



Technology Series: Introduction to ISDN - ETSI

1 OVERVIEW

This technology note will provide an overview of International ISDN technology, for both Basic and Primary Rate access.

Before ISDN (Integrated Service Digital Network) was introduced, dedicated networks were required to provide services of different nature, e.g. POTS (Plain Old Telephone Service) analog service, packet service, telex service, data service, etc. The PSTN (Public Switched Telephone Network) provides analog telephone services to customers; the PSTN (Public Switched Telephone Network) provides packet services to customers. Different networks were required because of the very different transmission characteristics. Dedicated and isolated network requirements lead to a number of drawbacks: high costs, low efficiency, and inconvenience. ISDN, based on the telephony network, was conceived of to provide multiple voice and non-voice services over a single network, and a digital user-network interface over regular phone lines, instead of dedicated and isolated user-network interfaces.

Using ISDN, users not only can do telephony, but can access additional benefits such as telecommuting, Internet access, and video conferencing. These services were not possible in large deployment with regular services provided by the phone companies. ISDN is an integrated solution for providing basic telephony and data services, whilst offering more telephony services such as supplementary services. Its proven technology

continues to be deployed and hence must be tested and maintained.

2 NETWORK ARCHITECTURE

ISDN provides complete digital capabilities. Figure 1 shows the basic ISDN architecture, revealing the user-network interface and network capabilities, as well as the signaling system in the network. An ISDN user can access the following services using an ISDN Terminal Equipment (TE):

- Packet-switched data
- Circuit-switched data
- Circuit-switched voice
- User-to-user signaling

There are three different types of signaling: user-network, intra-network, and user-to-user signaling. All three employ common-channel signaling technique. User-network signaling is used to control signaling between the user terminal equipment and the network. Intra-network signaling is used to control signaling between ISDN switches. User-to-user signaling is used between the end users and can be transparently transferred through the network.

2.1 User-Network Interface

In dedicated networks, different types of user-network interfaces are required to support the service to be delivered. In ISDN, there are certain criteria to minimize the number of compatible interfaces required to support different applications: generosity, portability,

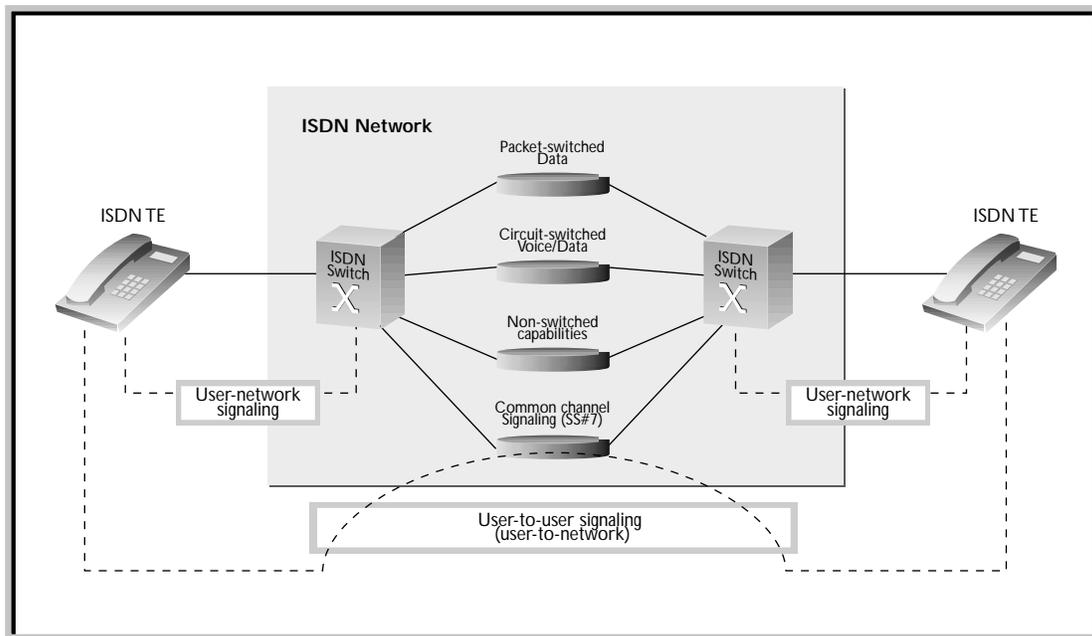


Figure 1 ISDN Architecture

independence, etc. The ITU-T has defined "reference configurations" for ISDN user-network interface. The configurations are based on association rules of functional groups and reference points. With the reference configurations, the interface requirement at different reference points is defined.

