Technical University of Cartagena

Telecommunications Engineering School

FUNDAMENTALS OF TELEMATICS

Laboratory Content 4. Study of the physical and link layers on ISDN

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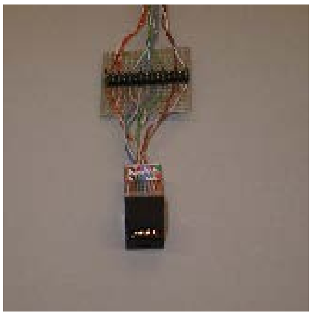
C O N T E N T S

1. Objectives

- Understand and analyze the physical level on ISDN. This knowledge is priority to goog comprehend the global system and, in particular, the protocols employed the link level. The comprehension of the network topology and the physical level is basic to understand the medium access mechanisms and the methods to solve the contends.
- The detailed knowledge of the physical level on ISDN must allow the student to obtain the capability of verifying the operation of the ISDN basic access and their installation/operation. Also, the student will learn about the possible errors of the installation. So, the student will use a device designed for this, called IBT5, a digital oscilloscope and a POD, all of that leads to test the ISDN line.
- Knowledge in detail the procedures for installing and operating a ISDN communication. It is described the different test to accomplish and the monitorization of the link level when appears some problem.

2. Elements

- 2 PCs including ISDN target and IBT-5 software
- 1 digital oscilloscope
- 2 IBT-5
- 1 POD using RJ-45 connection
- Cables for RJ-45 connection.
- 2 analog telephone
- The switchboard
- The NT1
- IBT5 Reference Manual



RJ45 POD

IBT 5

3. ISDN

3.1 Introduction

Rapid advances in computer and communication technologies have resulted in the increasing merging of these two fields. The lines have blurred amongcomputing, switching, and digital transmission equipment, and the same digital techniques are being used for data, voice, and image transmission. Merging and evolving technologies, coupled with increasing demands for efficient and timely collection, processing, and dissemination of information, are leading to the development of integrated systems that transmit and process all types of data. The ultimate goal of this evolution is the integrated services digital network (ISDN).

The ISDN is intended to be a worldwide public telecommunications network to replace existing public telecommunications networks and deliver a wide variety of services. The ISDN is defined by the standardization of user interfaces and is implemented as a set of digital switches and paths supporting a broad range of traffic types and providing value-added processing services. In practice, there are multiple networks, implemented within national boundaries, but from the user's point of view, there will be a single, uniformly accessible, worldwide network.

The impact of ISDN on both users and vendors will be profound. To control ISDN evolution and impact, a massive effort at standardization is underway. Although ISDN standards are still evolving, both the technology and the emerging implementation strategy are well understood.

Despite the fact that ISDN has yet to achieve the hoped for universal deployment, it is already in its second generation. The first generation, sometimes referred to as narrowband ISDN, is based on the use of a 64-kbps channel as the basic unit of switching and has a circuit-switching orientation. The major technical contribution of the narrowband ISDN effort has been frame relay. The second generation, referred to as broadband ISDN (B-ISDN), supports very high data rates (100s of Mbps) and has a packet-switching orientation. The major technical contribution of the broadband ISDN effort has been asynchronous transfer mode (ATM), also known as cell relay.

3.2 Transmission Structure

The digital pipe between the central office and the ISDN user is 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 is constructed from the following types of channels:

- B channel: 64 kbps
- D channel: 16 or 64 kbps
- H channel: 384(H0), 1536(H11), and 1920 (H12) kbps

The B channel is the basic user channel. It 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 must be destined for the same endpoint. Four 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 call-establishment dialogue does not take place over the B channel, but is done over the D, **as explained below.**
- **Packet-switched**. The user is connected to a packet-switching node, and data are exchanged with other users via X.25.
- **Frame mode**. The user is connected to a frame relay node, and data are exchanged with other users via LAPF.
- **Semipermanent.** This is a connection to another user set up by prior arrangement, and not requiring a call-establishment protocol; this is equivalent to a leased line.

The D channel serves two purposes. First, it carries 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., 100 bps) telemetry at times when no signaling information is waiting.
H channels are provided for user information at higher bit rates.

3.3 ISDN Access

Basic Access (2B+D). 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.
Primary Access (30B+D). Composed by 30 B channels and a full-duplex 64-kbps D channel.

