ISDN USER-NETWORK INTERFACE LAYER 3

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Abstract: The Integrated Services Digital Network (ISDN) offers access to a wide range of services over a single subscriber line. An important part of the ISDN is the ISDN user-network interface. The main feature of the ISDN user-network interface is to support the various service capabilities, including voice and non-voice applications in the same network. Comprehensive interface standards are therefore very important for achieving universal deployment and worldwide compatibility. This paper presents the signalling procedures, according to Recommendation I.451/Q.931, for circuit-switched connections using the B-channel at the ISDN user-network interface layer 3, also mentioning the new features developed in these Recommendations, according to the CCITT Blue book. In the last section of the article a possible conceptual software structure of the lowest three ISDN layers is presented.

Povzetek: Mreža ISDN ("Integrated Services Digital Network") omogoča uporabniku dostop do različnih storitev (prenos govorne, podatkovne, tekstovne in slikovne informacije) preko ene naročniške linije. Pomemben del mreže ISDN je ISDN vmesnik uporabnik-mreža, ki omogoča dostop do njenih storitev. Enotni standardi vmesnikov so zato eden od pomembnih dejavnikov za dosego svetovno enotnega razvoja mreže ISDN. V članku je predstavljen protokol 3. nivoja v ISDN vmesniku uporabnik-mreža za tokokrogovno komutacijo in dvotočkovno povezavo po standardu I.451/Q.931 (CCITT Modra knjiga). Zadnji del članka je namenjen predstavitvi možne programske strukture prvih treh nivojev ISDN.

1 Introduction

The Integrated Services Digital Network (ISDN) is a telecommunication network composed of a wide range of network capabilities which are described by standardized protocols and functions /7/. The key to handle such an all-embracing coverage of services in a single network is service integration. This approach permits the ISDN to be viewed as a whole, regardless of whether only the part of the functions supported by the ISDN are needed for a certain service. So, the main progress, from the economical and technical point of view, is a single network which forms the basis for supporting various voice and non-voice applications, instead of having a separate network for each service.

Comprehensive interface standards are one of the key elements in achieving the universal deployment and worldwide compatibility. The ISDN will also be recognized by the characteristics observed at the user-network interface rather than by its internal arhitecture, configuration or technology. Therefore, interfaces are central to ISDN and determine most of ISDN's principal features.

To achieve the idea of integrated use of speech, data and image requires complete end-to-end digital transport, although the process of change is considered as an ongoing evolutionary process; or vice versa, digital information standardization leads to integration of the transmission, switching, and control functions-hence the concept of ISDN /2/.

We already mentioned two fundamental elements for the ISDN, digital connectivity for information transfer and the multipurpose capability of user-network interfaces. The third element is common channel signalling in which signalling information relating to a multiplicity of circuits or functions or for network managment is conveyed over a single channel by addressed messages /7/.

In our discussion we will first briefly describe the ISDN user-network interface. Our attention will be directed to the layer 3 protocol according to Recommendation I.451/Q.931 which contain the signalling procedures for establishing, modifying and terminating network connections /4,6/ across an ISDN between communicating application

entities.

Call control procedures may be divided into functional and stimulus procedures. Functional operation is more convenient for autonomous user equipment meanwhile stimulus operation is more appropriate for manually operated user equipment. Therefore our discussion will be directed to the functional call control procedures for the establishing and clearing of circuit-switched connections using the B-channel /4,8,9/.

2 General

2.1 ISDN user-network interface

An objective of ISDN is that a small set of compatible user-network interfaces can economically support a wide range of user applications, equipment and configurations (Fig.1.)/7/.

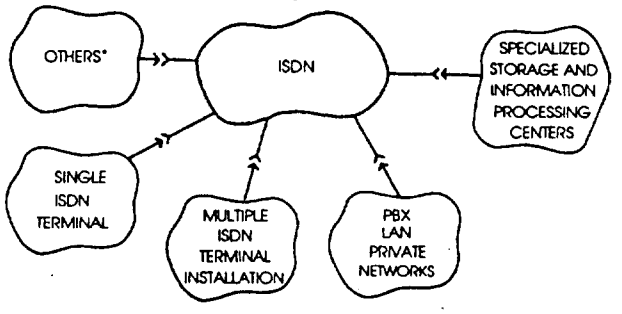
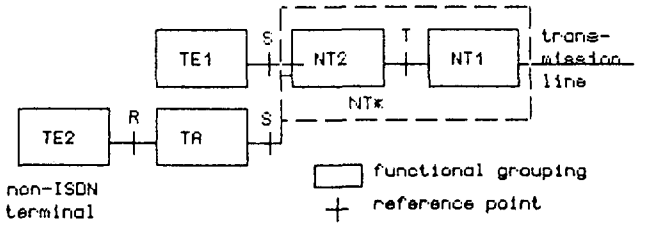


