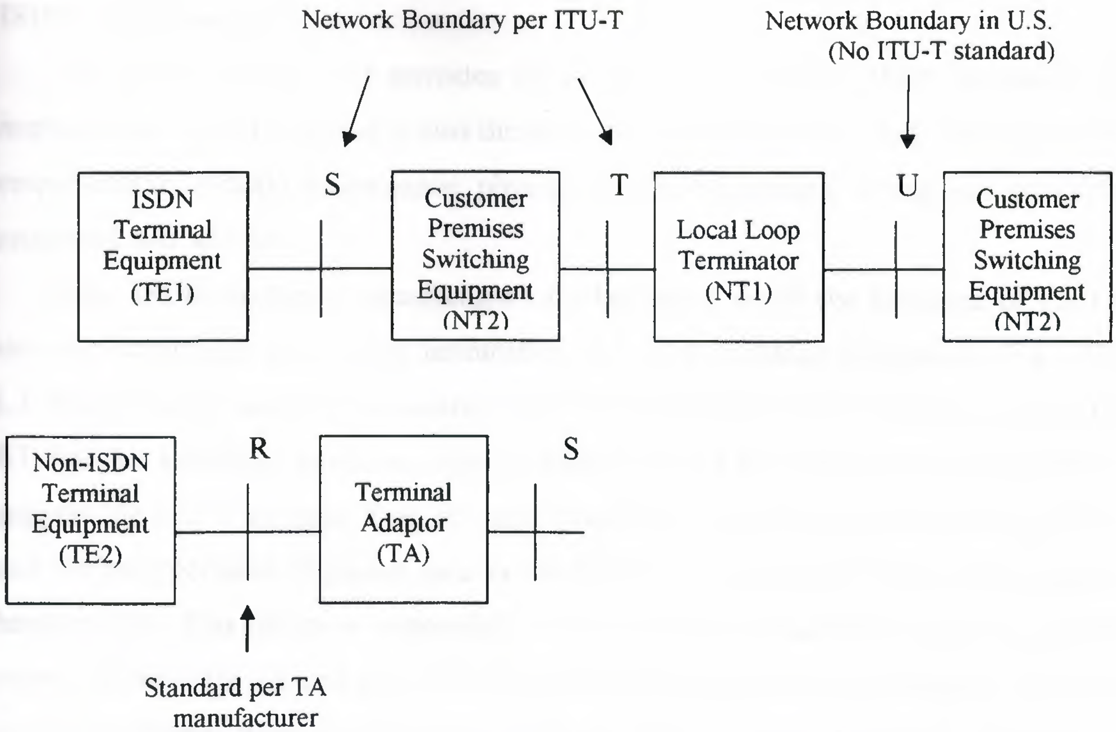


Figure 1.2 ISDN functional devices and reference points.

customer is concerned, the CPE is communicating directly with the exchange; the junction box is transparent.

Other equipment may also be present. If a PC is attached to the telephone network, for example, a modem will replace the telephone. In a PBX environment, the telephones and modems are attached to the PBX, which will provide on-site switching; the PBX is, in turn, connected to the LE.

Protocols describe the rules governing the communication between devices in a network. In today's communications environment it is often difficult to separate the devices from the functions they perform. The case of the PC communicating over the telephone network is an example. The ISDN standards define several different types of devices. Each device type has certain functions and responsibilities but may not represent an actual physical piece of equipment. For that reason, the standards call them functional devices.

Since the ISDN recommendations describe several functional device types there are several device-to-device interfaces, each requiring a communication protocol. Each of these functional device interfaces is called a reference point.

The paragraphs below describe the different functional devices and reference points, which are shown in figure 1.2.

ISDN Functional Devices

The network device that provides ISDN services is the LE. ISDN protocols are implemented in the LE, which is also the network side of the ISDN local loop. Other LE responsibilities include maintenance, physical interface operation, timing, and providing requested user services.

Some ISDN exchange manufacturers further break down the functions of the LE into two subgroups called local termination (LT) and exchange termination (ET). The LT handles those functions associated with the termination of the local loop, while the ET handles switching functions. Also included in the LE is equipment specialized to support the ISDN services. Two of these have to do with the signaling used in ISDN and the incorporation of packet data in the ISDN list of services. The first is a packet handler (PH). This device is responsible for the decoding of all ISDN signaling packets passed between the LE and the ISDN subscriber. It is also used to distinguish user data on the D-channel from signaling data and routes the user data toward its destination. The second device (or devices) is the network signaling system employed for ISDN. In today's environment this signaling system is signaling system NO.7 (SS7). The SS7 device is responsible for the creation and interpretation of signaling messages used in the ISDN.

Network termination type 1 (NT1), or local loop terminator equipment, represents the termination of the physical connection between the customer site and the LE. The NT1's responsibilities include line performance monitoring, timing, physical signaling protocol conversion, electrical conversion, and power transfer.

Network termination type 2 (NT2) equipment are those devices providing customer site switching, multiplexing, and/or concentration. This includes PBXs, multiplexers, host computes, terminal controllers, and other CPE for voice and data switching. An NT2 will be absent in some ISDN environments, such as residential or Centrex ISDN service. NT2s distribute ISDN services to other devices that attached to it. In this role, the NT2 might perform some protocol conversion functions as well as distribution functions. One of the primary distribution functions is the network signaling on behalf of the attached terminals. The NT2 is responsible for all signaling to the network. As an example, a PBX might terminate an analog telephone and allow access to an ISDN PRI for a connection to other subscribers. In this case the PBX is providing protocol conversion from the analog voice to the ISDN digital voice and is collecting the dialed digits from the telephone and creating a signaling message for the LE.

Terminal equipment (TE) refers to end-user devices, such as an analog or digital telephone, X.25 data terminal equipment, ISDN work station, or integrated voice/data terminal (IVDT). Terminal equipment type 1 (TE1) are those devices that utilize the ISDN protocols and support ISDN services, such as an ISDN telephone or workstation.

Terminal equipment type 2 (TE2) are non-ISDN compatible devices, such as the analog telephones in use on today's telephone network.

A terminal adapter (TA) allows a non-ISDN device (TE2) to communicate with the network. TAs have particular importance in today's ISDN marketplace; nearly every device in use in today's data and telecommunications environment is TE2. TAs allow analog telephones, X.25 DTEs, PCs, and other non-ISDN devices to use the network by providing any necessary protocol conversion.

ISDN Reference Points

The ISDN reference points define the communication protocols between the difference ISDN functional devices. The importance of the different reference points is that different protocols may be used at each reference point. Four protocol reference points are commonly defined for ISDN, called R, S, T, and U.

The **R** reference point is between non-ISDN terminal equipment (TE2) and a TA. The TA will allow the TE2 to appear to the network as an ISDN device, just like a modem allows a terminal or PC to communicate over today's telephone network. There are no specific standards for the R reference point; the TA manufacturer will determine and specify how the TA-TO-TE2 communication includes EIA-232-E, V.35, and the industry Standard Architecture (ISA) bus.

The **S** reference point is between ISDN user equipment (i.e., TE1 or TA) and network termination equipment (NT2 or NT1). The **T** reference point is between customer site switching equipment (NT2) and the local loop termination (NT1). ISDN recommendations from the ITU-T, the primary international standards body for ISDN, specifically address protocols for the S and T reference points. In the absence of the NT2, the user-network interface is usually called the S/T reference point.

One of the more controversial and pivotal aspects of ISDN is the definition of the transmission standard across the local loop between the NT1 and the LE, called the **U** reference point. The ITU-T considers the physical NT1 device to be owned by the network administration; that makes the local loop part of the network. Therefore, the ITU-T views the S or T reference points as the user-network boundary. ITU-T recommendations do not address internal network operations, so they have no standard for transmission across the local loop (U reference point).

The U.S. Federal Communications commission (FCC), however, does not adopt this same view. Since the NT1 is on the customer's site, the FCC considers it to be customer owned. Since network equipment (the LE) is on one side of the U reference point and user equipment (the NT1) is on the other, it is clearly the local loop that represents the user-network boundary according to the FCC. Furthermore, operation across the user-network boundary in the United States must be described by a public standard and, in fact, is the subject of a U.S. national standard from the American National Standards Institute.

Although not shown in figure 1.2, some manufacturers define a V reference point between the LT and ET within the LE. This reference point is an implementation-dependent feature of the C.O. switch that is transparent to the user.

1.8 ISDN Protocol Architecture

To fully appreciate the ISDN user-network interface, it is important to understand the protocols that are used across that interface. Protocols are nothing more than the set of rules that expedite communication. Just as people follow rules for diplomacy, religion, and the practice of medicine so must all telecommunications devices use protocols.

This section will briefly describe the ISDN protocol architecture.

1.8.1 Protocol Planes

Like other telecommunications networks, including today's telephone network, ISDN employs a number of protocols. As described earlier, messages between the user and the network as well as end-user data all flow simultaneously over the ISDN access channels. End-user data and user-network signaling information use different sets of protocols, although they share the same physical medium.

To support the implementation of carrying signaling and user information on separate data paths, the ITU-T has introduced the concept of the control plane (or C-plane) and the user plane (U-plane), as shown in figure1.3. Protocols associated with the C-plane are for the transfer of signaling information for the control of user services and/or network resources, such as call establishment, call termination, changing service characteristics during the call, and requesting supplementary services.

Protocols associated with the U-plane are for the transfer of information between user applications, such as digitized voice and video, and user data. Information in the U-plane may be carried between users transparently by the network or may be manipulated within the network (e.g., A-law-to-μ -law PCM conversion).

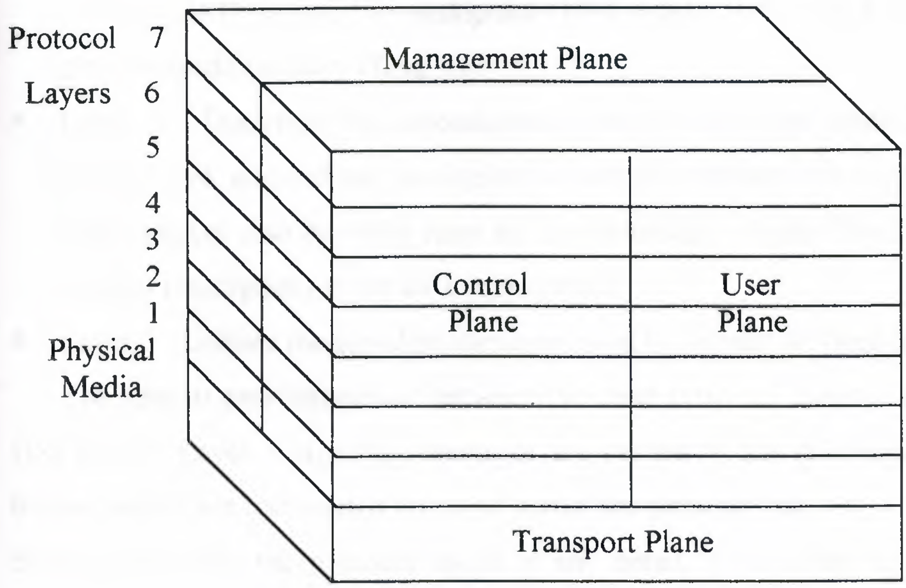


Figure 1.3 ISDN general protocol reference model

Note that all seven protocol layers may not be present on a given plane for a given application. For example, a voice call would only need end-to end agreement at layer 1 to define the compounding algorithm; no other and-to end protocols are supplied. Data applications will often only define the lower two or three protocol layers, since end-to-end functions (layers 4 through 7) will be supplied by the hosts and are transparent to the network.

Two other terms are defined by the ITU-T. The plane management function acts as a traffic manager to ensure that all traffic is carried using the appropriate protocol, which is associated with a given plane. C- and U-plane protocol data is carried over the physical medium, represented here by the transport plane.

1.8.2 Protocols, Channels, and Reference Points

The bulk of the ISDN protocol specifications carried over the D-channel. Signaling information corresponds to the C-plane protocols.

The ISDN C-plane protocols for the D-channel are functionally equivalent to the lower three layers of the OSI Reference Model (the chained layers). Since these protocols describe only the user-network signaling interface and not user-to-user communications, there are no C-plane counterparts for the OSI end-to-end layers.

- Layer 1. Describes the physical connection between the TE and the NT, including the connector, line coding scheme, framing, and electrical characteristics. The physical connection is synchronous, serial, and full-duplex; it may be point-to-point (PRI or BRI) or point-to-multipoint (BRI only). The D- and B-cannels share the physical medium using TDM.
- Layer 2. Describes the procedures to ensure error-free communication over the physical link and defines the logical connection between the user and the network. The protocol also provides rules for multiplexing multiple TEs on a single physical channel (multipoint) in the BRI environment.
- Layer 3. Defines the signaling messages used to request services from the network.

The peer-to-peer interaction between the three protocol layers is consistent with the OSI model. *Layer 3 signaling messages are carried in the information field of LAPD frames, which are transmitted bit by bit across the physical link.*

Before discussing the protocol layers in any detail, it is critical to pinpoint the place where each protocol layer has relevance. The ITU-T ISDN protocols describe the D-channel user-network interface at the S and T reference points (figure 1.4). Different protocol layers see these reference points differently. Note that the figure assumes that the S reference point is an ISDN interface.

The ISDN layer 1 protocol defines the physical connection between ISDN TE (TE1 or TA) and network termination equipment (NT2 or NT1). As discussed earlier, ITU-T ISDN recommendations do not describe the physical connection between the NT1 and the LE because the transmission line is considered to be internal to the network.

The ISDN layer 2 and 3 protocols define the logical link and signaling protocols, respectively, between ISDN TE (TE1 or TA) or customer-premises switching equipment (NT2), and the LE. The NT1 provides only a layer 1 service and, therefore, layers 2 and 3 are transparent to it.

