NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

DEPARTMENT OF COMPUTER ENGINEERING

BROADBAND ISDN

GRADUATION PROJECT
COM 400

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CHAPTER 1

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ABSTRACT

To be able to transport the MPEG compressed digital video signals through the network, from the encoder to the set top box for instance very powerful transmission mechanism is needed. Presently, the only technology that can fulfill all the requirements in terms of bandwidth

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 net- works coexists 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.

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).

The aim of this thesis is the analysis and interpretation of the BROADBAND ISDN, which can handle higher transmission speeds, can easily carry digitized video transmission, along with the digitized voice and data.

PREFACE

In B-ISDN we have see the applications in higher. Bit rates in the following chapter.

Initially I give the introduction of ISDN I have defined the purpose of Broadband network and wher we use B-ISDN the services and Application of B-ISDN.

Chapter 1: Gives the description of ISDN overview. It defines the Integrated digital network, A conceptual view of ISDN and A ISDN standard.

Chapter 2: Defines the ISDN Interfaces and functions ,User-Network interface configurations like service support, ISDN protocol Architecture, ISDN Connections and semiparmanent connections, Addressing and the other address structures, Interworking and ISDN-PSPDN interworking.

Chapter 3: Broadband network techonologies and History and background of B-ISDN, Abilities and benefits of B-ISDN, Bandwidth efficiency and Variable connection Quality.

Chapter 4: Described all Broadband ISDN the Terminal and Network solution , H – channels ,Higher Rate interfaces, Virtual containers and Tributary units, SDH (Synchronous Digital Hierarchy).

Chapter 5: Show the application table B-ISDN service requirements.

Chapter 6: Defines the Princples and Building Blocks of B-ISDN and the B-ISDN principles, Asynchronous Transfer mode, Optical transmission.

Chapter 7: Gives the description of B-ISDN network conceptand General architecture of the B-ISDN, Network techniques,layering and Signaling principles, Cababilities required for B-ISDN signaling and Signaling Virtual Channels.

Chapter 8: Defines the Evolution scenarios for B-ISDN, Fibre to the customer and Introduction of B-ISDN services ,Integration of TV distribution LANs/MANs into B-ISDN,Local and Metropolitan networks, Interworking units and scenarios.

INTRODUCTION

We begin this project with a look at the way in which public telephone and telecommunications networks have evolved to form integrated digital networks (IDNs). The IDN sets the stage for the development of the integrated services digital networks (ISDN). Then we provide a general overview of ISDN .The next section of the chapter examines the standards that define the ISDN.

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.

This project looks at a variety of issues related to ISDN architecture as seen by. On the whole, the user need not be concerned with the internal functioning or mechanisms of an ISDN. However, the user is concerned with the nature of the interface and the way in which services are requested and provided.

To be able to transport the MPEG compressed digital video signals through the network, from the encoder to the set top box for instance, a very powerful transmission mechanism is needed. Presently, the only technology that can fulfill all the requirements in terms of bandwidth, flexibility, and interactivity the digital video services have is the ATM protocol, the central element of the B-ISDN. This section will provide the background and the essential technical details of B-ISDN needed to enable a more detailed understanding of the key networking technologies, referred to in the later section dealing with "Video in Broadband Networks.

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 be 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.

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

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.

Despite the convincing advantages of this universal broadband ISDN for all services, the high development and investment costs mean that it cannot in the short or medium term achieve wide coverage. The aim must therefore be to expand and add to the present-day telecommunication networks - of these primarily the network with most subscribers of all, the telephone network - in a market an demand oriented manner with suitable technical concepts and in timed phase thereby achieving a gradual transition to the ubiquitous, multi-subscriber network of the future. Any intended individual solutions or intermediate solutions must be designed such that they can later be incorporated with the least possible expense in the intelligent integrated broadband network.

CHAPTER 1

ISDN OVERVIEW

We begin this chapter with a look at the way in which public telephone and telecommunications networks have evolved to form integrated digital networks (IDNs). The IDN sets the stage for the development of the integrated services digital networks (ISDN). Then we provide a general overview of ISDN .The next section of the chapter examines the standards that define the ISDN.

1.1 THE INTEGRATED DIGITAL NETWORK

Public telephone and telecommunications networks are rapidly evolving to the exclusive use of digital technology. The ways in which these networks employ digital technology are listed in Table 1.1. The movement toward digital technology has been pushed by the competitive desire to lower cost and improve the quality of voice transmission and networking services. A s the use of distributed processing and data communications has grown, this evolution of an all-digital network has been pulled by the need to provide a framework for ISDN.

The evolution of the existing telecommunications networks and specialized carrier facilities to integrated digital networks is based on two technological developments: digital switching and digital transmission. Both digital switching and digital transmission are, of course ,well established. The first T-carrier system was introduced into commercial service by AT&T in 1962, and the first large –scale time-division digital switch, the Western electric 4ESS ,was introduced in 1976 .More important than the benefits of either of these two technologies, however, was the revolutionary idea that the functions of transmission and switching could be integrated to form an integrated to form an integrated and is in network (IDN). The idea was proposed as early as 1959 [VAUG59] and is in the process of being implemented worldwide.

Switching The circuit –switching nodes of the network make use of digital time–division switching techniques rather than analog space-division switching techniques **Trunk(carrier) transmission** Digital transmission technology is used on the multiplexed trunks between switches although either analog or digital signaling may be used. Each trunk carries multiple voice and/or data channels using synchronous time division multiplexing. **Subscriber loop** Digital transmission technology may also be used between the subscriber and the switch the subscriber attaches over the "subscriber loop". This implies that digitized voice is employed and that full-duplex digital transmission over the subscriber loop is used. **Control signaling** Common-channel signaling over a packet-switched network embedded into the public telecommunications network is used. Packets contain messages used for routing, monitoring and control.

Table 1.1 Of Digital Technology in Public Telecommunications Networks

To understand the implications of an ISDN, consider figure1.1. Traditionally, the transmission and switching system of an analog telephone network have been designed and administered by functionally separate organizations. The two systems are referred to by the operating telephone companies as outside plant and inside plant, respectively. In an analog network, incoming voice lines are modulated and multiplexed (FDM) line. Then the constituent signals my pass through one or more intermediate switching centers before reaching the destination end office. AT each switching center, the incoming FDM carrier has to be demultiplexed and demodulated by an FDM channel bank, before being switched by a space-division switch (figure 1.1 a). After switching, the signals have to be multiplexed and modulated again to be transmitted. This repeated process results in an accumulation of noise as well as cot.

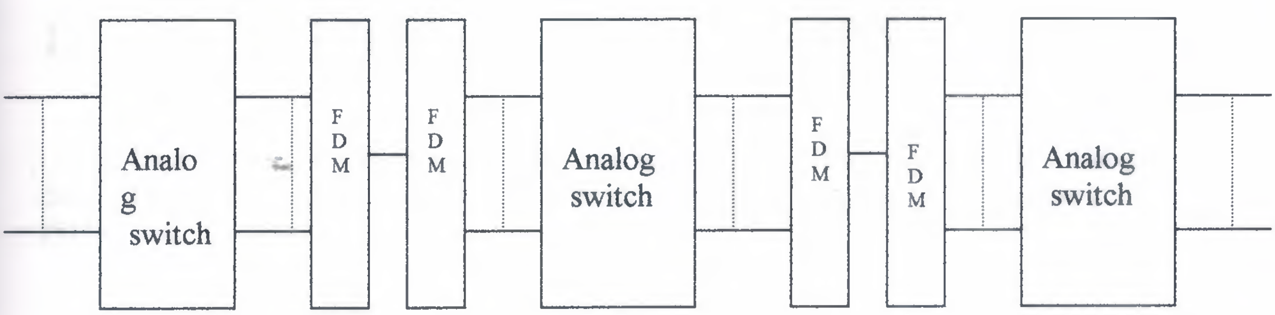
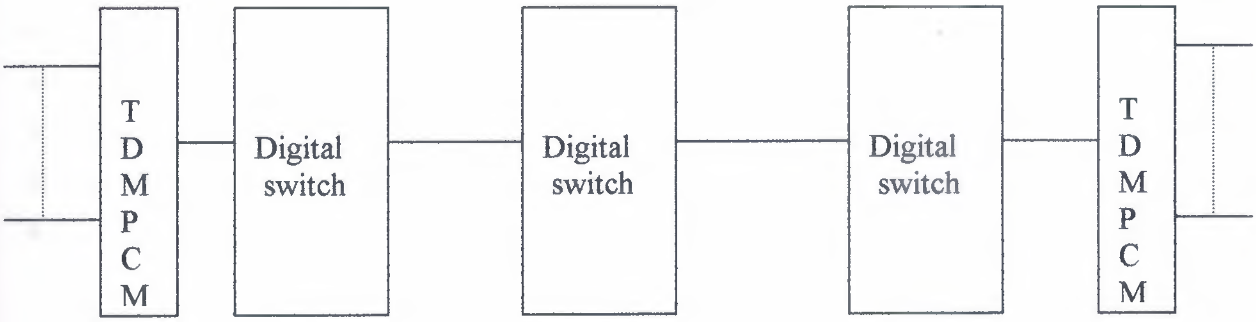


Figure 1.1 (a) nonintegrated



(b) integrated

Figure 1.1 The Integration of Transmission and Switching

When both the transmission and switching system are digital, integrating as in figure 1.1 b can be achieved. Incoming voice signals are digitized using pulse-code modulation (PCM) and multiplexed using time-division multiplexing (TDM). Time-division digital switches along the way can switch the individual signals without decoding them. Furthermore, separate multiplex channel banks are not needed at the intermediate offices, because that function is incorporated into the switching system.

The evolution from analog to digital has been driven primarily by the need to provide economic voice communications .The resulting network is also well suited to meet the growing variety of digital data service needs. Thus, the IDN will combine the coverage of the geographically extensive telephone network with the datacarrying capacity of digital data networks in a structure called the integrated services digital networks (ISDN). In this latter context ,the "integrated" of ISDN refers to the simultaneous carrying of digitized voice and a variety of data traffic on the same digital transmission links and by the same digital exchanges the key to ISDN is the small marginal cost for offering data services on the digital telephone network ,with no cost or performance penalty for voice services already carried on the IDN.

1.2 A CONCEPTUAL VIEW OF ISDN

ISDN is a massive undertaking in many ways, and it is difficult to provide a concise description of it. To begin to understand ISDN, we look in this section at the concept of ISDN from several different viewpoints:

- Principles of ISDN
- Evolution of the ISDN

- The user interface
- Objectives
- Benefits
- Services
- Architecture

1.2.1 Principles of ISDN

Standards 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 nonvice 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 nonvoice 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 nonswitched 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 nonswitched 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 protocols 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, which is based on LAPB.

- Standards can be developed and implemented 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. Principles of ISDN

1.1 The main feature of the ISDN concept is the support of a wide range of voice and non-voice applications in the some network. A key element of service integration for an ISDN is the provision of a range of service using a limited set of connection types and multipurpose user-network interface arrangements.

1.2 ISDNs support a variety of applications including both switched and non-switched and non-switched connections. Switched connections in an ISDN include both circuit-switched connections and their concatenations.

1.3 As far as practicable, new services introduce into an ISDN should be arranged to be compatible with 64kbit/s switched digital connections.

1.4 An 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 intelligence within the network or possibly compatible intelligence in the user terminals.

1.5 A layered protocol structure should be used for specification of the access to an ISDN. Access from a user to ISDN resources may very depending upon the service required and upon the status of implementation of national ISDNs

1.6 It is recognized that ISDNs may be implemented in a variety of configurations according to specific national situations.

2. Evolution of ISDNs

2.1 ISDNs will be based one the concepts for telephone IDNs and may evolve by progressively incorporating additional functionsand network features, including those of any other dedicated networks such as circuit-switching and packet-switching for data so as to provide for existing and new services

2.2 The transition from an existing network to a comprehensive ISDN may require a period of time extending over one or more decades. During this period arrangements must be developed for the networking of services on ISDNs and services on other networks.

2.3 In the evolution towards an ISDN, digital end-to-end connectivity will be obtained via plant and equipment used in existing networks, such as digital transmission; time-division multiplex switching and/or spacedivision multiplex switching. Existing relevant recommendations for these constituent elements of an ISDN are contained in the appropriate series of recommendations of CCITT and of CCIR.

2.4 In the early stages of the evolution of ISDNs, some interim user-network arrangements may need to be adopted in certain countries to facilitate early penetration of digital service capabilities. Arrangements corresponding to national variants may comply partly or wholly with I-Series recommendations. How ever, the intention is that they not be specifically included in the I-Series.

2.5 An evolving ISDN may also include at later stages switched connections at bit rates higher and lower than 64 kbit/s.

1.2.2 Evolution of ISDN

As we discussed in section 1.1, ISDN evolves from and with the integrated digital network (IDN). The evolution of the IDN has been driven by the need to provide economic voice communications. The resulting network, however, is also well suited to meet the growing variety of digital data service needs. Whereas the "I" in IDN refers to the integration of digital transmission and switching facilities, the "I" in ISDN refers to the integration of a variety of voice and data transmission services.

The second part of table 1.2 gives the ITU-T view of the way in which ISDN will evolve. Let us look at each of these points in turn.

Evolution from telephone ISDNs The intent is that the ISDN evolve from the existing telephone network. Two conclusions can be drawn from this point. First the IDN technology developed for and evolving within existing telephone networks forms the foundation for the services to be provided by ISDN Second, although other facilities, such as third-party (not the telephone provider) packet-switched networks and satellite links will play a role in ISDN, the telephone network will have the dominant role. Although packet switching and satellite providers may be less than happy with this interpretation, the overwhelming prevalence of telephone networks dictates that these networks form the basis for ISDN.

Transition of one or more decades. The evolution to ISDN will be a slow process. This is true of any migration of a complex application or set of applications from one technical base to a newer one. The introduction of ISDN services will be done in the context of existing digital facilities and existing services. There will be a period of coexistence in which connections and perhaps protocol conversion will be needed between alternative facilities and or services.

Use of existing networks. This point is simply an elaboration of point 2. For example ISDN will provide a packet-switched service. For the time being the interface to that service will be X.25. With the introduction of fast packet switching and more sophisticated virtual call control there may need to be a new interface in the future.

Interim user- network arrangements. Primarily the concern here is that the lack of digital subscriber lines might delay introduction of digital services particularly in developing countries. With the use of modems and other equipment existing analog facilities can support at least some ISDN services.

Connections at other than 64 KBPS. The 64-kbps data rate was chosen as the basic channel for circuit switching. With improvements in voice digitizing technology this rate is unnecessarily high. On the other hand this rate is too low for many digital data applications. Thus other data rates will be needed.

The details of the evolution of ISDN facilities and services will vary from one nation to another and indeed from one provider to another in the same country. These points simply provide a general description, from ITU-T's point of view, of the process.

1.2.3 The user Interface

Figure 1.3 is a conceptual view of the ISDN from a user or customer point of view. The user has access to the ISDN by means of a local interface to a digital "pipe" of a certain bit rate. Pipes of various sizes will be available to satisfy differing needs. For example, a residential customer may require only sufficient capacity to handle a telephone and a personal computer. An office will typically wish to connect to the ISDN via an on-premise digital PBX or LAN and will require a much higher-capacity pipe.

That more than one size of pipe will be needed is emphasized in Figure 1.4, taken from Recommendation 1.410. At the low end of demand would be a single terminal (e.g., a residential telephone) or multiple terminals in some sort of multi-drop arrangement (e.g., a residential telephone, personal computer, and alarm system). Offices are more likely to contain a network of devices attached to a LAN or PBX, with an attachment from that network acting as a gateway to the ISDN.

At any given point in time, the pipe to the user's premises has a fixed capacity, but the traffic on the pipe may be a variable mix up to the capacity limit. Thus, a user may access circuit-switched and packet-switched services, as well as other services, in a dynamic mix of signal types and bit rates. The ISDN will require rather complex control signals to instruct it how to sort out the time-multiplexed data and provide the required services. These control signals will also be multiplexed onto the same digital pipe.

An important aspect of the interface is that the user may, at any time, employ less than the maximum capacity of the pipe and will be charged according to the capacity used rather than "connect time." This characteristic significantly diminishes the value of current user design efforts that are geared to optimize circuit utilization by use of concentrators, multiplexers, packet switches, and other line-sharing arrangements.

1.2.4 Objectives

Activities currently under way are leading to the development of a worldwide ISDN. This effort involves national governments, data processing and communication companies, standards organizations, and others. Certain common objectives are, by and large, shared by this disparate group. The key objectives are as follows:

1. Standardization
2. Transparency
3. Separation of competitive functions
4. Leased and switched services
5. Cost-related tariffs
6. Smooth migration
7. Multiplexed support

1.2.5 Standardization

Is essential to the success of ISDN. Standards will provide for universal access to the network. ISDN-standard equipment can be moved from one location to another, indeed from one country to another, and be plugged into the network. The cost of such equipment will be minimized because of the competition

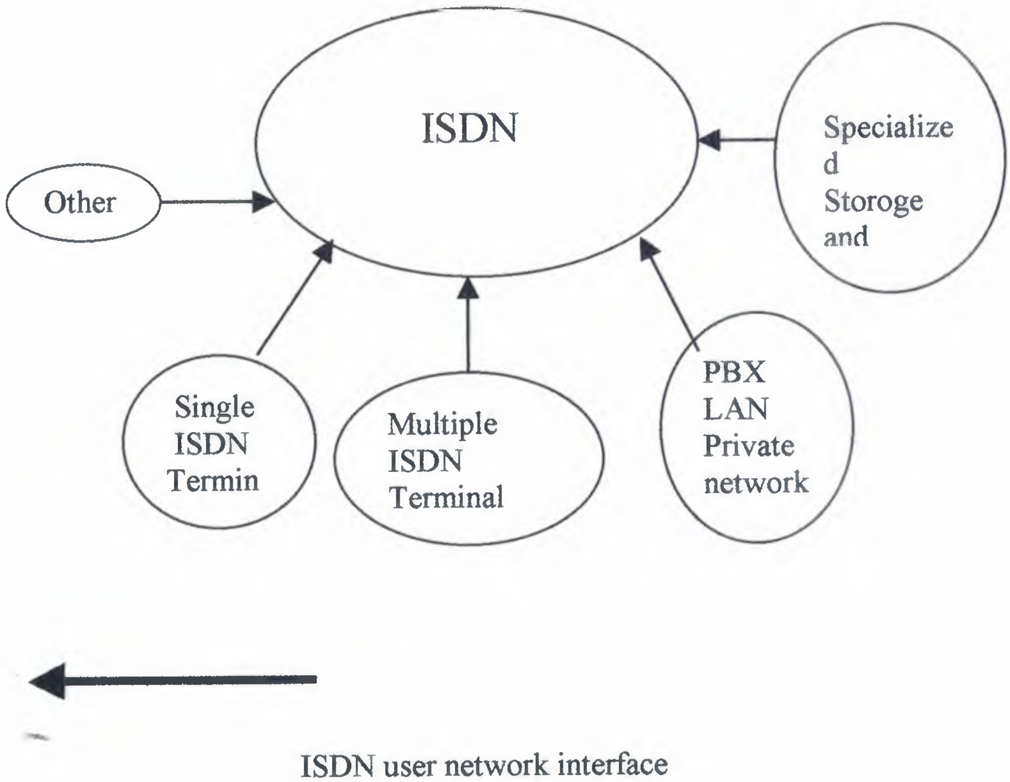


Figure 1.4 ISDN User-Network Interface Examples

among many vendors to provide the same type of functionality. In addition, the use of layered protocol architecture and standardized interfaces allows users to select equipment from multiple suppliers and allows changes to be made to a configuration in a gradual, piece-by-piece fashion.

It is also important that the digital transmission service have the property of **transparency**; that is, the service is independent of, and does not affect, the content of the user data to be transmitted. This permits users to develop applications and protocols with the confidence that they will not be affected by the underlying ISDN. Once a circuit or virtual circuit is set up, the user should be able to send information without the provider being aware of the type of information being carried. In addition, user-provided encryption techniques can be employed to provide security of user information.

The ISDN must be defined in a way that does not preclude the **separation of competitive functions** from the basic digital transmission services. It must be possible to separate out functions that could be provided competitively as opposed to those that are fundamentally part of the ISDN. In many countries, a single, government-owned entity will provide all services. Some countries desire (in the case of the United States, require) that certain enhanced services be offered competitively (e.g., videotext, electronic mail).

The ISDN should provide both **leased** and **switched services.** This will give the user the greatest range of options in configuring network services and allow the user to optimize on the basis of cost and performance.

The price for ISDN service should be related to cost and independent of the type of data being carried. Such a **cost-related tariff** will assure that one type of service is not in the position of subsidizing others. Price distinctions should be related to the cost of providing specific performance and functional characteristics of a service. In this way, distortions are avoided and providers can be driven by customer need rather than some artificial tariff structure.

Because of the large installed base of telecommunications equipment in the networks, and because of customer equipment with interfaces designed for those networks, the conversion to ISDN 'will be gradual. Thus for an extended period of time the evolving ISDN must coexist with existing equipment and services. To provide for a **smooth migration** to ISDN. ISDN interfaces should evolve from existing interfaces, and interworking arrangements must be designed. Specific capabilities that will be needed include adapter equipment that allows pre-ISDN terminal equipment to interface to ISDN, internetwork protocols that allow data to be routed through a mixed ISDN/non-ISDN network complex and protocol converters to allow interoperation of ISDN services and similar non-ISDN services.

In addition to providing low-capacity support to individual users **multiplexed support** must be provided to accommodate user-owned PBX and local area network (LAN) equipment.

There are, of course, other objectives that could be named. Those just listed are certainly among the most important and widely accepted and they help to define the character of the ISDN.

1.2.6 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 to these multiple services. The requirements of various users can differ greatly in a number of ways: for example, in 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.

1.2.7 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 Four 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.

1.2.8 Architecture

Figure 1.5 is an architectural depiction of ISDN. The ISDN will support a completely new physical connector for users, a digital subscriber line, and a variety of transmission services.

The common physical interface provides a standardized means of attaching to the network. The same interface should be usable for telephone, personal computer, and videotext terminal. Protocols are required to define the exchange of control information between user device and the network. Provision must be made for high-speed interfaces to, for example, a digital PBX or a LAN. The interface supports a *basic* service consisting of three time-multiplexed channels, two at 64 kbps and one at 16 kbps. In addition, there is a *primary* service that provides multiple 64-kbps channels.

For both basic and primary service, an interface is defined between the customer's equipment, referred to generically as terminal equipment (TE), and a device on the customer's premises, known as a network termination (NT). The NT forms the boundary between the customer and the network.

The subscriber line is the physical signal path from the subscriber's NT to the ISDN central office. This line must support full-duplex digital transmission for both basic and primary data rates. Initially, much of the subscriber line plant will be twisted pair. As networks evolve and grow, optical fiber will be increasingly used.

The ISDN central office connects the numerous subscriber lines to the digital network. This provides access to a variety of lower-layer (OSI layers 1-3) transmission facilities, including the following:

- **Circuit-switched capabilities:** Operating at 64 kbps, this is the same facility provided by other digital-switched telecommunications networks.

- **Nonswitched capabilities:** One such facility offers a 64-kbps dedicated link. A Nonswitched capability at a higher data rate is to be provided by broadband ISDN and will be in the nature of a permanent virtual circuit for asynchronous transfer mode (ATM) transmission.

- **Switched capabilities:** This refers to high-speed (> 64 kbps) switched connections using ATM as part of broadband ISDN.

- **Packet-switched capabilities:** This facility resembles packet-switched service provided by other data networks.

- **Frame-mode capabilities:** A service that supports frame relay.

- **Common-channel signaling capabilities:** These capabilities are used to control the network and provide call management. Internal to the network, Signaling System

Number 7(SS7) is used. The capability also includes user-to-network control dialogue. The use of control signaling for user-to-user dialogue is a subject for further study within ITU-T.

These lower-layer functions can be implemented with the ISDN. In some countries with a competitive climate, some of these lower-layer functions (e.g., packet switching) may be provided by separate networks that may be reached by a subscriber through ISDN.

1.3 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.

1.3.1 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 communication 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 to 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

In the case of ISDN. 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.

1.3.2 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/ CCITT's interest in ISDN. In 1968, CCITT established Special Study Group D (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 1.3. 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 1.3 Question 1 As Assigned to Special Study Group D (1969-1976) and to Study Group XVIII (1977-1992)

Study Period	Title of Question 1
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 1.4). 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 a 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

INTEGRATED SERVİCES DİGİTAL NETWORKS (ISDN)

The CCITT

Considering

(a) The measure of agreement that has so far been reached in the studies of integrated 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 towards 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 net-work management functions. This intelligence may not be sufficient for some new services and may have to be supplemented by either additional intelligence within the network. or possibly compatible intelligence in the customer terminals.

(6) (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 ISDNs.

Table 1.5 CCITT Recommendations G.705 (1980) of ISDN matters. The 1988 version of the I-series recommendations was sufficiently detailed to make preliminary ISDN implementations possible in the late 1980s

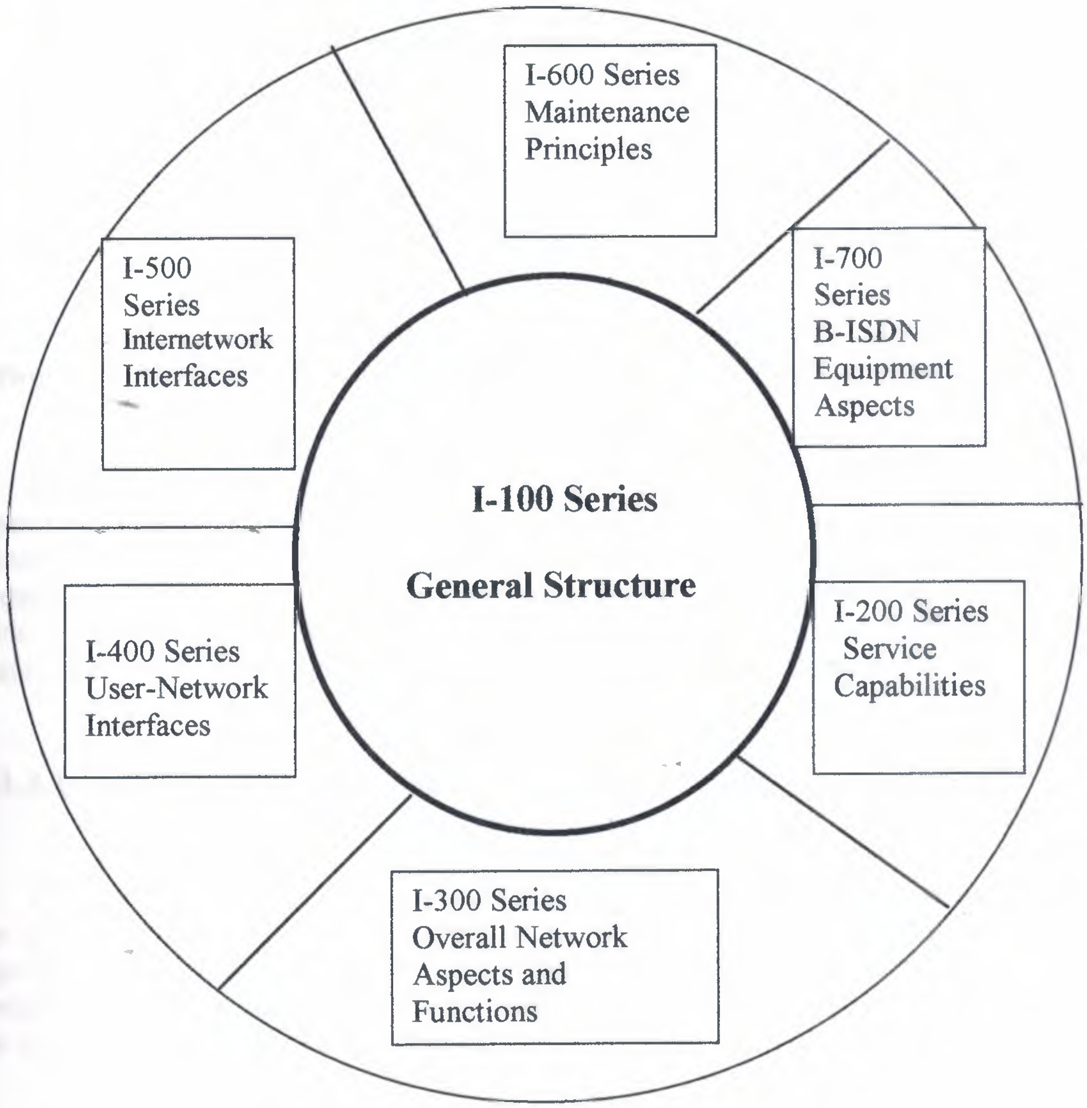


Figure 1.6 Structures of the I-Series Recommendations

1.3.3 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 interworking, and thus to achieve (1) and (2)

The current I-series recommendations related to ISDN (not including B-ISDN) are listed in Appendix 5B. Figure *1.6* 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.