Functional groups are sets of functions that may be needed in ISDN arrangements. Reference points are the conceptual points between two adjacent functional groups, along the access line. Functional groups and reference points are depicted in Figure 2.

2.2 Functional Groups

LT: Line Termination; a device at the exchange office terminates an ISDN circuit

NT1: Network Termination 1; a device at the customer premises (terminating an ISDN circuit) performs physical layer functions such as signal conversion synchronization; converts 2-wire U-Interface to 4-wire S/T Interface

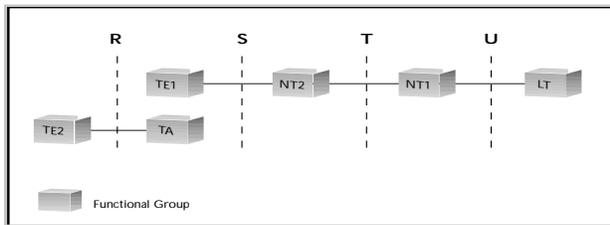


Figure 2 User-Network Interface Reference Points

NT2: Network Termination 2; a device with intelligence at the customer premises, performs data link layer and network layer functions

NT: Network Termination; a device which performs the combined functions of NT1 and NT2

TA: Terminal Adapter; a device which allows non-ISDN equipment to connect with an ISDN line

TE: Terminal Equipment; a user terminal which handles communications such as voice or data and supports protocol handling, maintenance functions, etc.

- TE1: Terminal Equipment, ISDN Ready Equipment (i.e. Digital ISDN Phone)
- TE2: Non-ISDN Ready Terminal Equipment

2.3 Basic Rate Interfaces

A typical configuration for ISDN Basic Rate Access in reference to functional groups is shown in Figure 3. A reference point is often referred to as an interface. The various interfaces are:

U: Full-duplex 2-wire interface, using echo-cancellation technique between the NT1 and the LT for basic rate ISDN. In most countries, a compression transmission line code called 2B1Q is used at this interface.

T: 4-wire interface between a NT1 and NT2

S: 4-wire interface connects an NT (or NT2) to a TE or TA

R: Non-ISDN interface between a non-ISDN compatible terminal and a TE2

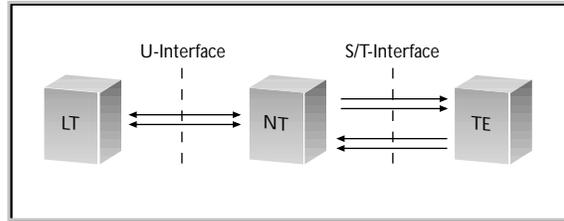


Figure 3 Groupings & Interfaces

3 STANDARDS AND OSI MODEL

The OSI (Open Standard Interconnection) concept was developed for computer-to-computer communications. Although ISDN was developed based on telephony network, its implementation requires the support from data terminal communications to make non-voice service possible. The OSI model was adopted to develop a suite of ISDN related standards. The standards also ensure interoperability and compatibility between equipment in a multi-vendor environment.

The Layer 1 characteristics of the user-network interface at S- and T-reference points (for the basic rate interface) are defined in ITU-T I.430. Layer 1 characteristics of the user-network interface at the primary rate interface, are defined in ITU-T I.431.