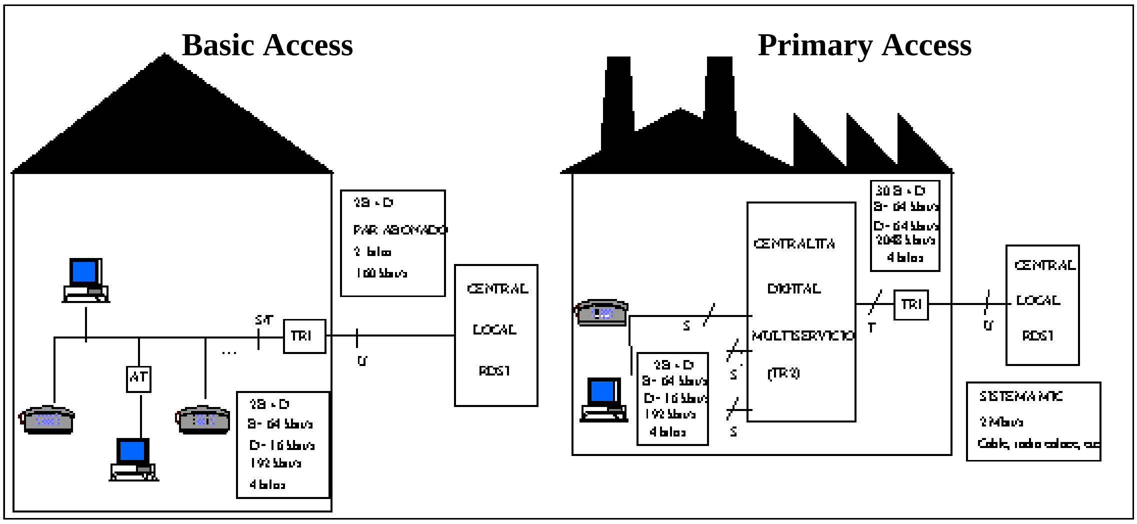


Fig. 2. ISDN Access

3.4 Functional groupings, Reference points and Topologies

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. Figure 4 shows the CCITT 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.

The architecture on the subscriber's premises is broken up functionally into groupings separated by reference points. This separation permits interface standards to be developed at each reference point; 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 impacting 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.

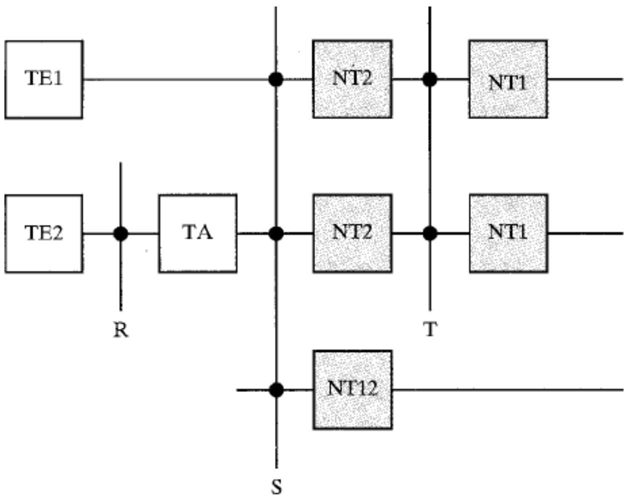


Fig. 3 ISDN reference points and functional groupings

Network termination 1 (NT1) includes functions associated with the physical and electrical termination of the ISDN on the user's premises; these correspond to OSI layer 1. 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 physical connector interface for user device attachment. In addition, the NT1 performs line maintenance functions such as loopback testing and performance monitoring. The NT1 supports multiple channels (e.g., 2B + D); 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 a single NT1 interface via a multidrop line.

Network termination 2 (NT2) is an intelligent device that can perform switching and concentration functions; it may include functionality up through layer 3 of the OSI model. Examples of NT2 are a digital PBX, a terminal controller, and a LAN. An example of a switching function is the construction of a private network using semipermanent circuits among a number of sites, each of which 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 an ISDN.

Network termination 1, 2 (NT12) is a single piece of equipment that contains the combined functions of NT1 and NT2; this points out one of the regulatory issues associated with ISDN interface development. In many countries, the ISDN provider will own the NT12 and provide full service to the user. In the Unite States, there is a need for a network termination with a limited number of functions to permit competitive provision of user premises equipment. Hence, the user premises network functions are split into NT1 and NT2.

Terminal equipment refers to subscriber equipment that makes use of ISDN; two types are defined. Terminal equipment type I (TE1) refers to devices that support the standard ISDN interface. Examples are digital telephones, 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 EIA-232-E, and host computers with an X.25 interface. Such equipment requires a terminal adapter (TA) to plug into an ISDN interface.