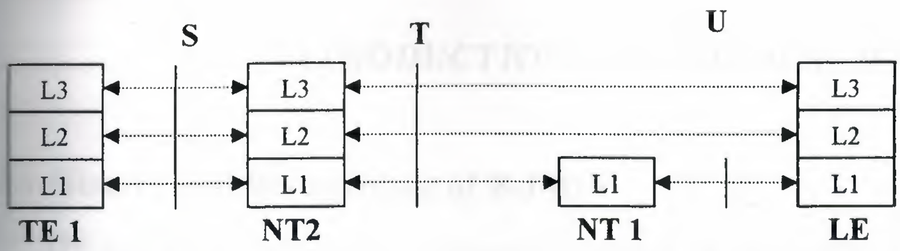


Figure 1.4 Protocol reference points and architecture for the ISDN D-channel

It is important to emphasize that the ITU-T ISDN C-plane protocols are specified only across the S and T reference points and only on the D-channel. The user may choose any protocol(s) for the bearer services and teleservices on the B- or H-channels. All channels share the same physical layer standard since B-, H-, D-channels are time division multiplexed on the same physical line (figure 1.5).

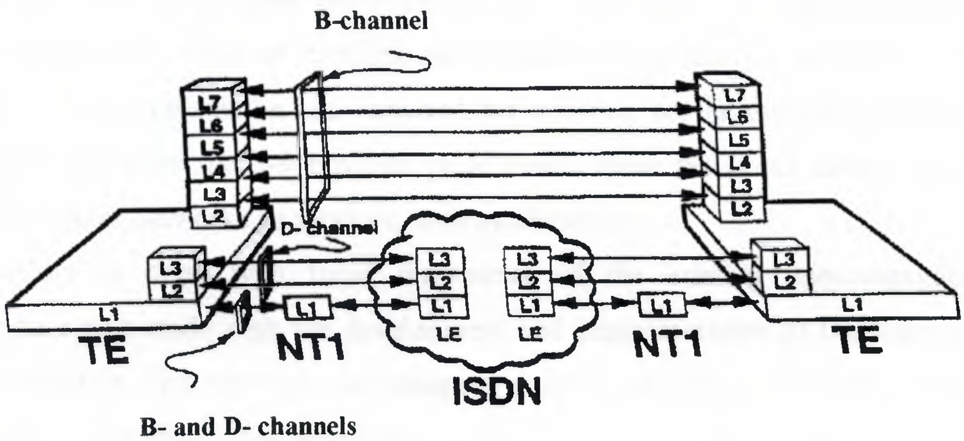


Figure 1.5 Relationship of B- and D-channel protocol architectures

2. INTRODUCTION TO BROADBAND ISDN

2.1 History and Background of B-ISDN

The concept of B-ISDN was originally defined in the late 1980s. It is a collection of technologies with ATM as the "cornerstone," which is expected to form a universal network. The B-ISDN is essentially characterized by the ability to convey all present and future types of information, at very high speeds, and in a cost efficient manner. This is a contrast to the present situation, where a multitude of different networks coexist to provide services of different kinds. The present structure, where the telephone network can transfer voice and data at low speeds, the X.23, or Frame Relay connection, which can transfer data at medium speeds, and broadcasting or cable TV, which can convey television, presents an inefficient use of resources. This is due to the fact that each and all of these networks must be installed and maintained separately Furthermore, when resources become available on one network, for instance, on the telephone network in the time interval after the 3-9 business peak hours, these resources cannot be made available for other networks or services, such as television.

An effort to cope with these drawbacks of the existing telecommunication infrastructure was made with the development and implementation of the Narrowband ISDN (N-ISDN). This network can transport, voice, data, and, in principle, video. The N-ISDN has some limitations, however.

- ISDN has a fairly limited bandwidth, namely 144 Kbps with the basic rate interface, and 2 Mbps with the primary rate interface. This is probably suitable for most uses presently, but within a short time normal bandwidth requirements are Likely to have risen beyond these rates. For example, a typical broadcast quality service carrying MPEG-2 compressed video; normally require at least 4 Mbps.
- N-ISDN is inflexible in many aspects. The user must for instance pay for the maximum bandwidth of the connection during a call, regardless of how much of the bandwidth capacity he actually uses.
- Only relatively few services supports the N-ISDN concept.

The next step in this evolution is B-ISDN. It has been the subject of much work, since the standardization body ITU in 1988 declared that ATM should be the basis of the future B-ISDN. Field trials have been done, and are still being done; all over the world in order to give telecom operators and equipment manufactures practical experience with B-ISDN. Presently, field trials involving B-1SDN networks with MPEG-2 compressed digital video services are done. The most important parts of B-ISDN, such as like ATM and SDH, have been finalized. Some standards may, however, still need to be developed further and refined, in order to enable a fully working B-ISDN that can cope with the multitude of potential new services.

2.2 Abilities and Benefits of B-ISDN

2.2.1 Introduction

There are a number of advantages of B-ISDN compared with the existing network structures. Some of the most important are the following six:

- Application independence
- Bandwidth efficiency
- LAN-MAN-WAN integration
- Bandwidth granularity
- Dynamic bandwidth
- Variable connection quality

It is mainly due to these qualities that ATM and B-ISDN have received so much attention in the tele/data communication business over the last years and now also in the video business. The details of these six overall advantage areas will here be dealt with in more detail.

2.2.2 Application Independence

With the B-ISDN only one network is needed to cover all the different possible services. It can convey information of different kinds, with different characteristics, namely:

- **Data**: Constant or variable bit rate data. Data transfer, such as LAN connections, often comes with bursts of traffic in short periods-typically in the range of milliseconds. Data transfer is normally not sensitive to delay in the network, unless real-time applications are involved. (A small delay in a file transfer is of no importance, for instance.) The bandwidth requirements of a data transfer are normally from 64 Kbps to 10 Mbps, but in principle there is no limit. Presently, 133 Mbps and even 622 Mbps connections to the desk top are being developed and commercially deployed

- **Video**: Video or television transmission, including everything from the relatively low VHS quality (or lower), all the way over HDTV quality to studio quality, is sensitive to delay, and especially to delay variation. It has constant (or in some cases varying) bandwidth demand of typically 180-270 Mbps in uncompressed format (e.g., MPEG-2), the bandwidth requirements typically lie in the range from 1.3-80 Mbps. The burst ness of variable bite rate video is normally lower than in the case of, let's say, data transfer connections.
- **Voice**: A constant 64 Kbps bandwidth requirement characterizes voice transfer from telephones, as we know it today. The transfer of voice is highly delaying sensitive, since even small delays or interrupts are perceived to be annoying by the human ear. Longer delays can make communication virtually impossible.
- Combinations of the above mentioned or multimedia applications, which could, for instance, be interactive TV, such as tele-shopping, tele-education, or transmission of other multimedia services, including text, images, sound, video, and possibly other types of information.

The fact that one network can convey all these different types of information, with different demands to bandwidth, burst ness, etc., is primarily due to ATM technology It conveys information in small cells' or packets of 33 bytes, 48 bytes for user information and 3 header bytes for different control purposes, as shown in figure 2.1. The information coming from the different services, such as file transfers or video transmissions, are segmented to fit into the ATM cell by the so called ATM adaptation layer (explained in detail later), and multiplexed into one stream of ATM cells.

The information flows from (or to) different users, for instance a specific type of video service can be collected in the network and transmitted via specific channels or paths, which can provide the required performance. The information of what channels or paths the information should be led via, is located in the 3 byte header of each ATM cell.

The fact that the ATM cell is of a fixed size instead of a varying size, enables simpler and much faster processing in all network components, such as interface cards and switches, as processing of the cells can be done in HW rather than SW. Furthermore, it is not necessary to calculate packet length, allocate varying buffer space, etc., as variable length packets require.

Finally, the ATM cell is only 33 bytes long. Hereby delay sensitive applications will not be delayed significantly from the time it takes to "fill" a cell with information.

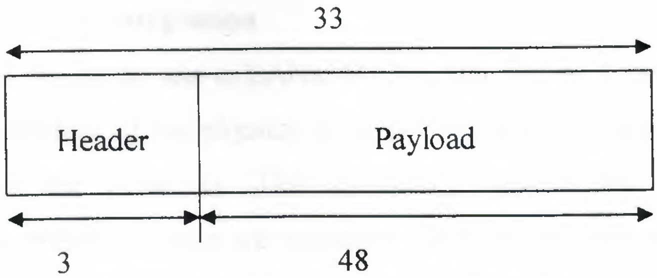


Figure 2.1 Structure of the ATM cell

2.2.3 Bandwidth Efficiency

In contrast to "synchronous transfer mode" or "time division multiplexing" (TDM) as it is normally called, ATM uses the bandwidth of a connection in a fairly efficient way. TDM is found in a great deal of the existing communications network, for instance, in the existing telephone network, utilizing the Plesiochronous Digital Hierarchy (PDH) technology. With TDM, the bandwidth of a given connection is shared in a fixed way among the users. Each user has a "time slot," which is available to him or her, whether it is needed or not. See figure 2.2. If for instance, one user is inactive, this causes a 33 percent capacity waste.

TDM guarantees the required bandwidth with an acceptable, constant delay. But it is inefficient in its use or the transmission capacity. In ATM the access to the network is in principle unlimited, dependent only on the capacity available. This is also referred to as "statistical multiplexing."

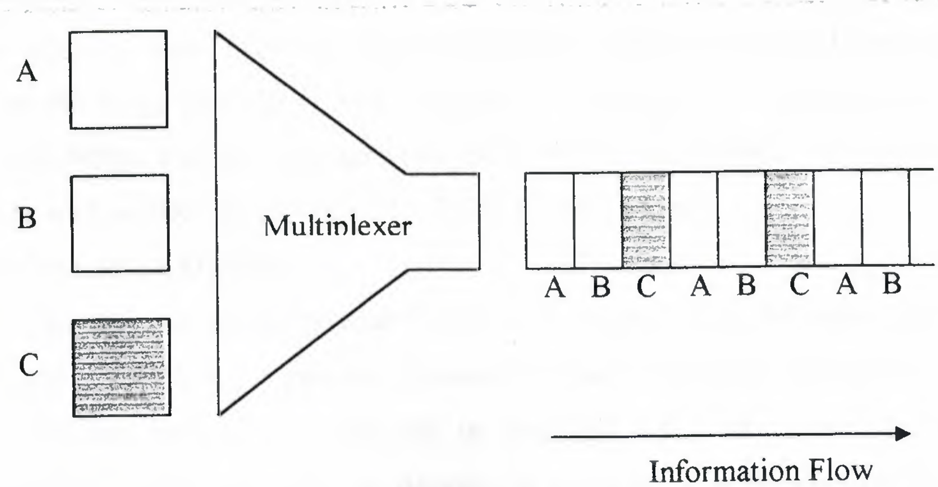


Figure 2.2 The structure of TDM

2.2.4 LAN-MAN-WAN Integration

B-ISDN is well suited for use in LANs, MANs, and WANs. Combined with the fact that ATM is independent of the physical layer protocols and cables, ATM cells can be transported on all the networks. This drastically reduces the need for protocol conversion, as we presently when we transport LAN traffic over a WAN connection. Furthermore, the independence of the physical layer means that the installed base of wiring can be re-used.

2.2.5 Bandwidth Granularity

Today, users and network element designers have to respect the discrete "blocks" in which bandwidth is available. These blocks are normally based on multiples of 64 Kbps, such as 2, 8, or 34 Mbps. With B-ISDN, it is the other way around. Here, the network can be tailored to closely fit to the bandwidth demands of the application, since the minimum unit of information is the 48 bytes of payload in the ATM cell. In practice, the bandwidth requirements, among other parameters, are specified at the time when the connection is established.

2.2.6 Dynamic Bandwidth

When a connection is initiated, the bandwidth requirements of the connection; in terms or traffic rate and burst ness, are "negotiated" with the network via the signaling procedures, as described later, if the demands change during the call, the connection parameters can be renegotiated. Furthermore, the user can be billed for the actual bandwidth he or she uses, if required. Expressed in a popular manner, he or she can be charged, "for the number of cells used." Finally, the B-ISDN has no upper limit with respect to bandwidth. This depends primarily on the capabilities of the physical layer components at a given time. Presently, the bandwidth available to the end user is typically lying in the range of TI/El (1.3 or 2 Mbps), T3/E3 (43 or 34 Mbps), or the ATM Forum 23.6 Mbps. For the core network; SDH STM-1 or SONET OC-3 (133 Mbps) is used, as well as SDH STM-4 or SONET OC-12 (622 Mbps).

2.2.7 Variable Connection Quality

It is possible for the user to specify what "Quality of service" (QoS) he wants from the network. In the B-ISDN, if, for instance, a moderate level of cell delay variation is a minor problem for the service used, this can be specified when the connection is initiated, and possibly renegotiated later as desired. In this way, it is possible for the user only to pay for what he needs, and chances are that the network is used more efficiently.

2.3 Broadband ISDN

Up to this point we have only considered ISDN based on 64 kbit/s B channels and 16 or 64 kbit/s D channels. However, for many applications even higher bit rates would be useful. Although video telephones may he acceptable at 64 kbit/s using a very small screen, for video conferencing, where a normal television size screen is needed, 384 kbit/s (6 x 64 kbit/s) is more attractive. Entertainment TV must be able to cope with situations in which successive frames are very different to meet the artistic aspirations of producers. For this reason there is little in the way of redundancy reduction possible and bit-rates in the tens of megabit/s are needed. High definition television requires bit-rates in the hundreds of megabit/s.

On the business side the interconnection of high speed LANs used for computer-aided design may well generate traffic at high rates. Of course there is also the general drift of people's expectation. The ability to handle facsimile pages in 4 seconds compared with the 30 seconds of the pre-ISDN era may be widely appreciated, but how long will it be before people expect the fax machine to operate at the same speed as the office photocopier, and in full colour? Thus not only can the need be foreseen for higher rates, but also the technology to offer service is available in the form of optical fibre and devices.