The other two upper layers, Layer 2 and Layer 3, are defined to enable that signaling be accomplished independently of the type of user-network interface

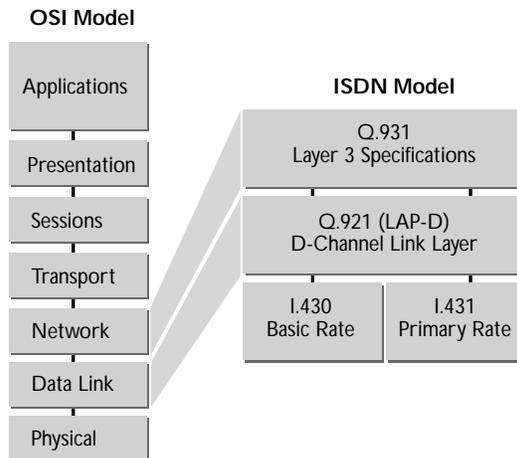


Figure 4 OSI & ISDN Models and Standards

involved. The characteristics of Layer 2 and Layer 3 are specified in ITU-T Q.921 and Q.931 respectively.

3.1 Layer 1 (ITU-T I.430, I.431)

- Encoding of digital data for transmission across the interface
- Full-duplex transmission of B-channel data
- Full-duplex transmission of D-channel data
- Multiplexing of channels to form basic or primary access transmission structure
- Activation and deactivation of the physical circuit
- Power feeding from network termination to the terminal
- Faulty terminal isolation
- D-channel contention access; this is needed when there is a multi-point configuration for basic rate access

3.2 Layer 2 LAP-D (ITU-T I.441, Q.921)

- Conveys user information between Layer 3 entities across ISDN using the D-channel
- Layer 2 employs Link Access Protocol on the D-channel (LAP-D)
- The LAP-D service will simultaneously support multiple logical LAP-D connections to enable:
 - Multiple terminals at the user-network installation
 - Multiple Layer 3 entities
- The LAP-D supports two types of multiple frame 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 sequence numbers and that are acknowledged. Error control and flow control procedures are included in the protocol. This type is also referred to in the standard as multiple-frame operation.

The Unacknowledge and Acknowledge operations may coexist on a single D-channel.

3.2.1 LAP-D Frame Format (ITU-T I.441, Q.921)

All LAP-D peer-to-peer exchanges are in frames according to the frame format shown in Figure 5. A frame may or may not contain an information field.

3.2.2 Address Field

- Composed of Terminal Endpoint Identifier (TEI) and Service Access Point Identifier (SAPI). The Address

Field is broken out of the Q.921 Frame Format in Figure 5.

- The TEI identifies the user device. A TEI may be assigned automatically or in a fixed manner, by the switch. Fixed TEIs are used in PRI or in BRI point-to-point configurations. Automatic TEIs are generally used with multi-point BRI terminals. Here are the values:
 - 0-63: Nonautomatic TEI assignment
 - 64-126: Automatic TEI assignment
- There are a number of messages associated with TEI Management built into Layer 2. Here are the messages and their definitions:
 - IDENT REQUEST: Identity Request; Sent in the User-to-Network direction, requests a TEI value assigned by the switch

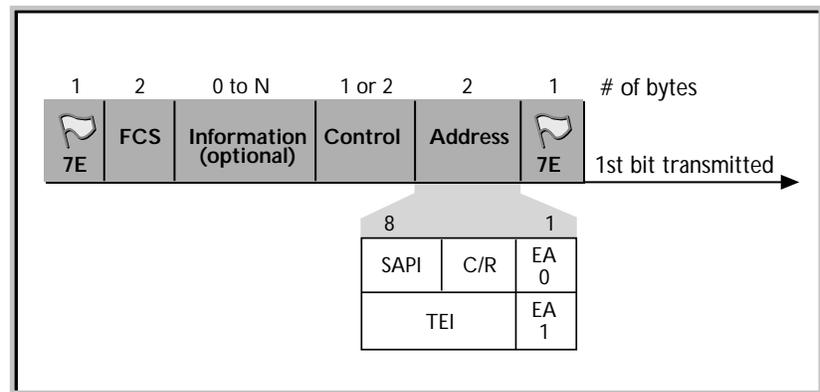


Figure 5 Q.921 Frame Format and Address Field

- IDENT ASSIGNED: Identity Assigned; Sent in the Network-to-User direction, assigns an AUTO TEI (64-126) from the switch
 - IDENT DENIED: Identity Denied; Sent in the Network-to-User direction, denies an Identity Request for a TEI
 - ID CHK REQUEST: Identity Check Request; Sent in the Network-to-User direction, requests a check on a specific TEI or all TEIs assigned
 - ID CHK RESPONSE: Identity Check Response; Sent in the User-to-Network direction, response to an ID Check Request of an assigned TEI
 - IDENT REMOVE: Identity Remove; Sent Network to User, removes a TEI which has been assigned
 - IDENT VERIFY: Identity Verify; Sent in the User-to-Network direction, requests verification of an assigned TEI
- A SAPI determines the function of the data link; it identifies a Layer 3 user of LAP-D, and thus corresponds to a Layer 3 protocol entity within a user device. Four values have been assigned:

- 0: Used for call control procedures for managing B-channel circuits
- 1: Used for packet-mode communication using ITU-T I.451; this could be used for user-to-user signaling
- 16: Reserved for packet-mode communication on the D-channel, using X.25 level 3
- 63: Used for exchange of Layer 2 management information
- The combination of TEI and SAPI is referred to as DLCI (Data Link Connection Identifier). At any one time, LAP-D may maintain multiple logical connections, each with a unique DLCI.

3.2.3 Control Fields

LAP-D defines three types of frames and the control field identifies the type of frame being transmitted:

Information transfer frames (I-frames) carry the data to be transmitted for the user. Flow and error control data, using the go-back-N ARQ (Automatic Repeat Request) mechanism, are piggybacked on a information frame.

Supervisory frames (S-frames) provide the ARQ mechanism when piggybacking is not used.

Unnumbered frames (U-frames) provide supplemental link control functions and are also used to support unacknowledged operation.

- The control field identifies the type of frame being transmitted.
- All of the control field formats contain the poll/final bit (P/F).
 - In command frames, it is referred to as the P bit and is set to 1 to solicit (poll) a response frame from the peer LAP-D entity.
 - In response frames, it is referred to as the F bit, and is set to 1 to indicate the response frame transmitted as a result of a soliciting command.
- The control field contains the Received frame number [N(R)] and Sent frame number [N(S)] fields, which keep track of the variables determining the sequence numbers of the I-frames.
- The SABME (Set Asynchronous Balanced Mode Extended) is a command used to set the multiple frame acknowledged mode. The initiator of this command receives an Unnumbered Acknowledgment (UA) response.

3.2.4 Information Field

- The information field is present only in I-frames and some unnumbered frames containing Layer 3 information.
- Maximum length of 260 octets

- Contains the message type and parameters; for example, a SETUP message is used to set up a call. It contains the bearer capability, originating and destination addresses, transit network selection, and other data.
- Layer 3 information is used for intra as well as interexchange calls using SS#7.

3.3 Layer 3 (ITU-T I.450, I.451, Q.931)

- Defines the D-channel call control signaling. See the Basic Call Control Procedure section later in this Note.
- Specifies the procedures for establishing connections on the B-channels that share the same interface to ISDN as the D-channel
- Provides user-to-user control signaling over the D-channel
- Packet switching signaling is also available using X.25 Layer 3 protocol. This is the same for using B-channel packet switching service. Layer 3 provides higher layer information for supporting various ISDN functions.
- Two basic types of user terminals are supported by ISDN: Functional and Stimulus
 - Functional terminals are intelligent devices and can employ the full range of ITU-T Q.931 messages and parameters for call control. All signaling information is sent in a single control message (en bloc sending).
 - Stimulus terminals are devices with a rudimentary signaling capability. A simple digital telephone is an example of a stimulus terminal.

4 CHANNEL TYPES

Different channel types are used to convey information across the user-to-network interface according to their specific purposes and requirements.

- B-channel: 64 kbit/s channel to carry user information (i.e., digitized voice or data)
- D-channel: 16 kbit/s channel for the BRI or 64 kbit/s channel for the PRI. Mainly used to carry signaling information for connection control. Since signaling information transmission does not occupy the channel all the time, it allows packet-switched service user information to be conveyed over the D-channel to maximize utilization.
- H-channels: Higher bit rate channels to support wider bandwidth applications, such as video conferencing, etc. Only available at primary rate.
 - H_0 channel: 384 kbit/s
 - H_1 channel: 1536 kbit/s (H_{11}) and 1920 kbit/s (H_{12})

5 ACCESS INTERFACES

ITU-T I.412 defines different interface structures for ISDN user-network physical interfaces at the S- and T-ISDN reference points.