1.3.3.1 I.100 Series-General Structure

The 1.100 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. 120 reproduced as Table 1.2, provides an overall description of ISDN and the expected evolution of ISDNs. Recommendation I.130 introduces terminology and concepts that are used in the I.200 series to specify services.

This chapter has covered much of what is in the I.100 series.

1.3.3.2 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 or RPOA to its customers tosatisfy 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 *telematic services:* teletex, facsimile, videotex, 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.

1.3.3.3 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.

1.3.3.4 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 issue 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.

1.3.3.5 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 interworking 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.

1.3.3.6 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 loopback. In general, loopback testing is used for failure localization and verification.

1.3.3.7 L700 Series B-ISDN Equipment Aspects

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

CHAPTER 2

ISDN INTERFACES AND FUNCTIONS

This chapter looks at a variety of issues related to ISDN architecture as seen by. On the whole, the user need not be concerned with the internal functioning or mechanisms of an ISDN. However, the user is concerned with the nature of the interface and the way in which services are requested and provided. Six areas are examined in this chapter

- **Transmissions structure**: The way in which logical channels providing bearer services are organized for transmission over the local loop

- **User-Network interface configurations:** The way in which user-ISDN interactions are organized functionally and how this guides the actual equipment configuration and the definition of the user –ISDN interface.

- **Protocol architecture:** The structure of user-network protocols and their relationship to the OSI model.

- **ISDN connections:** The types of end-to-end connection that are supported by ISDN.

- **Addressing:** The way in which a calling user specifies the called user so that the network can perform routing and delivery functions.

- **Interworking:** The capability for an ISDN subscribe to establish a connection to a subscriber on non-ISDN network

2 TRANSMISSION STRUCTURE

The digital pipe between the central office and the ISDN subscriber will be used to carry a number of communication channels. The capacity of the pipe and therefore the number of channels carried may vary from user to user.

The transmission structure of any access link will be constructed from the following types of channels:

- **B channel:** 64 kbps
- **D channel:** 16 or 64 kbps
- **H channel:** 384 (H0) 153(3 (H_{11}). or 1920 (H_{12}) kbps

The **B** channel is a user channel that can be used to carry digital data, PCM-encoded digital voice or a mixture of Lower-rate traffic including digital data and digitized voice encoded at a fraction of 64 kbps- In the case of mixed traffic all traffic of the B channel must be destined for the same endpoint: that is the elemental unit of circuit switching is the B channel. If a B channel consists of two or more subchannels, all subchannels must be carried over the same circuit between the same subscribers. Three kinds of connections can be set up over a B channel:

Circuit-switched: This is equivalent to switched digital service, available today. The user places a call and a circuit-switched connection is established with another network user. An interesting feature is that the call establishment does not take place over the channel, but is done using common-channel signaling.

Packet-switched: The user is connected to a packet-switching node and data are exchanged with other users via x-25.

Semipermanent: This is a connection to another user setup by prior arrangement and not requiring a call establishment protocol. This is equivalent to a leased line.

The designation of 64 kbps as the standard user channel rate highlights the fundamental disadvantage of standardization. The rate was chosen as the most effective for digitized voice, yet the technology has progressed to the point at which 32 kbps or even less will produce equally satisfactory voice reproduction. To be effective, a standard must freeze the technology at some defined point. Yet by the time the standard is approved, it may already be obsolete.

The D **channel** serves two main purposes. First, it carries common-channel signaling information to control circuit-switched calls on associated B channels at the user interface In addition, the D channel may be used for packet-switching or low speed (e.g., 100bps) telemetry at times when no signaling information is waiting Table 2.1 summarizes the types of data traffic to be supported on B and D channels

H channels are provided for user information at higher bit rates. The user ma use such a channel as a high-speed trunk or subdivide the channel according to the user's own TDM scheme. Examples of applications include fast facsimile, video high-speed data, high-quality audio, and multiplexed information streams at lower data rates.

These channel types are grouped into transmission structures that are offered as a package to the user- The best-defined structures (Figure 2.1) are the basic channel structure (basic access) and the primary channel structure (primary access).

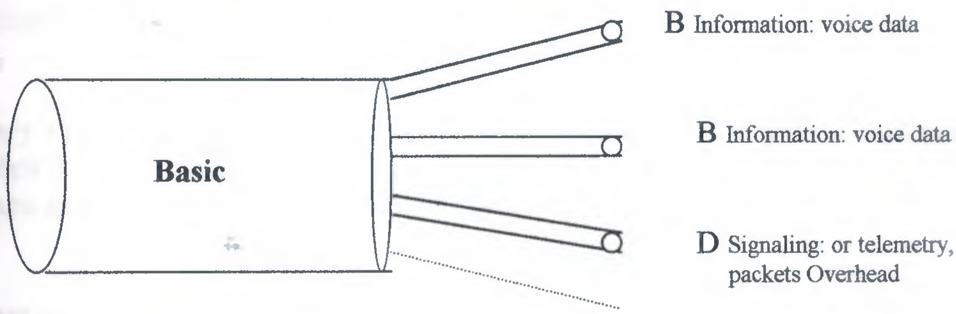
Basic access consists of two full-duplex 64-kbps B channels and a full-duplex 16-kbps D channel. The total bit rate, by simple arithmetic, is 144 kbps. However framing. Synchronization, and other overhead bits bring the total bit rate on a basic access link to 192 kbps: the details of these overhead bits are presented. The basic service is intended to meet the needs of most individual users. Including residential subscribers and very small offices. It allows the simultaneous use of voice and several data application, such as Internet access a link to a central alarm service, facsimile tetetex and so on These services could be accessed through a single multifunction terminal or several separate terminals. In either case a single physical interface is provided. Most existing two-wire local loops can support this interface.

Channel (64 kbps)	D channel(16 kbps)
Digital voice	**Signaling**
64 kbps PCM	Basic
Low bit rate (32 kbps)	Enhanced
High-speed data	**Low-speed data**
Circuit switched	Videotex
Packet switched	Teletext
	Terminal
Other	**Telemetry**
Facsimile	Emergency services
Slow-scan video	Energy management

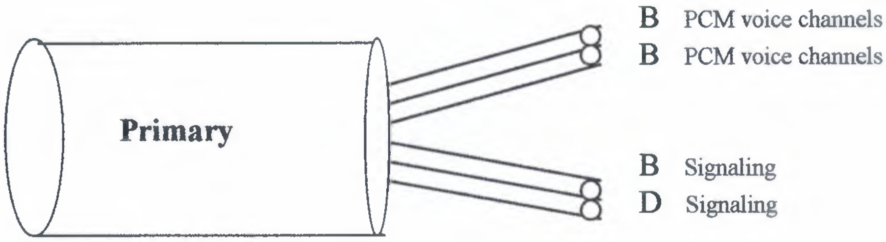
Table 2.1 ISDN Channel functions

In some cases, one or both of the B channels remain unused. This results in a B + D or D interface, rather than the 2B + D interface however, to simplify the network implementation the data rate at the interface remains at 192 kbps. Nevertheless, for those subscribers with more modest transmission requirements, there may be a cost savings .In using a reduced basic interface.

Primary access is intended for users with greater capacity requirements such as offices with a digital PBX or a LAN. Because of differences in the digital transmission hierarchies used in different countries, it was not possible to get agreement on a single data rate. The United States, Canada and Japan make use of a transmission structure based on 1.544 Mbps; this corresponds to the T-1 transmission



1- BASİC SERVİCE
Rate: 192 kbps
Composition: B+B+D channels, +synchronization and framing



2- PRİMARY SERVİCE
Rate: 1.544/2.048 Mbps
Composition: 2.048 Mbps :30 B channels at 64 Kbps each
1 D channels at 64 Kbps
1.544 Mbps : 23 B channels at 64 Kbps each
1 D channels at 64 Kbps

Figure 2.1 ISDN Channel structures.

Facility of AT&T. In Europe, 2.048 Mbps is the standard rate, Both of these data rates are provided as a primary interface service, Typically, the channel structure for the 1.544-Mbps rate will be 23 B channels plus one 64-kbps D channel and, for the 2.048-Mbps rate, 30 B channels plus one 64-kbps D channel. Again it is possible for a customer with lesser requirements to employ fewer B channels, in which case the channel structure is nB + D, where n ranges from 1 to 23 or from 1 to 30 for the two primary services. Also, a customer with high data rate demands may be provided with more than one primary physical interface. In this case a single D channel on one of the interfaces may suffice for alt signaling needs and the other interfaces may consist solely of B channels (24B or 31B).

The primary interface may also be used to support H channels. Some of these structures include a 64-kbps D channel for control signaling. When no D channel is present, it is assumed that a D channel on another primary interface at the same subscriber location will provide any required signaling. The following structures are recognized:

Primary rate interface H_0 channel structures: This interface supports multiple 384-kbps H_0 channels. The structures are $3H_0$ + D and $4H_0$ for the 1.544-Mbps Interface and $5H_0$ + D for the 2.048-Mbps interface.

Primary rate interface H_1 channel structures: The H_{11} channel structure consists of one 1536-kbps H_1 channel. The H_{12} channel structure consists of one 1920-kbps H_{12} channel and one-D channel.

Primary rate interface structures for mixtures of B and H_0 channels: These Consist of zero or one-D channel plus any possible combination of B and Ho Channels up to the capacity of the physical interface (e.g., $3H_0$ + 5B +D or $3H_0$ +6B for the 1.544-Mbps interface)

2.1 USER-NETWORK INTERFACE CONFIGURATIONS

2.1.1 Reference Points and Functional Groupings

To define the requirements for ISDN user access, an understanding of the anticipated configuration of user premises equipment and of the necessary standard interfaces is critical. The first step is to group functions that may exist on the user's premises in ways that suggest actual physical configurations. Figure 1.2 shows the ITU-T approach to this task, using

- **Functional groupings:** Certain finite arrangements of physical equipment or Combinations of equipment

- **Reference points:** Conceptual points used to separate groups of functions

An analogy with the OSI model might be useful at this point. The principal motivation for the seven-Layer OSI architecture is that it provides a framework for standardization. Once the functions to be performed in each layer are defined, protocol standards can be developed at each Layer. This effectively organizes the standards work and provides guidance to software and equipment providers. Furthermore, by defining the services that each layer provides to the next higher layer, work in each layer can proceed independently. So long as the interface between two layers remains stable, flew and different technical approaches can be provided within one layer without an impact on neighboring layers. In the case of ISDN, the architecture on the subscriber's premises is broken up functionally into groupings separated by reference points. This permits interface standards to be developed at each reference point. Again, this effectively organizes the standards work and provides guidance to the equipment providers. Once stable interface standards exist, technical improvements on either side of an interface can be made without impact on adjacent functional groupings. Finally, with stable interfaces, the subscriber is free to procure equipment from different suppliers for the various functional groupings, so long as the equipment conforms to the relevant interface standards.

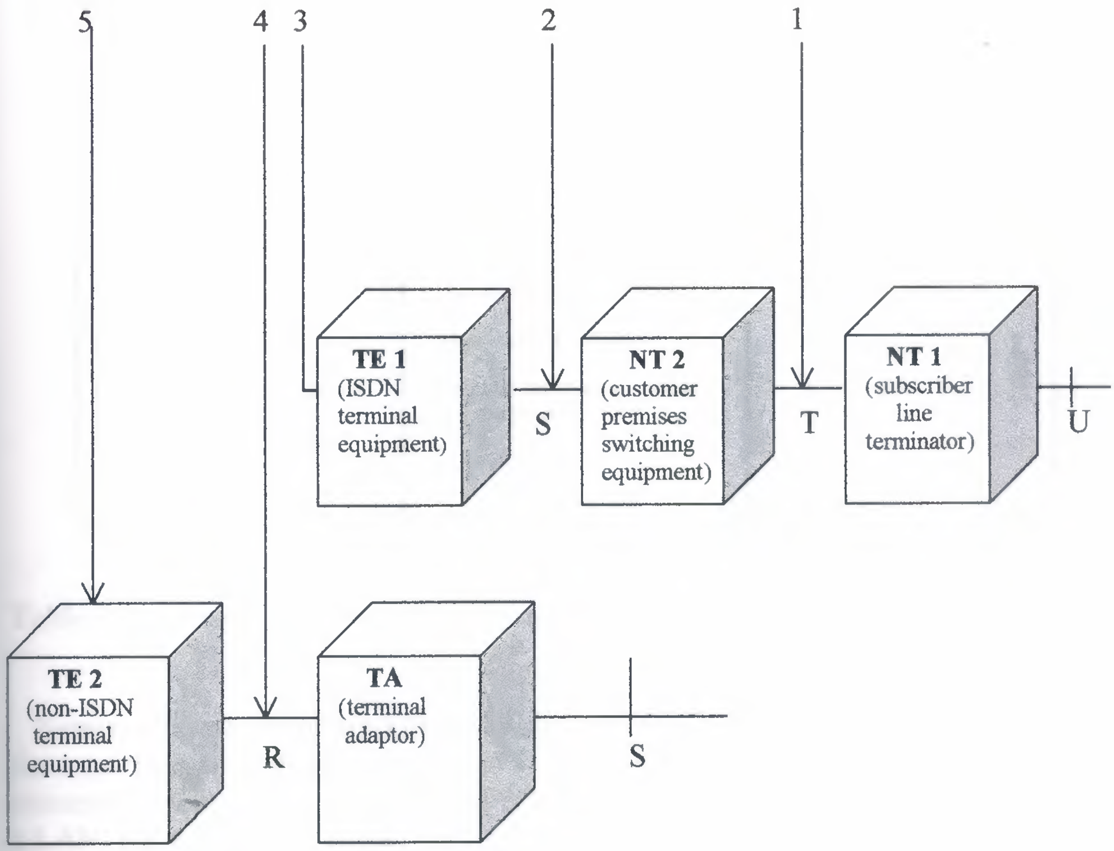


Figure 2.2 ISDN Reference Points and Functional Groupings

Let us consider first the functional groupings. **Network termination** 1(NT1) includes functions that may be regarded as belonging to OSI layer 1-that is, functions associated with the physical and electrical termination of the ISDN on the users premises (Table 2.2). The NT1 may be controlled by the ISDN provider and forms a boundary to the network. This boundary isolates the user from the transmission technology of the subscriber loop and presents a new physical connector interface for user device attachment. In addition, the NT1 will perform line maintenance functions such as loop back testing and performance monitoring. The NT1 supports multiple channels (e.g., at the physical level, the bit streams of these channels are multiplexed together, using synchronous time-division multiplexing). Finally, the NT1 interface might support multiple devices in a multidrop arrangement. For example, a residential interface might include a telephone, personal computer, and alarm system, all attached to single NT1 interface via a multidrop line. For such a configuration, the NTI includes a contention resolution algorithm to control access to the D channel.

NT1	NT2	TE
Line transmission termination Line maintenance and Performance monitoring Timing Power transfer Layer 1 multiplexing Interface termination, including multidrop termination employing layer 1 contention resolution	Layers 2 and 3 protocol handling Layer 2 and 3 multiplexing Switching Concentration Maintenance functions Interface termination and other layer 1 functions	Protocol handling Maintenance functions Interface functions Connection functions to other equipment

Table 2.2 Functions of ISDN Functional Groupings

Network termination 2(NT2) is an intelligent device that may include, depending on the requirement, up through OSI layer 3 functionality. NT2 can perform switching and concentration functions. Examples of NT2 are a digital PBX, a terminal controller, and a LAN. For example, a digital PBX can provide NT2 functions at layers 1,2, and 3. A simple terminal controller can provide NT2 functions at only layers 1 and 2. A simple time-division multiplexed can provide NT2 functions at only layer 1. An example of a switching function is the construction of a private network using semipermanent circuits among a number of sites. Each site could include a PBX that acts as a circuit switch or a host computer that acts as a packet switch. The concentration function simply means that multiple devices, attached to a digital PBX, LAN, or terminal controller, may transmit data across ISDN

Terminal equipment refers to subscriber equipment that makes use of ISDN. Two types are defined. **Terminal equipment type 1** (TE1) refers to devices that support the standard ISDN interface. Examples are digital telephone, integrated voice/data terminals, and digital facsimile equipment. **Terminal equipment type 2** (TE2) encompasses existing non- ISDN equipment. Examples are terminals with a physical interface, such as RS-232, and host computers with an X.25 interface. Such equipment requires a **terminal adaptor** (TA) to plug into an ISDN interface.

The definitions of the functional groupings also define by implication the reference points. **Reference point T** corresponds to a minimal ISDN network termination at the customer's premises. It separates the network provider's equipment from the user equipment **Reference point S** corresponds to the interface of individual ISDN terminals It separates user terminal equipment from network-related communications functions. **Reference point R** provides a non-ISDN interface between user equipment that is not IS DN compatible and adaptor equipment. Typically this interface will comply with an X series or V series ITU-T recommendation. The final reference point illustrated in

Figure 2.2 is reference point U. This interface describes the full duplex data signal on the subscriber line. At present this reference point is not defined in 1.411, which states that "there is no reference point assigned to the transmission line, because an ISDN user-network interface is not envisaged at this location."

Earlier drafts of 1.411 up through 1981. Defined such a reference point In 1981 this definition was dropped without explanation to be replaced by the flat assertion just noted which survived into the 1 984 final version of 1.411 and has not subsequently been removed. However it may be useful to define a U-interface standard to give the customer the option of having equipment from different vendors on the two sides of the interface.

There has been considerable work within the U.S standards groups affiliated with ITU-T to develop a U-interface standard based an echo cancellation techniques. This work has resulted in a U.S. standard. At this time it is not clear whether this standard will he adopted by ITU-T.

2.1.2 Service Support

The structure defined ill Figure 2.2 can be related to the ISDN services. This helps to clarify further the distinction between bearer services and teleservices while also clarifying the implications of the functional groupings and reference points.

Bearer services supported by ISDN are accessed at points 1 and/or 2 (reference points T and S) in both cases; the basic service concept is identical. Thus, for example a bearer service of *circuit-mode 64-khps 8-kHz structure unrestricted* can be supplied at either reference point. The choice between access points 1 and 2 depends and the configuration of the communications equipment at the customer premises

At access point 4 (reference point R), other standardized services (e.g.-, X series and V series interfaces) may be accessed. This allows terminals not conforming to the ISDN interface standards to be used in conjunction with the bearer services. For such terminals, a terminal adapter is required to adapt the existing standard to the ISDN standard. Such adoption can include data rate analog-to digital or other interface characteristics.

Access points 3 and 5 provide access to teleservices. ISDN teleservices incorporating terminals that conform to ISDN standards are accessed at access point 3. Teleservices that make use of terminals based on existing non-ISDN standards are accessed at point 6. For these services as with the bearer services a terminal adapter may be required.

2.1.3 Access Configurations

Based on the definitions of functional groupings and reference points, various possible configurations for ISDN user-network interfaces have been proposed by ITUT. These are shown in Figure 2.3. Note that on the customer's premises there may be interfaces at S and T , at S but not T, at T but not S, or at a combined S-T interface. The first case (S and T) is the most straightforward, one or more pieces of equipment correspond to each functional grouping. Examples were given previously when the functional groupings were defined.

In the second case (S but not T), the functions of NTl and NT2 are combined. In this case, the line termination function is combined with other ISDN interface functions. Two possible situations are reflected by this arrangement. The ISDN provider can provide the NT1 function. If that same provider also offers computer. LAN, and/or digital PBX equipment, the NTl functions can be integrated into this other equipment. Alternatively, the NT1 function need not be an integral part of the ISDN offering and can be supplied by a number of vendors. In this case, a LAN or digital PBX vendor might integrate the NTI function into its equipment.

In the third case (T but not S), the NT2 and terminal (TE) functions are combined. One possibility here is a host computer system that supports users but also acts as a packet switch in a private packet-switching network that uses ISDN for trunking. Another possibility is that terminal equipment is supported by non- ISDN standard interfaces. This latter possibility is illustrated in Figure 2.3f and discussed subsequently.

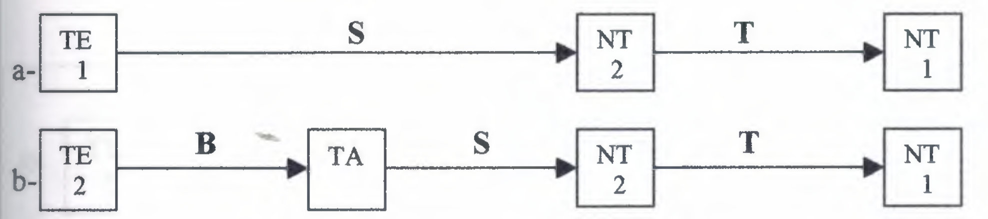
The final configuration (combined S-T interface) illustrates a key feature of ISDN interface compatibility: An ISDN subscriber device, such as a telephone, can connect directly to the subscriber loop terminator or into a PBX or LAN using the same interface specifications and thus ensuring portability.

Figure 2.4 provides examples of the ways in which a customer may implement the NT1 and NT2 functions. These examples illustrate that a given ISDN function can be implemented using various technologies and that different ISDN functions. Can be combined in a single device for example. Figure 2.4c illustrates that a LAN can interface to ISDN using a primary or basic access interface, whit the user devices make use of a very different interface (e.g.. a token-ring LAN interface).

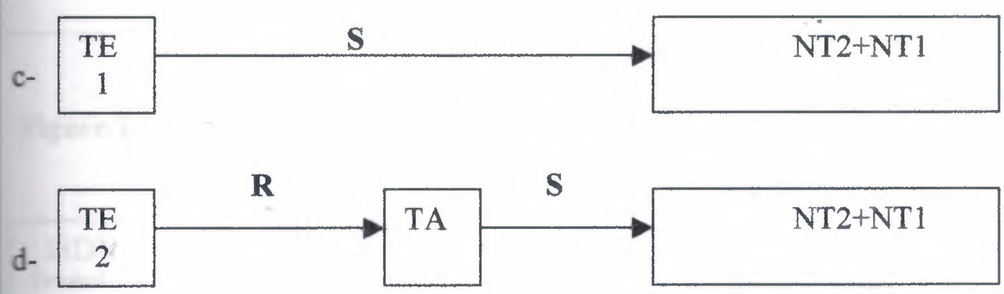
One additional set of configurations is suggested by ITU-T. These configurations cover cases in which the subscriber has more than one device at a particular interface point, but not so many devices that a separate PBX or LAN is warranted. In these cases, it is possible to have multiple physical interfaces at a single reference point Examples are shown in Figure 2.5. Figures 2.5a and 2.5b show multiple terminals connected to the network either through a multidrop line or through a multidrop NT1. These cases are not intended to require that individual terminals can talk to each other, as in a LAN, but rather that each terminal can communicate with the network.

Figures 2.5c and 2.5d provide multiple connections between TE1s and NT2. The two figures more or less correspond to PBX and LAN, respectively. Figure 2.5e shows the case of multiple NT1 equipment, whereas Figure 2.5f shows a case in which NTl provides a layer 1 multiplexing of multiple connections.

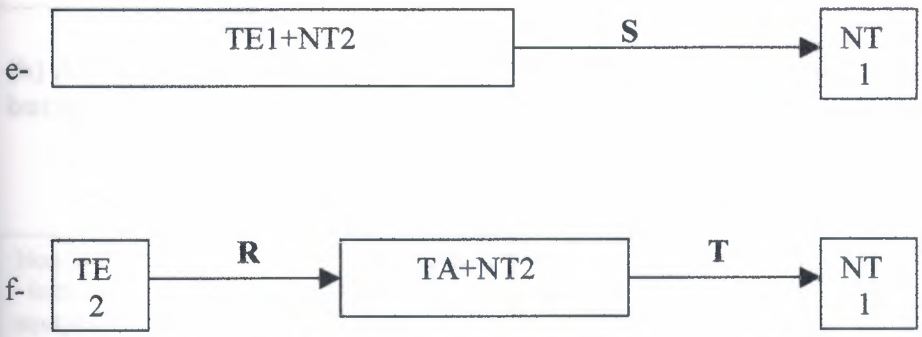
The ma two configurations indicate that either S or T but not both need not correspond to a physical interface in a particular configuration. We have already referred to the combination of NTl and NT2. In addition an NT2 can be equipped with the capability to attach TE2 equipment directly.