The definitions of the functional groupings also define, by implication, the reference points. Reference point T (terminal) corresponds to a minimal ISDN network termination at the customer's premises; it separates the network provider's equipment from the user's equipment. Reference point S (system) corresponds to the interface of individual ISDN terminals and separates user terminal equipment from network-related communications functions. Reference point U represents the digital transmission line between the client and the system and actually corresponds with the subscriber loop to two wires.

- **Topologies:**

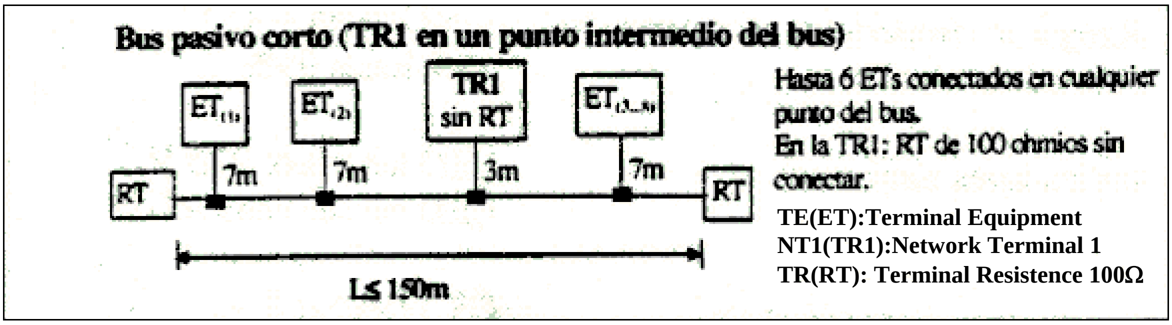


Fig. 4. Short Passive Bus with NT1 in the middle

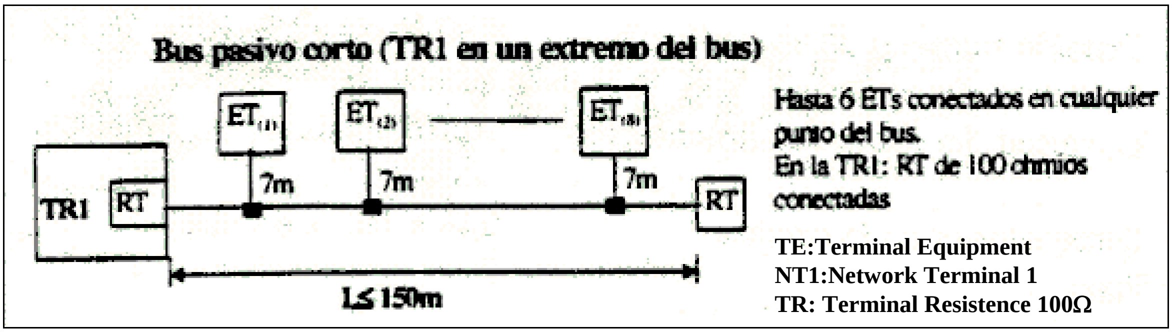


Fig. 5. Short Passive Bus with NT1 at the end

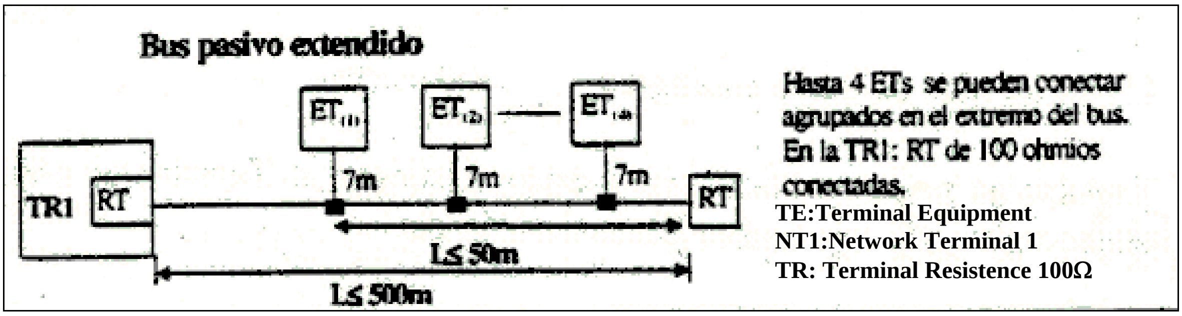


Fig. 6. Extended Passive Bus

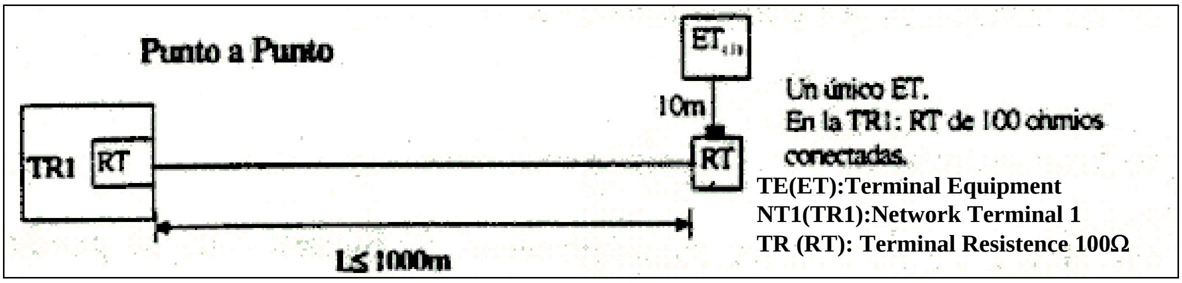


Fig. 7. Point-to-point

3.5 Services

Firstly, we deal with bearer services. They provides the capability for the transmission of signals between user-network interfaces and involves only three layers of the 7-layer model. It must distinguish between circuit mode switched bearer services and packet mode switched bearer services. In relation to the circuit mode, they are divided into:

64 kbps unrestricted to 8 Khz:

It allows data transfer at up to 64 kbps. Data rates below 64 kbps are catered for by rate adaptation techniques. Call progress tones and announcements are not provides (call progress information is done via D channel signaling), and no interworking with the PSTN is allowed.

8 Khz Speech:

It offers all the normal routing rules for speech (i.e echo control may be required). Motivated by the use of appropriate processing techniques for vocal signals to optimize network resources, it does not guarantee the integrity of the bit sequence.

3.1 Khz audio:

It offers similar features to the PSTN, allowing the transfer of audio information from modems, group 3 fax machines, etc. Echo control and Digital Circuit Multiplication Equipment are not used.