- Basic interface structure
- Primary rate B-channel interface structure
- Primary rate H-channel interface structure
- Primary rate interface structures for mixtures of B- and H_0 -channels

5.1 Basic Interface Structure

A typical configuration for ISDN Basic Rate Access is shown in Figure 6, illustrating the U- and S/T-interfaces.

- Composed of two B-channels and one 16 kbit/s D-channel, i.e., 2B+D
- The two B-channels may be used independently

5.2 Primary Rate B-Channel Interface Structure

A typical configuration for ISDN Primary Rate Access is shown in Figure 7. This illustrates the use of E1 primary rate connecting a PBX to the central office.

- E1 interface (2.048 Mbit/s)
- HDB3 Coding, PCM-31 framing
- Composed of thirty B-channels and one 64 kbit/s D-channel, i.e., 30B+D

- All thirty B-channels are always present at the user-network interface, but the number of B-channels supported by the network may be fewer.
- For multiple interfaces, the D-channel in one structure may carry signaling information for B-channels in another primary rate structure without an activated D-channel. The time slot for the non-activated D-channel may or may not be used to provide one additional B-channel over this structure.

5.3 Primary Rate H-Channel Interface Structure

- For primary rate at 2048 kbit/s, the 1920 kbit/s H_{12} -channel structure is defined
- Composed of one 1920 kbit/s H_{12} -channel and one 64 kbit/s D-channel
- In a multiple interface arrangements, a single D-channel may carry signaling information for channels in another interface.

5.4 Primary Rate Interface Structures for Mixtures of B- and H_0 -Channels

- Consists of one 64 kbit/s D-channel
- In multiple interface arrangements, a single D-channel may carry signaling information for channels in another interface.
- Any mixture of B- and H_0 -channels

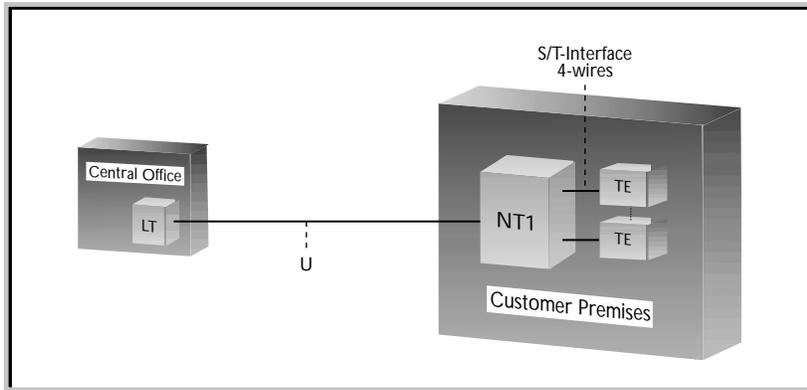


Figure 6 Typical BRI Circuit

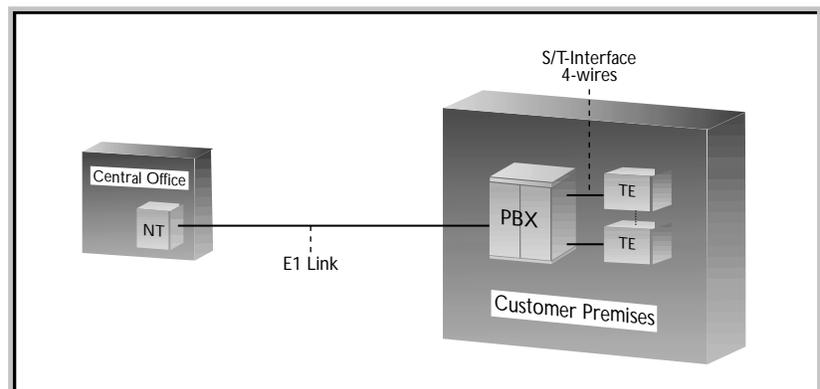


Figure 7 Typical PRI Circuit

6 S/T-INTERFACE TRANSMISSION

In European and most Asian countries, ISDN service provision via basic rate access interface structure is at the S-reference point, which becomes the service provision boundary between the user and the network. The physical interface is defined in ITU-T I.430. Telephone companies are responsible for the NT1 equipment provision at the customer premises.