Figures 2.3 shows how the data capacity of a public switched telephone network connection has increased as modems have developed and with the availability of the ISDN. The dotted lines give some plausible extrapolations for the future. The curved line indicates how modems have evolved under the constraint of Shannon's limit described. The straight line offers a demand for the future without the Shannon limit. Figure 2.4 summarizes the data rate needs of various services. The provision of channels above 64 kbit/s is generally referred to as Broadband ISDN or B-ISDN but perceptions as to what constitutes a B-ISDN and the applications that must be carried vary enormously.

Nx64kbit/s

At the lowest end of B-ISDN comes the concatenation of several 64 kbit/s channels. CCITT Standard H.221 provides for the control and allocation of bandwidth for service carried on such assemblies of 64 k bit/s channels. It is in this area that the BAS relating to transfer rates and terminal capabilities comes into its own. For example a BAS of

00101010 indicates a transfer rate of 384 kbit/s with 64 kbit/s allocated to audio information and 320 k/bits allocated to video.

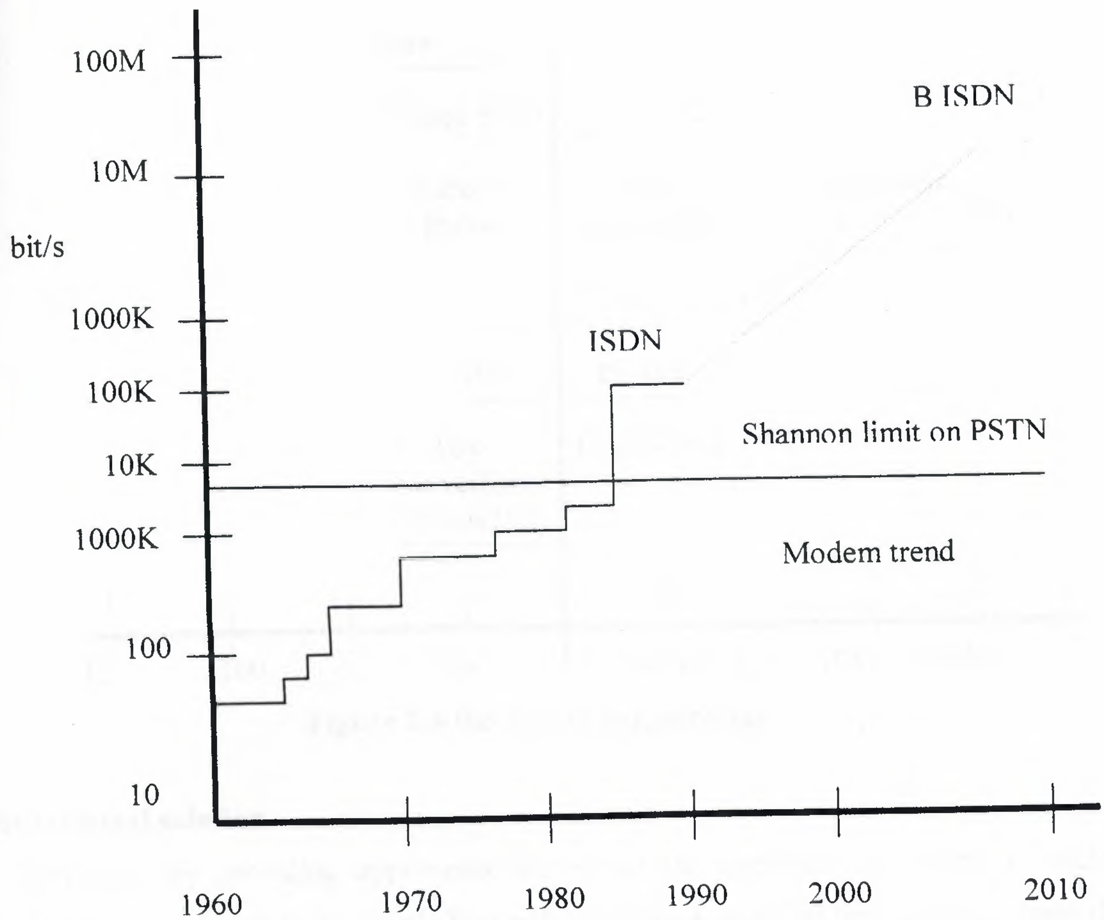


Figure 2.3 The rise of switched date rate

On the face of it the assembly of several 64 bit/s channels could be achieved on the ordinary ISDN by setting Up several 64 kbit/s calls to the same destination on a primary rate interface and concatenating the channels at the terminal. Unfortunately the network does not provide for channels set up in such a way to be subject to uniform delay. Time switching stages may introduce up to a frame's delay in one channel relative to another. More seriously there is no guarantee that channels will follow the same, or even similar, paths through the network. Different channels may be routed via different transmission line plant on different routes with different delays; the most extreme situation would be where one channel is carried by a satellite link and another is carried on a terrestrial link. The provision or alternative routing strategies in the network may also mean that one channel may pass through an extra switching node with its associated delays. There are two ways of overcoming these problems.

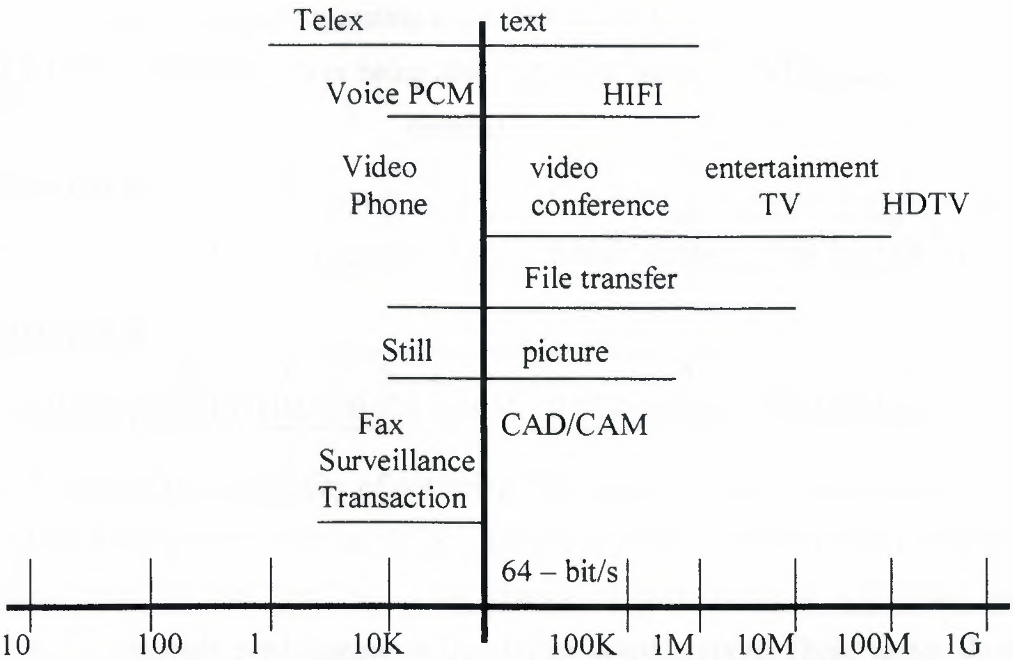


Figure 2.4 Bandwidth requirements

The terminal solution

Obviously by providing appropriate buffers at the terminals the delays in each channel can be padded to be equal. This will necessitate an initial 'investigation' period by the terminals to establish the delays. One assumption that may reasonably be made is that relative delays will not change during a call as; in general, networks do not normally reconfigure established calls. CCITT Standard H.221 includes strategies for establishing such connections. Bit 1 of frames 0, 2, 4, 6 in the multi-frame are allocated for this purpose. The strategy is that these bits in each channel would contain a 4-bit binary number, which is decremented on each multi-frame. These would be synchronized in each channel at the sending end and the receiving terminal could then determine the difference in delay between the various channels. Other standard procedures are also being developed.

The network solution

In this case the exchange processors would ensure that all channels are kept within a single time division multiplex and hence follow a common route. Apart from the need for additional software, the major problem is in design for traffic carrying capacity.

Routes are dimensioned to give an acceptable quality of service when channels are required singly. For example using Erlang's formula (implying the usual assumptions) a group of 30 or 23 trunks could be expected to carry 19.03 or 13.42 respectively erlangs of traffic and only 1 in 200 calls would be unable to find a free channel (i.e. a grade of service of 0.005). For a channel operating at this traffic level.

Table 2.1 The probability of not being able to provide an N x 64 kbit/s channel on demand.

30-channel system

N =	1	2	3	4	5	6	7	8	9	10	11	12
	0.005	0.008	0.012	0.018	0.026	0.037	0.050	0.066	0.086	0.108	0.134	0.163

23-channel system

N =	1	2	3	4	5	6	7	8	9	10	11	12
	0.005	0.008	0.014	0.023	0.034	0.051	0.072	0.098	0.129	0.166	0.207	0.253

Table 2.1 shows the probability of not being able to accept a multi-channel call of N channels. This is the grade of service for N x 64 kbit/s circuits in an environment where multi-channel calls are rare (and hence the chance of two arising is negligible) and single 64 kbit/s channels predominate in the design consideration. These tables show that the probability of being able to find six channels free on a 30-channel system is about one seventh of the basic grade of service. With 23-channel systems the same probability drops to one tenth of the basic grade of service. The grade of service offered for single 64 kbit/s channels, after setting up the 6 x 64 kbit/s channel, is to be found under the heading of N = 7 (i.e. 0.050 or 0.072 for 30 and 23 channels respectively). For these reasons it might be felt that N = 6 is about the largest multi-channel service that could be offered in this way. In many cases it may be felt that even this value of N might need a special provision. Of course in an exchange and trunk network there will be more than one 30-or 23-channel group from which to choose to give the N channels. However, on a single primary, rate access there is no advantage from this source.

3. PRINCIPLES AND BUILDING BLOCKS OF B-ISDN

3.1 B-ISDN Principles

The motivation to incorporate broadband features into ISDN is neatly documented in CCITT Recommendation 1.121 ('Broadband aspects of ISDN'):

The B-ISDN recommendations were written taking into account the following:

- The emerging demand for broadband services
- The availability of high-speed transmission, switching and signal processing technologies (bit rates of hundreds of Mbit/s are being offered).
- The improved data and image processing capabilities available to the user.
- The advances in software application processing in the computer and telecommunication industries.
- The need to integrate interactive and distribution services and circuit and packet transfer modes into one universal broadband network. In comparison to several dedicated networks, service and network integration has major advantages in economic planning, development, implementation, operation and maintenance. While dedicated networks require several distinct and costly customer access lines, the B-ISDN access can be based on a single optical fiber for each customer. The large-scale production of highly integrated system components of a unique B-ISDN will lead to cost-effective solutions
- The need to provide flexibility in satisfying the requirements of both user and operator (in terms of bit rate, quality of service etc.).

ISDN is conceived to support 'a wide range of audio, video and data applications in same networks. B-ISDN thus follows the same principles as 64 kbit/s based ISDN (cf.CCITT Recommendation 1.120 and is a natural extension of the latter):

- A key element of service integration is the provision of a wide range of services to a broad variety of users utilizing a limited set of connection types and multipurpose user network interfaces.

Whereas telecommunication networks of the pre-ISDN era have usually been specialized networks (e.g. for telephony or data) with rather limited bandwidth or throughput and processing capabilities, the future B-ISDN is conceived to become a universal (standardized) network supporting different kinds of applications and customer categories. CCITT Recommendation 1.121 presents an overview of B-ISDN capabilities:

- B-ISDN supports switched, semi-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 multi-media type and of a connectionless or connection-oriented nature and in a bi-directional or unidirectional configuration.
- A B-ISDN will contain intelligent capabilities for the purpose of providing advanced service characteristics, supporting powerful operation and maintenance tools, network control and management.

We believe the reader of this list of intended B-ISDN capabilities must be deeply impressed; B-ISDN is tailored to become the universal future network!

B-ISDN implementations will, according to the CCITT, be based on the asynchronous transfer mode (ATM).

3.2 Asynchronous Transfer Mode

The asynchronous transfer mode (ATM) is considered the ground on which BISDN is to be built:

Asynchronous transfer mode (ATM) is the transfer mode for implementing B-ISDN

The term transfer comprises both transmission and switching aspects, so a transfer mode is a specific way of transmitting and switching information in a network.

In ATM, all information to be transferred is packed into fixed-size slots called cells. These cells have a 48 octet information field and a 5 octet header. Whereas the information field is available for the user, the header field carries information that pertains to the ATM layer functionality itself, mainly the identification of cells by means of a label (see Figure 3.1).