Concerning to packet mode switched bearer services, the most remarkable services are the following ones:

Permanent virtual circuit bearer service

In this case, ISDN provides a circuit-switched connection between the user and the RPDCP Access.

Virtual Call.
In this scenario, ISDN has the necessary elements to support the packet switching. Also, it supports X.25 service.

Secondly, we deal with the **teleservice**s. Among them, we remark the telephony 3.1KHz, telephony 7KHz, videotelephony, videotex, teletex and mixed mode (transmission of documents with text and fixed images). Finally, we note the supplementary services such as Direct-dialling-In, Multiple Subscriber Number, Calling Line Identification Presentation, Calling Line Identification Restriction, Connected Line Identification Presentation (COLP), Connected Line Identification Restriction (COLR), Malicious call Identification, Calling name identification restriction, Call Transfer, Call Forwarding Busy, Call Hold, etc.

3.6 Number Identification

The number structure is the following one:

- Country code, 1 to 3 digits.
- National Destination Code, depending on the network and geographic area
- Subscriber number, longitud variable.
- ISDN subaddress, up to 40 digits.

3.7 Protocols

3.7.1 Physical Layer

The protocol is applicable both to the B-Channel and to the D-channel because both are multiplexed over the same frame:

Note: The following data are applied to the basic access.

- <u>Codification</u>. Use of pseudoternary coding scheme where "1"is absence of voltage and "0"is a positive or negative pulse of 750 mV ± 10%. Data rate is 192 kbps.
- <u>Multiplexing</u>. Multiplexing of 144 kbps over 192-kbps interface at S or T ref. pnt. Remaining capacity used for framing and synchronization purposes. 48-bit frames at a rate of one frame every 250 ms. Frame from TE to NT is later than the frame in opposite site by 2 bits.