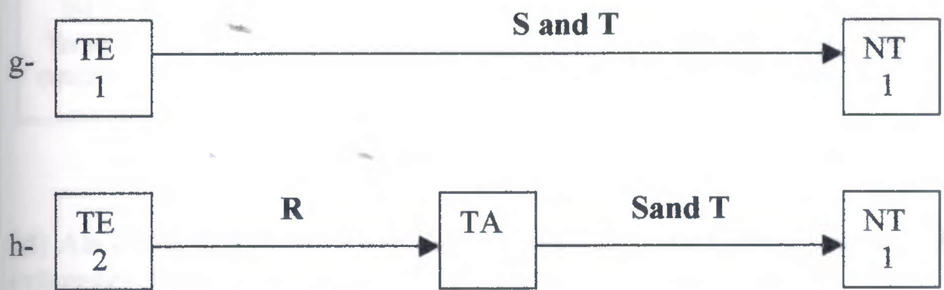
Configurations where ISDN physical interfaces occur at reference point S and T



Configurations where ISDN physical interfaces occur at reference point S only

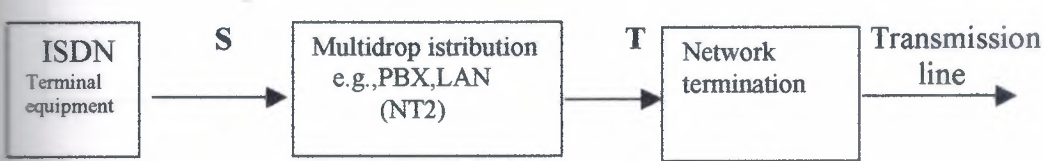


Configurations where ISDN physical interfaces occur at reference point T only

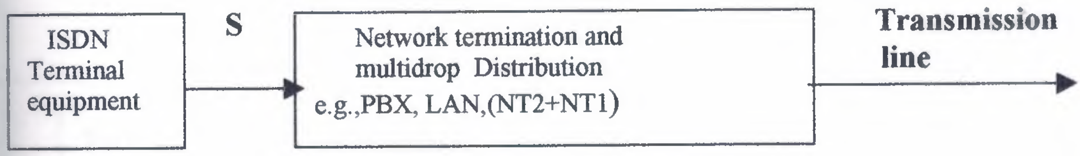


Configurations where ISDN physical interfaces occur at a location where reference points S and T coincide

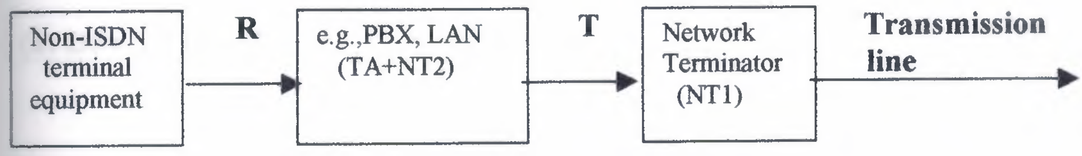
Figure 2.3 Examples of Physical Configurations for ISDN User-Network Interfaces



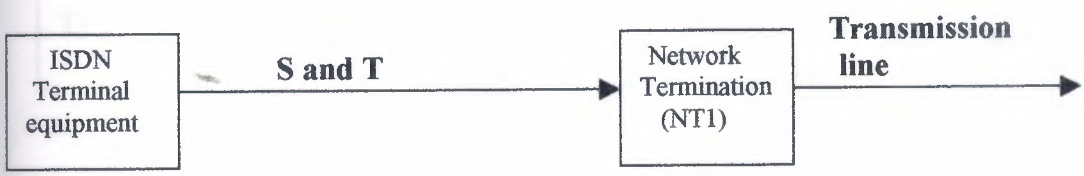
(a) An implementation where ISDN physical interfaces occur at reference points S and T (see figure 2.3 a)



(b) An implementation where ISDN physical interfaces occur at reference points S but not T (see figure 2.3 c)



(c) An implementation where ISDN physical interfaces occur at reference points T but not S (see figure 2.3 f)



(d) An implementation where ISDN physical interfaces occur at a location where reference points S and T coincide (see figure 2.3 g)

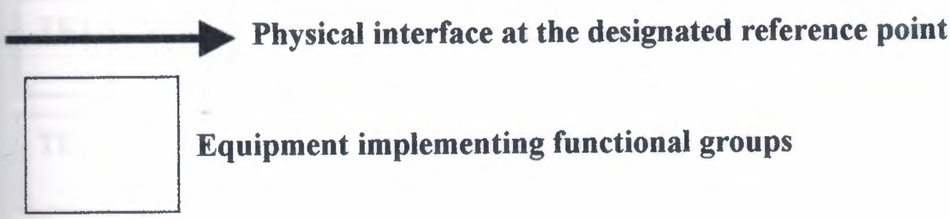
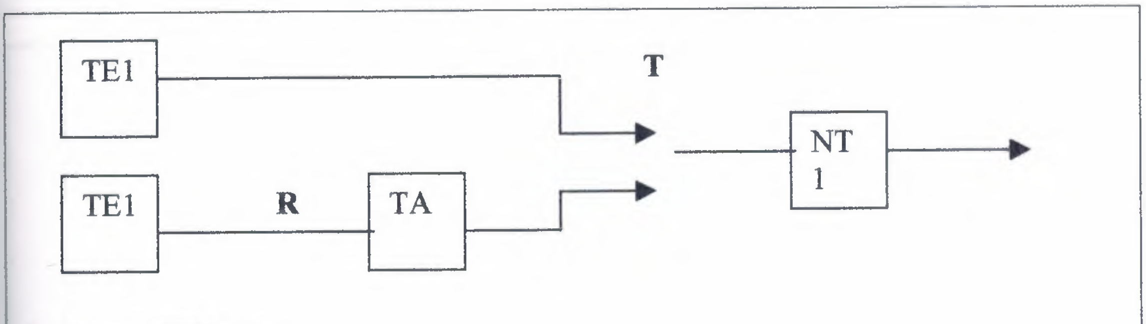
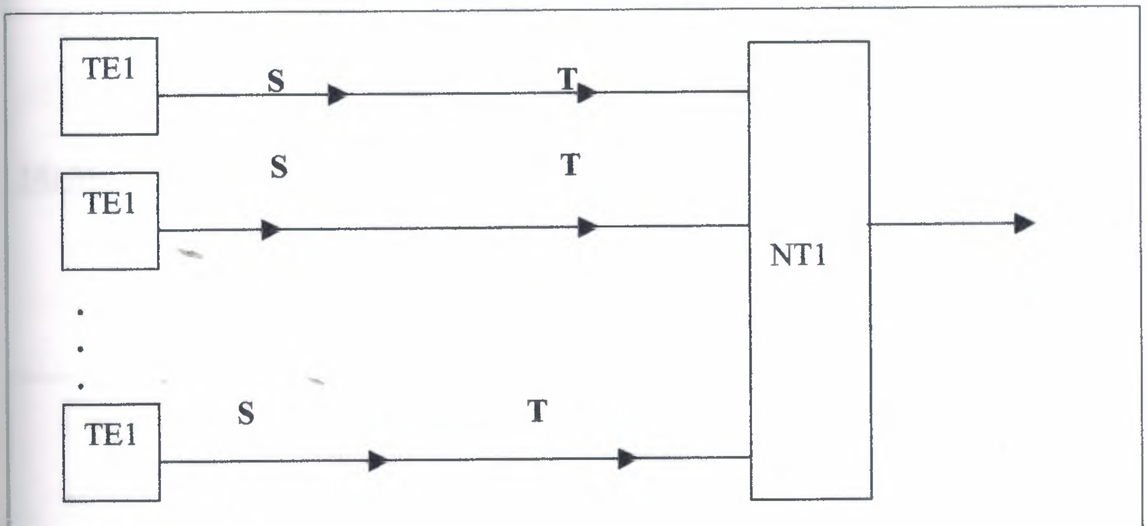


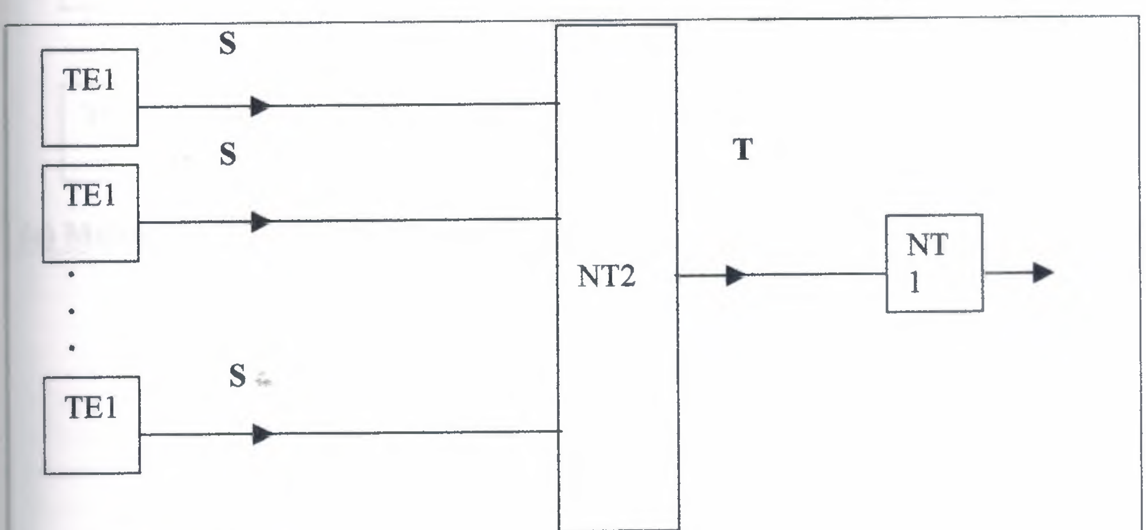
Figure 2.4 Examples of Implementations of NT1 and NT2 Functions



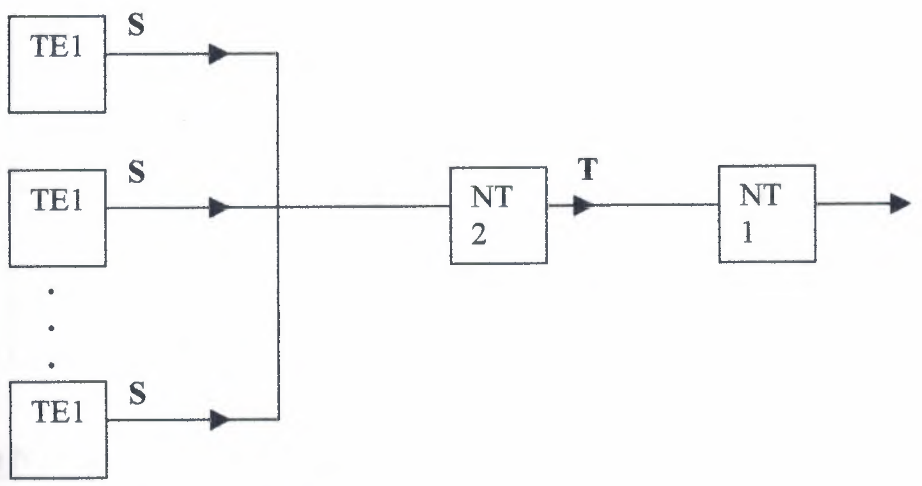
(a) Direct TE1-NT1



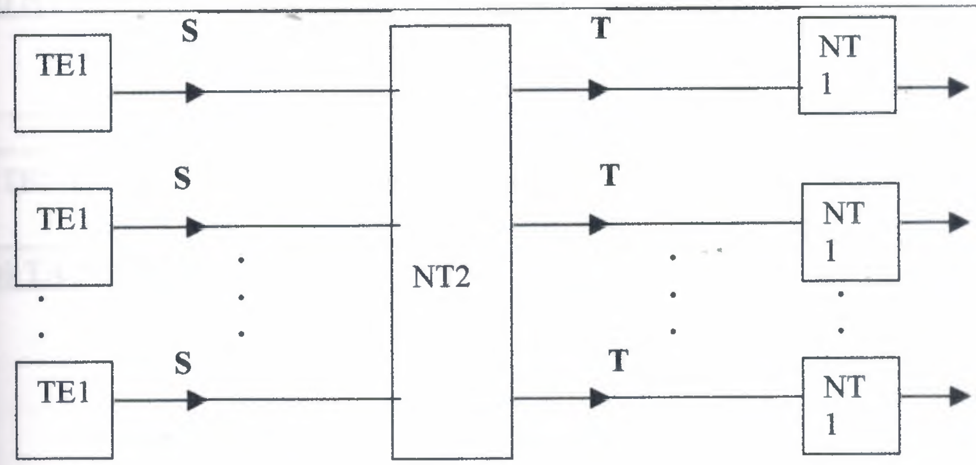
(b) Multiple TE1s



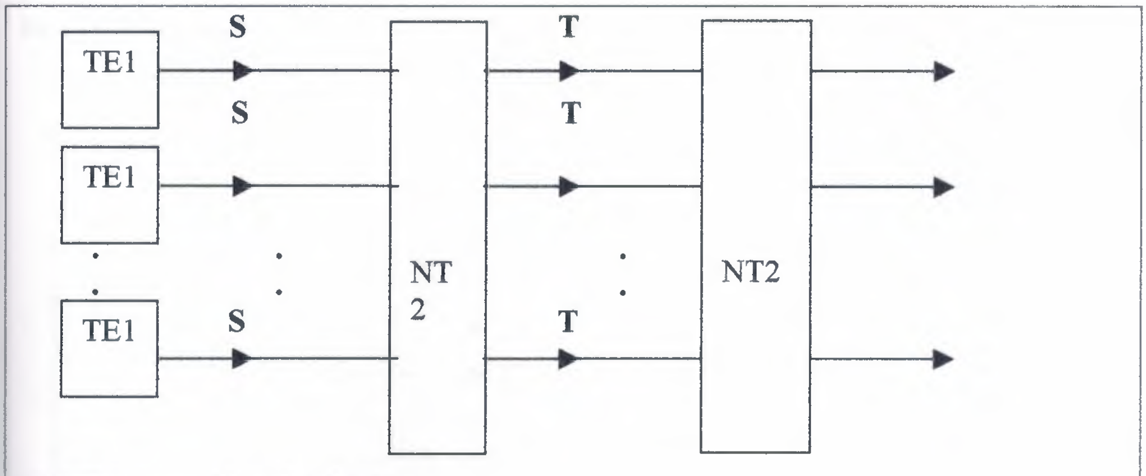
(c) Multiple NT2s to NT1



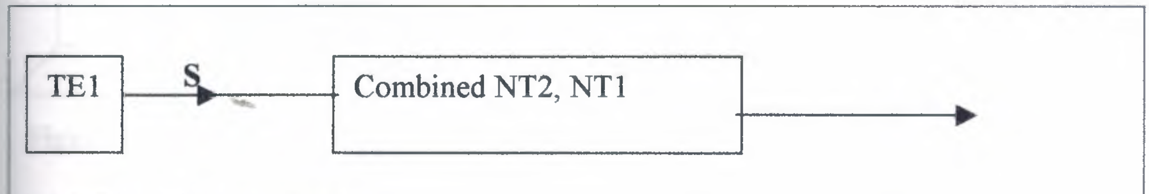
(d) Multiple TE1s to NT2, NT1



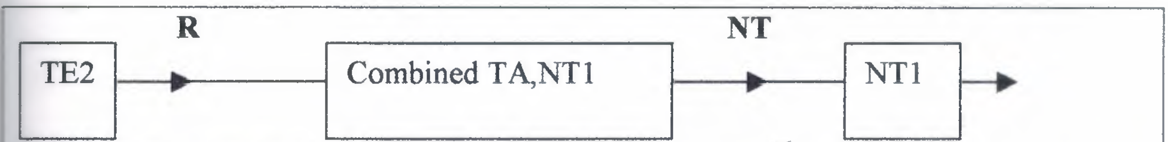
(e) Multiple NT2s, NT1 equipment



(f) NT1 upward multiplexing



(g) NT1, NT2 combined



(h) TA,NT2 combined

2.2 ISDN PROTOCOL ARCHITECTURE

The development of standards for ISDN includes the development of protocols for interaction between an ISDN user and the network and between two ISDN users. It would be desirable to fit these new ISDN protocols into the open systems inter-connection (OSI) model This would enable critical protocol architectural issues to be identified readily and facilitate the development of ISDN protocols.

Although general purpose in nature, the OSI model does not serve to represent all of the protocol functions required in an ISDN. In particular a simple seven layer stack does not capture the relationship between a control-signaling protocol on the D channel being used to set up, maintain, and terminate a connection on the B or H channel To accommodate this type of functionality, ITU-T has developed a more complex protocol reference model, defined in I.320 and illustrated in Figure 2.6. In this model, there are two layered stacks of protocol entities within a single functional grouping:

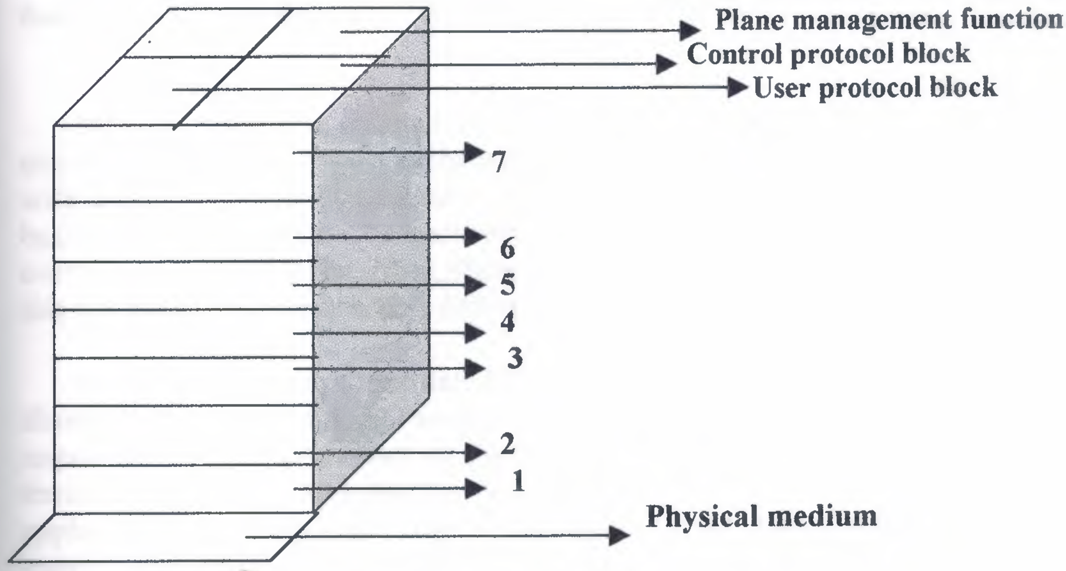


Figure 2.6 Global view of protocol Architecture

- User protocol block: Has the exclusive task of transparent transfer of user information

- Control protocol block: Has the exclusive task of supporting ISDN signaling

User protocols are the traditional protocols, such as X.25, that are modeled by the OSI model. Control protocols perform the following functions:

- Controlling a network connection (such as establishing and terminating)

- Controlling multimedia calls

- Controlling the use of an already established connection (e.g., change in service characteristics during a call)

- Providing supplementary services

Finally, the ISDN protocol reference model includes a plane management function that cuts across all of the protocol layers. The term plane refers to the cooperative interaction among protocols at the same layer on different system. The plane management function includes a variety of network management functions that enable a network management system to control the parameters and operation of remote systems and that enable a local system to collect configuration and operational data to be reported to a network management system.

Figure 2.7 depicts the ISDN-related protocols discussed in this part of the book in the context of the OSI model. Note that control signaling is essentially a D channel function but that user data may also be transferred across the D channel.

ISDN is essentially unconcerned with user layers 4-7. These are end-to-end layers employed by the user for the exchange of information. Network access is concerned only with layers 1-3. Layer 1, defined in 1.430 and 1.431, defines the physical interface for basic and primary access, respectively Because the B and D channels are multiplexed over the same physical interface, these standards apply to both types of channels. Above this layer, the protocol structure differs for the two channels.

For the D channel, a new data link layer standard, LAPD (link access protocol, D channel), has been defined. This standard is based on HDLC, modified to meet ISDN requirements. All transmission on the D channel is in the form of LAPD frames that are exchanged between the subscriber equipment and an ISDN switching element. Three applications are supported: control signaling, packet switching, and telemetry. For **control signaling,** a call control protocol has been defined (Q.931). This protocol is used to establish, maintain, and terminate connections on B channels. Thus, it is a protocol between the user and the network. Above [ayer3. there is the possibility for higher-layer functions associated with user-to-user control signaling. These are a subject for-further study. The D channel can also be used to provide **packet-switching** services to the subscriber. In this case, the X.25 level 3 protocol is used, and X25 packets are transmitted in LAPD frames. The X.25 level 3 protocol is used to establish virtual circuits on the F) channel to other users and to exchange packetized data. The final application area, **telemetry,** is a subject for further study.

The B channel can be used for circuit switching, semipermanent circuits, and packet switching. For circuit switching, a circuit is set upon a B channel on demand. The 0 channel call control protocol is used for this purpose. Once the circuit is setup, it may be used for data transfer between the users.

A semipermanent **circuit** is a B channel circuit that is set up by prior agreement between the connected users and the network. As with a circuit-switched connection, it provides a transparent data path between end Systems

With either a circuit-switched connection or a semipermanent circuit, it appears to the connected stations that they have a direct full-duplex link with each other. They are free to use their own formats, protocols, and frame synchronization. Hence, from the point of view of ISDN, layers 2-7 are not visible or specified. In addition, however, ITU-T has standardized I.465/V.120, which does provide common link-control functionality for ISDN subscribers.

In the case of **packet** switching a circuit-switched connection is set up on a B channel between the user and a packet-switched node using the D channel control protocol. Once the circuit is set up on the B channel, the user employs x.25 levels 2 and 3 to establish a virtual circuit to another user over that channel and to exchange packetized data.

2.3 ISDN CONNECTIONS

Narrowband ISDN provides six types of service for end-to-end communication.

- Circuit-switched calls over a B or H channel
- Semipermanent connections over a B or H channel
- Packet-switched calls over a B or H channel
- Packet-switched calls over a D channel
- Frame relay calls over a B or H channel
- Frame relay calls over a D channel

2.3.1 Circuit switching

The network configuration and protocols for circuit switching involve both the B and D channels. The B channel is used for the transparent exchange of user data. The communicating users may use any protocols they wish for end-to-end communication. The D channel is used to exchange control information between the user and the network for call establishment and termination and access to network facilities.

Figure 2.8 depicts the protocol architecture that implements circuit switching. The B channel is serviced by an NT1 or NT2 using only layer 1 functions. The end users may employ any protocol, although generally layer 3 will be null. On the D channel, a three-layer network access protocol is used and is explained subsequently. Finally, the process of establishing a circuit through ISDN involves the cooperation of switches internal to ISDN to set up the connection. These switches interact using signaling system Number 7.

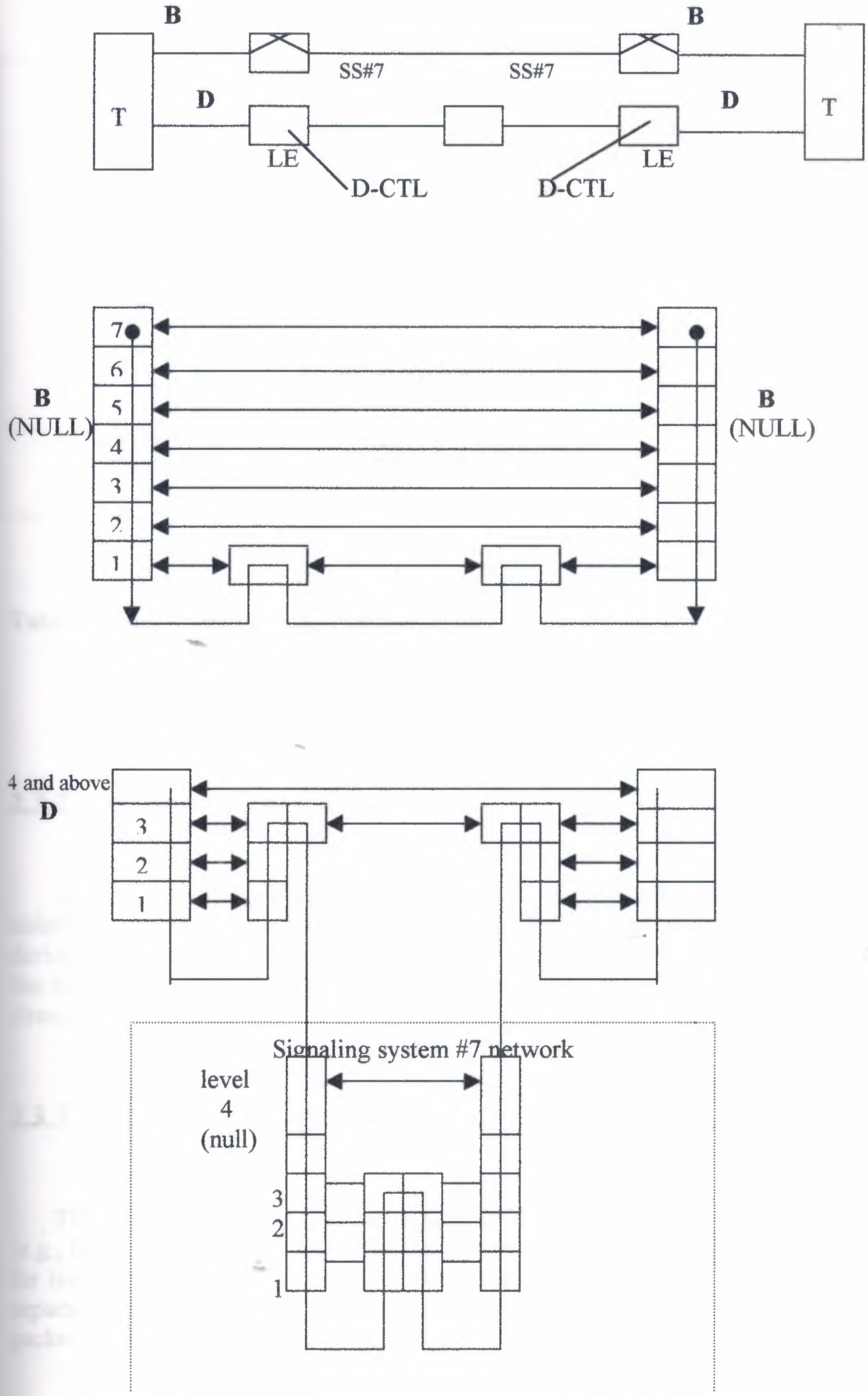


Figure 2.8 Network Configuration and Protocols for Circuit Switching

B	=	An ISDN B channel
D	=	An ISDN D channel
T	=	Terminal
D-CTL	=	D channel controller
SS 7	=	ITU-T signaling system 7
STP	=	Signaling transfer point
(Null)	=	Channel not present
7,6,5,4,3,2,1	=	Layers in ISO basic reference model
LEVEL	=	Levels in SS 7
LE	=	Local exchange
TE	=	Transit exchange
PSF	=	Packet-switching facility
Horizontal line	=	Peer-to-peer protocol
Vertical line	=	Layer-to-layer data flow

Table 2.3 Key to Figures 2.8, 2.11, and 2.1

2.3.2 Semipermanent Connections

A semi permanent connection between agreed points may be provided for an indefinite period of time after subscription, for a fixed period, or for agreed periods during a day, week, or other interval. That is, only layer 1 functionality is provided by the network interface; the call control protocol is not needed, because the connection already exists.

2.3.3 Packet Switching

The ISDN must also permit user access to packet-switched services for data traffic (e.g., interactive) that is best serviced by packet switching. There are two possibilities for implementing this service: Either the packet-switching capability is furnished by a separate network, referred to as a packet-switched public data network (PSPDN), or the packet-switching capability is integrated into ISDN.

2.3.4 PSPDN Service

When the packet-switching service is provided by a separate PSPDN, the access to that service is via a B channel. Both the user and the PSPDN must therefore be connected as subscribers to the ISDN. In the case of the PSPDN, one or more of the packet-switching network nodes, referred to as packet handlers, are connected to ISDN. We can think of each such node as a traditional X.25 DCE supplemented by the logic needed to access ISDN. Any ISDN subscriber can then communicate, via X.25, with any user connected to the PSPDN, including.

- Users with a direct, permanent connection to the PSPDN
- Users of the ISDN that currently enjoy a connection, through the ISDN, to the PSPDN

The connection between the user (via a B channel) and the packet handler with which it communicates may be either semipermanent or circuit switched. In the former case, the connection is always there, and the user may freely invoke X.25 to set up a virtual circuit to another user. In the latter case, the D channel is involved and the following sequence of steps occurs (figure 2.9)

1- The user requests, via the D channel call control protocol (Q.931), a circuit-switched connection on a B channel to a packet handler.

2- The connection is set up by ISDN and user is notified via the D channel call control protocol.

3- The user sets up a virtual circuit to another user via the X.25 call establishment procedure on the B channel. This requires that first a data link connection, using LAPB, must be set up between the user and the packet handler.

4- The user terminates the virtual circuit using X.25 on the B channel.

5- After one or more virtual calls on the B channel, the user is done and signals via the D channel to terminate the circuit-switched connection to the packet-switching node.

6- The connection is terminated by ISDN.