Header 5 octets	Information field 48 octets

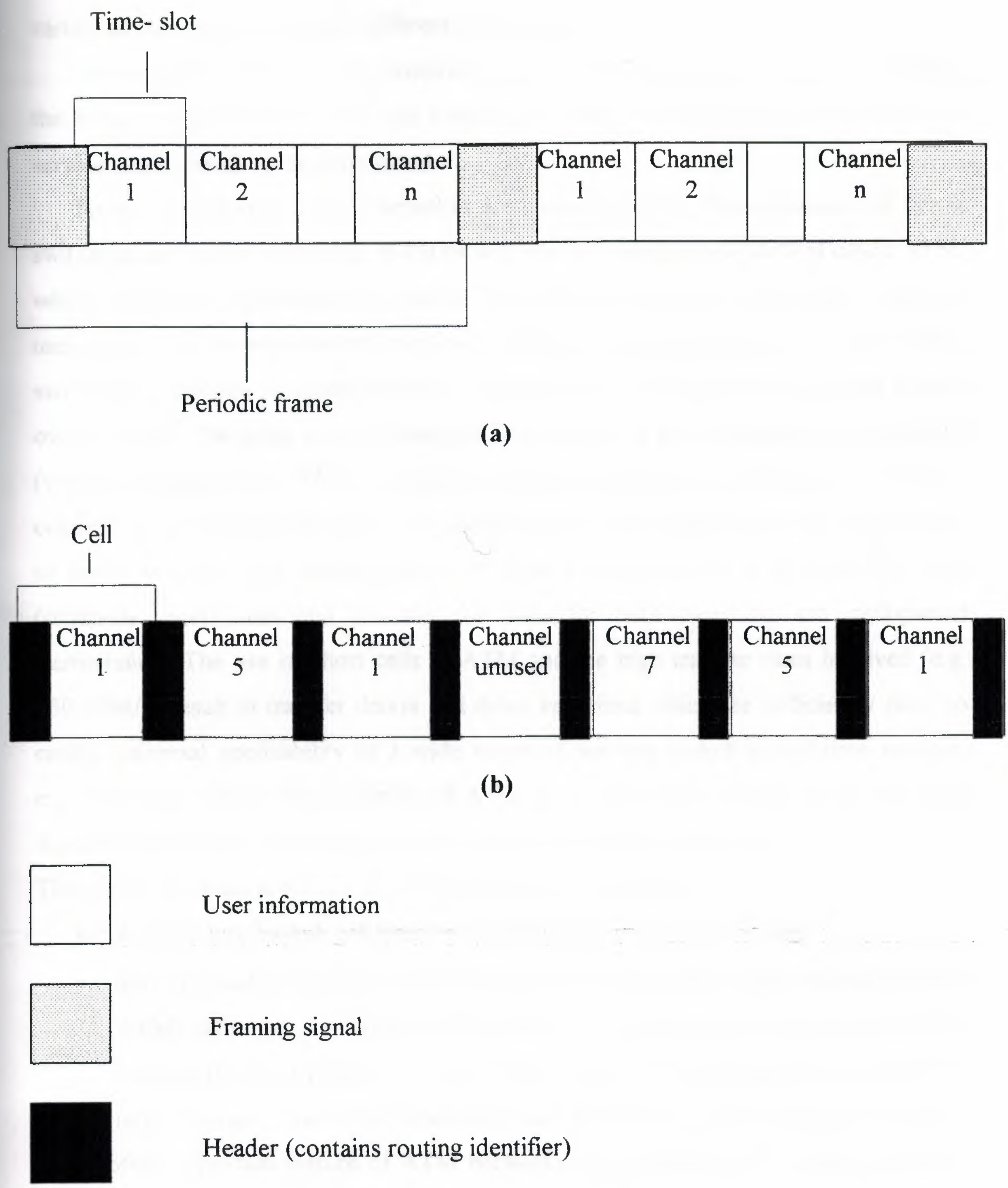
Figure 3.1: ATM cell structure

ATM allows the definition and recognition of individual communications by virtue of the label field inside each ATM cell header; in this respect, ATM resembles conventional packet transfer modes. Like packet switching techniques, ATM can provide a communication with a bit rate that is individually tailored to the actual need, including time-variant bit rates.

The term asynchronous in the name of the new transfer mode refers to the fact that, in the context of multiplexed transmission, cells allocated to the same connection may exhibit an irregular recurrence pattern as cells are filled according to the actual demand. This is shown in Figure 3.2(b).

In the synchronous transfer mode (STM) (see Figure 3.2 (a)), a data unit associated with a given channel is identified by its position in the transmission frame, while in ATM (Figure 3.2 (b)) a data unit or cell associated with a specific virtual channel may occur at essentially any position. The flexibility of bit rate allocation to a connection in STM is restricted due to predefined channel bit rates and the rigid structure of conventional transmission frames. These normally will not permit individual structuring of the payload or will only permit a quite limited selection of channel mixes at the corresponding interface at subscription time. Otherwise the network provider would have to manage a host of different interface types, a situation that the designer would try to avoid for obvious reasons (for example, STM switching of varying B and H channel mixes per interface requires switching equipment that can simultaneously handle all sorts of channels potentially used by customers at any time).

In ATM-based networks the multiplexing and switching of cells is independent of the actual application. So the same piece of equipment in principle can handle a low bit rate connection as well as a high bit rate connection, be it of stream or burst nature. Dynamic bandwidth allocation on demand with a fine degree of granularity provided. So the definition of high peed channel bit rates is now, in contrast to the situation in a STM environment, a second-rank task.



(a) Synchronous transfer mode. **(b)** Asynchronous transfer mode

Figure 3.2: STM and ATM principles

The flexibility of the ATM-based B-ISDN network access due to the cell transport concept strongly supports the idea of unique interface which can be employed by a variety of customers with quite different service needs.

However, the ATM concept requires any new problems to be solved. For example, the impact of possible cell loss, cell transmission delay and cell delay and variation on service quality needs to be determined.

To sum up whereas today's networks are characterized by the coexistence of circuit switching and packet switching, B-ISDN will rely on a single, new method called ATM, which combines advantageous features of both the circuit, and packet- oriented techniques. The former requires only low overhead and processing, and, once a circuit-switched connection is established, the transfer delay of the information being carried over it is low. The latter is much more flexible in terms of bit rate assigned to individual (virtual) connections. ATM is a circuit-oriented, hardware-controlled, low overhead concept of virtual channels which (by contrast with X. 25 access) have no flow control or error recovery. The implementation of these virtual channels is done by fixed-size (relatively short) cells and provides the basis for both switching and multiplexed transmission. The use of short cells in ATM and the high transfer rates involved (e.g. 150 Mbit/s) result in transfer delays and delay variations which are sufficiently small to enable universal applicability to a wide range of services including real-time services, e.g. voice and video. The capability of ATM to multiplex and switch on the cell level supports flexible bit rate allocation, as is known from packet networks.

The overall protocol architecture of ATM networks comprises:

- A single link-by-link cell transfer capability common to all services
- Service-specific adaptation functions for mapping higher layer information into ATM cells on an end-to-end basis, e.g. packetization/depacketization of continuous bit streams into/from ATM cells or segmentation/reassembly of larger blocks of user information into/from ATM cells (core-and-edge concept).

Another important feature of ATM networks is the possibility of grouping several virtual channels into one so-called virtual path. The impact of this technique on the B-ISDN structure will be addressed in the following chapter.

3.3 Optical Transmission

The development of powerful and economic optical transmission equipment was the other big driving force for B-ISDN. Optical transmission is characterized by:

- Low fiber attenuation (allowing for large repeater distances)
- High transmission bandwidths (up to several hundred Mbit/s)
- Comparably small diameter (low weight/volume)
- High mechanical flexibility of the fiber
- Resistance against electromagnetic fields
- Low transmission error probability
- No cross-talk between fibers
- Tapping much more difficult.

The high bandwidth of optical transmission system—currently up to Gbit/s can be transported via one optical link— has led to early implementations in public networks to support existing services like telephony. Fiber-based local area networks are also widely in use nowadays, providing a bit rate in the order of magnitude of a hundred Mbit/s to the users.

So for B-ISDN the use of optical fiber-based transmission system is straightforward from a technical viewpoint, at least in the trunk network and in the local access part of the network where considerable distances have to be bridged (Technical details on optical transmission to be deployed in B-ISDN)

In B-ISDN at least about 150Mbit/s will be offered to the user across the broadband user-network interface. Though much higher bit rates could comfortably be transmitted on optical fiber links, the costs of the electronics involved in the transmission equipment (e.g. sender/receiver in network terminations, terminals etc) together with considerations on expected service needs i.e. bit rates simultaneously required at the interface led to the conclusion that a B-ISDN 'basic' interface at about 150Mbit/s would be sufficient and adequate in many case.

In addition, a second interface type with at least 600 Mbit/s in the direction from the network to the user is also foreseen. Handling of 600 Mbit/s ATM signals is still a challenge, the economic implementation of which is currently not so assured.

The deployment of highly reliable optical transmission system with rather low bit error probabilities benefits a simplified network concept with, for example, potentially reducible data link layer functionality.

4. B-ISDN NETWORK CONCEPT

4.1 General Architecture of the B-ISDN

The architectural model of the B-ISDN is described in CCITT Recommendation I.327 According to this recommendation, the information transfer and signaling capabilities of the B-ISDN comprise:

- Broadband capabilities
- 64 kbit/s based ISDN capabilities
- User-to-network signaling
- Inter-exchange signaling
- User-to-user signaling.

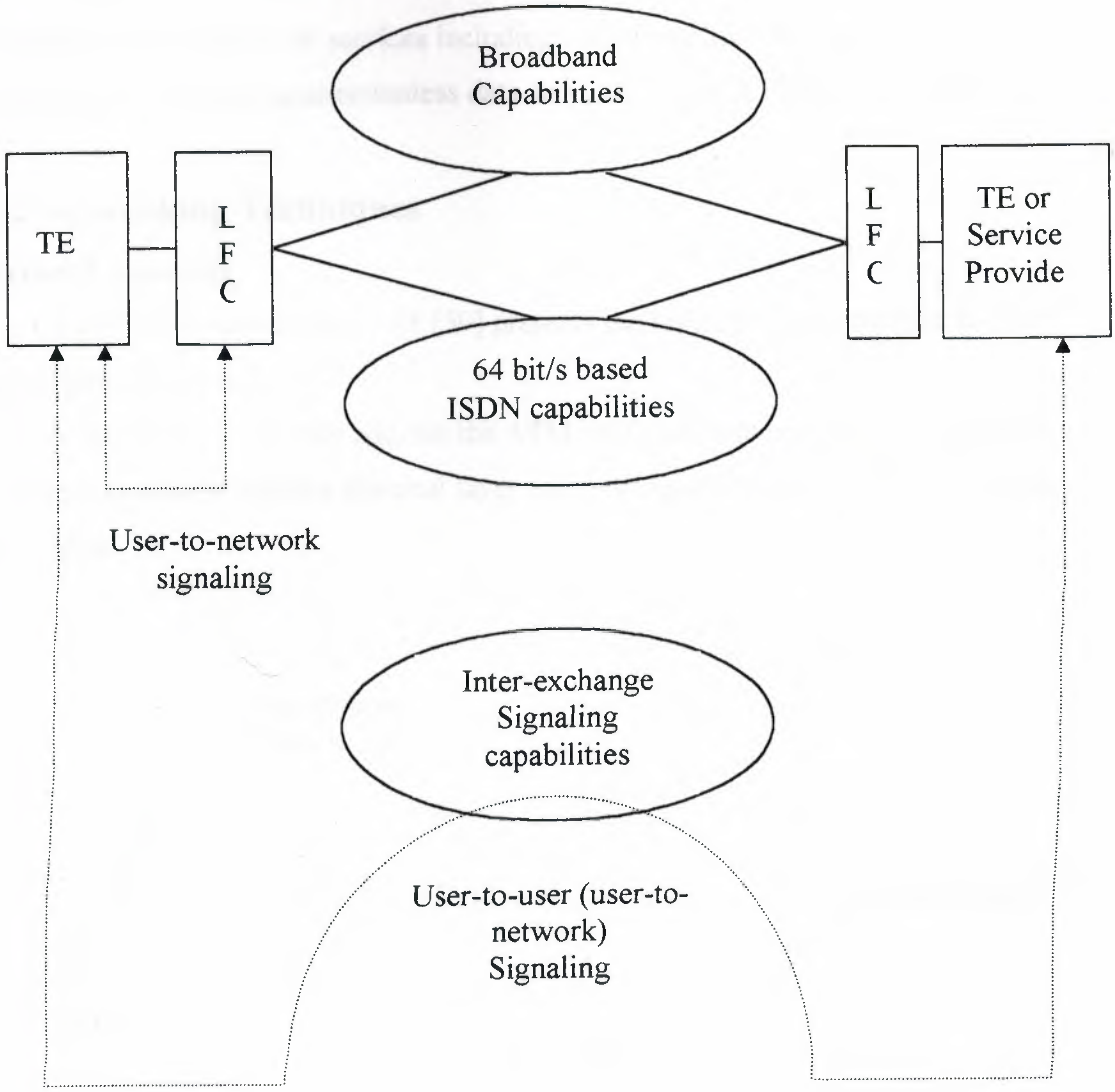
This is depicted in figure 4.1.

ATM provides broadband information transfer. The ATM data unit is the cell, a fixed-size block of 53 octets. The 5-octet cell header caries the necessary information to identify cells belonging to the same virtual channel. Cells are assigned on demand depending on the source activity and the available resources.

ATM guarantees (under normal, i.e. fault-free, conditions) cell sequence integrity. This means that a cell belonging to a specific virtual channel connection can nowhere in the network overtake another cell of the same virtual channel connection that has been sent out earlier.

ATM is a connection-oriented technique. A connection within the ATM layer consists of one or more links, each of which is assigned an identifier. These identifiers remain unchanged for the duration of the connection.

Signaling information for a given connection is conveyed using a separate identifier (out-of band signaling).