6.1 S/T-Interface Characteristics

- 8-wire interface
- Two symmetrical wire pairs, one for each direction of signal transmission
- Two wire pairs for power feed
- Overall transmission bit rate of 192 kbit/s, including 144 kbit/s 2B+D channels and 48 kbit/s overhead information for synchronization, activation and deactivation, and D-channel contention resolution in multi-point configuration
- Pseudo-ternary coding is used such that a binary ONE is represented by no line signal, whereas a binary ZERO is represented by a positive or negative pulse. Balance bit is used to balance the number of binary ZEROS in a frame.
- Supports point-to-multi-point configuration in which up to 8 S-interface terminals can be connected to the same S-interface.

6.2 S/T Power Feed

- Power Source 1 (PS1) phantom power feed to the TE is provided normally from local AC power. In local power failure condition, the polarity of PS1 is reversed. This condition is referred to as restricted power mode. PS1 shall supply sufficient power for one TE to maintain emergency service.
- An optional Power Source 2 (PS2) may or may not be available.

7 U-INTERFACE TRANSMISSION

The U-interface is between the network side of the NT1 and the line termination of the ISDN exchange form (part of the access digital section of the basic rate access). In some countries, e.g., the US, ISDN service provision, according to the basic interface structure, is at this U reference point, which becomes the service provision boundary between the user and the network. It is up to the customer to select an NT1, which converts the 2-wire U-interface into the S/T-interface.

Regenerative repeaters can be used to extend the local loop. The maximum local loop distance without a U repeater can be up to 5,486 meters, as per ETSI ETR 080.

The twisted pair needs to be pre-qualified to ensure that the 2B1Q transmission can be handled.

7.1 U-Interface Characteristics

The transmission system characteristics at this interface are defined in ITU-T G.961, ETSI ETR 080, and ANSI T1.601. They are summarized as follows:

- 2 B-channels and 1 D-channel with a total bit rate of 144 kbit/s
- Overhead at 16 kbit/s
 - 12 kbit/s for synchronization
 - 4 kbit/s for five M channels, where M1 to M3 are combined to provide an embedded operations channel (*eoc*); M4, M5, M6 channels are used to handle transceiver operations and maintenance functions. More specifically, the M5 and M6 carry CRC (Cyclic Redundancy Check) information
 - Total transmission bit rate = 160 kbit/s
- One symmetrical wire pair for both directions of transmission. The duplex transmission over one pair of wire is based on echo-cancellation technique.

7.2 2B1Q

The U-interface has a rate of 160 kbit/s and the 2B1Q encoding sends 2 bits per symbol. The first bit is the sign bit, which determines polarity. The second bit

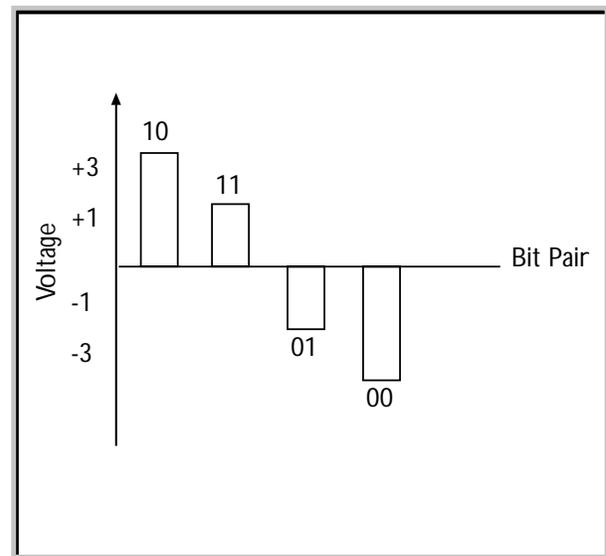


Figure 8 2B1Q Encoding

determines the amplitude of the line signal (see Figure 8). As each symbol is sending 2 bits, the overall rate is 80 kSymbols/s. The highest bandwidth reached by this transmission occurs when a maximum positive symbol is

sent simultaneously with the maximum negative symbol. This results in a pseudo-sine wave signal with a frequency of 40 kHz (refer to Figure 9).