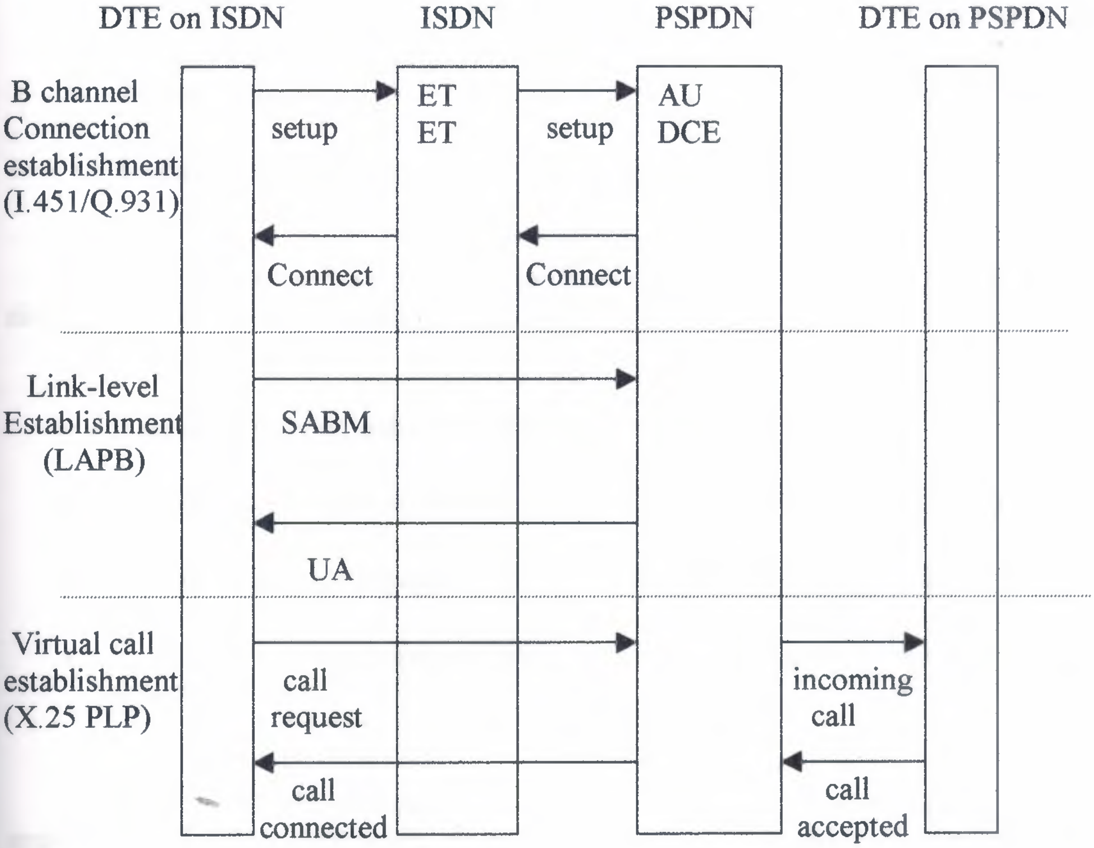


Figure 2.9 Virtual Call Setup

2.3.5 ISDN service

When the packet-switching service is provided by ISDN, the packet-handling function is provided within the ISDN, either by separate equipment or as part of the exchange equipment. The user may connect to a packet handler either by a B channel or the D channel. On a B channels, the connection to the packet handler may be either switched or semipermanent, and the same procedures described previously apply for switched connections. In this case, rather than establish a B channel connection to another ISDN subscriber that is a PSPDN packet handler the connection is to an internal element of ISDN that is packet handler.

2.4 ADDRESSING

In the worldwide public telephone network, calls are placed based on the telephone number of the called party. For worldwide telephone connectivity, each subscriber must have a unique telephone number, and the network must be able to determine the location of the subscriber based on that number. A telephone number supports two important functions:

- It routes the call
- It activates the necessary procedures for proper call charging

Similarly, a numbering plan is needed for ISDN. The numbering scheme for ISDN should be based on the following requirements:

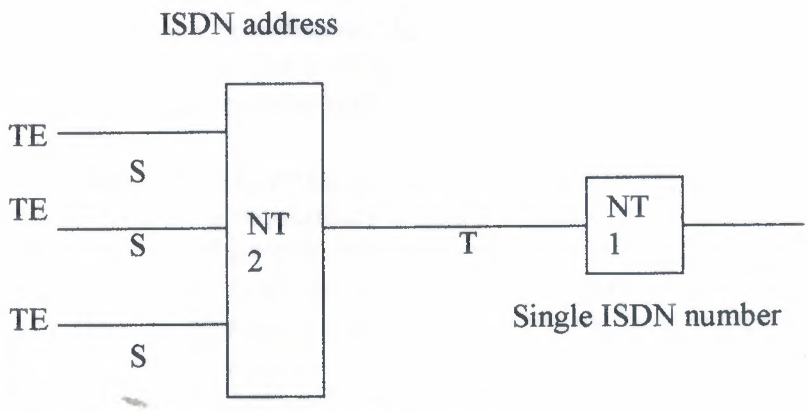
- It should be easily understood and used by the subscriber.
- It should be compatible with existing and planned switching equipment.
- It should allow for expansion of the size of the subscriber population.
- It should facilitate interworking with existing public network numbering schemes.

As work on ISDN proceeded through the early 1980s, there was considerable sentiment that ISDN numbering should be based on the current numbering plan for telephony, embodied in ITU-T E.164. However, E.164 allows for only 12 decimal digits and was felt to be inadequate for the large number of subscribers anticipated for ISDN. ISDN must accommodate not only telephones but also a large population of data devices. The result was the adoption of a numbering scheme that is an enhancement of E.164. This schema embodies the following principles:

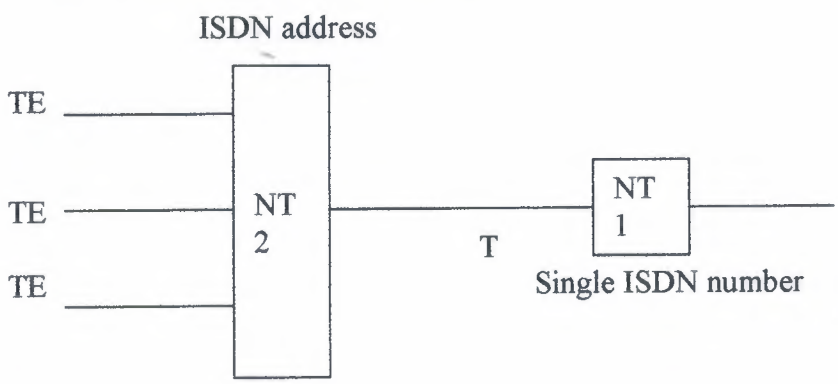
- As mentioned, it is an enhancement of E.164. In particular, the telephone country code specified in E.164 is used to identify countries in the ISDN numbering plan.
- It is independent of the nature of the service (e.g., voice or data) or the performance characteristics of the connection.
- It is a sequence of decimal digits (not alphanumeric).
- Interworking between ISDNs requires only that the use of the ISDN number.

2.4.1 ISDN Address structure

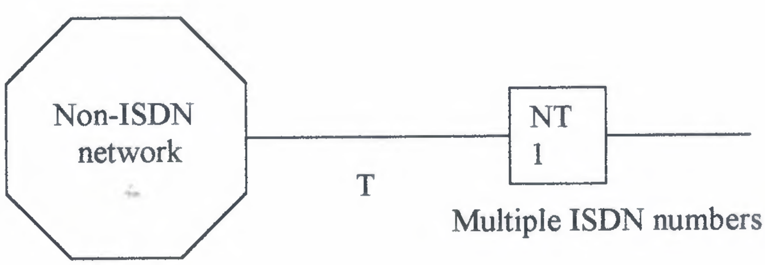
ITU-T makes a distinction between a number and an address. An ISDN number is one that relates to the ISDN network and ISDN numbering plan. It contains sufficient information for the network to route a call. Typically, but not always, an ISDN number corresponds to the subscriber attachment point to the ISDN (i.e., to the T reference point). An ISDN address comprises the ISDN number and any mandatory and/or optional additional addressing information. This additional information is not needed by the ISDN to route the call but is needed at the subscriber site to distribute the call to the appropriate party. Typically, but not always, an ISDN address corresponds to an individual terminal (i.e., to the S reference point). This situation is illustrated in figure 2.10a, which shows a number of terminals connected to an NT2 (e.g., a PBX or LAN). The NT2 as a whole has a unique ISDN number, while each individual terminal has an ISDN address. Another way to express the distinction between ISDN numbers and address. Another way to express the distinction between ISDN numbers and addresses is that an ISDN number is associated with a D channel, which provides common-channel signaling for a number of subscribers, each of which has an ISDN address.



(a) Single ISDN number at T interface



(b) Direct dialing-in



(c) Non-ISDN network

Figure 2.10 ISDN Addressing.

Other correspondences between reference points and ISDN number and addresses are possible; these are discussed subsequently.

Figure 2.11 shows the format of the ISDN address. An address in this format would appear in call setup messages communicated in common-channel signaling protocols such as signaling system number 7 the element of the address are as follows:

- **Country code:** Specifies the destination country (or geographic area) of the call. It is composed of a variable number of decimal digits (1 to 3) and is defined in recommendation E.164 (existing telephony numbering plan)

- **National destination code:** Is of variable length and a portion of the national ISDN number. If subscribers within a country are served by more than one ISDN and/or public switched telephone network (PSTN), it can be used to select a destination network within the specified country. It can also be used in a trunk code (area code) format to route the call over the destination network to a particular region of the network. The NDC code can, where required, provide a combination of both of these functions.

- **ISDN subscriber number:** It also of variable length and constitutes the remainder of the national ISDN number. Typically, the subscriber number is the number to be dialed to reach a subscriber in the same local network or numbering area

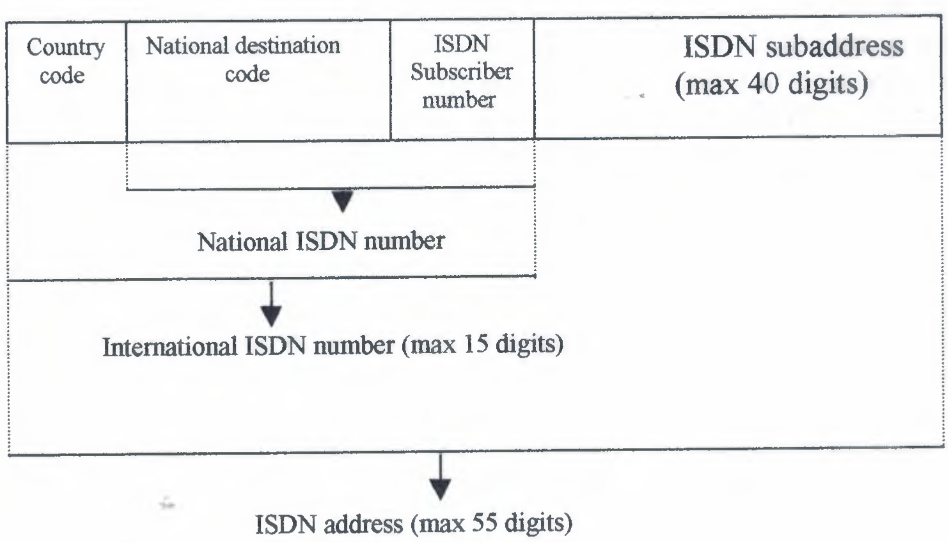


Figure 2.11 Structure of the ISDN Address

- **ISDN subaddress:** Provides additional addressing. Information and is a maximum of 40 digits in length. The subaddress is not considered part of the num- Bering plan but constitutes an intrinsic part of the ISDN addressing capability.

The national destination code plus the ISDN subscriber number form a unique national ISDN number within a country. This plus the country code form the international ISDN number, which is at present limited to a maximum of 15 digits. ITU-T is considering expanding this to 16 or 17 digits. The ISDN subaddress is added to the international ISDN number to form an ISDN address with a maximum of 55 digits

2.4.2 Address Information

Figure 2.10a shows the most straightforward way of employing ISDN number 5, and addresses: Each T reference. point is assigned an IŞDN number , and each S reference point is assigned an ISDN address The last field of the ISDN address, known as subaddress, allows multiple subscriber to be discriminated at the subscriber site in a fashion that is transparent to the network. As an example, consider a site consisting of a digital PBX supporting some number of telephones. The national ISDN number for the PBY could be 617-543-7000. To address a local telephone with extension number 678, a remote caller would need to dial 617-543-7000-678. The ISDN would route the call based on the first 10 digits; the remaining 3 digits would be used by the PBX to connect the call to the appropriate extension.

An alternative use of numbers and addresses is suggested by Figure 2.10b. In this case, a number of terminals each have their own ISDN number. This feature is referred to as **direct dialing-in** (DDI). With DDI, the numbering scheme for local terminals is built into the national scheme. For example, again suppose a digital PBX with a main number of 543-7000, with an extension to that PBX of 678. To dial the extension directly from the outside, a user would dial 543-7678, and the 543- 7XXX block would be lost for use except for 999 extension possibilities for that PBX. DDI is simpler for the subscriber than subaddressing, because fewer digits are needed to place a call. With DDI, the ISDN still routes on the basis of the ISDN number. In addition, the last few digits forming the end of the ISDN number are transferred to the called subscriber's installation. The number of digits used varies and depends upon the requirement of the called subscriber's equipment and the capacity of the numbering plan used. DDI must be used sparingly to assure that sufficient ISDN numbers are available to support all subscribers.

It is possible to combine DDI and subaddressing. This would allow direct dial- ing-in to certain intermediate equipment on site; such as terminal concentrators, with the subaddress used to discriminate devices attached to the intermediate equipment.

Another alternative is to assign multiple ISDN numbers to a single reference point. For example, at an ISDN interface, a user might have an attachment to a non- ISDN network, such as a private packet-switching network (Figure 2.10c). Although physically there is only a single attachment point to the ISDN, it might be desirable to provide visibility to ISDN of a number of the devices on the private network by assigning a unique ISDN number to each.

2.4.3 Numbering Interworking

For some extended-transition period,'theie will be a number of public networks in addition to ISDN, including public switched telephone networks (PSTN) and pub- lic data networks, such as X.25 packet-switching networks and telex networks. A variety of standards have been issued that deal with the address structure and address assignment for fhese various; networks. Unfortunately, although these stan- dards have been developed with knowledge of the others, they are not compatible with each other or with the ISDN numbering plan. This creates the problem of how addressing can be performed between an ISDN subscriber and a subscriber on another network that has connection to ISDN.

2.4.4 Other Address structures

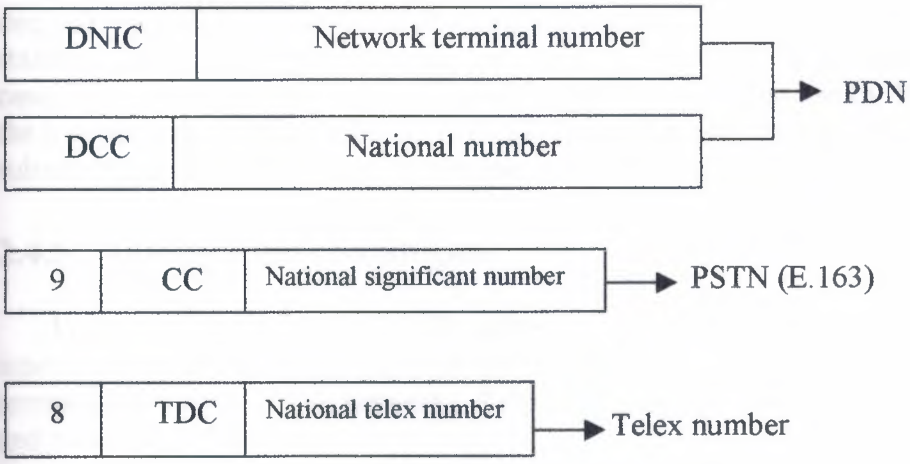
Figure 2.12 illustrates the address structure for the major international public network standards. The international PSTN standard, E.164, makes use ofa 12-digit number. The country code is the same as the 'country code used iw ISDN-The national significant number of the PSTN corresponds to the national ISDN number, although-the latter may contain three more digits. Thus, E.164 and the ISDN stan- dard are reasonably compatible.

X.121, provides a standard for public data networks. As can be seeıi, there are a number of variations, depeııding on the network. If a data terminal is accessed through a public data network, then the E.164 number, prefixed by a 9; is used. For public data networks, a data country code is used, which nnfortunately is not the same as a telephone country code. Nor 'is the national data number related in any way to the national telephone number. The telex numbering scheme also bears no relation to E.164.

Finally, ISO has developed an inteinational numbering scheme in the context of the OSI model. The authority and format identifier (AFI) portion of the ISO , address confines one of six subdomains of the global network addressing domain:

CC	National significant number

(a) E.164: PSTN



(b) X.121 data networks

(c) ISO 7498

CC: Country code
DNIC: Data network identification code
DCC: Data country code
TDC: Telex destination code
AFI: Authority and format identifier
IDI: Initial domain identifier
DSP: Domain specific part

Figure 2.12 International Network Numbering.

- A set of four domains, each of which corresponds to a type of public telecom-inunications network (i.e., packet-switched, telex, PSTN, and ISDN), all of which are administered by ITUT-T.

- An ISO geographic domain that is aüocated and corresponds to individual countries. ISO member bodies within each country are responsible for assign ing these addresses.

- An ISO international organization domain that is allocated and corresponds to different international organizations (e.g., NATO).

In addition, the AFI specifies the format of the IDI part and the structure of the DSP part. The initial domain identifier is the initial (and perhaps only) part of the actual address and is interpreted according to the value of the AFI. Finally, the DSP part, if any, provides additional addressing information.

For ISDN networks, the AFT has a value of 44 for ISDN numbers expressed as decimal digits and 45 for ISDN numbers expressed as binary numbers. The latter is not standard ISDN procedure, but may be employed by a user in an OSI context; in that case; the number would have to be converted to decimal for use by ISDN. In general, the international ISDN number is identical to the initial domain identifier, and the ISDN subaddress is identical to the domain-specific part of the ISO address.

2.4.5 Interworking Strategies

From the point of view of ISDN addressing, interworking is defined as a procedure whereby an ISDN subscriber can set up a call to subscribers or services terminated on other public networks. Two general approaches are possible: single- stage and two-stage selection.

With the **single-stage approach,** the calling party designates the address of the called party in the call setup procedure. This address contains sufficient information for

- ISDN to route the call to a point at which the called network attaches to ISDN
- The called network to route the call to the called party

ITU-T suggests two ways in which single-stage addresses could be constructed. In the first method, the address begins with a prefix that identifies the particular net- work to be accessed; the remainder of the address is in the format used by that net- work (Figure 2.13a). In this approach, the calling address would have to identify the called numbering plan as part of the calling procedure. An example of such a pre- fix is the authority and format indicator of the ISO address structure. In the ISDN signaling protocol (Q.931).

An alternative address structure for the Single stage approach is one that con- forms to the ISDN address structure. In this case, some national destination codes (NDCs; see Figure 2-11) could be specially assigned for interworking purposes. This is a less general solution than the prefix approach, as the number of available NDCs is limited.

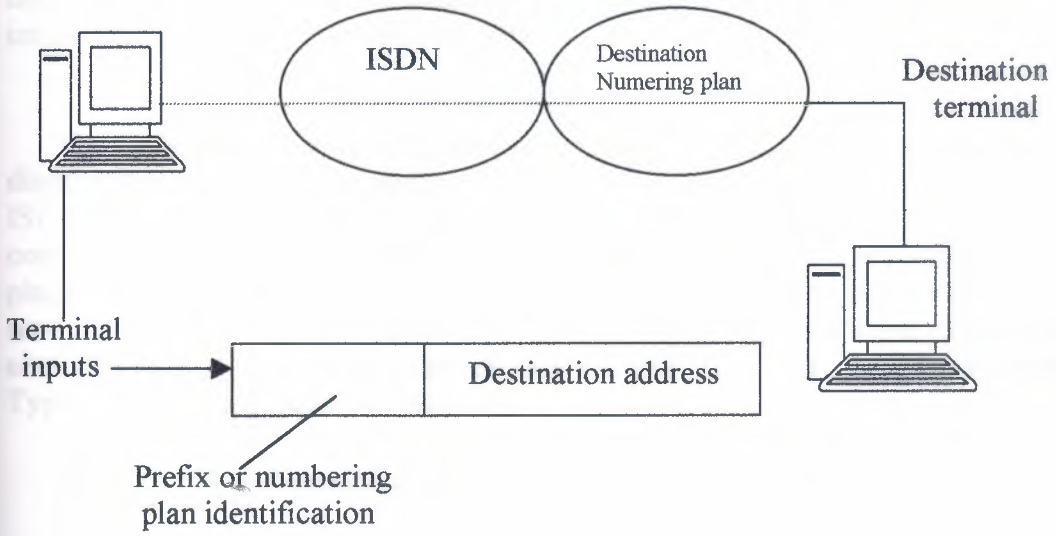
With the two-stage approach, the first stage of selection provides-the calling party access via ISDN to an interworking unit (IWU) associated with the point of attachment of the called network to the ISDN. The calling party uses an ISDN number up a connection to the IWU. When a connection is established, the IWU responds. The necessary address information for the called party on that particular network is then forwarded, as a second stage of selection, through the ISDN and the IWU to complete the call in the non-ISDN network (Figure 6.13b).

The main disadvantages of the two-stage approach are as follows:

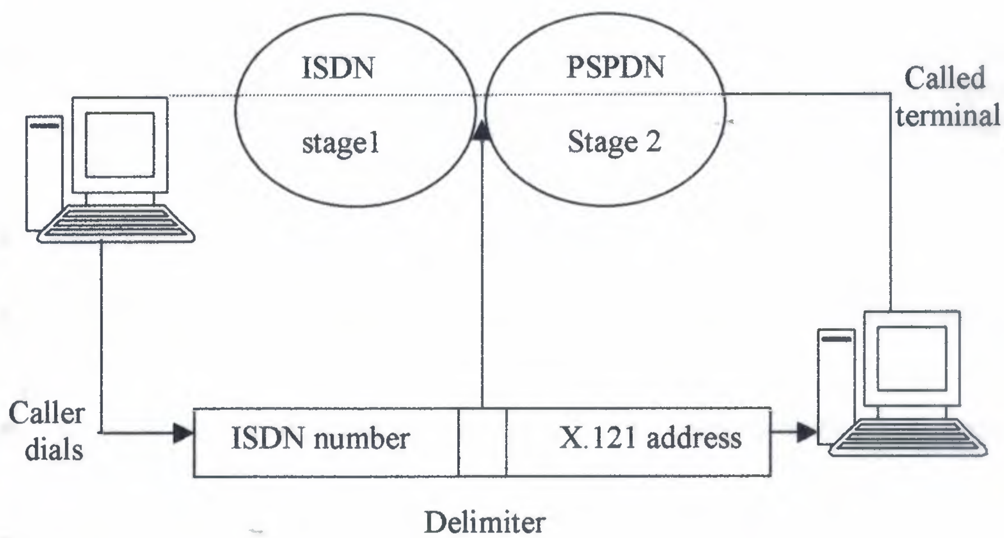
- Additional digits must be dialed by the caller.
- The caller must employ two numbering plans.

- A delimiter or pause is necessary between the two stages (e.g., a second dial tone)

For these reasons, ITU-T prefers the one-stage approach but allows the two-stage approach.



(a) Single-stage interworking



(b) Two-stage interworking

Figure 2.13 Strategies for numbering Interworking

2.5 INTERWORKING

It is clear that there is never likely to be a single, monolithic worldwide ISDN. In r the near term, there will be a variety of non-ISDN public networks operating, with d for the subscribers on these networks to connect to subscribers on ISDN networks. Even in the case of different national ISDNs, differences in services-or the attributes of services may persist indefinitely. Accordingly, ITU-T has addressed the issue of the interworking of other networks with ISDN.

One related to interworking, that of interworking between numbering plans, was discussed in the preceding section. The interworking of numbering plans allows an ISDN subscriber to identify a non-ISDN subscriber for the ,purpose of establishing a connection and using some service. However, for successful communication to take place there must be agreement on, and the capability to provide, a common set of services and mechanisms. To provide compatibility between ISDN and existing network components and terminals, a set of interworking functions must be implemented. Typical functions include the following:

- Provide interworking of numbering plans.
- Match physical-layer characteristics at the point of interconnection between the two networks.
- Determine if network resources on the destination network side are adequate to meet the ISDN service demand.
- Map control signal messages such as services identification, channel identifi- cation, call status, and alerting between the ISDN's common-channel signal- ing protocol and the called network's signaling protocol, whether the latter is in channel or common channel.
- Ensure service and connection compatibility.
- Provide transmission structure conversion; including information modulation technique and frame structure.
- Maintain synchronization (error control, flow control) across connections on different networks.
- Collect data required for proper billing.
- Coordinate operation and maintenance procedures to be able to isolate faults.

Thus, interworking may require the implementation of a set of interworking functions, either in ISDN or the network attached to ISDN. The approach identified by ITU-T for standardizing the interworking capability is to define additional reference points associated with interworking and to standardize the interface at that reference point. This is a sound strategy that should minimize the impact both on ISDN and on other networks. The inclusion of these additional reference points is illustrated in Figure 2.14. As before, ISDN-compatible customer equipment attaches to ISDN via the S or T reference point. The following additional reference points are defined:

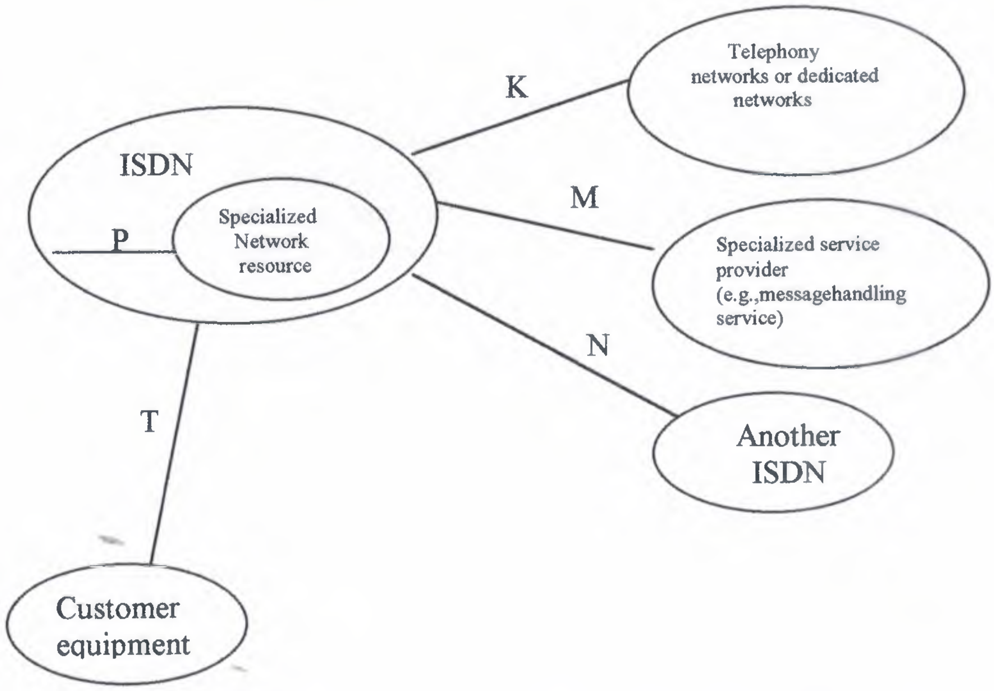


Figure 2.14 Reference Points Associated with the Interconnection of Customer Equipment and Other Networks to an ISDN

- **K:** Interface with an existing telephone network or other non-ISDN network requiring interworking functions: The functions are performed by ISDN.

- **M:** A specialized network, such as teletex or MHS. In this case, an adept ion function may be needed; to be performed in the specialized network.

- **N:** Interface between two ISDNs Some sorts of protocol is needed to determine the degree of service compatibility.

- **P:** There may be some specialized resource that is; provided by the ISDN provider but that is clearly; identifiable as a separate component or set of components.

In I.510, ITU-T identifies five other types of networks that support telecommunication services, that are also supported by an ISDN and that are candidates, therefore; for interworking with an ISDN:

- Another ISDN

- Public-switched telephone network (PSTN)
- Circuit switched public data network (CSPDN)
- Packet-switched public data network (PSPDN)
- Telex

Table 2.4, from I. 510, depicts the type of interworking functions that may be required for each interworking configuration. In this context, a connection is a network-oriented function relating to the establishment of an information transfer path through the network, while a communication is a user-oriented function relating to the end-to-end protocols needed for the exchange of information between subscribers.