LFC Local function capabilities

TE Terminal equipment

Figure 4.1 Information transfer and signaling capabilities

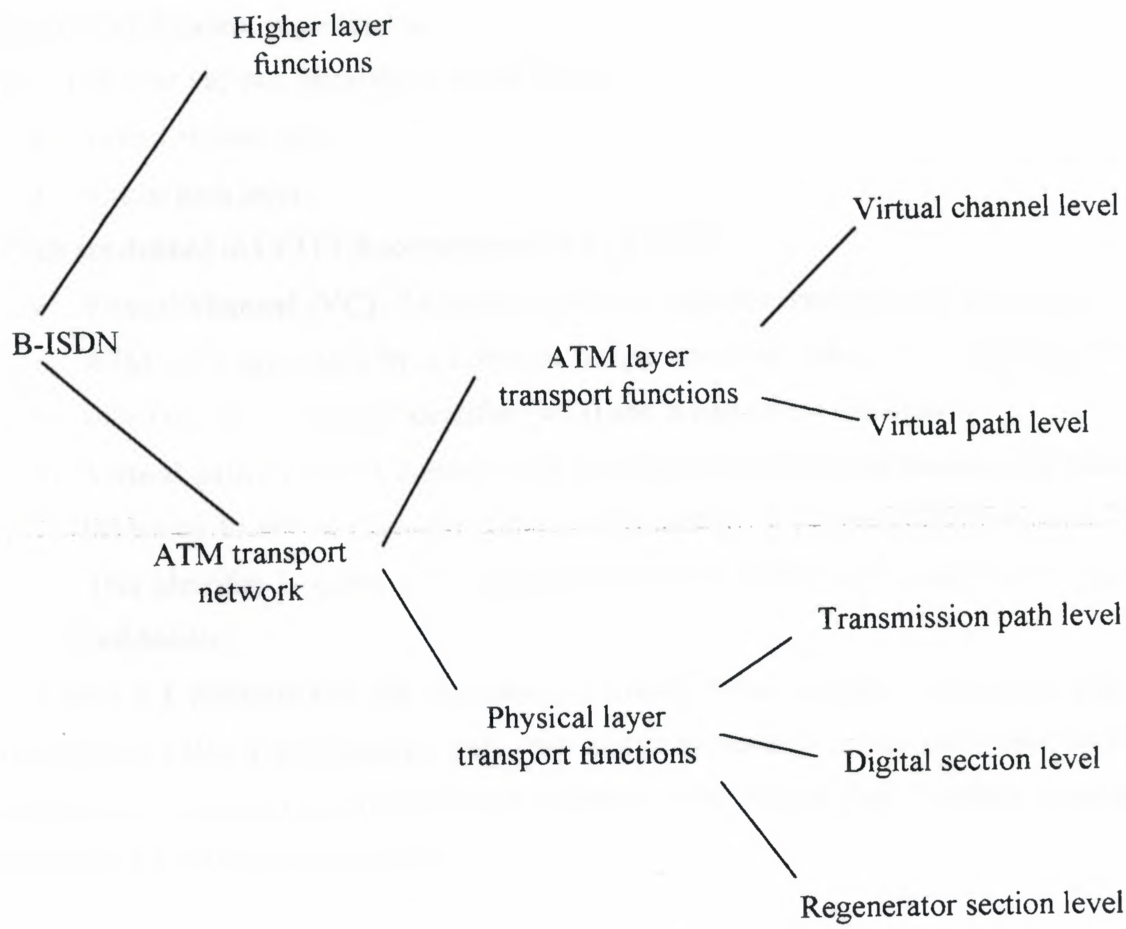
Though ATM is a connection-oriented technique, it offers a flexible transfer capability common to all services including connectionless data services. The proposed provision of connectionless data services via the ATM-based B-ISDN.

4.2 Networking Techniques

Network Layering

CCITT recommendation I.311 [50] presents the layered structure of the B-ISDN depicted in figure 4.2

In this section, we only address the ATM transport network whose functions are split into two pails, namely physical layer transport functions and ATM layer transport functions.



ATM Asynchronous transfer mode

Figure 4.2 B-ISDN layered structure

Both the physical layer and the ATM layer are hierarchically structured. The physical layer consists of

- Transmission path level
- Digital section level
- Regenerator section level

Which are defined in the following way:

Transmission path: The transmission path extends between network elements that assemble and disassemble the payload of a transmission system (the payload will be used to carry user information; together with the necessary transmission overhead it forms the complete signal).

Digital section: The digital section extends between network elements, which assemble and disassemble continuous bit or byte streams.

Regenerator section: The regenerator section is a portion of a digital section extending between two adjacent regenerators.

The ATM layer has two hierarchical levels, namely:

- Virtual channel level
- Virtual path level

Which are defined in CCITT Recommendation I.113 [45]

- **Virtual channel (VC):** "A concept used to describe unidirectional transport of ATM cells associated by a common unique identifier value." This identifier is called the virtual channel identifier (VCI) and is part of the cell header.
- **Virtual path (VP):** "A concept used to describe unidirectional transport of cells belonging to virtual channels that are associated by a common identifier value." This identifier is called the virtual path identifier (VPI) and is also part of the cell header.

Figure 4.3 demonstrates the relationship between virtual channel, virtual path and transmission path: a transmission path may comprise several virtual paths and each virtual path may carry several virtual channels. The virtual path concept allows grouping of several virtual channels.

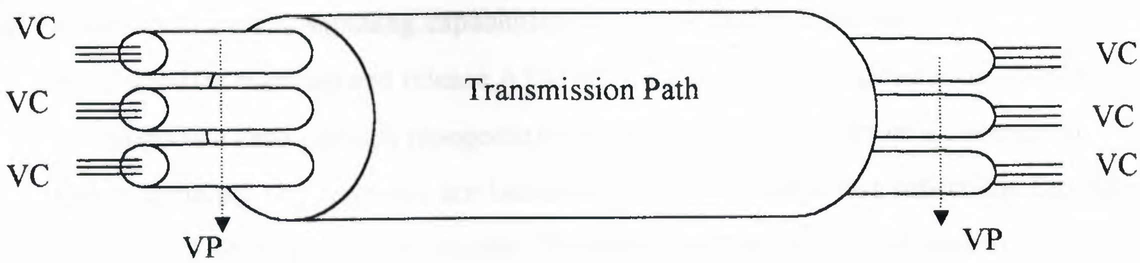


Figure 4.3 Relationship between virtual channel, virtual path and transmission path

Concerning the levels of the ATM layer (virtual channel and virtual path), it proved helpful to distinguish between links and connections:

- **Virtual channel link**: A means of unidirectional transport of ATM cells between a point where a VCI value is assigned and the point where that value is translated or removed.

4.3 Signaling Principles

4.3.1 General Aspects

B-ISDN follows the principle of out-of-band signaling that has been established for the 64 kbit/s ISDN where a physical signaling D channel has been specified. In B-ISDN the VC concept provides the means to separate logically signaling channels from user channels.

A user may now have multiple signaling entities connected to the network call control management via separate ATM VCCs. The actual number of signaling connections and the bit rate allocated to them can be chosen in B-ISDN in a way that satisfies a customer's need optimally.

4.3.2 Capabilities Required for B-ISDN Signaling

B-ISDN signaling must be able to support:

- 64 kbit/s ISDN applications
- New broadband services.

This implies that existing signaling functions according to CCITT Recommendation Q.931 [74] must be included in B-ISDN signaling capabilities; on the other hand, the nature of B-ISDN, the ATM transport network-and the increasing desire for advanced communication forms like multi-media services require specific new signaling elements. In the following, an overview of necessary B-ISDN signaling capabilities is given. (More details on the implementation of such functions will be even.)

ATM network-specific signaling capabilities have to be realized in order to:

- Establish, maintain and release ATM VCCs and VPCs for information transfer
- Negotiate (and perhaps renegotiate) the traffic characteristics of a connection.

Other signaling requirements are basically not ATM related but reflect the fact that more powerful service concepts appear. Examples are the support of multi-connection calls and multi-party calls.

For a multi-connection call, several connections have to be established to build up a 'composite' call comprising, for example, voice, image and data. It must also be possible to remove one or more connections of a call or to add new connections to the existing ones. A certain capability in the network to correlate the connections of a call is required. In any case, release of a call as a whole must be possible. These correlation functions should be performed in the origination and destination B-ISDN switch only, since the transit nodes should not be burdened with such tasks.

A multi-party call consists of several connections between more than two endpoints (Conferencing). Signaling to indicate establishment/release of a multi-party call and adding/removing one party is required. (A communication that is part of a multi-party call may be of multi-connection nature itself.)

In a broadband environment, asymmetric connections (i.e. low or zero bandwidth in one direction and high bandwidth in the other) will gain relevance; signaling elements to support such connection types have to be established.

Another broadband issue impacting signaling is inter-working, e.g. B-ISDN with non B-ISDN services, or between video services with different coding schemes.

4.3.3 Signaling Virtual Channels

In B-ISDN signaling messages will be conveyed out-of-band in dedicated signaling virtual channels (SVCs). Different types of SVC are provided; they are shown in table 4.1.

There is one meta-signaling virtual channel (MSVC) per interface. This channel is bi-directional and permanent. It is a sort of interface management channel used to establish, check and release the point-to-point and selective broadcast SVCs.

Whereas the meta-signaling virtual channel is permanent, a point-to-point signaling channel is allocated to a signaling endpoint only white it is active.

A signaling endpoint at the user side may be located in a terminal or in the B-NT2 (e.g. private branch exchange). In a multi-functional terminal, multiple signaling endpoints may occur.

Table 4.1: Signaling virtual channels at B-ISDN UNI

SVC Type	Directionality	Number of SVCs
Meta-signaling channel	Bidirectional	1
General broadcast SVC	Unidirectional	1
Selective broadcast SVC	Unidirectional	Several possible
Point-to-point SVC	Bidirectional	One per signaling endpoint

The point-to-point signaling channels are bi-directional. They are used to establish, control and release VCCs or VPCs to carry user data (VPCs as well as VCCs may also be established without using signaling procedures, e.g. by subscription).

The broadcast SVCs are unidirectional (network-to-user direction only). They are used to send signaling messages either to all signaling endpoints in a customer's network or to a selected category of signaling endpoints. The general broadcast SVC reaches all signaling endpoints; it is implemented in any case, Selective broadcast SVCs may be provided in addition as a network option to be able to address all terminals belonging to the same service profile category (a B-ISDN service profile contains information which is maintained by the network to characterize the services offered by the network to the user; the service profile may be specified as in CCITT Recommendation Q.932, Annex or otherwise)

The provision of SVCs in the network is currently under discussion; so far no firm decisions have been taken but the principles outlined here are expected to apply.

To illustrate the SVC concept of B-ISDN, an example (based on CCITT Recommendation I.311) is given in Figure 4.4, which highlights different possibilities for carrying signaling information from the customer to the network and vice versa.

Four different VP links/connections are depicted in the figure. The first (a) is a signaling VP link, which transports all the signaling information to be exchanged between the customer and the local exchange, including meta-signaling. When a signaling capability to a point in the network other than the local exchange is required (e.g. in order to communicate with a special service provider located elsewhere), such signaling can be done on an extra VPC (c) which may carry signaling and user data. This VPC goes through the local exchange and is terminated at the appropriate place. (The other two VPs (b) and (d) have shown for completeness in the figure carry user data only. In case (b) the corresponding VCs are switched in the local exchange and in case (d) the VP as a whole goes transparently through the local exchange.)

4.4 Broadband Network Performance

Broadband networks based on ATM call transfer must meet certain performance requirements in order to be accepted by booth potential users and network providers. ATM-related performance parameters and measures need to be specified in addition to the performance parameters already introduced for existing networks. In this section, we only deal with ATM layer-specific network performance. What the user will perceive as quality of service may be influenced not only by the ATM transport network performance but also by higher layer mechanisms. In some cases, these will be able to compensate for shortcomings in the ATM transport network performance but also by higher layer mechanisms. In some cases, these will be able to compensate for shortcomings in the ATM transport network.

Cells belonging to a specified virtual connection are delivered from one point in the network to another, e.g. from A to B. A and B may denote the very endpoints of a virtual connection, or they may delimit a certain portion of the cell transport route, e.g. A and B may indicate national network boundaries of an international ATM connection. Due to a certain transfer delay, cells sent from A arrive at B within $\Delta t > 0$ (see Figure 4.5). Note that the cell exit event occurs according to CCITT Recommendation I.35B when the first bit of the ATM cell has completed transmission across A, and the cell entry event occurs when the last bit of the ATM cell has completed transmission across B.