Fig.1. ISDN user-network interface examples

Fig.2. illustrates a more datailed view of the reference configurations for ISDN user-network interfaces /9/.



TE1-terminal equipment type 1 (digital telephones, data terminal equipment and integrated work stations)
NT2-network termination 2 (PABX, local area networks and terminal controllers)
TA-terminal adapter
NT*-NT2 and NT1 are combined as NT for a single interface

Fig.2. Reference configurations for the ISDN user-network interface

Each square represents a functional grouping which is a set of functions, needed in ISDN user access arrangements. The crosses represent the reference points which are dividing functional groupings. The reference points S and T are specially important because the ISDN user-network interface Recommendations in the I-series apply to physical interfaces at these reference points. Now we can also explain the term user-network interface as the interface between the TE and the NT. The TE is the equipment that provides the functions necessary for the operation of the access protocols by the user meanwhile the NT provides the functions necessary for the network access.

2.2 Communication contexts

Fig.3. will help us to understand the communication contexts for circuit-switched connections /5/. As we see, four communication contexts are shown:

- Context A is the realm of user-user information transfer over the circuit-switched connection.
- Context B is the realm of user-network signalling between the left TE (terminal equipment) and the ISDN.
- Context C is the realm of inter-network signalling.
- Context D is the realm of user-network signalling between the right TE and the ISDN.

There are three phases for establishing a call from a calling user to a called user:

a) the user-network phase (context B - signallization over the D-channel)
b) the internetwork phase (context C - the Signalling System No.7), and
c) the network-user phase (context D - signallization over the D-channel).

We will describe the establishing and clearing of a call in the user-network phase and touch the internetwork phase. The network-user phase is almost the same as the user-network phase, only with few modifications. The modifications depend on whether multipoint or point-to-point terminal configuration exist. If we carefully analyze the protocol blocks which represent the right and the left TE, we see that the user plane (U-plane) is a 7-layer hierarchical structure. The control plane (C-plane) is represented as a 3-layer structure because the higher four layers are used for user-user signallization, represented as context A. Context B and context D represent the signallization over the D-channel - the theme of our discussion. The internetworking phase (context C) is under an another signallization - the Signalling System No.7 meanwhile the user-user transfer (conext A) is a combination of both signallizations mentioned above - the signallization over the D-channel and the SS (Signalling System) No.7 /2,8,9/.

2.3 Concepts of layering

According to the layering technique (OSI), communication among application processes is viewed as being logically partitioned into an ordered set of layers (Fig.3.). The vertical communication between adjacent layers takes place with primitives, which represent, in an abstract way, the logical exchange of information and control /6/.