Table 2.4 ISDN Supports of Telecommunication Services in an Interworking. Configuration (I.510)

Service Supported by ISDN	**ISDN**	**PSTN**	**CSPDN**	**PSPDN**	**TELEX**	**Other Dedicated Network**
Telephony	O	N	-	-	-	N
Data Transmission	(L)	N,L	N,(L)	N,(L)	-	N,(L)
Telex	O	-	-	-	N,L	N.L
Teletex	O	N,L	N,L	N,L	-	N,L,H
Facsimile	O	N,L	N,L	N,L	-	N,L,H

O : No interworking function foreseen
N : Connection-dependent interworking needed
L : Lower-layer communication-dependent intenworking needed
H : Higher-layer communication-dependent interworking needed
X : X may be needed

2.5.1 ISDN-ISDN Interworking

The simplest case of interworking involves two ISDNs: If the two ISDNs provide identical bearer services and teleservices, then no interworking capabilities are required.

However, it may be the case that the two networks differ in the attribute values that they support for one or more services. In that case, interworking is needed. The interworking would occur in two phases. In the *control phase,* a service negotiation takes place in order to reach a service agreement. A service agreement can be reached if the maximum common service that can be provided across the two networks equals or exceeds the minimum service that the caller will accept. If agreement is reached, then the connection is established, which involves splicing together connections from the two ISDNs to form a single connection from the user's point of view. User-to-user communication can then take place in the *user phase.*

2.5.2 ISDN-PSTN Interworking

In many countries, digitization of the existing public switched telephone network (PSTN) has been ongoing for a number of years, including implementation of digital transmission and switching facilities and the introduction of common-channel signaling. The availability of digital subscriber loops has lagged behind the introduction of these other digital aspects. In any case, such networks exhibit some overlap with the capabilities of a full ISDN but lack some of the services that an ISDN will support. Thus, it will be necessary for some time to provide interworking between ISDN and PSTN facilities.

Table 2.5 (from I.530) identifies the key characteristics of an ISDN and a PSTN, indicating possible interworking functions to accommodate dissimilar

The interworking between an ISDN and a PSTN is reasonably straightforward. The number plan of the telephone network is the same as that used for ISDN, so no conversion is required. The interworking function must include a mapping between the control signaling used in ISDN and that used in the telephone network. Finally a conversion is needed between digital and analog forms of user information.

2.5.3 ISDN-CSPDN Interworking

A circuit switched public data Network, as the name implies, provides a digital transmission service using circuit switching. The interface for DTEs to this type of network is X.21. Like X.25, X.21 is actually a three-layer set of protocols that, includes in band control signaling for setting up and terminating' connections: In the Cases of X.21, the connections are actual rather than virtual circuits.

The interworking functions for this case have not been fully worked out; much has been left for further study. A mapping is required between the call control protocol of X.21 and that used in ISDN. For addressing, ISDNs and CSPDNs utilize differing numbering plans (i.e., E.164 and X.121, respectively). A one-stage address translation, as described in the previous section, is specified.

Table 2.5 : Key ISDN and PSTN Characteristics

	ISDN	PSTN	Interworking Functions
Subscriber interface	Digital	Analog	a
User-network Signaling	Out of band (I.441/I.451)	Mainly in band (e.g.,DTMF)	b,e
User terminal Equipment supported	Digital TE (ISDN NT ,Tel or TE2+TA)	Analog TE(e.g.,dial Pulse telephones PBXs,modem-equipped DTEs)	c
Interexchange Signaling	SS7 ISDN user, Part (ISUP)	Inband (e.g.,R1,R2, SS4,SS5) or out of Band(e.g.,SS6,SS7 TUP)	d,e
Transmission facilities	Digital	Analog/digital	a
Information transfer mode	Circuit/packet	Circuit	f
Information transfer capability	Speech, digital Unrestricted,3.1kHz Audio, video, etc.	3.1-kHz audio (voice/voiceband data)	f

a = Analog-to-digital and digital-to-analog conversion on transmission facilities.

b = Mapping between .PSTN signals in the subscriber access and I.451 messages ,for intra-exchange calls

c = Support of communication between on modem-equipped PSTN DTEs and ISDN terminals.

d= Conversion between the PSTN signaling system and signaling system No. 7 ISDN user part.

e=Mapping between signals in the ISDN subscriber (I.441. I.451) access and PSTN inband interexchange signaling (e.g. R1).

f= Further study required.

2.5.4 ISDN-PSPDN Interworking

A packet-switched public data network provides a packet-switching service using an X.25 interface. There are two interworking cases:

- A circuit-mode bearer service is used on ISDN.
- A packet-mode bearer service is used on ISDN.

In the first case, interworking is achieved by means of a circuit-mode connection across ISDN from an ISDN subscriber to a packet handler in the PSPDN (see Figure 2.10). In the second case, the ISDN functions as a packet-switching network (Figure 2.13). For this case, there is an established interworking protocol to be used between two public packet-switching networks: X.76. In essence, X.75 acts as a splicing mechanism to tie together two virtual circuits in the two networks in such a way that it appears as a single virtual circuit to the two end DTEs. .

2.6 SUMMARY

The functions performed by an ISDN can be defined by the services that it supports and the functions visible at the user-network interface. Among the most important defining characteristics of ISDN are the following:

- **Transmission structure:** ISDN offers a service structured as a set of channels. The B channel is a user channel that supports circuit-switched, semipermanent, and packet-switched use. The D channel supports user-network control signaling and packet switching. The two standard transmission offerings are the basic service, consisting of two B channels and one D channel, and the primary service, consisting of 24 or 31 B channels and one D channel.

- **User-network interface configurations:** The user-network interface is defined in terms of reference points and functional groupings. This approach provides for standardized interfaces that facilitate the use of equipment from multiple vendors and that simplify access to ISDN.

- **Protocol architecture**: The interaction between ISDN and a subscriber can be described within the context of the OSI protocol reference model. Essentially, the ISDN recommendations deal with layers 1 to 3 of that model. A physical layer specification covers both basic and primary access for all channels: For the D channel, LAPD is defined at the data link layer, and Q.931 (call control) and the X.25 packet level (packet-mode service on the D channel) are specified for the network level. For the B channel, ISDN supports the use of X.25 and LAPB for packet-mode service and also provides I.465/V.120 as a common optional data link mechanism.

Chapter 3

Broadband Network Technologies

3.1 Broadband Network Technologies-On a Page

To be able to transport the MPEG compressed digital video signals through the network, from the encoder to the set top box for instance,a very powerful transmission mechanism is needed. Presently, the only technology that can fulfill all the requirements in terms of bandwidth, flexibility, and interactivity the digital video services have is the ATM protocol, the central element of the B-ISDN. This section will provide the background and the essential technical details of B-ISDN needed to enable a more detailed understanding of the key networking technologies, referred to in the later section dealing with "Video in Broadband Networks.' The following will be covered:

- The reasons for defining 'the B-ISDN-the history and background.
- The major interface points and network elements in the B-ISDN are defined in order to provide insight in the basic functional blocks and reference points.
- A detailed description of the organization of the different layers and protocols used in B-ISDN. The most cental aspects of these layers and protocols will then be dealt with in detail. This will cover the description of function and structure of:
- The physical layer and the transmission convergence layer, with special focus on some of the most central protocols, DS-3, E-3 PDH and, in particular. SONET OC-3/SDH STM-l.

- The ATM layer, including the ATM layer Quality of Service (QoS) aspects relevant for transporting digital video over ATM.

- The ATM adaptation layers with special focus on the protocols relevant for transporting MPEG-2 compressed digital video, AAL-1 and AAL-3, and finally the higher protocol layers with special focus on signaling, particularly the ITU protocol for UNI Signaling Q.2931.

3.2 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 net- works 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 9-3 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-ISDN 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.

3.3 Abilities and Benefits of B-ISDN

3.3.1 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/datacommunication 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.

3.3.2 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 band- width requirements of a data transfer is 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 every- thing 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 delay 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.

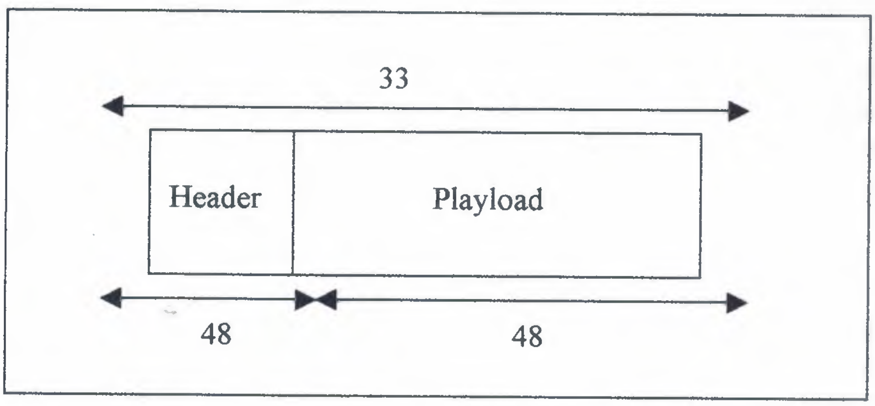


Figure 3.1 Structure of the ATM cell

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 Fig. 3.1. The information coming from the different services, such as file transfers or video trans- missions, 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.

3.3.3 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 tele- phone 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 Fig. 3.2. 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 of 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.”

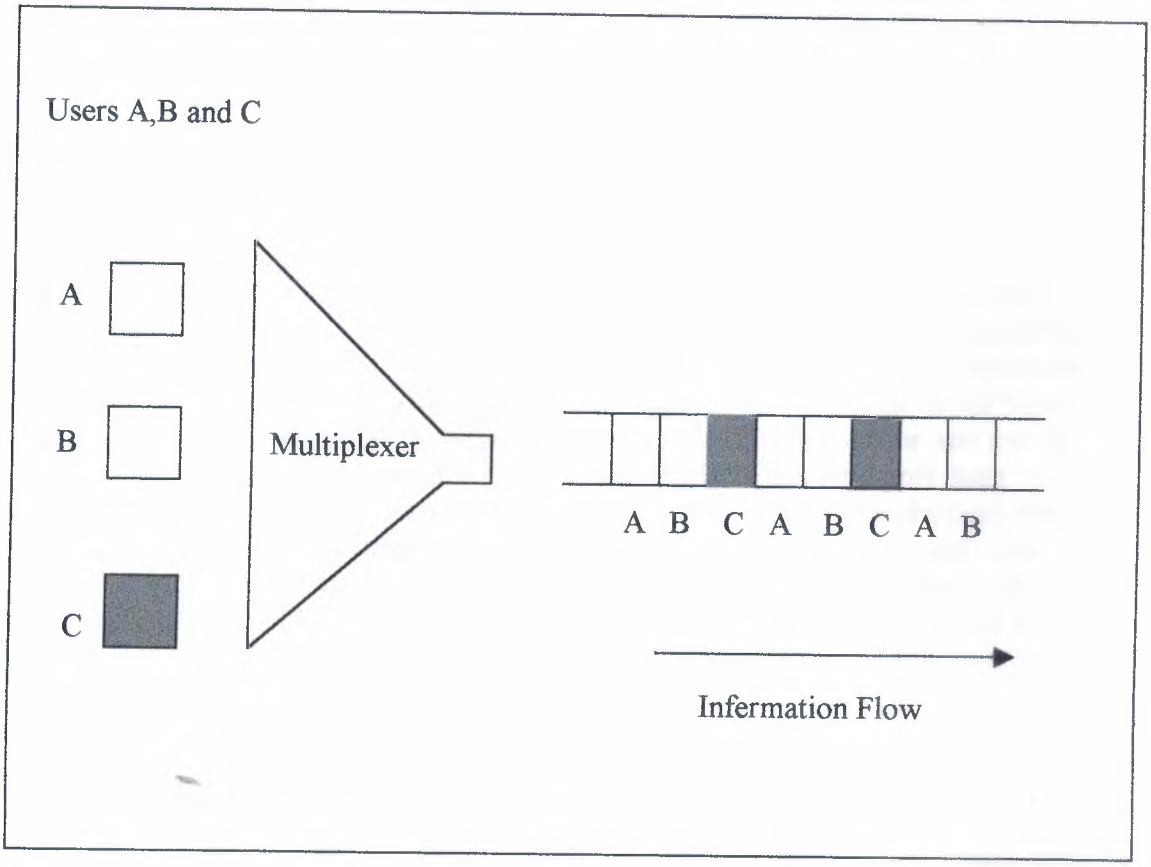


Figure 3.2 The sutructure of TDM

3.3.4 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.

3.3.5 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.

3.3.6 Dynamic Bandwidth

When a connection is initiated, the bandwidth requirements of the connection; in terms of 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 T1/E1 (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).

3.3.7 Variable Connection Quality

It ıs 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.

Chapter 4

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 be 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 4.1 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 9.2 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.

4.1 N x 64 kbit/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 kbit/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 001 01010 indicates a transfer rate of 384 kbit/s with 64 kbit/s allocated to audio information and 320 k/bits allocated to video.

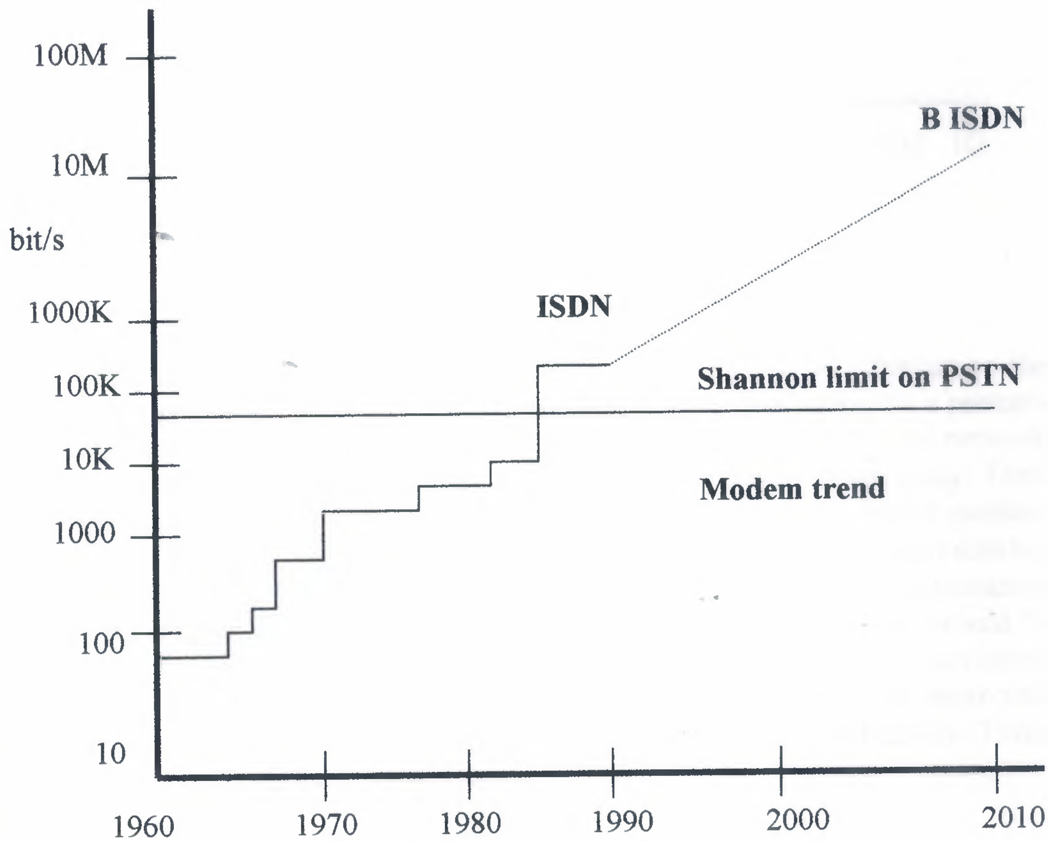


Figure 4.1 The rise of switched date rates

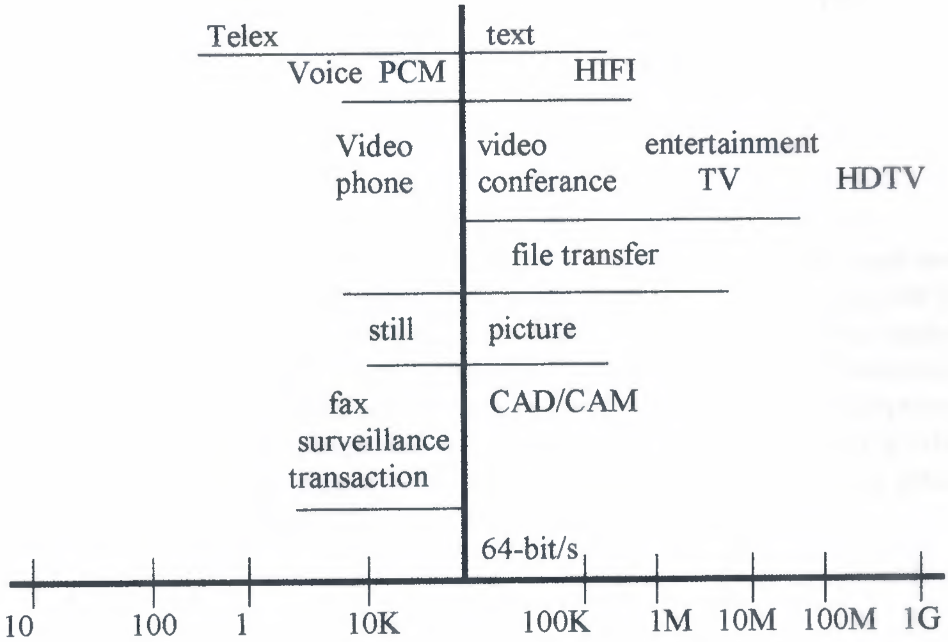


Figure 2.2 Bandwidth requirements

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 of alternative routing strategies in the net- work 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.

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 multiframe 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 multiframe. 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 4.1
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 4.1 shows the probability of not being able to accept a multichannel call of N channels. This is the grade of service for N x 64 kbit/s circuits in an environment where multichannel 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 larget multichannel 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

4.2 H-CHANNELS

Referring to Figures 4.1 and 4.2, one might identify some specific steps in the rates offered above 64 kbit/s. These have been identified by CCITT as:

(a) HO at 384 kbit/s (i.e. 6 x 64 kbit/s). This would be specifically attractive for video conference codecs and hifi sound. The potential effect of this on traffic design has already been discussed in Section 9.1. It is assumed that the interface to the customer for HO channels will be the primary rate interface. The 1.544 Mbit/s primary rate can accommodate three HO channels in timeslots 1-6, 7-12, 13-18. If a signaling channel is not required then a fourth HO channel can be accommodate in timeslots 19-24. At 2.048 Mbit/s five HO channels can be accommodated and the preferred assignment is to use channels 1-6, 7-12, 13-19 (excluding 16), 20-25, 26-31. Any timeslots not used for HO channels can be used for B channels.

(b) Hl channels. Two forms of Hl channel have been identified:

Hl1 at 1.536 Mbit/s. This may be carried on a 1.544 Mbit/s primary rate interface but a signaling channel would have to be provided separately. Alternatively it can be carried in timeslots 1-25 (excluding 16) of a 2.048 Mbit/s primary rate interface. Signaling can then be carried in channel 16.

Hl2 at 1.920 Mbit/s. This may be carried in timeslots 1-31 (excluding 16) of a 2.048 Mbit/s primary rate interface. Channel 16 is used for signaling as usual.

Because of the large chunks of capacity that H1 channels would absorb in the switching fabric of a switch based on the switching of 64 kbit/s channels, it is most likely that either a new switching network will be provided or special provision will be made within switches for them.

(c) CCITT has also identified some other H channels: H21 around 34 Mbit/s, H22 around 55 Mbit/s, H4 around 135 Mbit/s.

4.3 HIGHER RATE INTERFACES

Optical fibres offer virtually unlimited bandwidths and their use in the local network is widely predicted. Given the demand the technical and economic problems of providing service to customers can undoubtedly be overcome. Even if it is - unacceptable to use one fibre per connection, then wavelength division multiplexing offers enormous capacity, particularly if associated with coherent detection techniques.

Various channel rates have been identified above, but it is not necessary that there are interfaces to the customer operating at that rate. The whole concept of the ISDN is that there should be a minimum number of interfaces identified so that a wide range of compatible equipment should become available. So far only two interfaces have been identified-the basic rate and the primary rate (although this comes in the North American and Rest of World versions). Continuing to higher rates, once again there is pressure to have only two more interfaces; the proposal is that these should operate at about 150 and 600 Mbit/s. This does not mean that only channels at these rates would be available. In fact, as will be seen, the plan is that many channels of a wide range of rates will be multiplexible on to these interfaces, so that a wide range of terminal equipment can be connected to them. At the 150 Mbit/s rate it can be seen that all services except high definition TV can be accommodated. 600 Mbit/s could accommodate several standard TV channels or HDTV, simultaneously with lower rate services. When studying Figure 4.2 it is important to appreciate that the horizontal scale is logarithmic; on a linear scale the small capacity required for the lower rate services would be more easily appreciated because the ranges would be invisible on the left-hand side. The real problem is how services with such a wide range of rates could be efficiently multiplexed on to a common bearer and two solutions are being followed.

One is based on synchronous multiplexing, but with a format which can be configured to match the needs of the user under his control; this is called the Synchronous Digital Hierarchy (SDH). The other extends the use of packed mode services to a very lightweight protocol called Asynchronous Transfer Mode (ATM) which because of its simplicity can be implemented at these high speeds.

4.4 SYNCHRONOUS DIGITAL HIERARCHY (SDH)

A new international multiplexing standard, the Synchronous Digital Hierarchy (SDH), is currently being adopted by many networks for their high speed transmission networks. SDH evolved from the American optical interface standard, SONET, which was designed to solve the shortcomings of the transmission hierarchy currently in use, the Plesiochronous Digital Hierarchy (PDH). After modifications to accommodate European interface rates, it was adopted by the CCITT as a worldwide transmission Standard, and is detailed in the CCITT Recommendations G.707, G.708, and G.709.

The current PDH transmission network multiplexes channels into higher bit-rate structures on a stage-by-stage basis, with each stage using its own multiplexing and framing methods. As aresult it is very difficult to access individual channels rates, removing or adding individual channels generally requires the high rate signal to be totally demultiplexed to gain access to the constituent channels. This reqires a complate range of multıplex equipment to be used, resulting in complexity and cost. Figure 4.3 shows an example of the various multiplexing stages required by the North American and European PDH(note: the 140 Mbit/s interface is rarely used in North America)

In contrast SDH provides a considerably improved method of multiplexing channels into high bit-rate interfaces of 150 Mbit/s and above. Compared to the PDH, SDH is able to offer:

- One worldwide standard for multiplexing and interworking.
- Direct access to lower rate channels without having to demultiplex the entire signal.
- Simplified evolution to higher bit-rates.
- Comprehensive provision for network management.
- Interconnection between independent networks without introducing frame slips.
- The ability to carry new broadband channels, as they appear, such as the transport of ATM based services.

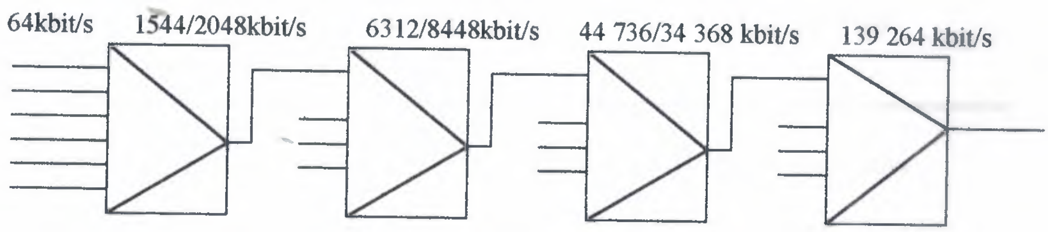


Figure 4.3
PDH multiplex structure in North America/Europe.

4.4.1 Virtual containers

In the SDH standards the transmission network is segregated into regenerators, multiplexes, and the functions required to transport information between the end points of the network. The regenerator and multiplexing functions are handled by the section layers of the protocol, the end-to-end functions are provided by the protocol's path layer.

This path layer transports the information across the network by encapsulating it inside structures called Virtual Containers (VC). These virtual containers consists of two parts:

1. The container (C), which holds the data to be transported.
2. The Path Overhead (POH), which provides maintenance channels and control information that is associated with the path across the network.

Different classes of virtual container have been defined, each designed to transport the various channel types currently found in the network. Table 4.2 shows the different types of virtual container that are available.

Information inside a virtual container is normally carried transparently by the SDH network. However, the VC-l s can also carry channels that are synchronized to the SDH data stream. This gives the SDH multiplexes direct access to the individual 64 kbit/s channels within the VC-1.

Table 4.2 Virtual container sizes

Virtual Container	Container Capacity	Services Supported
VC-11	1.7 Mbit/s	1.544 Mbit/s North american channel rates
VC-12	2.3Mbit/s	2.048 Mbit/s europen channel rates
VC-2	6.8Mbit/s	6.312 Mbit/s channels(rarely used). VC-2s can also be concatenated together to carry higher rate services
VC-3	50Mbit/s	34.368 Mbit/s and 44.736 Mbit/s channels
VC-4	150Mbit/s	139.264 Mbit/s channels and other high bit-rate services

4.4.2 Tributary units

VC-3s and VC-4s can be transported by the STM-1 frame using the AU mechanism detailed above. Lower rate VCs require an additional step to permit the mixing of different types of lower rate VC in the frame, and also to accommodate VCs originating from different sources.

Lower rate VCs are first placed inside structures called Tributary Units (TUs) before being placed inside a larger VC-3 or VC-4. The tributary unit is similar to the

AU mechanism. TU pointers permit lower-order VCs to 'float' independently of each other and of the higher order VC transporting the TUs. This is shown schematically in Figure 4.4.

A VC-4 can carry three VC-3s directly, using a TU-3 structure similar to the AU-3. However, the transport of VC-1s and VC-2s inside a VC-3 or VC- 4 is more complicated. An additional step is required to simplify the process of mixing the different types of VC-1 and VC-2 into the higher order VC.

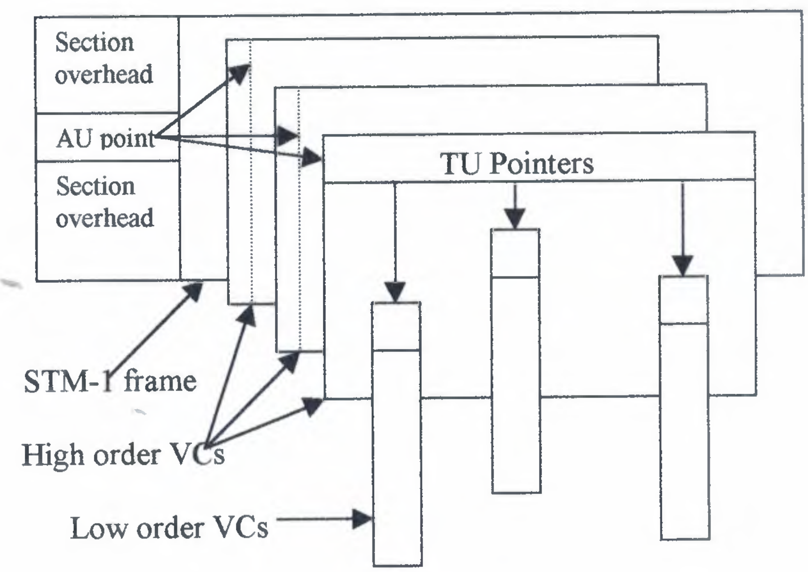


Figure 4.4 Transport of lower rate VC-s using the TU structure

Once the VC-l s and VC-2s have been formed into their TUs, these are placed inside a Tributary Unit Group (TUG). This TUG-2 is a 9 row by 12-column structure, which can contain either four VC-11s, three VC-12s, or a single VC-2. Each TUG-2 can only contain a single type of VC, but this TUG-2 can be freely intermixed with TUG-2s containing other 'JC types. The fixed size of the TUG-2 removes the differences between the sizes of the VC-l s and VC-2s, thus making it easier to multiplex mixtures of VC types inside the higher order VC. Throughout the process of multiplexing TUs into a TUG-2, and TUG-2s into a VC-3 or VC-4, byte interleaving is used to minimize buffering delays. An example of VC-l s and VC-2s being placed inside a higher order VC-3 is shown in Figure 4.5.