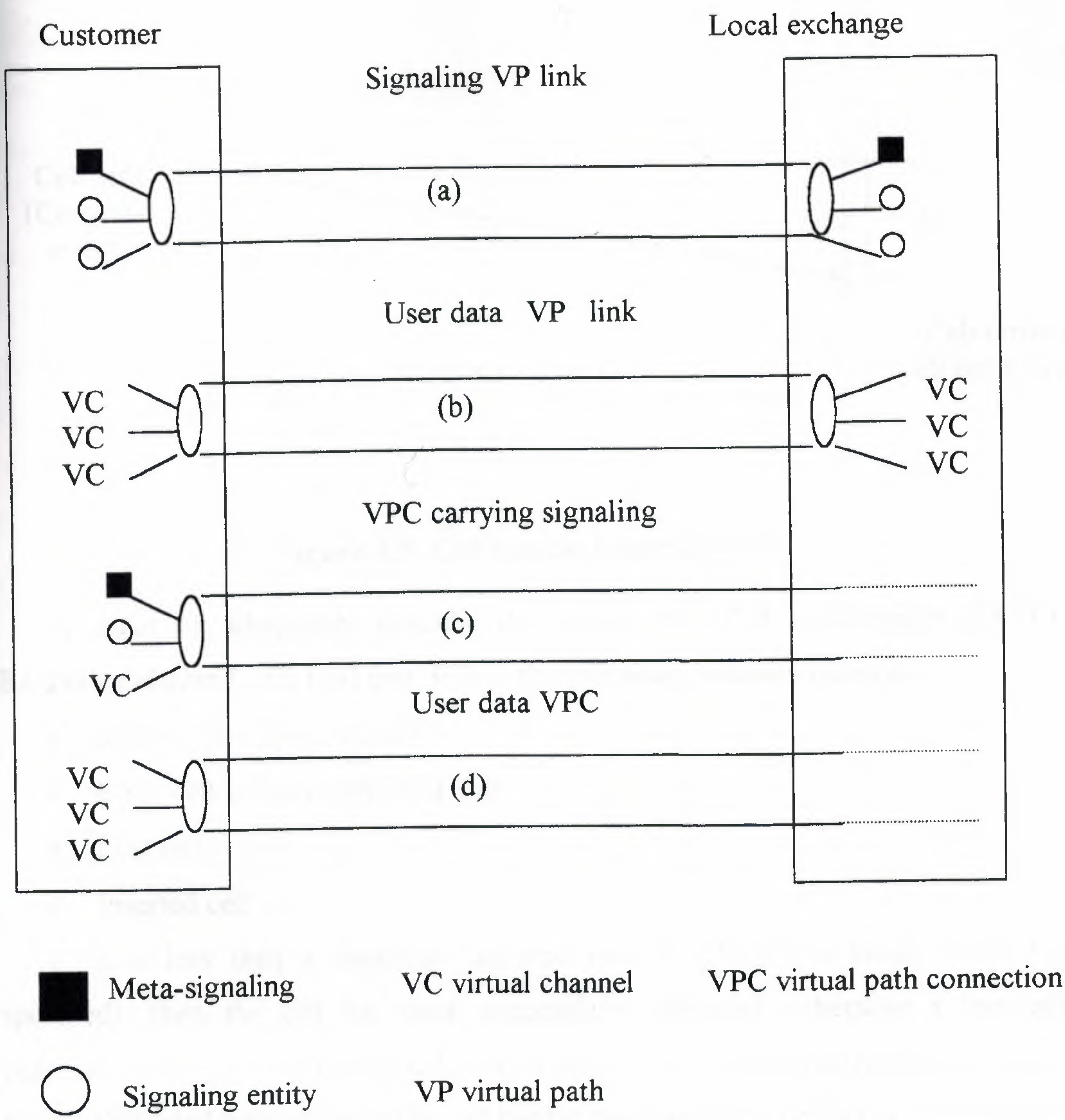


Figure 4.4 Allocation of signaling virtual channels to a customer

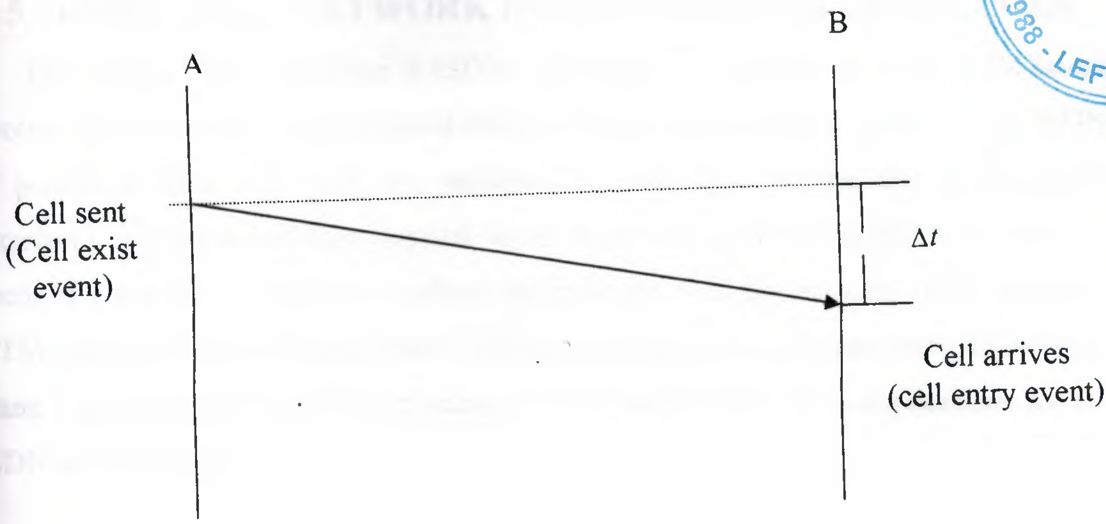


Figure 4.5: Cell transfer (schematically)

In order to adequately describe the quality of ATM cell transfer, CCITT Recommendation I.35B [44] first defines the following outcome categories

- Successfully delivered cell
- Error cell and severely error cell
- Lost cell
- Inserted cell.

If Δt is less than a maximum allowed time T (the exact value is not yet specified), then the cell has been successfully delivered, otherwise a lost cell outcome occurs (i.e. either the cell arrives after T or it never reaches B). Errors in the VC/VP label field of the ATM cell header that cannot be corrected or cell buffer overflows in the network (e.g. in an ATM switch) lead to lost cells.

5. B-ISDN USER-NETWORK INTERFACES AND PROTOCOLS

This chapter deals with the B-ISDN user-network interface and with ATM-based protocols. In section 5.1 the protocol reference model developed by CCITT for B-ISDN is presented. The next sections, sections 5.2 and 5.3, describe the user-network interfaces in general and their physical layer properties. Then in the following sections, sections 5.4 and 5.5, functions, codings and procedures of the adjacent ATM layer and ATM adaptation layer are described. Higher layer aspects of both user plane and control plane (signaling) are described in section 5.6. In section 5.7 some applications for B-ISDN are described.

5.1 B-ISDN Protocol Reference Model

5.1.1General Aspects

In modern communication systems, a layered approach is used for the organization of all communication functions. The functions of the layers and the relations of the layers with respect to each other are described in a protocol reference model (PRM).

A description of the PRM for the existing ISDN is given in CCITT Recommendation I.320 [51]. In particular it has introduced the concept of separated planes for the segregation of user, control and management functions. This PRM is the basis for the PRM of the broadband aspects of ISDN (B-ISDN PRM) which is described in CCITT Recommendation I.321 [52]. The new recommendation has the purpose of taking into account the functionalities of B-ISDN. Therefore, expansions of the PRM contained in CCITT Recommendation I.320 were necessary.

5.1.2 Relationship between the B-ISDN PRM and the OSI Reference Model

The OSI reference model for CCITT applications is defined in CCITT Recommendation X.200 [80]. OSI is a logical architecture which defines a set of principles including protocol layering, layer service definition, service primitives and independence. These principles are appropriate for the definition of the B-ISDN PRM (e.g. independence).

The OSI reference model uses seven layers (see Table 5.1). Each layer has its own specific functions and offers a defined service to the layer above using the service provided by the layer below. This approach is also well suited for the B-ISDN PRM. Unfortunately, the exact relationship between the lower layers of the OSI reference model and those of the B-ISDN PRM is still not fully clarified.

Layer	Name
7	Application layer
6	Presentation layer
5	Session layer
4	Transport layer
3	Network layer
2	Data link layer
1	Physical layer

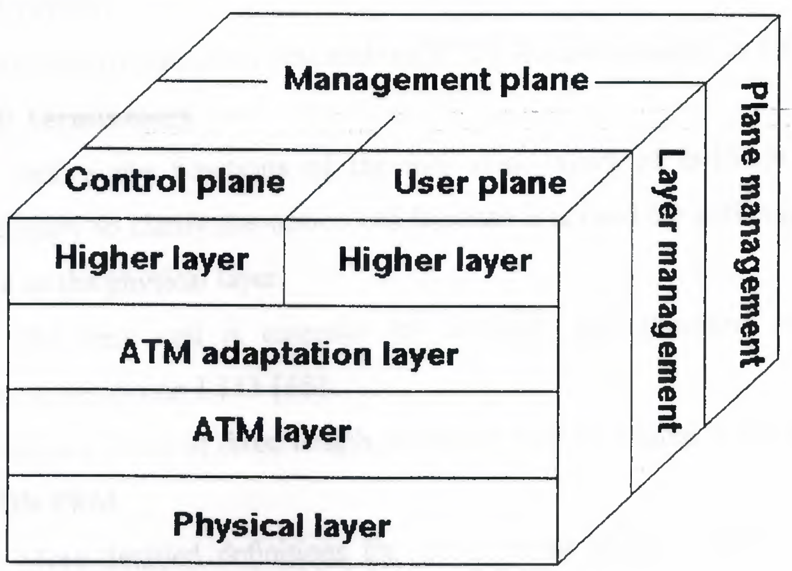
Table 5.1: OSI reference model

5.1.3 B-ISDN PRM Description

Figure 5.1 shows the B-ISDN PRM. It consists of the following three planes:

- User plane
- Control plane
- Management plane.

The management plane includes two types of functions called layer management functions and plane management functions. All the management functions which relate to the whole system are located in the plane management. Its task is to provide coordination between all planes. No layered structure is used within this plane.



ATM Asynchronous transfer mode

Figure 5.1: B-ISDN protocol reference model

The layer management has a layered structure. It performs the management functions relating to resources and parameters residing in its protocol entities (e.g. meta-signaling). For each layer the layer management handles the specific OAM information flows. More details about these management functions are presented in CCITT Recommendation Q.940 [76].

The user plane provides for the transfer user information. All associated mechanisms like flow control or recovery from errors are included. A layered approach is used within the user plane.

Within the control plane a layered structure is also used. This plane is responsible for call control and connection control functions. These are all signaling functions which are necessary to setup, supervise and release a call or a connection.

The functions of the physical layer (PL) and the ATM layer are the same for the control plane and the user plane. Different functions may occur in the ATM adaptation layer (AAL) as well as in higher layers.

5.1.4 Layer Functions

The functions of the physical layer, the ATM layer and the ATM adaptation layer, the primitives exchanged between layers, and the primitives exchanged between these layers and the management plane are described in the following subsections. The functions of the higher layers cannot be presented here because at present they are not well defined.

These descriptions are contained in CCITT Recommendations I.321 [52] and I.413 [59].

Cell Terminology

Before the functions of the individual layers of B-ISDN can be specified it is necessary to clarify the notion cell because it is used for definitions in the ATM layer as well as the physical layer.

The term cell is essential for B-ISDN, and therefore it is defined in CCITT Recommendation I.113 [45]:

A cell is a block of fixed length. It is identified by a label at the ATM layer of the B-ISDN PRM.

More detailed definitions for the different kinds of cells are presented in CCITT Recommendation I.321 [52]:

- Idle cell (physical layer): A cell which is inserted/extracted by the physical layer in order to adapt the cell flow rate at the boundary between the ATM layer and the physical layer to the available payload capacity of the transmission system used.

- Valid cell (physical layer): A cell whose header has no errors or has been modified by the cell header error control (HEC) verification process.
- Invalid cell (physical layer): A cell whose header has errors and has not been modified by the cell HEC verification process. This cell is discarded at the physical layer.
- Assigned cell (ATM layer): A cell which provides a service to an application using the ATM layer service.
- Unassigned cell (ATM layer): An ATM layer cell which is not an assigned cell.

Only assigned and unassigned cells are passed to the ATM layer from the physical layer. The other cells carry no information concerning the ATM and higher layers and therefore they will only be processed by the physical layer.

Physical Layer Functions

The physical layer is subdivided into the physical medium (PM) sub-layer and the transmission convergence (TC) sub-layer.

The PM sub-layer is the lowest sub-layer and includes only the physical medium dependent functions. It provides the bit transmission capability including bit alignment. Line coding and, if necessary, electrical/optical conversion is performed by this sub-layer. In many cases, an optical fiber will be used for the physical medium. Other media, like coaxial cables, are also possible. The transmission functions are medium specific.

The functions of bit timing are generation and reception of waveforms which are suitable for the medium, the insertion and extraction of bit timing information, and the line coding if required.

The TC sub-layer performs five functions. The lowest function is the generation and recovery of the transmission frame.

The transmission frame adaptation is responsible for all actions which are necessary to adapt the cell flow according to the used payload structure of the transmission system in the sending direction. In the opposite direction it extracts the cell flow out of the transmission frame. This frame may be cell equivalent (no external envelope is used), a synchronous digital hierarchy (SDH) envelope or an envelope according to CCITT

Recommendation C.703 [33]. For the B-ISDN UNI, CCITT proposes a SDH envelope or the cell equivalent structure [62].

The function mentioned so far are transmission frame specific. All other TC sub-layer functions, which are presented in the following, can be common to all possible transmission frames.

Cell delineation is the mechanism which enables the receiver to recover the cell boundaries. This mechanism is described in CCITT Recommendation I.432 [62]. To protect the cell delineation mechanism from malicious attack the information field of a cell will be scrambled before transmission. Descrambling will done at the receiving side.

HEC sequence generation is done in the transmit direction. The HEC sequence is inserted in its appropriate field within the header. At the receiving side the HEC value is recalculated and compared with the received value. If possible, header errors are corrected; otherwise the cell will be discarded.

In the sending direction the cell rate decoupling mechanism inserts idle cells in order to adapt the rate of ATM cells to the payload capacity of the transmission system. In the receiving direction this mechanism suppresses all idle cells. Only assigned and unassigned cells are passed to the ATM layer.

ATM Layer Functions

The layer above the physical layer is the ATM layer. Its characteristic features are independent of the physical medium. Four functions of this layer have been identified.

In the transmit direction, cells from individual VPs and VCs are multiplexed into one resulting cell stream by the cell multiplexing function. The composite stream is normally a non-continuous cell flow. At the receiving side the cell demultiplexing functions splits the arriving cell stream into the individual cell flows appropriate to the VP or VC.

At ATM switching nodes and /or at cross-connect nodes, the VPI and VCI transmission has to be performed. Within a VP switch the value of the VPI field of each incoming cell is translated into a new VPI value for the outgoing cell. At a VC switch the values of the VPI as well as the VCI are translated into new values.

The cell header generation/extraction function is applied at the termination points of the ATM layer. In the transmit direction, after receiving the cell information field from the AAL, the cell header generation adds the appropriate ATM cell header except for the HEC value. VPI/VCI values could be obtained by a translation from the SAP identifier. In the opposite direction the cell header extraction function removes the cell header. Only the cell information field is passed to the AAL. This function could also translate a VPI/VCI into a SAP identifier.