		8 bits						8 bits				8 bits				8 bits			
F	L	B1	E	D	A	F_A	N	B2	E	D	M	B1	E	D	S	B2	E	D	L

a) Frame format NT -> ET

F	L	B1	L	D	L	F_A	L	B2	L	D	L	B1	L	D	L	B2	L	D	L

b) Frame format ET -> NT

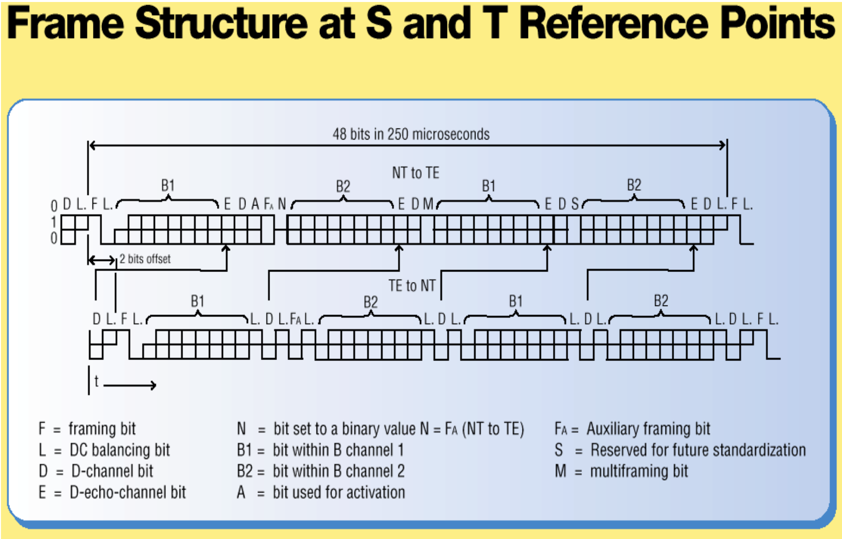


Fig.8 Frame Structure

3.7.2 Data Link Layer

All traffic over the D channel employs a link-layer protocol known as LAPD (Link Access Protocol-D Channel). The LAPD standard provides two forms of service to LAPD users: the unacknowledged information-transfer service and the acknowledged information-transfer service. The unacknowledged in,formation-transfer service simply provides for the transfer of frames containing user data with no acknowledgment. The service does not guarantee that data presented by one user will be delivered to another user, nor does it inform the sender if the delivery attempt fails. The service does not provide any flow control or error-control mechanism. This service supports both point-topoint (deliver to one user) or broadcast (deliver to a number of users); it allows for fast data transfer and is useful for management procedures such as alarm messages and messages that need to be broadcast to multiple users. The acknowledged information-transfer is the more common service, and is similar to that offered by LAP-B and HDLC. With this service, a logical connection is established between two LAPD users prior to the exchange of data.

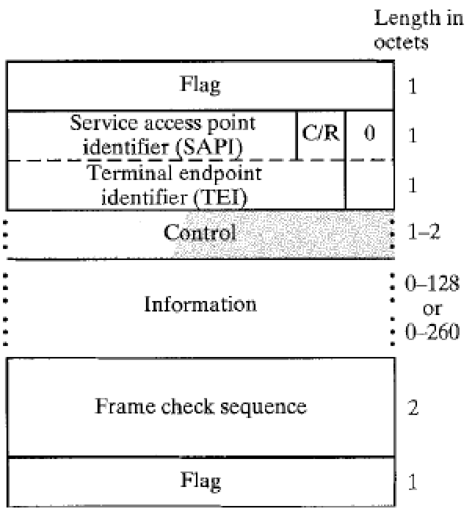


Fig.9 LAPD format

The LAPD protocol is based on HDLC. Both user information and protocol-control information and parameters are transmitted in frames. Corresponding to the two types of service offered by LAPD, there are two types of operation:

- **Unacknowledged operation**. Layer-3 information is transferred in unnumbered frames. Error detection is used to discard damaged frames, but there is no error control or flow control.
- **Acknowledged operation**. Layer-3 information is transferred in frames that include acknowledged sequence numbers. Error control and flow control procedures are included in the protocol. This type is also referred to in the standard as multiple-frame operation.

These two types of operation may coexist on a single D channel, and both make use of the frame format illustrated in Figure 9. This format is identical to that of HDLC, with the exception of the address field.

To explain the address field, we need to consider that LAPD has to deal with two levels of multiplexing. First, at the subscriber site, there may be multiple user devices sharing the same physical interface. Second, within each user device, there may be multiple types of traffic: specifically. packet-switched data and control signaling. To accommodate these levels of multiplexing, LAPD employs a two-part address, consisting of a terminal endpoint identifier (TEI) and a service access point identifier (SAPI).

Typically, each user device is given a unique terminal endpoint identifier (TEI). It is also possible for a single device to be assigned more than one TEI; this might be the case for a terminal concentrator. TEI assignment occurs either automatically when the equipment first connects to the interface, or manually by the user. In the latter case, care must be taken that multiple equipment attached to the same interface do not have the same TEI. The advantage of the automatic procedure is that it allows the user to change, add, or delete equipment at will without prior notification to the network administration. Without this feature, the network would be obliged to manage a data base for each subscriber that would need to be updated manually. Figure 10 shows the assignment of TEI numbers.