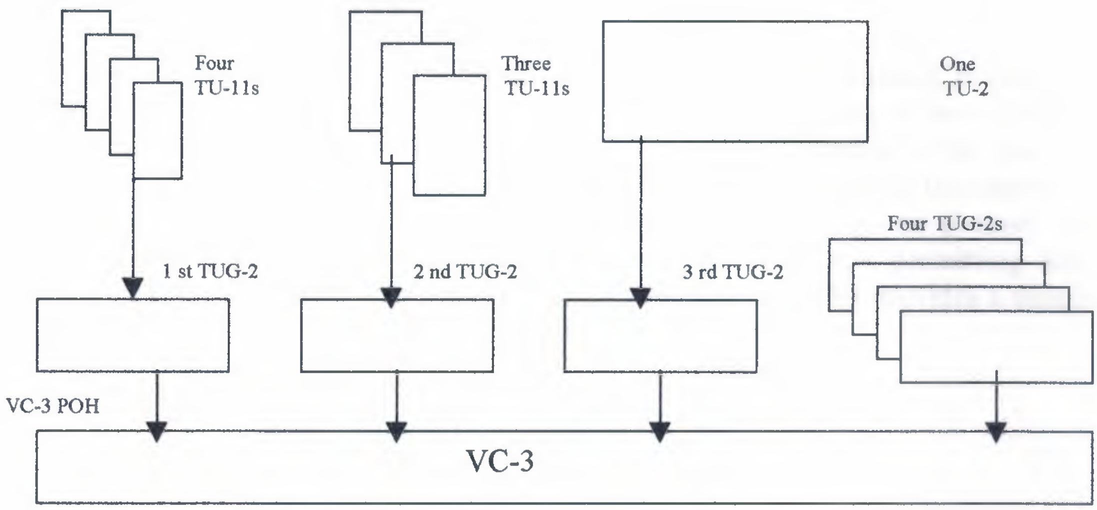


Figure 4.5 Placing TUGs inside a VC-3

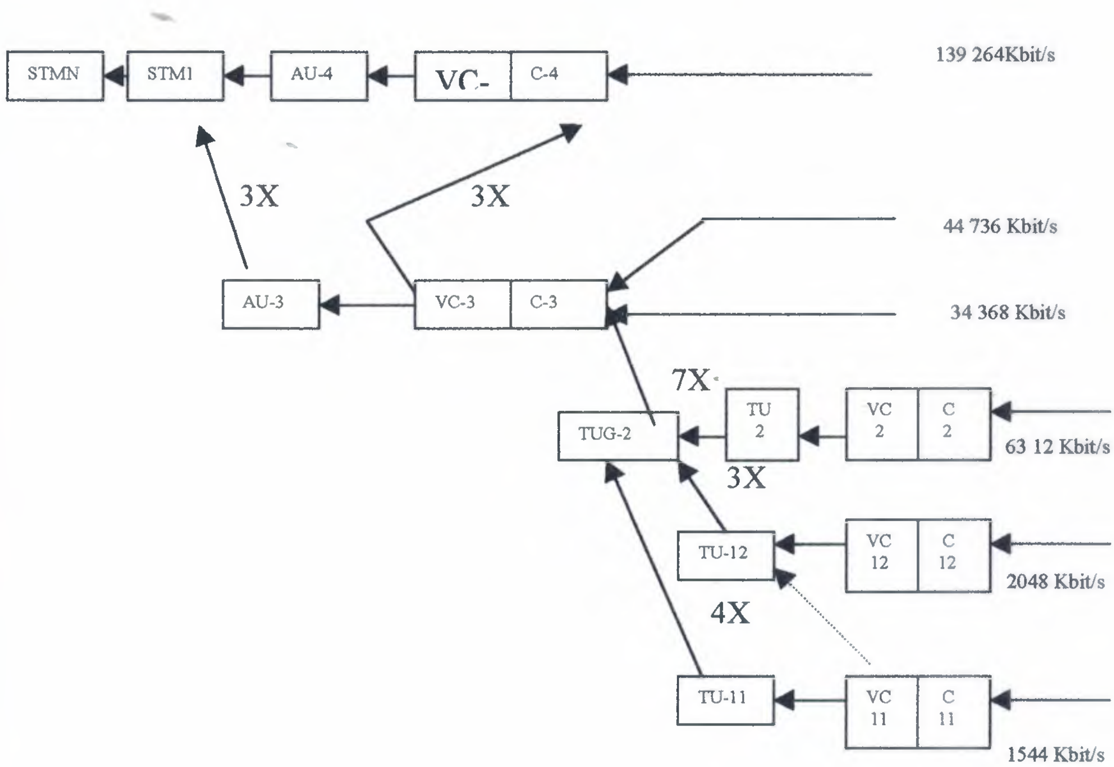


Figure 4.6 SDH multiplex structure

The above description has shown that several steps are required to multiplex low bit-rate channels into the high bit-rate SDH interface. These steps are summarized in Figure 4.5. In North America lower order VCs are transported using VC-3s. In Europe the lower order VCs are carried directly by a VC-4, and the VC-11 is carried using the TU-12 mechanism (with the addition of padding bytes).

Although the multiplexing mechanisms used appear to be complicated, in reality it is not too difficult for the multiplexing equipment to locate the position of the individual low bit-rate streams using the pointers. This results in a large decrease in the cost and complexity of the multiplexing equipment compared to the PDH. Also the ability of VCs to 'float' independently simplifies the process of removing one channel and replacing it with another channel originating from a different source, permitting 'add-drop' multiplexes to be implemented economically. Additionally SDH provides a simple method of extending the interface to bit-rates of 622 Mbit/s or higher.

Chapter 5

B-ISDN Service requirements

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

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.

B-ISDN will support services with both constant and variable bit rates ,data, voice (sound),still and moving picture transmission ,and of particular note ,multi-media applications which may combine ,say, data, voice and picture service components.

Some examples may be used to illustrate the capabilities of B-ISDN. In the business area ,videoconferencing is already a well-established but still not commonly used method which facilitates the rapid exchange of information between people. As travelling can be avoided ,videoconferencing helps to save time and costs .B-ISDN may considerably improve the current situation and allow videoconferencing to become a widespread telecommunication tool as it allow for high picture quality (at least today's TV quality or even better), which is crucial for the acceptance of videoconferencing by its user, and is able to provide connections between all potential users via standard interfaces.

Another salient feature of B-ISDN is the (cost-adequate) provision of high speed data links with flexible bit rate allocation for the interconnection of customer networks.

The residential B-ISDN user may appreciate the combined offer of text ,graphics, sound ,still images and films giving information about such things as holiday resorts, shops or cultural events

Tables 5.1 , 5.2 , 5.3 , 5.4 , 5.5 give an overview of possible broadband services and applications as presented by CCITT.

According to CCITT Recommendation ,services are classified into interactive and distribution services .Interactive services comprise conversational ,messaging and retrieval services; distribution services can be into services with or without user-individual presentation control.

Conservation services can effect the mutual exchange of data , whole documents, pictures and sound .Examples are given in Table 5.1 B-ISDN messaging services include mailbox services for the transfer of sound ,pictures and/or documents (Table 5.2).Retrieval services (Table 5.3). can be used for example , to obtain video films at any time or to access a remote software library. Finally ,some examples of distribution services (Tables 5.4 and 5.5) are electronic publishing and TV programmed distribution with existing and ,in the future , enhanced picture quality ,e. g, high definition TV(HDTV).

Type of information	Examples of broadband services	Applications
Moving Pictures and sound	Broadband Video-telephony	Communication for the transfer of voice(sound),moving pictures ,and video-scanned still images and documents between two locations(person-to-person) • Tele-education • Tele-shopping • Tele-advertising
	Broadband videoconference	Multi point communication for the transfer of voice(sound)),moving pictures ,and video-scanned still images and documents between two or more locations (person-to-group ,group-to-group) • Tele-education • Business conference • Tele-advertising
	Video-surveillance	• Building security • Traffic monitoring
	Video/audio information transmission service	• TV signal transfer • Video/audio dialogue • Contribution of information
Sound	Multiple sound-programmer signals	• Multi-lingual commentary channels • Multiple programmer transfers
Data	High speed unrestricted digital information transmission service	• High speed data transfer LAN interconnection MAN interconnection Computer-computer interconnection • Transfer of video information • Transfer of other information types • Still image transfer • Multi-site interactive CAD/CAM
	High volume file transfer service	• Data file transfer
	High speed teleaction	• Real time control • Telemetry • Alarms
Document	High speed telefax	User -to- user transfer of text ,images ,drawings ,etc
	High resolution image communication service	• Professional images • Medical images • Remote games
	Document communication service	User -to- user transfer of mixed documents

TABLE 5.1:*Conversational services*

Type of information	Examples of Broadband services	Applications
Moving pictures (video) and sound	Video mail service	Electronic mailbox service for the transfer of moving pictures and accompanying sound
Document	Document mail service	Electronic mailbox service for mixed documents

TABLE 5.2:*Messaging services*

Type of information	Examples of Broadband services	Applications
Text ,data, graphics, sound, still images, moving pictures	Broadband videotext	• Videotext including moving pictures • Remote education and training • Telesoft ware • Tele-shopping • Tele-advertising • News retrieval
	Video retrieval service	• Entertainment purposes • Remote education and training
	High resolution image retrieval service	• Entertainment purposes • Remote education and training • Professional image communications • Modical image communications
	Document retrieval service	Mixed documents *retrieval from information centers, archives ,etc.
	Data retrieval service	Telesoftware

TABLE5.3:*Retrieval services*

Type of Information	Example of broadband services	Applications
Data	High speed unrestricted digital information distribution service	• Distribution of unrestricted data
Text, graphics still images	Document distribution service	• Electronic newspaper • Electronic publishing
Moving pictures and sound	Video information distribution service	• Distribution of video/audio signals
Video	Existing quality TV distribution service(NTSC, PAL, SECAM)	TV programmed distribution
	Existing quality TV distribution service • Enhanced definition TV distribution service • High quality TV	TV programmed distribution
	High definition TV distribution service	TV programmed distribution
	Pay-TV (pay-Per-view ,pay-Per-channel)	TV programmed distribution

TABLE5.4:*Distribution services without user-individual Presentation control*

Type of information	Examples of broadband services	Applications
Text graphics Sound, still, images	Full channel broadcast video graphy	• Remote education and training • Tele-advertising • News retrieval • Telesoftware

TABLE5.5: *Distribution services with user-individual Presentation control*

To be able to derive ,from assumed broadband services , the network requirements to be met by B-ISDN ,tried to compile technical characteristics of major B-ISDN applications. The results can be found in table 5.6.

SERVİCE	BİT RATE (MBİT/S)	BURSTİNESS
Data transmission (connection-oriented)	1.5 530	2 - 50
Data transmission (connectionless)	1.5 530	5
Document transfer /retrieval	5.5 45	5 - 20
Videoconference /video-telephony	1.5 530	5 - 5
Broadband videotext /video retrieval	1.5 530	5 - 20
TV distribution	30 530	5
HDTV distribution	530	5

TABLE 5.6: *Characteristics of broadband services*

This table exhibits the following remarkable properties of broadband applications:

- Not all services require very high bit rates ,but some do ,especially moving picture services with high resolution .In table 5.6 ,bit rates of 30 to 530 Mbit /s for TV distribution and 530 Mbit /s for HDTV distribution are given. Though these values may decrease in the future –e.g. there are ongoing activities to encode TV video signals with about 50 Mbit /s –the resulting bit rates will still be far above those employed form conventional ISDN services. The most demanding service will be HDTV which will consume at least a bit rate above 50 Mbit/s Per HDTV channel.

- Several communication types are highly bursty in nature; if this feature was adequately reflected in network design , considerable economizing on network resources might be achieved (statistical multiplexing gain).In the case of TV and HDTV distribution the statistical multiplexing gain is hard to realize due to the nature of the source signals , therefore the burstiness is set to 5 in table 5.6

The variety of possible B-ISDN services and applications as shown here obviously requires a network with universal transfer capabilities to :

- Cater for services which may employ quite different bit rates
- Support burst-type traffic
- Take into account both delay and loss-sensitive applications

The network concept which is assumed to meet all these requirements will be presented in the following chapters.

Chapter 6

Principles and Building Blocks of B-ISDN

6.1 B-ISDN Principles

The motivation to incorporate broadband features into ISDN is neatly documented in CCITT Recommendation I.121 ('Broadband aspects of ISDN'):

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

- The emerging demand for broadband services (candidate services have been listed in the previous chapter).
- 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 the same network's. B-ISDN thus follows the same principles as 64 kbit/s based ISDN (cf. CCITT Recommendation I.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* inter*faces.*

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 I.121 presents an overview of B-ISDN capabilities:

- *B-ISDN supports switched, semi-permanent and permanent, point-to-point and point-to-multipoint connections and provides on demand, reserved and permanent services. Connections in B-ISDN support both circuit mode and packet mode services of a mono- and/or 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);

6.2 Asynchronous Transfer Mode

The asynchronous transfer mode (ATM) is considered the ground on which B-ISDN 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 6.1).

Header 5 octets	Information field 48 octets

Figure 6.1: *ATM cell structure*

A detailed description of the ATM layer functions and ATM header structure and coding will be given in Section 3.3. The protocol reference model for ATM-based networks will be addressed in Section 1.1; the boundaries between the ATM layer and other layers will be defined.

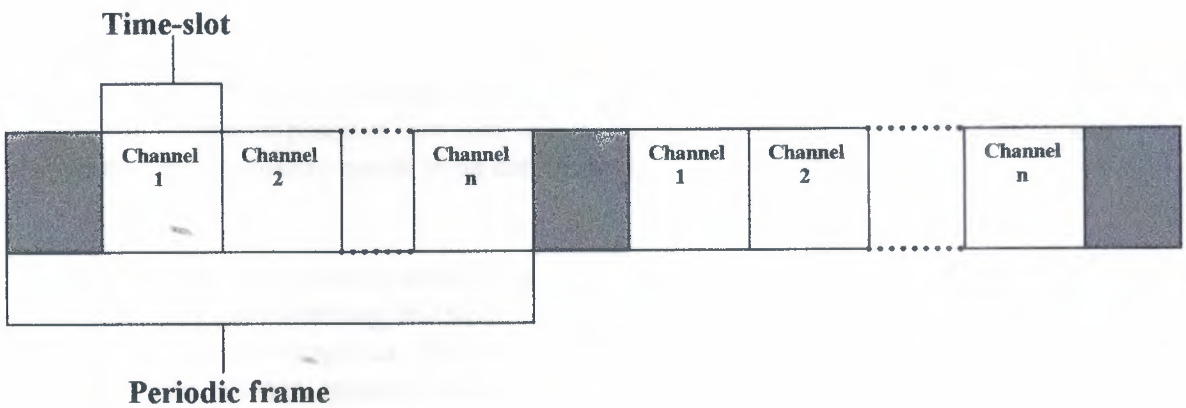
ATM allows the definition and recognition of individual communications by virtue of the label field inside each ATM cell header; in this respect, ATM resembles conventional packet transfer modes. Like packet switching techniques, ATM can provide a communication with a bit rate that is individually tailored 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 6.2(b).

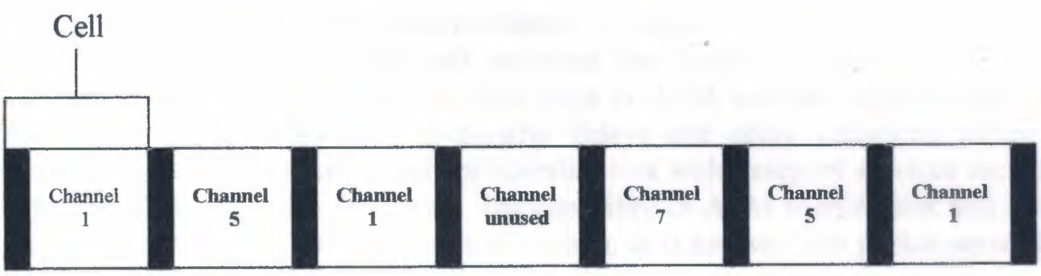
In the *synchronus transfer mode* (STM) (see Figure 6.2(a)), a data unit associated with a given channel is identified by its position in the transmission frame, while in

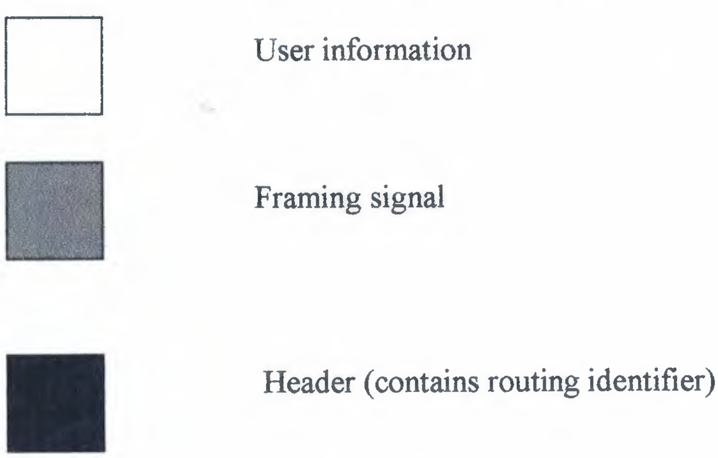
ATM (Figure 6.2(b)) a data unit or cell associated with a specific virtual channel may occur at essentially any position. The flexibility of bit rate allocation to a connection in STM is restricted due to predefined channel bit rates and the rigid structure of conventional transmission frames. These 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).

(a) Synchronous transfer mode



(b) Asynchronus transfer mode





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.

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 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.

6.3 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 fibre 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 fibre
- Resistance against electromagnetic fields
- Low transmission error probability
- No cross-talk between fibres
- Tapping much more difficult.

The high banwidth of optical transmission system–currently up to Gbit/s can be tranported via one optical link– has led to early implementations in public networks to support existing services like telephony. Fibre-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 the use of optical fibre-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 brodband user-network interface. Though much higher bit rates could comfortably be transmitted on optical fibre links, the costs of the electronics in-volved 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 seond 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.

Chapter 7

B-ISDN Network Concept

7.1 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.

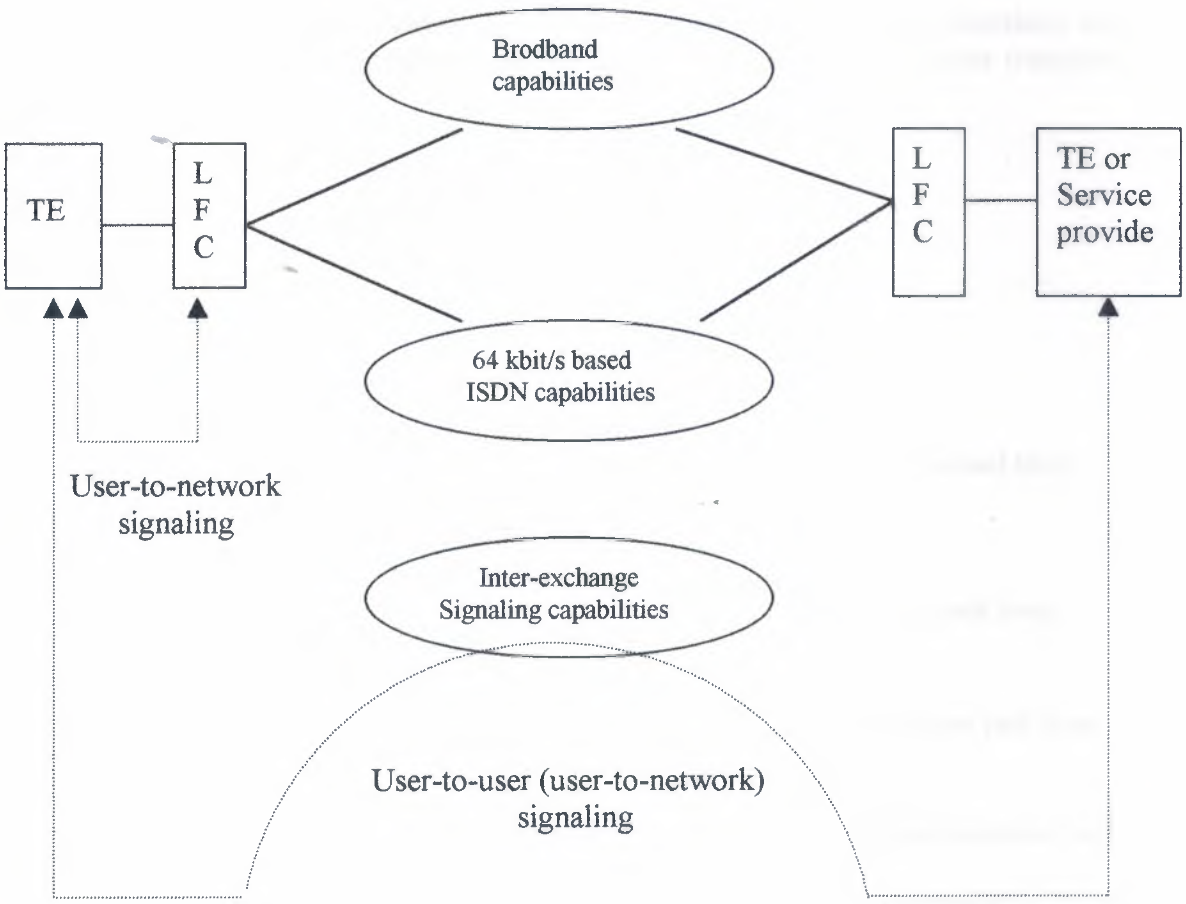
This is depicted in Figure 7.1.

ATM provides broadband information transfer. The ATM data unit is the cell, a fixed-size block of 53 octets. The 5-octet cell header carries 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 7.1 Information transfer and signalling capabilities

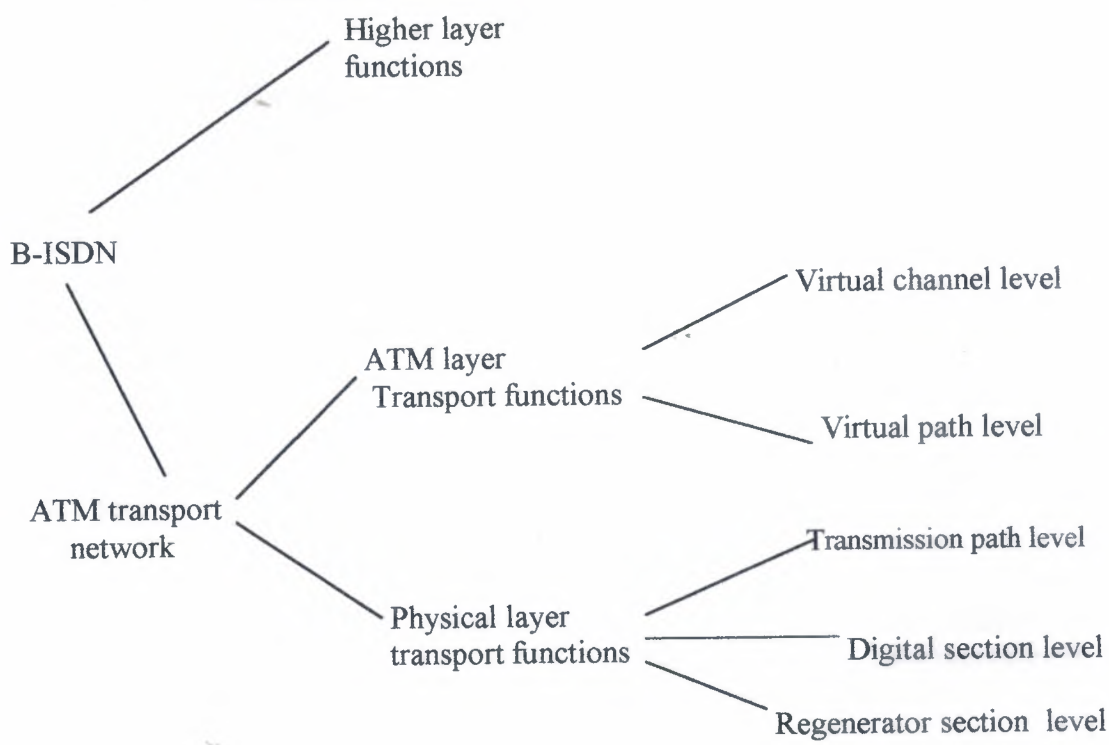
Though ATM is a connection-oriented technique, it offers a flexible transfer capability common to all services including connectionless data services. The proposed provision of connectionless data services via the ATM-based B-ISDN.

7.2 Networking Techniques

7.2.1 Network Layering

CCITT recommendation I.311 [50] presents the layered structure of the B-ISDN depicted in figure 7.2

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



ATM Asynchronous transfer mode

Figure 7.2: 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:

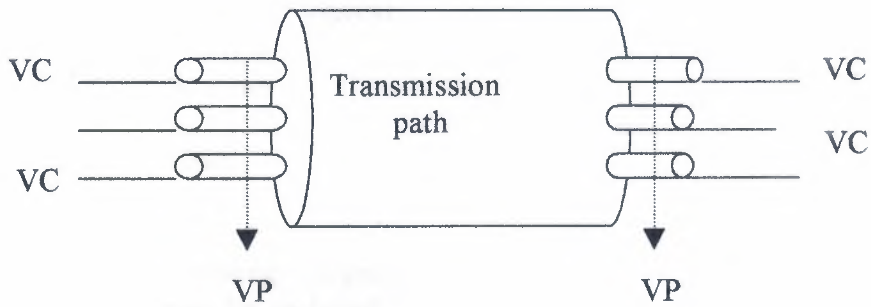
- Virtual channel level
- Virtual path level

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 7.3 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.



VC Virtual channell
VP Virtual path

Figure 7.3 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.'

7.3 Signaling Principles

7.3.1 General Aspects

B-ISDN follows the principle of out-of-band signaling that has been esta6lished 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.

7.3.2 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 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 multiconnection 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 *interworking,* e.g. B-ISDN with non B-ISDN services, or between video services with different coding schemes.

7.3.3 Signaling Virtual Channels

In B-ISIN 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 7.1.

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 while 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.