The GEF function is only defined at the B-ISDN UNI. GFC supports the control of the ATM traffic flow in a customer network. It can be used to alleviate short-term overload conditions. The specific GFC information is carried in assigned or unassigned .5the convergence sub-layer (CS). The functions of the AAL are described in CCITT Recommendation I.362 [55].

The AAL is between the ATM layer and higher layers. Its basic function is the enhanced adaptation of the services provided by the ATM layer to the requirements of the higher layer. Higher layer PDUs are mapped into the information field of an ATM cell. The AAL entities exchange information with their peer AAL entities to support the AAL functions.

The functions of the AAL are organized in two sub-layers. The essential functions of the SAR sub-layer are, at the transmitting side, the segmentation of higher layer PDUs into a suitable size for the information field of the ATM cell (48 octets) and, at the receiving side, the reassembly of the particular information fields into higher layer PDUs. The CS is service dependent and provides the AAL service at the AAL-SAP.

Between these two sub-layers, no SAP has yet been defined. The need for such SAPs needs further study. Different SAPs for higher layers can be achieved by different combinations of SAR and CS. For some applications, neither a CS nor a SAR is necessary and therefore they will be empty.

To minimize the number of AAL protocols, CCITT proposed a service classification which is specific to the AAL. This classification was made with respect to the following parameters:

- Timing relation
- Bit rate
- Connection mode.

5.2 General Aspects of the User-Network Interface

5.2.1 Transfer Mode

As was mentioned before, the B-ISDN user-network interface (UNI) fully exploits the flexibility inherent in ATM. This means that the payload capacity of the interface (i.e. the whole of the transmission capacity besides the small portion that is needed to operate the interface properly) is completely structured into ATM cells.

As at the UNI, there is no pre-assignment of cells to specific user applications; the actual use of cells for connections to be established across the interface can change dynamically. Different traffic mixes can easily be supported as long as the cell transfer capacity is not exceeded.

5.2.2 Bit Rates

Two different interface bit rates are foreseen: one around 150 Mbit/s and the other around 600 Mbit/s. The exact figures will be discussed in a moment.

The 150 Mbit/s interface is symmetric with respect to bit rate, i.e. it offers 150 Mbit/s in the network-to-user direction and in the user-to-network direction as well. This sort of interface will predominantly be used for interactive services like telephony, video-telephony and data services. The extension of such an interface to a higher bit rate in order to be able to meet the needs of users with large traffic volumes seems quite natural. Thus, a bit rate symmetric 600 Mbit/s interface was also conceived. (The reason for choosing 600 Mbit/s will soon become clear.) Users who are expected to have a much higher traffic load from the network to themselves than in the other direction may get an asymmetric version of the 600 Mbit/s interface with a reduced upstream capacity (user-to-network direction) of only 150 Mbit/s. The latter interface type would, for example, be suitable for simultaneous transmission of several television programmes to a residential customer who only needs the standard capacity for interactive services but a higher bit rate for distribution services like TV or sound programmes.

The definition of two separate interface bit rates was a comprise between two diverging requirements, namely a very limited number of different interface types on the one side and the cost-effectiveness of the interface on the other side.

The exact interface bit rates are:

- 155.520 Mbit/s
- 622.080 Mbit/s.

These bit rates are identical to the two lowest bit rates of the SDH as defined in CCITT Recommendation G.707 [34]. SDH is a new transmission hierarchy which was adopted by CCITT in 1988 [34, 35, and 36].It is based on the North-American SONET concept [6] that was developed with the main goal to:

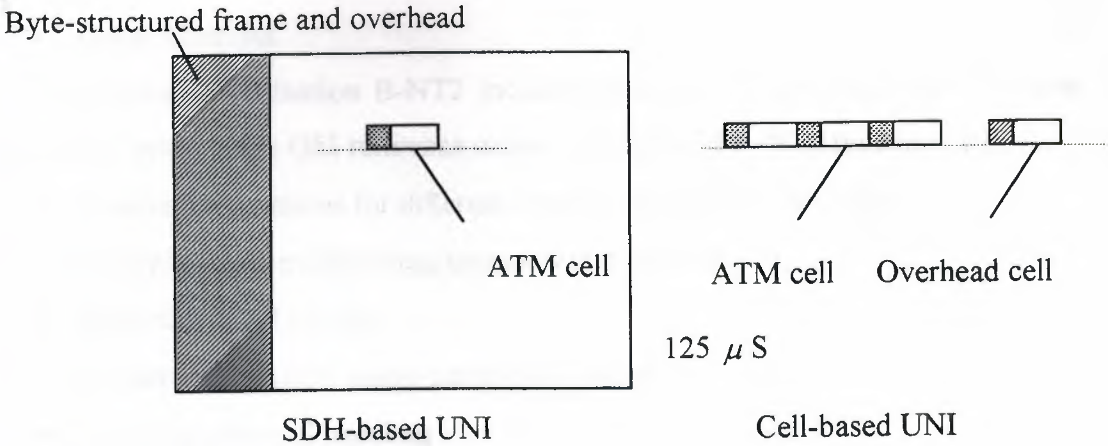
- Set a standard for optical transmission in order to react on the upcoming variety of manufacturer-specific implementations of optical transmission systems and interfaces.
- Provide transmission facilities with flexible add/drop capabilities to allow for simpler multiplexing/demultiplexing of signals than in the existing plesiochronous digital hierarchy (PDH) [32]
- Grant generously dimensioned transmission overhead capacity to cater for various existing and assumed network operation and maintenance applications that were not, or at least only with difficulties, realizable in PDH.

5.2.3 Interface Structure

SDH has an inherent flexibility to transport quite different types of signals like ISDN channels, according to CCITT Recommendation I.412 [58], or ATM cells. So SDH-being a universal transmission concept-was proposed as the B-ISDN interface structure [24]. Such a user-network interface with the network-node interface. This avoids otherwise necessary conversion of signals that are sent from the user through the network to other users. This property is extremely useful in the introductory phase of B-ISDN where a complete network infrastructure does not yet exist. Customers may easily be provided with access to a broadband network node which is a cross-connect or a switch and which may be located in a place different to that of the 64 kbits/s ISDN local exchange that usually serves the customer, via SDH equipment, which in some networks will be implemented prior to the realization of B-ISDN.

However, the SDH-based B-ISDN user-network interface has some drawbacks. A minor one is the fact that large overhead capacity provided by DH is not actually needed at the user-network interface, but some Mbit/s in relation to a 150 Mbit/s interface bit rate; however, this is no stringent argument against using SDH. Generation of the byte-structures SDH frame requires additional interface functionality that would not be necessary if the interface was completely cell structured (this is a possible solution as no 'physical' channels are foreseen, as in the case of the 64 kbit/s ISDN. Insertion of ATM cells from several terminals into one SDH frame in a passive bus configuration (such a configuration was standardized for the 64 kbit/s ISDN, see CCITT Recommendation I.430 [60]) is almost impossible for realistic transmission lengths due to individually varying transmission delays and the high bit rates involved.

For this reasons, two interface types were standardized [59, 62]: one based on SDH and the other based on mere cell multiplexing (see figure 5.2).



ATM Asynchronous transfer mode
SDH Synchronous digital hierarchy
UNI User-network interface

Figure 5.2 User-network interface options

Whereas the SDH interface is already to be implemented, the cell-based interface is not yet fully defined, e.g. coding and allocation of OAM functions is not sufficiently clear. Remarkably, though the interface bit rate of the cell-based interface is basically not determined by any frame structure but might freely be chosen, it was agreed within CCITT to adopt the same bit rate for both interface types in order to facilitate interworking between the cell-based UNI and SDH in the network.

5.2.4 B-ISDN UNI Reference Configuration and physical realizations

The ISDN reference configuration for the basic and primary rate access was applied to B-ISDN with only minor modifications of notation. A reference configuration of the user-network access is a generic description based on the following two elements:

- Functional groups
- Reference points

As shown in figure 5.3

Figure 5.3 mainly shows broadband functional groups and reference points. The corresponding entities for the 64 kbit/s ISDN are described in CCITT Recommendation I.411 [57].

The broadband network termination B-NT1 includes functions broadly equivalent to layer 1 of the OSI reference model [80]. Examples of B-NT1 functions are:

- Line transmission termination

- Transmission interface handling
- OAM functions.

The network termination B-NT2 includes functions broadly equivalent to layer 1 and higher layers of the OSI reference model. Examples of B-NT2 functions are:

- Adaptation functions for different interface media and topologies
- Multiplexing/demultiplexing/concentration of traffic
- Buffering of ATM cells
- Resource allocation; usage parameter control
- Signaling protocol handling
- Interface handling
- Switching of internal connections.

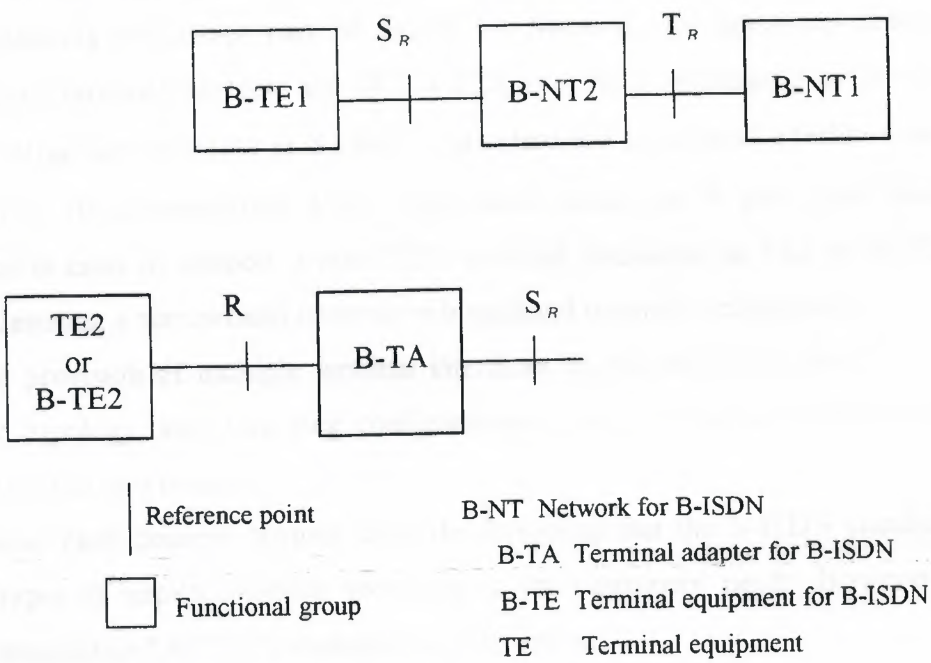


Figure 5.3 B-ISDN UNI reference configuration

The generic term 'B-NT2' covers a host of actual implementation: it may be non-existent ('null B-NT2' provided that interface definitions allow direct connection of terminals to the B-NT1), consist solely of layer 1 connections (wires), provide concentrating and/or multiplexing functions, or be a full-blown switch (private branch exchange). The B-NT2 functions may be concentrated or distributed, e.g. in a bus or ring with its access nodes.

S_B and T_B denote reference points between the terminal and the B-NT2, and the B-NT1 and B-NT2, respectively. Physical interfaces need not occur at a reference point in any case.

It is also possible for the terminal to include B-NT2 functionality. If the same interface standard applies to both S_B and T_B, S_B and T_B may coincide, thus permitting direct connection of a terminal to the B-NT1.

B-ISDN will also offer 64kbit/s ISDN services and interfaces. Terminals TE1 complying with CCITT Recommendation I.430 [60] (basic access) can be connected via such standard interfaces at the S reference point.

Of course the B-NT2 may provide multiple interfaces of each type at S and S_B reference points.

Finally, to complete this brief description of the B-ISDN reference configurations, let us address the lower part of figure 5.3 Showing the functional groups B-TA (broadband terminal adaptor) and TE2/B-TE2, and the R reference point between both functional groups, whereas at S_B and T_B standardized broadband interfaces (according to CCITT Recommendation I.432 [62]) must occur, at R any other (non-ISDN) interface is used to connect a non-ISDN terminal (indicated as TE2 or B-TE2 in the figure denoting a narrowband terminal or broadband terminal, respectively).

The provision of multiple terminal interfaces by the B-NT2 is not restricted to a specific topology; star, bus, ring configurations or even mixtures of those topologies, e.g. stares bus, are possible.

It may have become obvious from the foregoing that the B-ISDN standard allows many types of implementations according to the customers' needs. However, CCITT Recommendation I.413 [59] contains two restrictions:

1. At T_B reference point, only one interface per B-NT1 is allowed.
2. The interfaces are point-to point at the physical layer 'in the sense that there is only one sink (receiver) in front of one source (transmitter)' [59].

5.3 Physical Layer

Figure 5.4 represents the possible configurations users can adopt when connecting to a B-ISDN network. NT represents the network terminating equipment. NT1 is the interface between the users' phone system and the B-ISDN network provider. NT2 will exist when the users has an internal phone system, i.e. this is the companies private telephone exchange. The TA is a device used to connect non ISDN equipment to a B-ISDN network. The TE is the terminal equipment: type 1 is ISDN aware, type 2 is not.

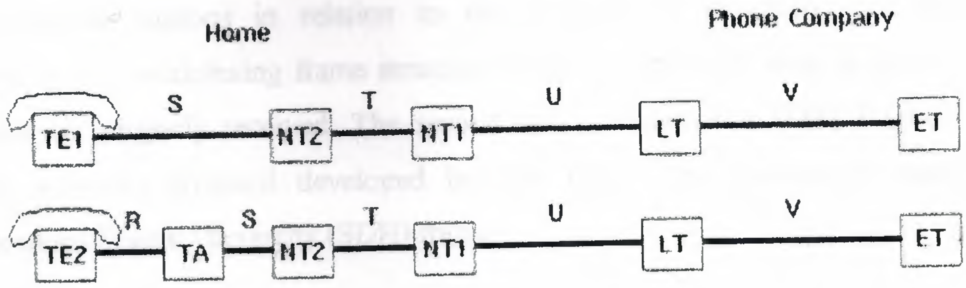


Figure 5.4: User Access Configuration

Currently no protocol has been developed for the S transmission line as it is possible to multiplex several TE devices. However for the point-to-point T line some protocol Standards have been developed.