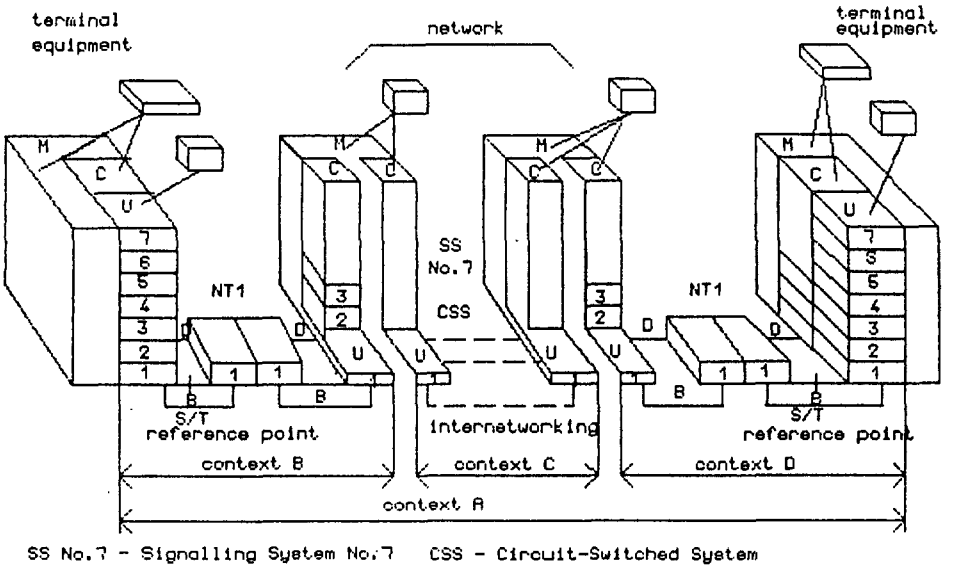


Fig.3. Communication contexts for circuit-switched connections via B-channel

Layer 3 provides to the user the functions associated with the establishment and operation of network connections. It also makes invisible how it utilizes underlying resources such as data link connections to provide a network connection. The main features of the layer 3 protocol can be summarized as follows /2,3/:

a) handling of a wide variety of connections through the same user-network interface which includes establishing and clearing of data link connections;
b) message structure consisting of elements common to all the message types;
c) symmetrical protocol for outgoing and incoming calls to enable direct user-to-user connection etc.

3 Signalling procedures

3.1 Call states

A call is, during the establishing, maintaining or clearing phase, in a specific state. The basic call control states are divided into call states at the user or the network side of the interface (Fig.4.)/8,9/.

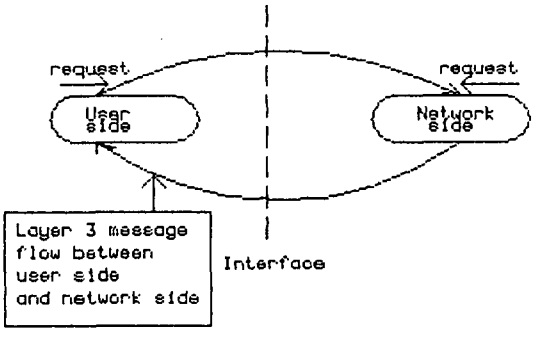


Fig.4. Convention for message transmission.

Because several calls may exist simultaneously at a user-network side it is obvious that the state of the interface itself cannot be unambiguously defined. Table 1 illustrates the user states (U) and the network states (N) /9/.

TABLE 1
User call states and network call states

User states	Network states
U0-null	N0-null
U1-call initiated	N1-call initiated
U2-overlap sending	N2-overlap sending
U3-outgoing call proceeding	N3-outgoing call proceeding
U4-call delivered	N4-call delivered
U6-call present	N6-call present
U7-call received	N7-call received
U8-connect request	N8-connect request
U9-incoming call proceeding	N9-incoming call proceeding
U10-active	N10-active
U11-disconnect request	N11-disconnect request
U12-disconnect indication	N12-disconnect indication
U15-suspend request	N15-suspend request
U17-resume request	N17-resume request
U19-release request	N19-release request
	N22-call abort
U25-overlap receiving	N25-overlap receiving

3.2 Message structure

The application entities communicate with the exchange of messages. Each message, according to the Recommendation I.451 /9/, includes:

a) a brief description of the message direction and use,
b) a table listing the information elements (mandatory or optional) contained in the message.

Table 2 lists the messages for circuit-mode connection control.

TABLE 2
Messages for circuit mode connection control

Call establisment messages	Call info. phase messages
ALERTing	MODIFY
CALL PROCeeding	MODIFY ACKnowledge
CONNect	MODIFY REJect
CONNect ACKnowledge	RESUME
PROGress	RESUME ACKnowledge
SETUP	RESUME REJect
SETUP ACKnowledge	SUSPEND
	SUSPEND ACK
	SUSPEND REJect
	USER INFOrmation
Call clearing messages	**Miscellaneous messages**
DISConnect	CONgestion CONtrol
RELease	NOTIFY
RELease COMPlete	INFOrmation
RESTart	STATUS
RESTart ACKnowledge	STATUS ENquiry

Within the Recommendation I.451, every message shall consist of the following parts (Fig.5.):
a) Protocol discriminator distinguishes I.451 call control nad maintaince messages from all other OSI network layer protocol (i.e. X.25 Packet Layer Protocol, etc.) on the D-channel.
b) Call reference means for tracing active calls and associated resources which are being utilized. The call reference value is assigned by the call originator ath the begining of the call and remains fixed for the life of the call.
c) Message type identifies the function of the message.
d) Mandatory and optional information elements which contain the required information.