(a) TEI Assignments

TE1 value	User type
0–63	Nonautomatic TEI assignment user equipment
64–126	Automatic TEI assignment user equipment
127	Used during automatic TEI assignment

(b) SAPI Assignments

SAPI value	Related protocol or management entity
0	Call control procedures
16	Packet communication conforming to X.25 level 3
32–61	Frame relay communication
63	Layer 2 management procedures
All others	Reserved for future standardization

Fig.10 SAPI and TEI assignments

The service access point identifier (SAPI) identifies a layer-3 user of LAPD, and thus corresponds to a layer3 protocol entity within a user device. Four specific values have been assigned, as shown in Figure 10. A SAPI of 0 is used for callcontrol procedures for managing B-channel circuits; the value 16 is reserved for packet-mode communication on the D channel using X.25 level 3; and a value of 63 is used for the exchange of layer-2 management information. Finally, values in the range 32 to 62 are reserved to support frame-relay connections.

For acknowledged operation, LAPD follows essentially the same procedures described for HDLC. For unacknowledged operation, the user information (UI) frame is used to transmit user data. When a LAPD user wishes to send data, it passes the data to its LAPD entity, which passes the data in the information field of a UI frame. When this frame is received, the information field is passed up to the destination user. There is no acknowledgment returned to the other side. However, error detection is performed, and frames in error are discarded.

A summary of other fields is the following:

Flag Fields. Flag fields delimit the frame at both ends with the unique pattern 01111110. A single flag may be used as the closing flag for one frame and the opening flag for the next. On both sides of the user-network interface, receivers are continuously hunting for the flag sequence to synchronize on the start of a frame. While receiving a frame, a station continues to hunt for that sequence to determine the end of the frame. However, it is possible that the pattern 01111110 will appear somewhere inside the frame, thus destroying frame-level synchronization. To avoid this, a procedure known as bit stuffing is used. Between the transmission of the starting and ending flags, the transmitter will always insert an extra 0 bit after each occurrence of five 1s in the frame. After detecting a starting flag, the receiver monitors the bit stream. When a pattern of five 1s appears, the sixth bit is examined. If this bit is 0, it is deleted. If the sixth bit is a 1 and the seventh bit is a 0, the combination is accepted as a flag. If the sixth and seventh bits are both 1, the sender is indicating an abort condition.

With the use of bit stuffing, arbitrary bit patterns can be inserted into the data field of the frame. This property is known as data transparency.

Address Field. The address field identifies the secondary station that transmitted or is to receive the frame. This field is not needed for point-to-point links, but is always included for the sake of uniformity. The address field is usually eight bits long but, by prior agreement, an extended format may be used in which the actual address length is a multiple of seven bits. The least significant bit of each octet is 1 or 0, depending on whether it is or is not the last octet of the address field. The remaining even bits of each octet form part of the address. The single-octet address of 11111111 is interpreted as the all-stations address in both basic and extended formats. It is used to allow the primary to broadcast a frame for reception by all secondaries.

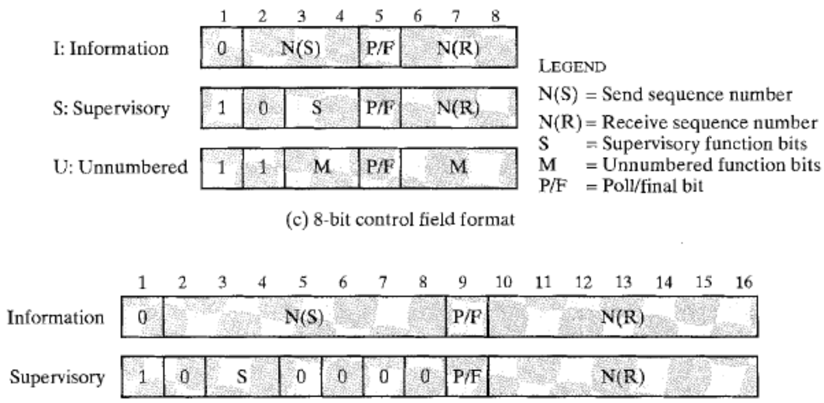


Fig.11 16-bit control field format

Control Field. It defines three types of frames, each with a different control field format. Information frames (I-frames) carry the data to be transmitted for the user. Additionally, flow- and error-control data, using the ARQ mechanism, are piggybacked on an information frame. Supervisory frames (S-frames) provide the ARQ mechanism when piggybacking is not used. Unnumbered frames (U-frames) provide supplemental link control functions. The first one or two bits of the control field serves to identify the frame type. The remaining bit positions are organized into subfields.