There are currently three options for transmission:

- Full duplex at 155.52 Mbps
- User to network at 155.52 and network to user at 622.08 Mbps
- Full duplex at 622.08 Mbps

These options need to be taken into consideration in the physical layer. The physical layer is responsible for basic physical layer activities such as information synchronization, bit timing, transmission frame generation and recovery, transmission frame adaptation, cell delineation, HEC sequence generation and cell header verification, as well as cell rate decoupling.

These functions are handled by two sub layers the physical medium sub layer and the transmission convergence sub layer. The physical medium sub layer handles the medium dependent processes, while the transmission convergence sublayer handles the remaining functions.

Physical Medium Sublayer

Correctly there are line control protocols for both an electrical and optical interface. With the optical interface a binary one is represented by an emission of light while a binary zero is depicted by no emission of light. This is known as non return to zero. The electrical interface is slightly more complicated with a binary zero being represented by a positive transition at the midpoint of the binary unit time interval. While a binary one is represented by a constant signal level.

Transmission Convergence Sublayer

This layer handles the way the ATM cells are multiplexed. There are two implementation options in relation to the transmission structure. The first is to incorporate no multiplexing frame structure. With this the HEC field is used to ensure the cells are properly received. The second option utilizes the SONET (synchronous optical network) protocol developed by Bell Core. This protocol is based on a Synchronous Digital Hierarchy (SDH) frame.

5.4 ATM Layer

The ATM layer is responsible for:

- Cell multiplexing and demultiplexing
- Virtual path identification (VPI), and virtual channel identification (VCI)
- Cell header generation/extraction
- Generic Flow Control

The cell multiplexing functions enable multiple logical connections across a single interface. Cell header information in appended by the sending device for use by the receiving device, this is handled by the cell header generation/extraction functions. Placement of cells is handled by the generic flow control functions.

Virtual Paths and Virtual Channels

A virtual channel represents a given path between the user and the destination. This can be represented by user to user connections, user to network connections, or network to network connections. A virtual path is created by multiple virtual channels heading to the same destination. With virtual paths the multiple virtual channels are switched together. This helps reduce network overheads and, therefore, helps keep network speed up.

5.5 ATM Adaptation Layer

The ATM Adaptation Layer consists of two sublayers. The segmentation and reassemble sublayer, SAR, and the convergence sublayer, CS. The convergent sublayer provides specific application support for applications using AAL. This sublayer is service dependent as applications attach to the AAL at specific service access points. The segmentation reassemble sublayer packs the information received from CS into cells for transmission and handles unpacking at the other end. The SAR must pack all

SAR header and trailer information as well as CS header and trailer information into 48-octet blocks.

ITU-T has defined four types of service classifications. Type 1 - this classification requires constant bit rate, maintenance of timing relation, and is a connection oriented classification. Type 2 - This includes variable bit video, i.e., video conference. Here the application is connection oriented, timing is important, however the bit rate will vary over time. Type 3/4 - initially this was two classifications, however, ITU-T combine them due to similarity in processing. This type represents data transfer applications, and with varying bit rates, no timing requirements with type three being connection oriented, and type four being connectionless orientated. Type 5 is a new classification which was introduced to provide streamline transport facilities.

Note: A PDU is a Protocol Data Unit. A PDU is used to pack the information from the higher layers into a manageable unit that will be passed to the ATM layer.

AAL Type 1

Type one operations deal with a constant bit rate. It is therefore, the responsibility of the SAR protocol to pack and unpack cells for transmission. Blocks contain a sequence number so that error PDU's can be trapped. A sequence number protection field is also contained in the cell to assist with error detection and correction. The CS for type one deals with clocking and synchronization, therefore no CS information is required to be transmitted with the cell.

AAL Type 2

This type deals with variable bit rate transmissions. Type two has been set up to deal with analog transmission of video and sound. This type of transmission requires a constant connection, but data bit rates will change based on the amount of activity. Initially, ITU-T provided a specification for the type two protocols; however, this has been recalled and is currently under review. Due to this recall, there are no CS and SAR protocols.

AAL Type 3/4

As with type two this type handles variable bit rate transmission. This type may be either connection based or connectionless, and can be either message-mode or streaming-mode.

As the ATM layer transfers data in cells of 48-octets, the AAL layer must provide segmentation and reassemble functions. For type 3/4, the higher layer passes a block of data to the CS, and then converts this to a PDU incorporating a CPCS (common part convergent sub layer) header and trailer.

The CPCS header consists of a common part indicator, one octet, a beginning tag, one octet, and buffer allocation size, two octets. The beginning tag contains the identification for the CPCS-PDU. The buffer allocation size is used by the receiving device to determine the buffer size necessary for the storage of the entire CPCS-PDU. The CPCS trailer contains an alignment of one octet, an end tag of one octet, and a length indicator of two octets. The alignment is filler that ensures the trailer is 32 bits, while the end tag is used in conjuncture with the beginning tag and the length represents the length of the CPCS PDU payload.

This CPCS PDU is then transferred to the SAR sub layer. In the SAR sub layer the CPCS PDU is segmented into SAR PDU's. Each SAR PDU consists of a SAR header, the SAR PDU payload, and the SAR trailer.

The SAR header consists of three sections the segment type, sequence number and the message identifier. Four type of segment types exist. The first occurs if a CPCS PDU will fit into a single SAR PDU. The remaining three types refer to a CPCS PDU that spans more than one SAR PDU. In this case the segment type may either be a beginning of message, BOM, a continuation, COM, or an end of message, EOM. The sequence number defines the sequence of PDU; this is similar to a frame number. Finally the message identifier is used to identify the CPCS that a SAR PDU belongs to. The SAR trailer has only two sections the length indication, and CRC. The CRC is a ten bit CRC used for error detection on the SAR PDU. The length indicator shows the number of octets that exist in the SAR PDU that are from the CPCS PDU.

AAL Type 5

This type was introduced to minimize protocol processing that exists in type 3 / 4. This is done by moving most of the protocol information from the SAR PDU back to the CPCS PDU. Thus the CPCS PDU in type five contains a 32 bit CRC, user identification, interpretation identification, and a length field. This reduces the processing in the SAR. The only function now performed by the SAR is the segmentation of the CPCS PDU into 48 octet cells for passing to the ATM layer.

5.6 Higher Layers

In the previous sections the functions of the lower layers (physical layer, ATM layer, AAL) of the B-ISDN PRM were described. Aspects of higher layer protocols will be presented in this section.

5.6.1 User Plane

The higher layers of the user plane comprise all service-specific protocols which are necessary for the end-to-end communication. The higher layer protocols should be independent of the protocols used at the underlying layers.

In principle, existing higher layer protocols may be suitable. For some applications the existing higher layer protocols can be simplified because functions of higher layers are already performed by the ATM layer or the AAL. In other cases the extension of existing protocols may be necessary. In the long run, new optimized protocols may be developed to make the most efficient use of the ATM-based networks.

5.6.2 Control Plane

The control plane higher layers provide signaling message transport capabilities and connection/call control. In a first step (initial solution), these control functions at the B-ISDN UNI can be based on the existing protocols for user-network signaling [70, 71, 72, 73, 74, 75]. Some modification will be necessary or advantageous, e.g.:

- Several layer 2 functions (cf. CCITT Recommendations Q.921 and Q.922 [71, 72]) are already provided by the ATM layer and the AAL (type 3 or 4) and need no longer be performed at layer 2. Addressing is done by means of VPI/VCI in the ATM layer and segmentation and reassembly are AAL functions.
- Layer 3 functions (cf. CCITT Recommendation Q.931 [74]) must be extended by the new information elements for the characterization of ATM connections. In a first step, only the establishment and release of point-to-point VCCs is foreseen. To this aim at least allocation and identification of VCIs has to be realized. (VPC establishment can be done via ATM layer management procedures or even on subscription basis, therefore layer 3 support is not necessarily required.)

Similarly, inter-exchange signaling in the starting phase of B-ISDN can rely on the common channel signaling system no.7 (SS7) [69] that is being implemented for 64 kbit/s ISDN. Again, specific enhancements will be necessary to cater for ATM connections (e.g. VCI allocation/identification). For signaling transport the existing SS7 network can be used.

The target solution for signaling will be a completely revised protocol which should not only take into account broadband aspects but also upcoming non-broadband specific features like multi-media services or intelligent network capabilities.

5.7 Applications for B-ISDN

Most of the applications for ISDN have reached the extent of their development, and now the focus has shifted to services that be provided across broadband ISDN cables. The ITU-T defines the services and associated standards of ISDN communications, have recommended the two service area for application with B-ISDN, Interactive Services, and Distribution Services.

Table 6.1 The applications for broadband ISDN

Service Categories		Example Services
Interactive Services	Conversational Services	TV Conference
	Messaging Services	Video Mail
	Retrieval Services	Videotext
Distribution Services	Without User Presentation Control	TV Broadcast
	With User Presentation Control	Videography

5.7.1 Interactive Services

Broadband video telephony services

Video telephony is the transfer of voice, moving pictures and scanned images and documents between two points. Areas utilizing such technology are sales, consulting, teaching and legal services. The problem with gaining widespread use of video telephony is the prohibitive costs of terminal equipment. In the future as demand and competition increases the cost of such equipment will fall, and the service will become more widespread.

Other services that are expected to be implemented using video telephony include video conferencing and video surveillance.

High speed unrestricted data and information transmission services

This type of service will include LAN's(Local Area Networks), and WAN's (Wide Area Networks), as well as internet and other computer networking. Other Applications include document transfers, facsimile and multimedia documents including text, graphics, voice, and audio visual information.

Messaging Services

Messaging services is the transmission of information on a user to user basis, but not requiring the availability of both users at once. Due to this area consisting mainly of text transfers it doesn't take much of the available resources. The application of this is primarily email, but could be expanded in the future to include paging services and more.

Retrieval Services

Retrieval services as the name suggests involves retrieval of information stored at remote sites. T his information would be available at public sites, and supplied to the user on a demand basis. Items transferred in this way could include medical information, share market information and transmission of audio and video files. Unfortunately the amount of bandwidth required for transferring such resources restricts the number of transmissions that can occur at any one time.

5.7.2 Distribution Services

Distribution services are divided into distribution with presentation control, and distribution without presentation control. Distribution services provide a continuous flow of o information from a central source to any number of users. All of the users have access to the information but not control over it. This type of service includes TV program distribution, and document distribution.

TV program distribution (without presentation control)

TV program distribution is the most common application within distribution services. With the capacities of broadband ISDN, higher quality, higher resolution, interference free television can be provided. This quality should be equal to that provided in cinemas, but will require transfer rates around 1Gbps. ITU-T have suggested that data compression be used to reduce the bit-rate requirements and enhance coexistence with multiple broadband ISDN services.

Distribution with presentation control

This type of distribution is centrally located but information will be transmitted in cycles. The user has individual access to the cyclical distributed information, but unlike TV program distribution the user has control over the start and order of presentation. Applications of such systems would be in education training and other services where it is essential for users to be able to control the time of access.

CONCLUSION

The communications today grow very vastly and everyday we contact with a variety of modern communication systems and communication media the most common being the telephone, radio, television and internet service. Electronic mail and facsimile transmission have made it possible to rapidly communicate written messages across great distances. As the 21st century begins, telecommunications and data communications are converging. Both customer-premises equipment and transmission facilities are increasingly using digital technology. Digital PBXs are being used to integrate voice and data with digital phones. LANs and PBXs can be connected to packet switching networks, frame relay network, and IP networks allowing communications among devices attached to any of them. In addition, transmission of still images, using fax, or moving images, using video, once performed only by analog transmission methods can now be done digitally. Digital transmission of voice is possible by using a digitizing method known as pulse code modulation, or PCM. In PCM, an analog signal is typically converted to a 64 kbps digital signal, using 8000 samples per second and eight bits per sample.

High-bandwidth digital transmission facilities are playing a major role in communications today. The Integrated Services Digital Network, or ISDN, is a set of standards for a digital network carrying both voice and data communications. The ITU (CCITT) led the international standard development effort, specifying both interface standards for connecting to the public network and network services. ISDN provides different types of transmission paths, known as channels. The B-channel, or bearer channel, is a 64 kbps digital channel used for signaling information and sometimes for low-priority data packets. The A-channel is similar to today's analog voice circuits, and the C-channel provides a low speed 16 kbps data channel for use with low-speed devices.

The basic-rate interface includes 2 B-channels and 1 D-channel and is intended for residential or individual business users; this interface provides voice and data communication, as well as extensive signaling capability, for an individual user. The primary rate interface contains 23 or 30 b-channels and 1 D-channel and is aimed primarily at larger business users. The 23 B+D version is intended for using in North America and intended for using in Europe, where 2.048 Mbps transmission equipment currently exists. The hybrid interface contains both an A-channel and a C-channel and provides analog phone users with some of the benefits of ISDN.

Broadband ISDN, or B-ISDN, an even-faster class of interface standards, is currently being deployed, B-ISDN, which can handle higher transmission speeds, can easily carry digitized video transmission, along with digitized voice and data. A mixture of fiber optic and cooper cable is being used for B-ISDN. The transmission technology that is used to implement B-ISDN is Asynchronous Transfer Mode, or ATM. ATM fragments data into fixed-size chunks, or cells, so that voice, video data, or any other information can be sent over the same network. The ATM form is promoting the rapid development and deployment of the ATM specification. ISO, ITU (CCITT), and ANSI have all recognized ATM as the standard of choice for B-ISDN.

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