The coding of information elements is formulated to allow each equipment to process the information elements important to it, and yet remain ignorant of information non-important to it.

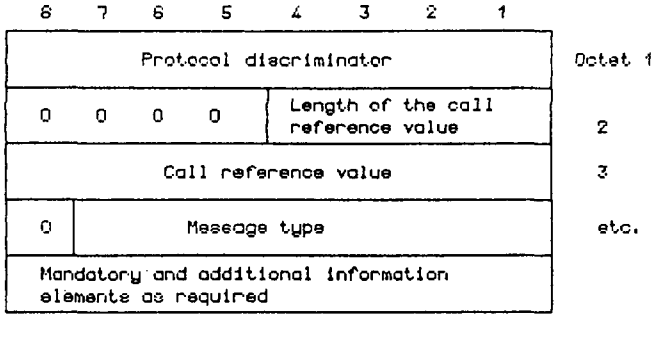


Fig.5. General message structure.

The information elements are the most important part of the message because they carry the user information meanwhile the protocol discriminator, call reference and the message type are used for control functions. There are two categories of information elements:
a) single octet information elements which can be everywhere in the message; and
b) variable length information elements with certain extension mechanisms.

For example, the bearer capability information element carries the information about the transfer mode (circuit, packet), information transfer rate, configuration (point-to-point, multipoint), information transfer capability etc. We have described only a part of the bearer capability information element to indicate the complexity and the numerous information carried in an information element.

3.3 Call establishment

After the user has initiated call establishment (similar as pick up the receiver), he enters data via a keyboard (the called party address). Layer 3 (of the terminal) sends now a SETUP message to the network (context B in Fig.3.) /1,4,8,9/. The SETUP message may contain all or part of the called party address, depending on whether en-bloc or overlap sending is being used respectively. If en-bloc sending is used, the SETUP message will contain all the information (complete called party address) required by the network to process the call. In case of overlap sending only a part of the information will be sent.

If the network determines, after receiving the SETUP message or during overlap sending, that the call information received from the user is invalid, it will initiate call clearing.

If the user terminal can monitor the status of channels in use, he shall not transfer a SETUP message across the user-network interface in case all appropriate channels controlled by the D-channel are in use. In the opposite case, when the user terminal does not monitor the status of channels in use, he may send a SETUP message during an all channels busy condition. The network responds with a RELease COMPlete message.

In the SETUP message the user terminal can indicate one of the following:
a) channel is indicated, no acceptable alternative; or
b) channel is indicated, any alternative is acceptable; or
c) any channel is acceptable.

If no indication is included, alternative (c) is assumed. The selected B-channel is indicated in the first message returned by the network. If the specified channel in case (a) is not available, or no channel in cases (a) and (b), a RELease COMPlete message with an appropriate cause is sent by the network.

The terminal selects a call reference for the call which is unique within the scope of a call. In case of en-bloc sending the network will send a CALL PROCeeding message to the user terminal to indicate that the call is being processed.

If overlap sending is used, the SETUP message contains either:

a) no called number information; or
b) incomplete called number information; or
c) called number information which the network cannot determine to be complete.

On receipt of such a SETUP message, the network sends a SETUP Acknowledge message to the user. After receiving the SETUP Acknowledge message, the user terminal sends the remainder of the information (if any) in one or more INFOrmation messages. An INFOrmation message may contain, besides the possible called party number, also aditional call information (i.e. for supplementary services). After the network has received a sending complete indication or has analyzed that all necessary call information has been received, it shall send a CALL PROCeeding message. The CALL PROCeeding message indicates that access to the requested service and supplementary service is authorized and available.

The originating exchange will transmit the call through the network to the destination exchange and then to the called terminal. During call establishment, the call may leave an ISDN environment because of interworking with a non-ISDN network (context C in Fig.3.). The calling user terminal shall be informed with a SETUP ACKnowledge/CALL PROCeeding/ALERTing/CONNect message and change the state of a call or with a PROGress message when no state change is appropriate. If the interface at which the message originates is the point at which a call enters the ISDN environment from a non-ISDN environment, appropriate progress indicator information elements shall be included in the SETUP message sent to the network.