Note that the basic control field for S- and I-frames uses 3-bit sequence numbers. With the appropriate set-mode command, an extended control field can be used for S- and I-frames that employs 7-bit sequence numbers. U-frames always contain an 8-bit control field.

Information Field. The information field is present only in I-frames and some U-frames. The field can contain any sequence of bits but must consist of an integral number of octets. The length of the information field is variable up to some system-defined maximum.

Frame Check Sequence Field. The frame check sequence (FCS) is an error-detecting code calculated from the remaining bits of the frame, exclusive of flags. The normal code is the 16-bit CRCCCITT. An optional 32-bit FCS, using CRC-32, may be employed if the frame length or the line reliability dictates this choice.

3.7.2.1 Operation

In table 1, it appears different typical commands and responses for this type of service.

• Initialization: It is requested by a SABME frame containing the TEI+SAPI of the level3 module which requests the connection. If the other side accepts this request, then the HDLC module on that end transmits an unnumbered acknowledged (UA) frame back to the initiating side. If the request is rejected, then a disconnected mode (DM) frame is sent.
• Data Transfer: The N(S) and N(R) fields of the I-frame are sequence numbers that support flow control and error control. S-frames are also used for flow control and error control through RR frames (Receive Ready), RNR frames (Receive Not Ready) or REJ frames (Reject).
• Disconnect: Either module can initiate a disconnect, either on its own initiative if there is some sort of fault, or at the request of its higher-layer user. HDLC issues a disconnect by sending a disconnect (DISC) frame. The other side must accept the disconnect by replying with a UA.

3.7.2.2 Management Operation

Management operations are accomplished by the UI frames (User Information), which are a subtype of U frames, and, therefore, they do not require an acknowledgment. The functionality is twofold: TEIs management and definition of configurable parameters.

By management of TEIs, it assigns a TEI to a TE. This mechanism can start either by a level3 module transmitting information/establishing a logic connection or by a level3 module itself. In any case, the LAP-D sends a UI frame including SAPI=63 and TEI=127, and an information field requiring a TEI assignation and a reference number to difference of other requests. If the network terminal has a free-TEI in the 64-126 range, it responses with a UI frame including SAPI=63 y TEI=127 and an information field indicating clearly that it is a TEI assignation frame, the same reference number and an indicator containing the assigned TEI. In the case of not assigning a TEI, it is indicated as reject assignation in the information field.

Name	Control Field	C/R	Description
I (Information)	0-N(S)-P-N(R)	C	Exchange User Data
RR (Receive Ready)	10000000*-N(R)	C/R	Positive ack ready to receive I frame
RNR (Receive Not Ready)	10100000*-N(R)	C/R	Positive ack, not ready to receive
REJ (Reject)	10010000*-N(R)	C/R	Negative ack, go back n
SABME (Set Asynchronous Balanced Mode)	1111P110	C	Request logical connection
DM (Disconnected Mode)	1111F000	R	Unable to establish or maintain logical connection
UI (Unnumbered Information)	1100P000	C	Used for ack information transfer service
DISC (Disconnect)	1100P010	C	Terminate logical connection
UA (Unnumbered Acknowledge)	1100F110	R	Ack SABME or DISC
FRMR (Frame Reject)	1110F001	R	Reports receipt of unacceptable frame
XID (Exchange Identification)	1111*101	C/R	Exchange Identification Information

*=P/F bit

Table 1. LAP-D commands and responses

3.7.3 Network Layer

The network layer of the D channel offers the necessary tools to establish the connections between users through circuit switching or packet switching. This level3 dedicated to signaling, either a connection via circuit switching or connection of the B channel via packet switching is deeply described by the Q.931 recommendation. This recommendation corresponds to the Digital Signaling System for subscribers Nº1 and specifies the following aspects:

- Format of the signaling messages
- Procedures exchanged by the user and the central in the establishment, maintenance, and termination of the calls. These procedures are defined in terms of messages exchanged by the D channel of the interface structure to basic and primary speed.

On the other hand, in the case of accomplishing a communication via packet switching using D channel, it is possible to deploy the X.25 protocol.