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	Oneper signalling endpoint

Table 7.1 : Signaling virtual channels at B-ISDN UNI

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)

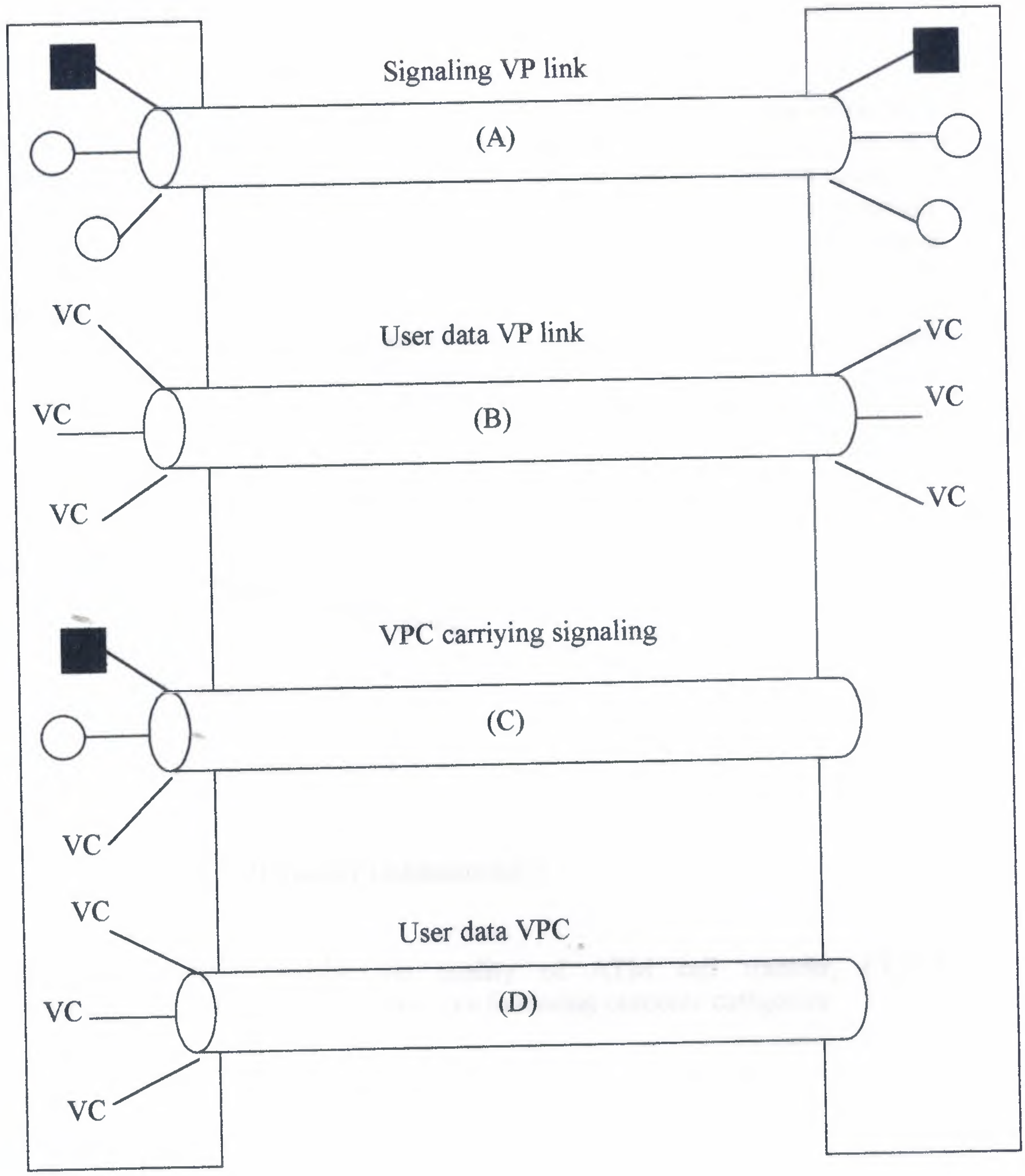
The provision of SVCs in the network is currently under discussion; so far no firm decisions have been taken but the principles outlined here are expected to apply.

To illustrate the SVC concept of B-ISDN, an example (based on CCITT Recommendation I. 311) is given in Figure 7.4, 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) 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.)

7.4 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 parematers and measures need to be specified in addition to the performance paremater already introduced for existing networks. In this section, we only deal with ATM layer-specific network performance. What the user wil 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.



Meta-signaling entity VC: Virtual channel VPC: Virtual path connection

Signaling entity VP: Virtual path

Figure 7.4: Allocation of signalling virtual channels to a customer

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 ad 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 7.5). 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.

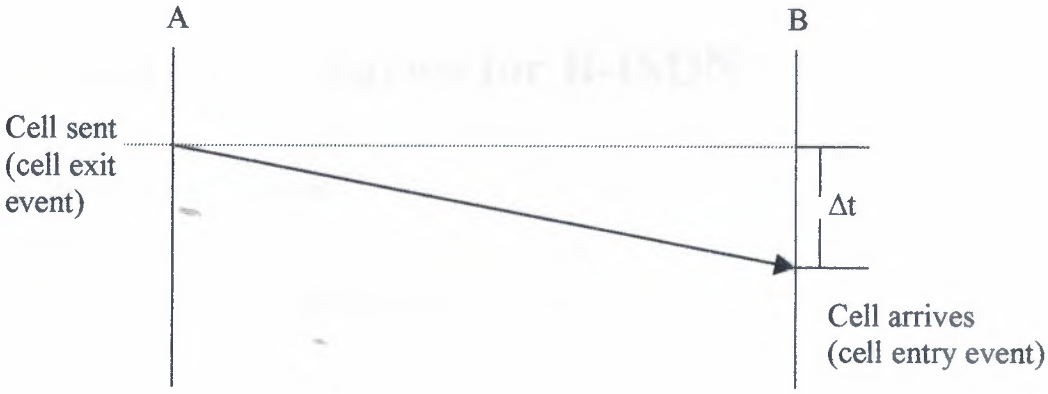


Figure 7.5: Cell transfer (schematically)

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
- Errored cell and severely errored 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.

Chapter 8

Evolution Scenarios for B-ISDN

B-ISDN, being based on

- Optical fibre transmission
- Asynchronous transfer mode (i.e. a new switching and networking concept;
- New service categories (e.g. multi-media services involving video)
- And, last but not least, new network features like *intelligent network* (IN) a *telecommunications management network* (TMN) that are conceptually not tied to B-ISDN but will most probably be implemented in a future network like B-ISDN.

is obviously a challenging task for network providers and manufacturers as wel its acceptance by potential customers requires a careful introduction strategy an evolution concept.

'Despite the convincing advantages of this universal broadband ISDN for all services, the high development and investment costs mean that it cannot in the short or medium term achieve wide coverage. The aim must therefore be to expand and add to the present-day telecommunication networks - of these primarily the network with most subscribers of all, the telephone network - in a market an demand oriented manner with suitable technical concepts and in timed phase thereby achieving a gradual transition to the ubiquitous, multi-subscriber network of the future. Any intended individual solutions or intermediate solutions must be designed such that they can later be incorporated with the least possible expense in the intelligent integrated broadband network.

As the existing telecommunication network structures differ from country to country and the customers' needs also differ, there cannot be a single valid evolution path towards B-ISDN all over the world. So necessarily all evolution scenarios are only examples whose steps may shed some light on the development characteristics of networks towards B-ISDN but may not be taken as a straightforward implementation plan for B-ISDN that would be viable in every country.

Introduction and evolution towards B-ISDN must in any case consider the strong need to interwork with existing services and networks, e.g. telephony, 64 kbit/s ISDN, data (packet) networks and TV distribution networks. So in the following the interworking with, and in a later phase the integration of, such services and networks will be addressed. In the opinion of most market experts the era of broadband (public) networks will be ushered in with fast data services that are requested by business customers. To support currently installed customer networks (LANs etc.), which are usually run with connectionless protocols the future B-ISDN will have to offer connectionless service capabilities from the beginning. This aspect will be described in Section 8.4.

A quite different introduction scenario foresees provision of optical fibres to the homes of residential customers (cf. Sections 8.1 - 8.3) who might above all be interested in entertainment programmers. Interactive services in addition to plain telephony may gradually be offered according to the customers' wishes.

8.1 Fibre to the Customer

The demand for broadband services will develop only gradually, and `it therefore seems advisable if the introduction of fibre optic technology for the subscriber access is not coupled firmly to new interactive broadband services. Instead, solutions are initially needed whereby optical fibres can be economically brought as close as possible to the subscriber, also for already existing services (television, telephony, data transfer).

Thus, the magic spell is *fibre to the* office or *fibre to the home,* respectively. In the case of business customers with large or at least quickly expanding traffic volumes, it may already pay for network providers to install individual optical fibre lines. Due to their vast transmission capacity, they are deemed to be a future-proof investment. In the case of residential customers the hope for quick returns is not so justified. So in this case, resource-sharing concepts have to be considered in order to be able to be cost-effective.

One of those concepts is the passive optical network (PON). A single fibre from the exchange feeds a number of customers via passive optical branching (see. Figure 8.1). This technique permits fibre sharing and laser sharing (in the local exchange) for several customers. A TDM signal is broadcast from the exchange to all terminals on a single optical wavelength.

After detection by an optical receiver, each customer's equipment demultiplexes only the channels intended for that destination.

In the return direction, data from the customers is inserted at a predetermined time to arrive at the exchange within an allocated time-slot.

This simple PON architecture admittedly has some drawbacks, e.g.:

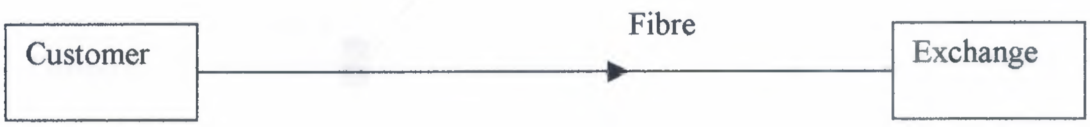


Figure 8.1 : Passive optical network technology

- Limited bandwidth **for** interactive services per customer
- Multiplexing of upstream signals requires sophisticated measures
- Privacy and security problems may arise
- Restricted upgradability (how to overcome this problem will be discussed later on).

The PON concept can well support:

- Unidirectional distribution services (TV and sound programmes)
- Telephony and other 64 kbit/s ISDN services.

Different optical wavelengths x1, . . . xn may be employed to separate services (and, possibly, transmission directions), e.g. x1 for telephony, x2 for broadcast TV, x3 for video retrieval services etc; see Figure 8.2. Note that different customers may wish to receive different service mixes.

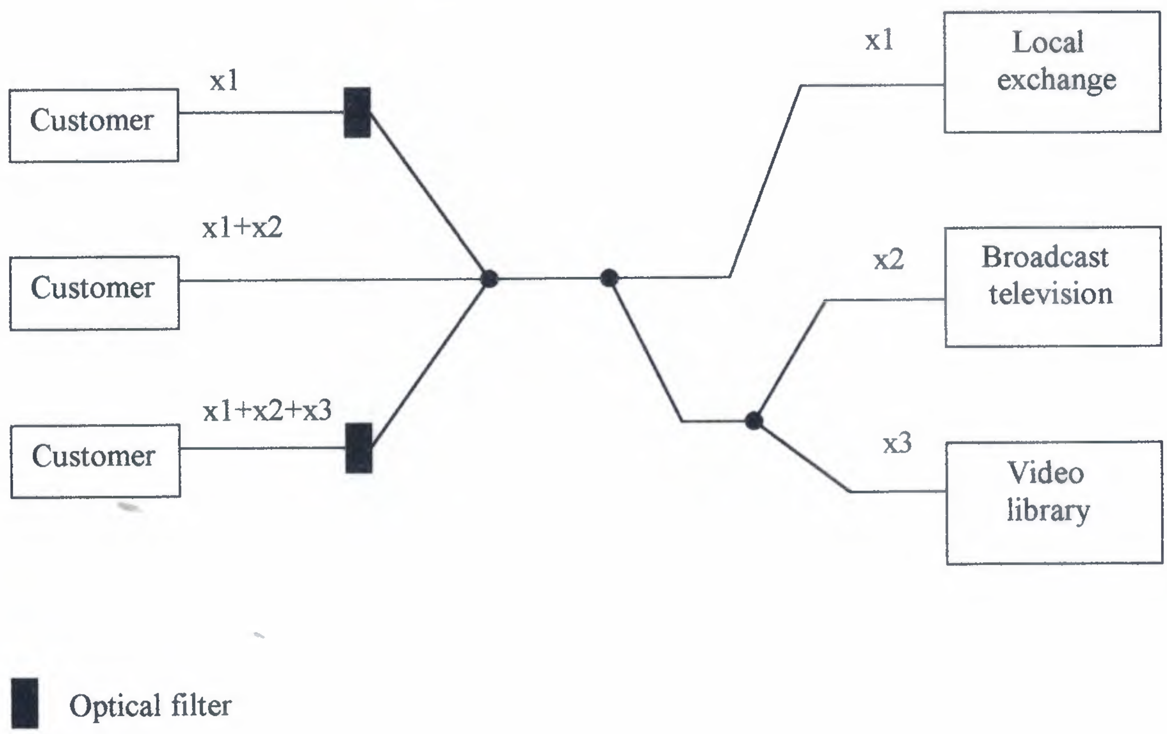


Figure 8.2: Upgraded passive optical network

In the long term it might be feasible according to [92] to provide a separate wavelength to every customer with a specific mix of services multiplexed on to the wavelength as required by the customer. However, this concept can only work as long as the number of customers connected to one PON is not too large.

Several modifications of the above concept are conceivable. Instead of wavelength division multiplexing (WDM) (i.e. use of several xi) or' in addition to WDM, more than one fibre could be installed; e.g. one for TV distribution and the other for interactive services. Implementation of both service categories could thus be decoupled to a great extent.

Figure 8.3 shows an access configuration where two fibres are deployed, one for TV distribution and the other for telephony (or 64 kbit/s ISDN services). After conversion of optical signals into electrical ones close to the customers' premises, a bus-structured coaxial distribution system is used to deliver TV programmes to the customers, and a star structure is used to provide a customer with a copper-based two-wire telephony access.

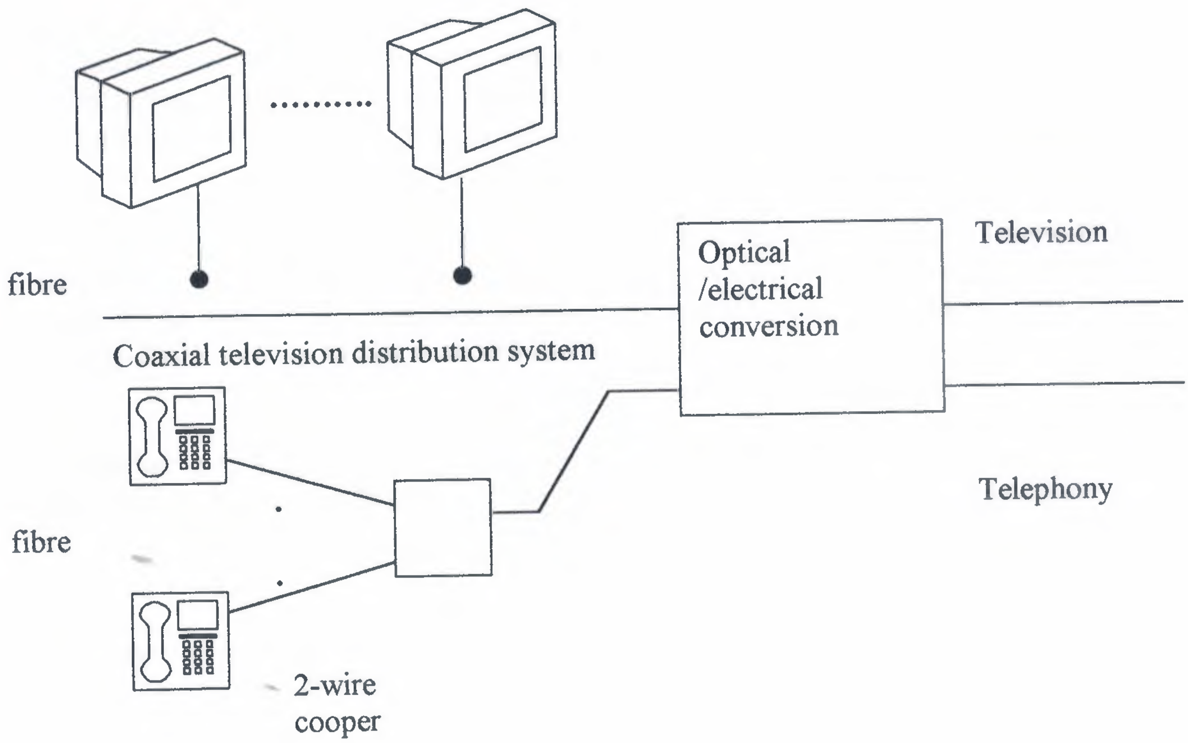


Figure 8.3 : Alternative fibre to the home architecture

As in the example shown in Figure 8.3 the opto-electrical conversion that is necessary to serve present electrical terminal interfaces is done only once for a couple of customers; so considerable economizing on cost may be achieved.

In view of developing a PON towards a full B-ISDN, it may be advantageous to install additional 'dark' fibres from the outset, which are not immediately used but can support later point-to-point connections of individual customers to the local exchange.

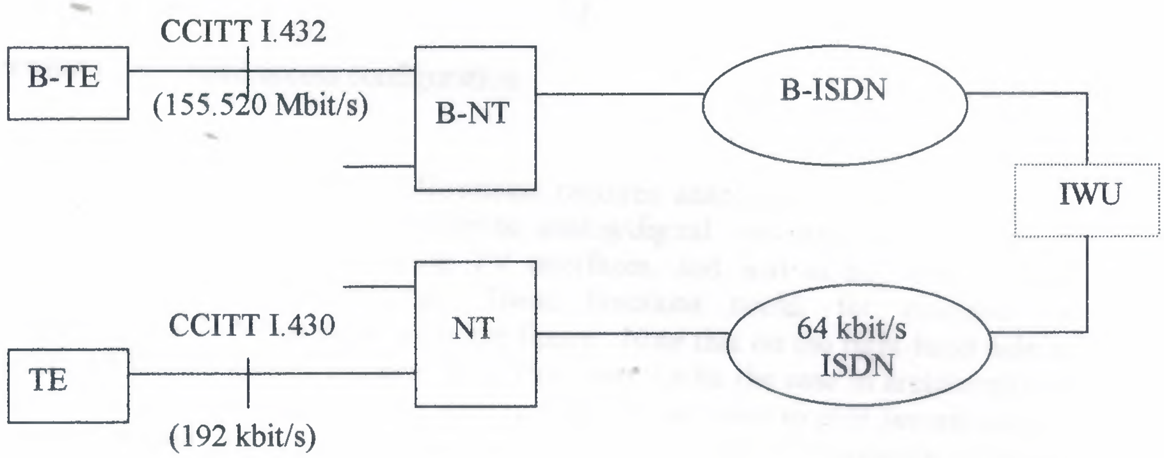
8.2 Introduction of B-ISDN Services

Deployment of optical fibre in the customer access network need not automatically be combined with the introduction of B-ISDN services in the network as has been pointed out in the previous section. Although B-ISDN is conceived to support - at least in the long run - all types of services, the customers' main interest in the new B-ISDN will be concentrated on services that cannot be offered (or only at greater expense) by existing networks.

B-ISDN will therefore co-exist in the beginning with other networks like public data networks, analog telephone networks, 64 kbit/s ISDN, TV distribution networks etc. The services offered by B-ISDN might be restricted to 'typical' broadband services, e.g. interactive services with bit rates above 1.5 Mbit/s or 2 Mbit/s, respectively. Access to other services (e.g. 64 kbit/s ISDN bearer ser- vices) would still be provided by other existing interfaces like that according to CCITT Recommendation I.430 (basic access) .

Interworking facilities between B-ISDN and the other networks would have to be provided as, for example, a customer using a bifunctional video-telephony /telephony set should be able to communicate with 64 kbit/s ISDN telephony users. This quite simple B-ISDN overlay model is shown in Figure 8.4.

Another step might be to introduce integrated access to different networks via a single, optical fibre-based B-ISDN interface on the network side of the B-NT1.



B-NT Network termination for B-ISDN

NT Network termination

B-TE Terminal equipment for B-ISDN

TE Terminal equipment

IWU Interworking unit

Figure 8.4: Pure B-ISDN overlay network

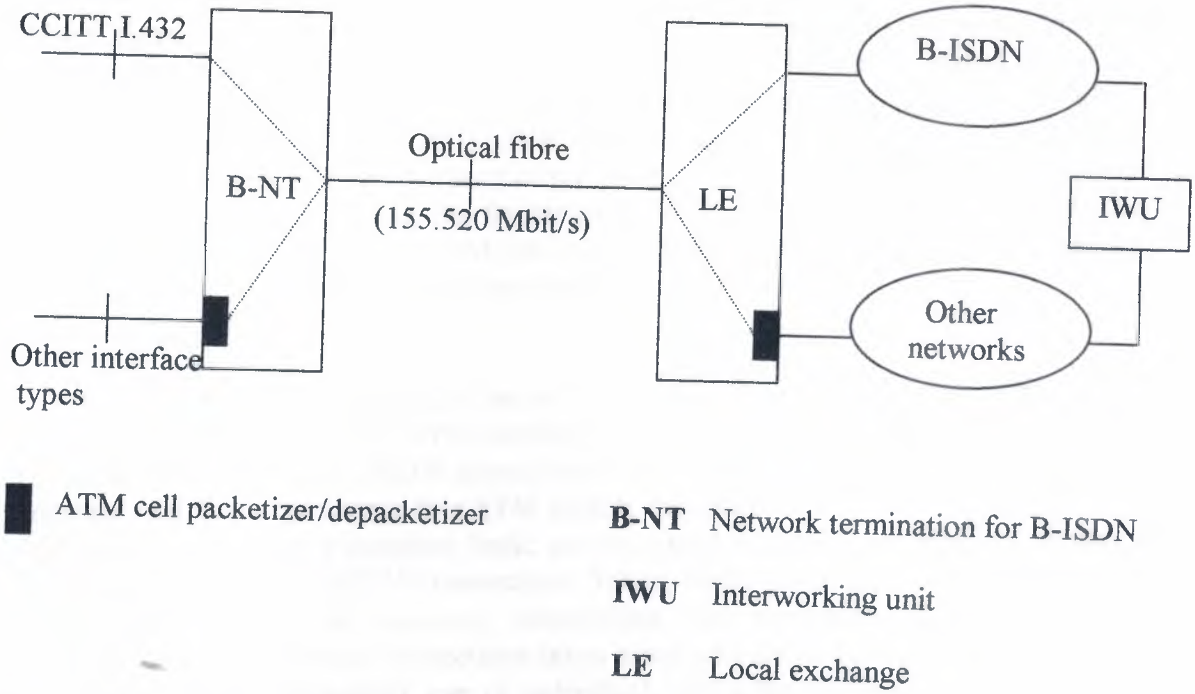


Figure 8.5 : Integrated access configuration

On the customer side, this configuration requires adaptation of non-ATM interfaces to ATM format. This may comprise analog/digital conversion in the case of analog telephone interfaces or analog TV interfaces, and will in any case include STM/ATM conversion (ATM-izing). These functions could, for example, be implemented in the B-NT as depicted in the figure. Note that on the right-hand side of the B-NT, ATM cells convey all user data. This need not be the case in architecture as shown in Figure 8.2 where several optical wavelengths are used to split several service categories. Though one single transmission link is used in the configuration of Figure 8.2, there is no correlation between the service categories offered. For example, services using the wavelength x1 could be digital whereas broadcast TV could be analog.

The integrated access configuration of Figure 8.5 reduces OAM expenditures, as only a. single customer access has to be maintained. On the other hand, it requires conversion and adaptation equipment at the customer termination and at the exchange termination as long as STM interfaces, terminals and networks exist. To connect B-ISDN with other networks, interworking functions are still necessary.

Some specific problems arise with configurations like those of Figure 8.5. As signals from different networks may be multiplexed on one single access line, OAM activities on this access line have to be performed in a way that will not interfere with connections actually established by any network. Therefore, an entity responsible for coordination of OAM activities on a customer's access is required.

The ATM-izing of non-ATM signals in the B-NT and in the corresponding unit in the network can be effected in different ways. Considering, for example, the basic access signal, which comprises two 64 kbit/s B channels, the 16 kbit/s D signaling channel and transmission and OAM overhead, either the entire signal could be ATM-ized or each channel separately. In the latter case the mapping of the 16 kbit/s signaling D channel on signaling VC/VP connections would also have to be defined. Information contained in the overhead of the basic access signal need not be transmitted completely to the network, e.g. the framing bits of CCITT Recommendation I.430 are no longer required. However, OAM information like activation/deactivation indication may still have to be exchanged between the B-NT and the network.

The choice of the mapping of the 64 kbit/s ISDN basic access signal on the cell stream of the ATM-based B-ISDN interface may depend on the signal processing in the network. When 64 kbit/s ISDN connections and B-ISDN connections are routed to separate switches - the former to a STM switch, the latter to an ATM switch - then it is advantageous to have a compact basic access signal including its relevant signaling information on a single VC/VP connection. When, however, a common ATM-based B-ISDN switch handles all incoming connections, and separation of 64 kbit/s ISDN connections and broadband connections takes place only behind the local exchange (i.e. into separate trunk networks), use of individual VCCs for the **B** channels and the D channel information seems to be more adequate.

8.3 Integration of TV Distribution

TV programmers could be offered to the B-ISDN customer as switched or non-switched services (see Figure 8.6).

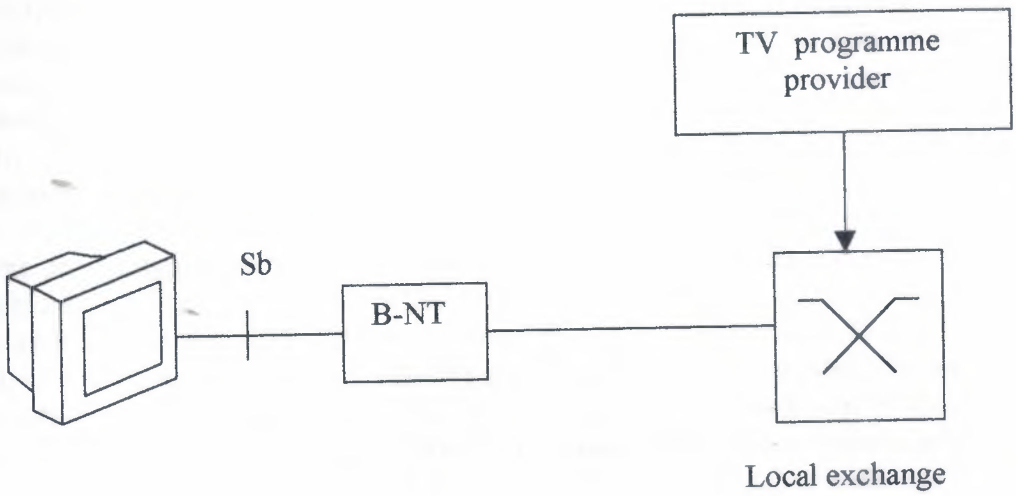
Figure 8.6(a) show full integration of TV distribution into B-ISDN. TV programmers are fed into the local exchange, which has sole responsibility for operation, administration and maintenance of the customer's access link. Programmed selection is done via the usual B-ISDN signaling channels and procedures.

This solution fully complies with the idea of an integrated broadband network; however, it may have market drawbacks. Compared with today's TV distribution to the customer via satellite or cable-based transmission systems, switched TV programmers via optical fibres cannot compete in terms of cost. This fact may inhibit such a solution at least in several countries. Moreover, as the network provider has knowledge about the actual choice of TV programmers to be watched by customers, some critics are concerned about possible infringement upon privacy effected by unauthorized transfer of such knowledge to people who might be interested in making use of it. From a purely technical viewpoint the provision of switched TV programmers has the highest flexibility, as there is in principle no limitation in the number of programmers to be offered.

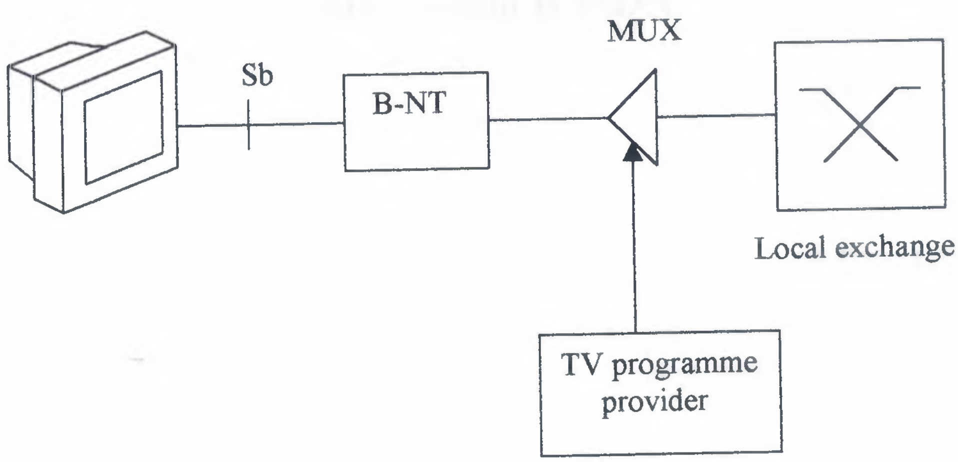
Figure 8.6(b) shows an architecture where a fixed block of TV programmers is fed from the TV programmer's provider directly into the access link. The customer can choose a specific programmer either in his or her TV set or, optionally, in a customer-owned TV switch (to be located in the B-NT2).