After receiving the SETUP message, the called terminal will check the compatibility and respond with an ALERTing message. The called user will be informed with ringing (similar as the telephone ringing), and a ring back indication will be sent back to the calling user (analogy with the telephone - the calling user hears the ringing at the called party). If the called user answers (e.g.,picks up the telephone), a CONNect message will be sent to the destination exchange and then through the network to the originating exchange and the calling user. Now the connection is established and the call at both sides of the interface enters the Active state or the maintaining phase of the call. To confirm that the call is in the maintaining phase, a CONNect ACKnowledge message is sent from the originating to the destination exchange.

During the maintaining phase, the user notification procedure allows the network or the user to notify, by sending a NOTIFY message, the remote user of any call-related event. Another possibility, during the maintaining phase, is also to change the bearer capability for a call with a MODIFY message.

Upon receiving an indication that the network or the called user is unable to accept the call, the network shall initiate call clearing.

3.4 Call clearing

Under normal conditions, call clearing is usually initiated by the user or the network. We will only explain the call clearing initiated by the user (calling or called user hangs up). The signalling procedures for call clearing initiates by the network are almost the same.

The terminal forms and transfers a DISConnect message across the user-network interface, starting a timer, disconnecting the B-channel and entering the Disconnect Request state. After the network has received the DISConnect message, the B-channel used in the call is disconnected and a RELease message is sent back to the user and a timer is started. On receipt of the RELease message, the user shall cancel the started timer, release the B-channel and the call reference, and send in response a RELease COMPlete message. After the network has received the RELease COMPlete message from the user, it shall stop the started timer and release both the B-channel and the call reference. If the timer, started by the user, expires, the user shall again send to the network a RELease message with the cause number originally contained in the DISConnect message; start again the same timer and enter the Release Request state. The network will, after the expiry of its timer, again send a RELease message and restart the timer. After the second expiry of the timer (e.g., no RELease COMPlete message was received), the network shall place the B-channel in a maintaince condition, release the call reference and return to the Null state. The B-channel in the maintaince condition can be activated with the restart procedure.

5 A possible software implementation of the first three layers of the ISDN

Fig.7. illustrates a possible task based conceptual software solution of the ISDN. The principle is similiar to the concept of the MINIX operating system. The first layer is a compound of software drivers which have to manage the appropriate hardware unit. Therefore software drivers are strictly tied to the hardware structure. The adjacent higher layer consists of tasks. They do not have to know the physical structure of the hardware but only the logical functions of every hardware unit. Managers are the logical highest units which communicate with the hardware with the assistance of tasks and handlers. The hierarhy concept is similar to the TOP DOWN design. The basic program structure of all three types of units is the same: they operate in an endless loop. An example of the pseudo-cod is represented.