4. Development of the Laboratory Content.

4.1 Codification.

To study the frame format and line code on ISDN, the student will tab a basic access line during a communication. To this end, we will establish a telephone communication through an ISDN equipment. As ISDN equipment, the student will use ISDN target of the PC or an IBT-5, which will be connected to the ISDN access through a RJ-45 POD. Done this, the student will call through the switchboard to another ISDN equipment of the laboratory or analog telephone of the workbench. The POD allows to access to the four pairs of RJ-45 cables.

To accomplish the different issues of this laboratory content, the student will use the digital oscilloscope. During the session, the student must appropriately configure the oscilloscope thus using the memory capture. Supported by the oscilloscope, the student will determine the following aspects:

- The pair of cables used for transmitting
- The pair of cables used for receiving. **[1]**
- Voltage employed for the line codification **[2]**
- Decoding of a bit sequence from the voltages shown on the screen **[3]**

4.2 Frame Format.

A scheme of the frame format is shown in Figure 8. This must be used to compare with the picture captured by the oscilloscope. Employing the available channels, it is possible to store the transmission and reception frames simultaneously. To carry out the snapshot, the student must accomplish an ISDN communication and tab the bus on the condition that the connection is established. Comparing the snapshot and Figure 8, the student must identify:

- Beginning and ending of each of frames.
- Identify each field within the frame.
- Measure the frame duration and bit time. **[4]**

4.3 Basic Access.

Keeping the communication between both ISDN devices, the student will determine the channels used **[5].** In each workbench, there is a S0 bus which has two communication channels named B1 and B2. To check the use of these channels, the student will carry out a communication between a PC and an analog telephone.

Checked the employed channel, the student will establish another communication using the another PC of the workbench and another telephone. Done this, the student will check if both channels are busy and if another communication is possible in the same S0 bus. **[6]**

5. Link Layer on ISDN

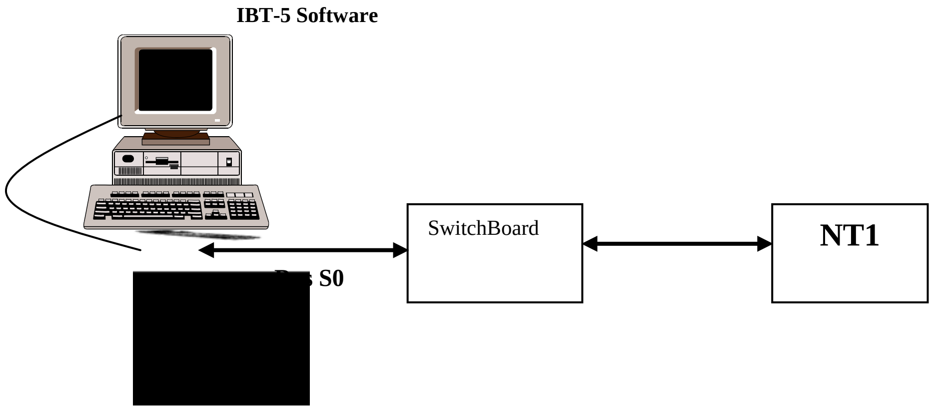


Fig. 12. Configuration of the workbench

Figure 12 shows the elements participants of this part of the laboratory content. The IBT5 is connected by the serial port with the goal of downloading the frames.

In this section, we will accomplish the analysis of the link level through the capture of frames transmitted between the ISDN equipment and the switchboard. To capture the frames, we will employ the IBT-5 along with the specific software which allows to download the frames transmitted during a communication of the PC via serial port.

5.1 Capture and download of call frames

To this end, the student must connet the provided cable to the side IBT-5 and, on the other hand, to one of the serial ports of the PC. The IBT-5 must be configured to provide the downloaded frames to the PC. So, once done the suitable configuration on “CONFIGURACIÓN” (see IBT-5 manual), it will select “VOLCADO DE TRAMAS” and “EN TIEMPO R(real)”, on “ACTIVO”.

Execute the *Windows PC Detail Decoder* program whose icon appears in the desktop. Upon selecting the device (IBT-5), the student must push PLAY at the corresponding icon (*3.8 IBT-5 manual*).

- Execute a call by analog telephone and wait for two tones before picking up (*telephone mode of the IBT-5*)
- Passed some seconds, the student must hang up. Store the obtained result.
- Analyze the frames shown on the screen **[1]**. The student must compare them with the LAP-D protocol (Table 1).

5.2 Capture and download of a bearer service test.

Keep the previous configuration and carry out a bearer service test *(point 3.4 of the IBT-5 manual*) using the IBT-5 while the student activates the frame capture through the software of the PC. Analyze the frames shown on the screen.**[2]**