This method limits the number of different TV programmers that can be received due to the limited bandwidth of the access line. The bit rate required for trans- mission of digital TV signals (including one or more sound channels and additional data channels for control purposes) will be at least about 10 - 30 Mbit/s for conventional TV quality and may be

(a)



(b)



B-NT Network termination for B-ISDN
MUX Multiplexer
TV Television

Figure 8.6 : Examples of provision of TV programmes to the B-ISDN customer

considerably higher for advanced quality pictures. So even with 600 Mbit/s links, only up to about 25 different TV programmers could be transmitted. In the case of future provision of HDTV (high definition TV), which may require 100 Mbit/s or more per TV channel, such a rigid distribution scheme would fail unless more powerful methods like coherent transmission could be employed.

A mixture of switched and non-switched provision of TV programme channels might also be realized: in addition to a block of some fixed TV channels the user could be given the option to select from a TV programme pool.

TV programme selection (unless merely performed in the customer network) makes some requirements of the signaling procedures. The network must be able to handle quickly numerous simultaneous signaling messages. Changing the TV channel must not take longer than the time that people are used to nowadays. Perhaps this is easier to achieve by (in-band) end-to-end-signaling between user and TV programme provider after establishment of the connection. In this case, however, coordination between the customer equipment (TV sets and/or B-NT2), the local exchange and the TV programme providing unit is necessary to avoid conflicts and to make economic use of the available access line bandwidth. (When, for example, on the customer's premises a TV set is switched on and a TV channel is selected, a new connection normally has to be established unless the required TV channel is already provided to another TV set. If a new connection is to be established, it must be checked in the network, e.g. in the local exchange, whether this can be done without interference with other currently existing connections on the customer's access line.)

8.4Integration of LANs/MANs into B-ISDN

8.4.1 Local Area Networks

Local area networks (LANs) are primarily employed for data, communications in the in house area. They are used for the interconnection of terminals, workstations hosts, printers, databases as well as manufacturing systems. The traffic carried is characterized by short data bursts requiring high transmission speed. Normally, LANs support only connectionless services.

LANs cover an area of up to 10 km. One hundred or more users can share a common transmission medium with a transmission speed in the range of usually 1 - 16 Mbit/s. The access to the common medium is controlled by the *media access control* (MAC) procedure (decentralized control).

The number and types of LANs have dramatically increased within the last few years. LANs can be classified by their topology (bus, ring, star), the transmission medium (twisted pair, coax cable, and optical fibre) or the MAC procedure (carrier sense multiple access, token passing). In the following, only the most frequently deployed LAN types will be presented. These LANs have different MAC protocols whereas in higher layers identical protocols may be used.

The carriers sense multiple accesses with collision detection (CSMA/CD) is the first standardized MAC procedure . Xerox called Ethernet bases it on a development. CSMA/CD uses a bus system with a specified transmission rate of 10 Mbit/s. A station having a packet to send listens to the carrier before sending. If the channel is idle the station begins sending, otherwise it waits till the channel becomes idle. Collision may occur when two or more stations begin sending at the same time. This will be detected by the sending stations and they will stop their packet transmission. The collision is resolved by the back-off algorithm (each station tries to send after a random time). In low loaded systems, this protocol behaves very well (low packet delay). But due to collisions the performance deteriorates with increasing load.

The token 6us system uses a coax cable with specified transmission rates of 1, 5 or 10 Mbit/s. All stations are passively coupled to the medium. Access to the channel is controlled by a token-passing protocol. The token is delivered from one station to its neighbour. The neighbourhood is not related to physical locations but defined by addresses. The number of packets, which can be sent during the interval a station possesses the token, is determined by the token-passing protocol. In order to fulfils different performance requirements, each station uses four internal priority classes.

The token, ring network is made up of point-to-point unidirectional links interconnecting adjacent stations (active coupling) in order to form a closed loop. Transmission rates of 4 and 16 Mbit/s are specified for shielded twisted pair cables. The access to the ring is again controlled by a token-passing protocol. A station that is ready to send a packet has to wait for the token, which it will receive from its physical neighbour. Different priorities can be attached to tokens but only one token can circulate at a time. During high load situations, token protocols prevent packet collisions whereas for low network load their performance is not very good due to the token rotation time.

8.4.2 Metropolitan Area Networks

The increasing demand for data communication beyond the local area leads to the introduction of metropolitan area *networks* (MANs). MANs can be considered as an evolution of LANs, and their first application will be the interconnection of existing LANs. The characteristic features of MANs are:

- Covering areas of more than 50 km in diameter

- Sharing a common medium
- Distributed access control
- High transmission rate (100 Mbit/s or more)
- Provision of isochronous, connection-oriented and connectionless services
- Evolution to B-ISDN in terms of capabilities and services.

The expected MAN installations can be divided into the *private* and *public* MAN. A private MAN will be owned or leased by a single customer. Only the MAN carries that customer's traffic. This simplifies billing as well as functions of privacy and security.

However, many MANs will be shared by a varying number of customers. From the point of view of the network operator, functions for accurate billing and additional management functions are necessary. Security and privacy will become serious issues because customers would not like to see their confidential data passing through the building of their competitor.

8.4.2.1 Fibre-Distributed Data Interface II

The fibre-distributed data interface II (FDDI-II) could be used for MAN implementation. This is an enhanced version of FDDI which is a ring system using an optical fibre for transmission with a data rate of 100 Mbit/s. The access to the ring is controlled by a modified token-passing protocol, which is specially designed for high-speed transmission systems.

For reasons of reliability, two rings (with opposite transmission directions) are used which make the system capable of surviving a cable break or station failure. In the case of such a failure, only one ring will be used. The total length of both rings is limited to 200 km. Up to 1000 stations with a maximum distance between two stations of 2 km can be attached to the ring.

FDDI supports only packet-switched traffic types. In addition to these traffics, FDDI-II is able to handle isochronous traffic like voice or video.

8.4.2.2 Distributed Queue Dual Bus

The *distributed queue dual bus* (DQDB) which has been proposed as a MAN/LAN standard is the result of the continued development of the *queue packet and synchronism circuit exchange* (QPSX). Isochronous, connection-oriented and connectionless services can be supported simultaneously.

The DQDB MAN consists of two unidirectional buses with opposite transmission directions and a multiplicity of nodes attached to these buses (see Figure 8.7). DQDB is independent of the underlying physical medium. This allows the use of existing PDH systems with transmission rates of, for example and 140 Mbit/s as well as SDH-based transmission systems according and possibly future systems with transmission rates in the Gbit/s range.

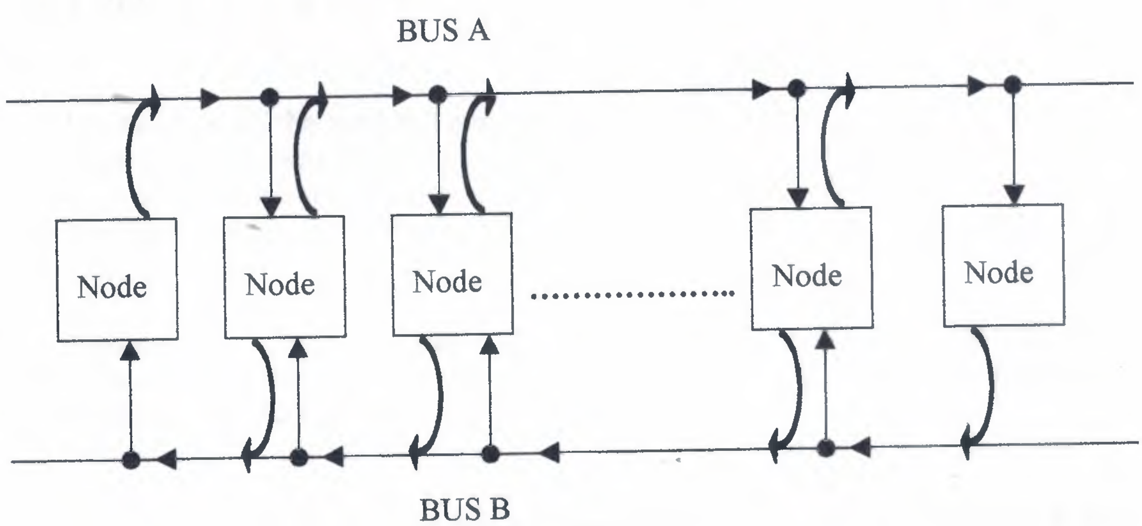


Figure 8.7 : Distributed queve dual bus network

The dual buses can be looped or open-ended. In the looped bus the head and tail of each bus are co-located but not interconnected. Looping allows the reconfiguration of the bus system in the case of bus failures. Head and tail will then be interconnected, and close to the location of the failure, new head and tail points will be generated. Each node can act as head or tail. Due to this self-healing mechanism the looped bus configuration seems preferable.

All information in the DQDB network is transported within *slots*. A slot consists of a header with 5 octets and an information field with 48 octets. Its size is identical to the size of an ATM cell. In Appendix B the PDUs used for connectionless services in the B-ISDN are compared with those used in the DQDB network. The commonality of DQDB and B-ISDN simplifies the interconnection of these two networks.

At the head of cache bus the slot generator is located. It creates empty slots and writes them on the bus. Isochronous services *use pre-arbitrated* slots. These slots are marked by the slot generator and have the appropriate VCI value inserted in the slot header.

All non-isochronous information is transported within *queue-arbitrated* slots. Pre-arbitrated and queue-arbitrated slots are distinguished by different values in the *slot type* field of the slot header. The queue-arbitrated slots are managed by the distributed queuing protocol (media access control). In contrast to the existing MAC procedures in a distributed queue system, each station buffers the actual number of slots waiting for access in the total network. With this in mind, a station, which has a slot ready to send, determines its own position in the distributed queue. After satisfying the queued slots its own slot will be transported.

8.4.3 Interworking Units

For many years the need for interconnection of individual computing systems and terminals has been increasing. Today, numerous networks co-exist and the increasing communication requirements demand the interconnection of these networks. For this purpose, interworking units (IWUs) are necessary.

Two networks which are located close to each other can be coupled directly via an IWU. Networks which are far from each other can only be interconnected via intermediate subnetworks.

For the following description it is assumed that different protocols are used at layer (N -1). The protocols of layer *N* and above are identical in the networks, which will be interconnected. Coupling of networks can be achieved by different approaches:

- **(1)**-Interconnection of the heterogeneous systems is achieved by protocol conversion on layer (N - 1). Often, this protocol transformation is difficult and not all functionalities can be maintained after the conversion because functions in one network are not present in the other one.

- **(2)**-In the second approach, a common global protocol sublayer is placed on top of the different network protocols. This requires an additional adaptation sublayer between all layer (N - 1) protocols and the common global protocol.

- **(3)**-Coupling of two networks can also be performed at the first common layer. This approach avoids difficult protocol conversion but it results in higher transfer delay due to the processing of an additional layer within the IWU.

Beyond the selection of a protocol level at which different networks will be inter-connected the IWU is also involved in other important issues. Naming, addressing and routing are the functions, which are necessary for the correct delivery of data to its appropriate destination. *Congestion control* has to be applied if the speeds of the networks mismatch. When different maximum packet sizes are defined for the individual networks the IWU has to perform segmentation and reassembly functions.

For today's networks the following interconnection approaches are commonly used:

- A repeater interconnects two networks at layer 1. Its main purpose is the enlargement of small networks.
- Bridges perform interconnection at layer 2.
- A router interconnects two networks at layer 3.
- An IWU coupling networks at higher layers is called a gateway. Normally, only layer 4 gateways and application layer gateways (layer 7) are used.

8.4.4 Integration Scenarios

The first step in coupling LANs was the interconnection via existing networks like the circuit switched public data network (CSPDN), the packet switched public data network (PSPDN) or the ISDN. LANs use transmission rates of up to 16 Mbit/s whereas in the existing networks the transmission rates are very low (e.g. 64 kbit/s). Obviously, this interworking strategy has no good performance.

In order to achieve good LAN-like services across wide areas, LANs will be coupled via high-speed networks like MANs or the B-ISDN. Several evolutionary steps are described below that could follow in chronological order.

8.4.4.1 Interconnection of LANs via MANs

Nowadays, MANs are becoming a reality whereas B-ISDN is still in the planning and development phase. So in the first evolutionary stage, LANs are coupled via IWUs to MANs. Figure 8.8 shows the present application of MANs.

The MAN may be private or public. In both cases the increasing communication requirements will lead to the interconnection of MANs via dedicated links (see Figure 8.8).

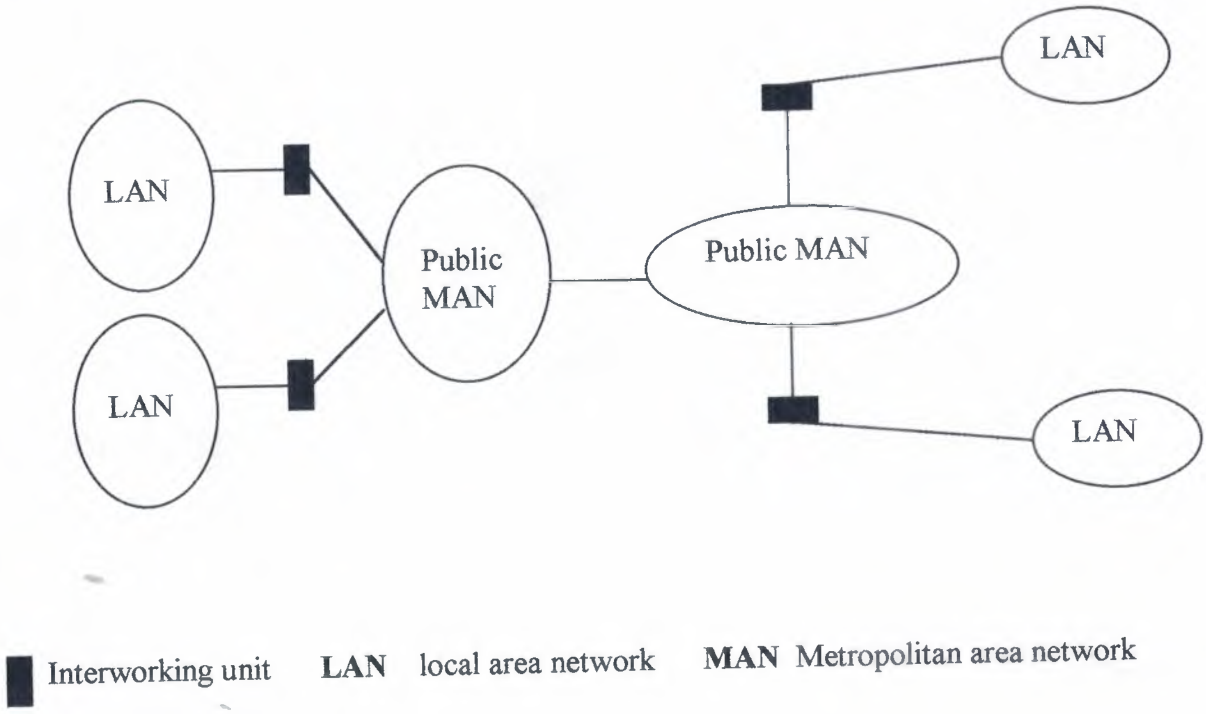


Figure 8.8 Interconnection of LANs via MANs

At first, MANs will only provide connectionless services and be used for LAN interconnection . But in a future stage, MANs could be extended to support isochronous and connection-oriented services.

8.4.4.2 Interconnection of MANs via B-ISDN

The introduction of B-ISDN will be enforced by the need for interconnecting MANs. This approach allows access to wider areas with more flexibility, low delay and high throughput. Figure 8.9 depicts this evolutionary stage.

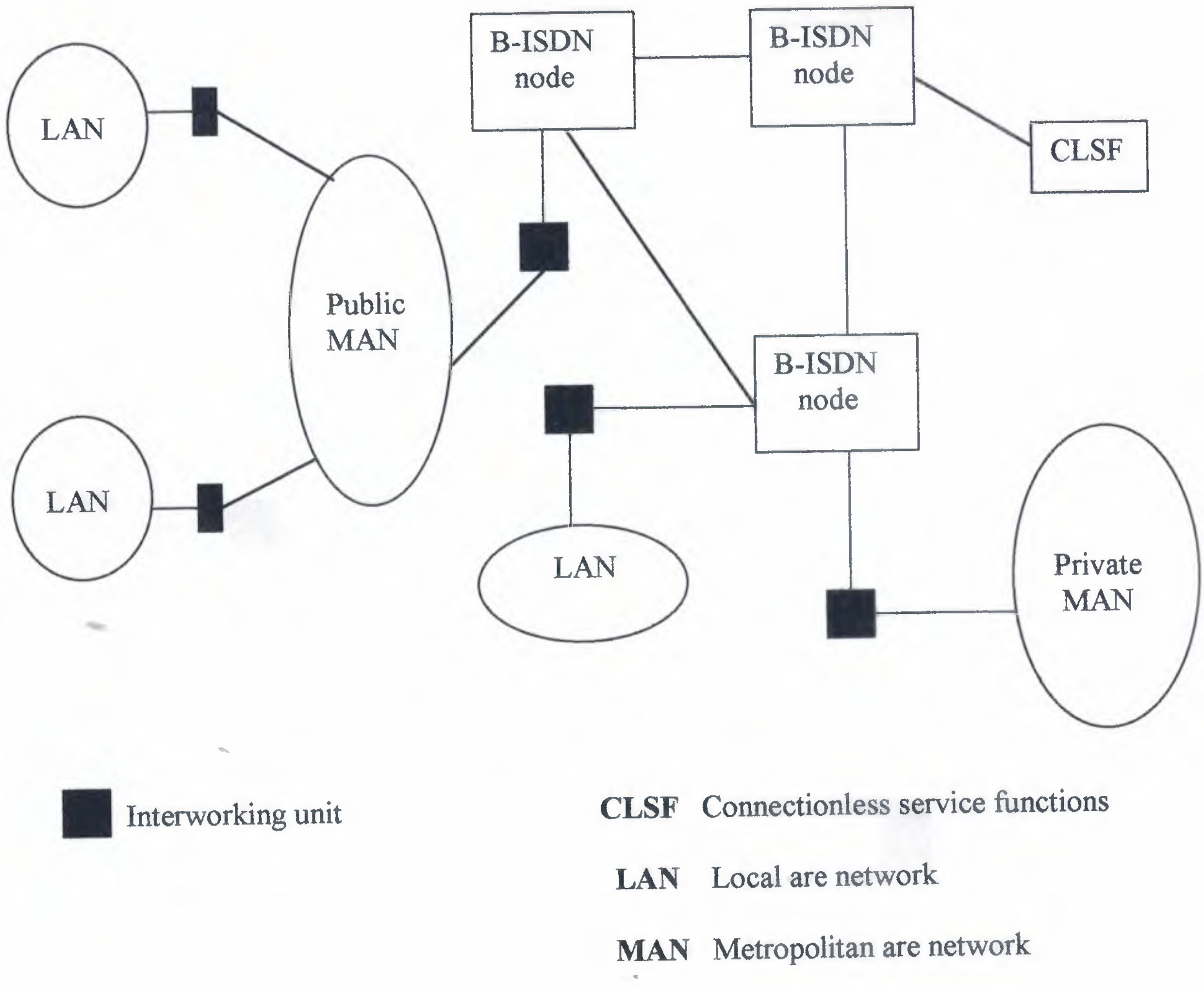


Figure 8.9: Interconnection of MANs and B-ISDN

With the introduction of B-ISDN, LANs or private MANs can be directly coupled to the B-ISDN. During this phase it is expected that more and more users will be attracted by the offered services and be encouraged to pass over the initial stage of the evolutionary path and immediately connect to the B-ISDN.

8.4.4.3 Co-existence of MANs and B-ISDN

Simultaneously with the introduction of B-ISDN, broadband terminals and new brodband CNs will be offered. These new CNs may have a star structure or they may be shared medium configurations like bus or ring which are well known from LANs. In figure 8.10 the intermediate stages is shown when LANs, MANs, B-ISDN and new CNs co-exist.

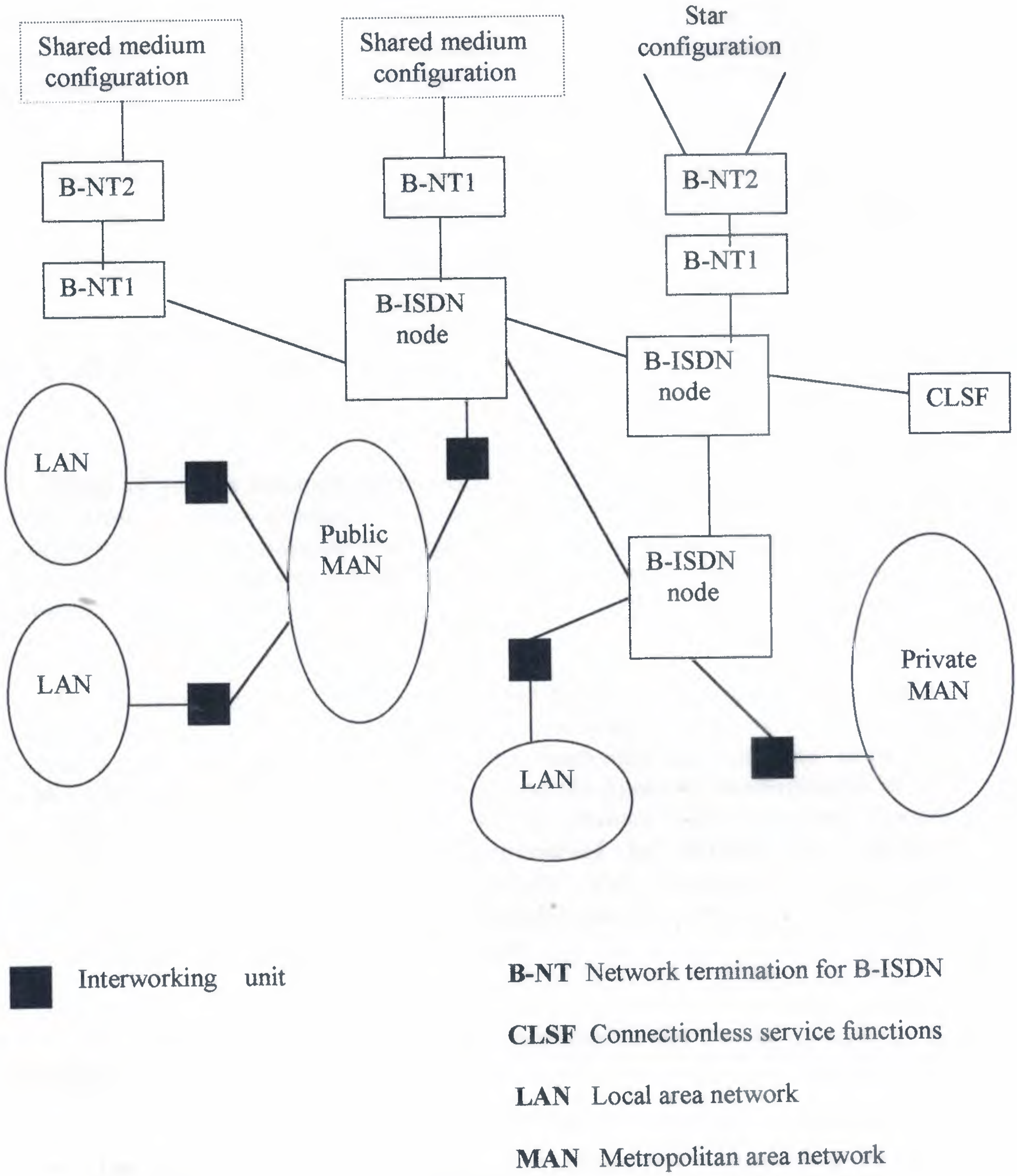


Figure 8.10 : Co-existence of MANs and B-ISDN

8.4.4.4 Replacement Strategies

It is assumed that B-ISDN is able to offer more flexibility and an equivalent or better set of services with cheaper costs than are available from MANs. Therefore, the spread of MANs will be reduced and in the long term MANs may be pushed out without deterioration of the offered services. Replacement of MANs will start in the trunk network and may end in the local network. Customers wanting private MANs may also use the B-ISDN as within B-ISDN virtual private networks can be created.

Replacement is not restricted to the public network. It may also happen in the private area. Existing LANs may be substituted by new CNs. These CNs will be based on ATM technology and, in addition to the services supported by LANs, new services with higher bandwidth requirements will be provided.

8.5 B-ISDN Trials

Many of today's communication requirements can be satisfied by the 64 kbit/s ISDN. However, a few genuine broadband applications already exist. In the in- house area, high-speed data communication has been facilitated by LANs, and in the public area, videoconferencing was introduced by using dedicated broadband circuit-switched networks.

Future communication will be characterized by high bandwidth utilization, multi-media applications and point-to-point as well as multipoint connections. These facts require a new network with more intelligence, bandwidth and flexibility. In order to obtain this target solution, new technologies and the complete standardization of new services and interfaces are necessary. But the obvious interest for new services, applications and systems is always accompanied by elements of uncertainty (acceptance, demand, technology, economy and organization). Laboratory implementations, field trials with pilot applications and test networks make it possible to overcome these uncertainties at an early stage.

Further goals of field trials and pilot applications for the preparation of the intelligent B-ISDN are:

- The design of realistic communication scenarios for supporting important applications
- Requirements specification of commercial services and terminals
- Influencing international standardization
- Information and motivation of potential users, service providers, network operators and manufacturers.

All around the world, laboratory ATM switching nodes are realized and field trials with pilot applications and test networks are running or are being planned. Within the framework of the *Research and Development of Advanced Communication in Europe* (RACE), several groups are working towards ATM demonstrators.

8.5.1 The BERKOM Trial

In 1986 the BERKOM (Berliner Kommunikationssystem) project started in Berlin. The objective of this trial is the design, development and demonstration of applications for B-ISDN. The following items are included in the BERKOM project

- Text and document processing in an office environment · High quality printing and publishing
- High speed transfer of medical images (e.g. X-ray images)
- Applications in the field of computer-aided design (CAD) and computer integrated manufacturing (CIM)
- Distribution of high definition television (HDTV) programmers
- Access to information bases containing text, pictures and movies
- Use of high quality audio and video information in the residential area.

In autumn 1989, Siemens installed an ATM switch as part of the BERKOM trial .The switch fabric transfers cells (2 octet header and 30 octet information field) of 16 inlets to 16 outlets, all operating at 140 Mbit/s. The participants are located in Berlin and are attached via single-mode fibres to the ATM switching node.

Typical applications using this ATM switch are

- Interconnection of LANs
- Video communications with 64 kbit/s, 2 Mbit/s and 34 Mbit/s
- Joint editing over broadband links
- Interconnection of HICOM-PBXs via ATM (private networking)
- Access to 64 kbit/s ISDN via an EWSD exchange.

CONCLUSION

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 64kbps 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 T-1 standard, developed by AT&T, provides a 1.544 Mbps 24 path now available from almost all of the common carriers. T-1 carrier can provide 24 channels, each able to carry 64 kbps of digitized voice or 56kbps of data over two twisted pairs; analog transmission of 24 voice channels would require 24 pairs of wires.

Even with the added expense of repeaters and digital transmission equipment, T-1 is an economical alternative for users with high-volume communications traffic. There are several different methods for carrying signaling information using T-1 carrier. The T-1 channels can also be broken down into several lower speeds channels by submultiplexing. In addition, voice and data compression can further increase the effective bandwidth of T-1 circuits. Finally, there are higher speed digital transmission facilities than T-1, such as T-1C and T-3, providing 48 and 672 channels, respectively.

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 primaryrate interface contains 23 or 30 B-channel and 1 D-channel and is aimed primarily at larger business users. The 23 B+D version is intended for use in North America and intended for use 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 BISDN, an even-faster class of interface standards, is currently being deployed. BISDN, 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 BISDN. The transmission technology that is used to implement BISDN 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 BISDN.

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