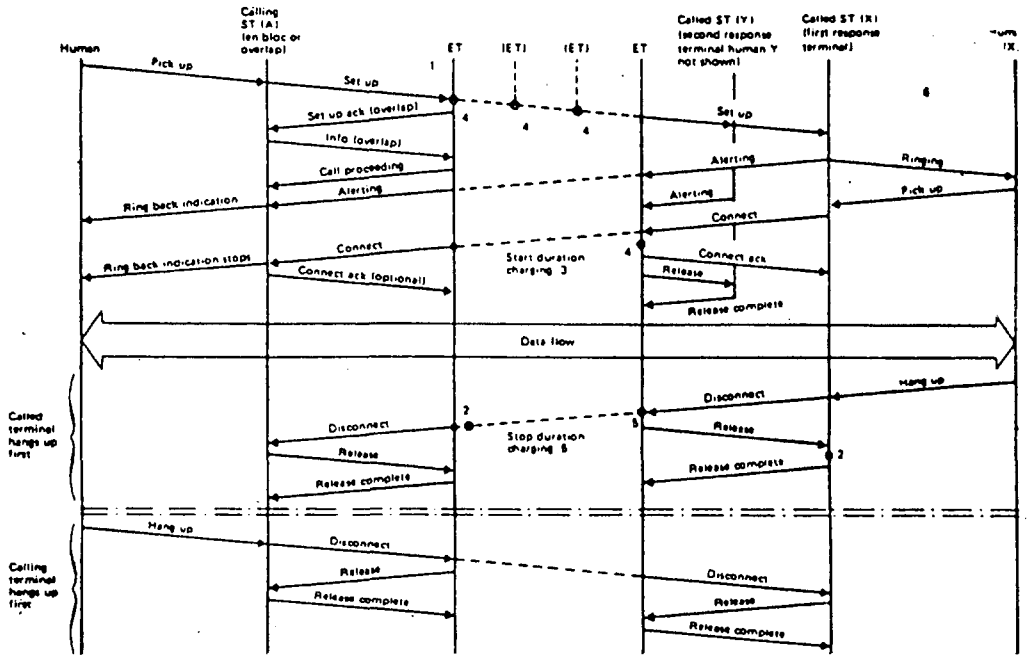


Fig.6. Call establishment and release

```
repeat
  wait_for_request;
  case request of
    req_1: actions_1;
    req_2: actions_2;
        .
        .
        .
    req_n: actions_n;
  end;
forever;
```

When a logical unit (handler, task, manager) executes the procedure wait_for_request and no request is present the process (executive unit) is suspended - it is in the WAIT state and so the process is not burdening the processor. The process can be reactiveted with a software (from a higher) or hardware interrupt (from a lower layer).

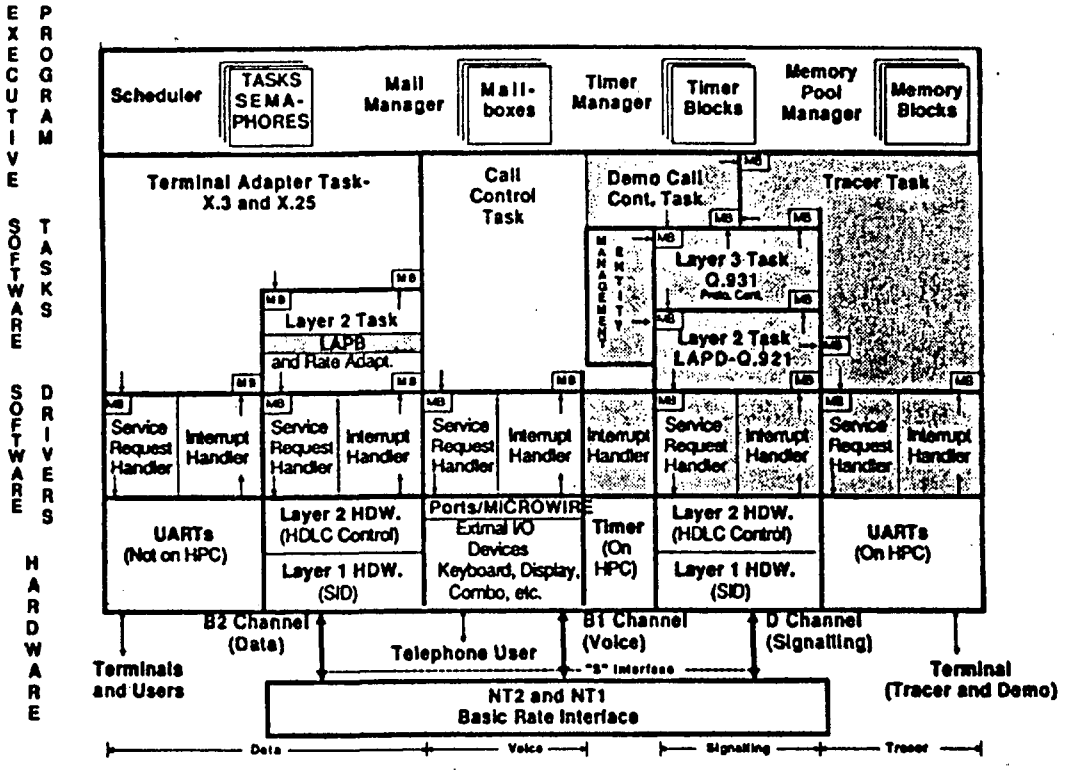


Fig.7. Conceptual software structure for the first three layers of the ISDN

6 Conclusion

Over the years, the concept of the ISDN has evolved from a vision to its technical realization. The current state of a part of the ISDN user-network interface layer 3 has been presented in this paper. We have concentrated on the signalling procedures for establishing, maintaining and clearing of circuit-switched connections using the B-channel, according to Recommendation I.451/Q.931, Blue book. In the last part of the article a conceptual program solution for the three lowest layers of the ISDN has been presented.

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