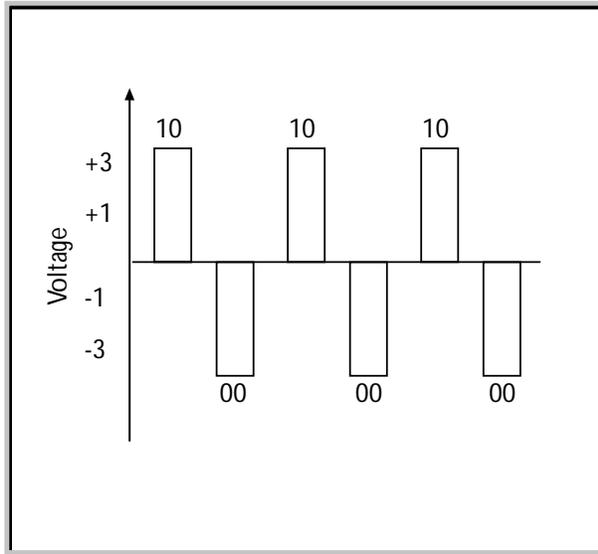


Figure 9 2B1Q Maximum Bandwidth

Since on a copper wire circuit the amplitude steadily decreases as a function of the frequency, and that in the function of the U-interface the maximum frequency transmitted is 40 kHz, if the 40 kHz line loss test passes, the line will carry the 2B1Q signal and U-interface traffic with no problem. That is of course, if no other interference is present.

7.3 U-Power Feed

Phantom power is fed from the switch over the U-interface to power the NT1 and one of the TE connected to the NT1. This maintains a minimum service in case of local power failure at the customer premises.

The PS1 phantom power at the S/T-interface of the NT1, obtains power from local AC mains in normal operating conditions. It derives power from the network at the U-interface when the local feed is lost. The voltage polarity of PS1 is reversed in this case. This is known as the restricted mode of operation.

Only one of the TEs (normally an ISDN phone) connected to the S/T-interface will be configured to allow operation with reverse power, so as to maintain telephony service. PS2 obtains its power from the local AC mains feed.

8 ISDN SERVICES

The concept of ISDN is to provide different services over a unified digital network. ISDN services are grouped in three service categories:

- Bearer service
- Teleservice
- Supplementary service

8.1 Bearer Service

This is a type of service provided by the ISDN network, offering the capability for the transmission of signals between user-network interfaces. A bearer service is limited to the three lower layers of the OSI model. The bearer services are the basic services provided by the ISDN and include:

- 64 kbit/s unrestricted
- 3.1 kHz audio
- Speech

8.2 Teleservices

Teleservice is a type of telecommunication service that is offered at the user-terminal interface rather than at the S/T-interface points, as the bearer services are. Therefore, the service includes the capability of the network and the terminal equipment functions. Examples of teleservices are:

- Telephony
- Teletex
- Fax
- Videotext

8.3 Supplementary Services

A supplementary service adds value to the basic functions of a telecommunication service. Since it complements an existing service, a supplementary service cannot exist on its own. Here are just a few examples of available supplementary services:

- Direct Dialing In (DDI)
- Multiple Subscriber Number (MSN)
- Calling Line Identification Restriction (CLIP)
- Connected Line Identification Presentation (COLP)
- Sub-addressing (SUB)
- Call Transfer (CT)
- Call Forwarding Busy (CFB), etc.

Networks may or may not offer one or more of the supplementary services defined by ITU-T.

9 BASIC CALL CONTROL PROCEDURE

There are three phases in a basic call control procedure:

- Call set up
- User data transfer
- Call Clear-down

Figure 10 depicts the call control procedure of an ISDN circuit switched call. It shows the message types at the user-network interface throughout the process. The call is from an ISDN user connected to one exchange, to a user connected to another exchange. The two exchanges are interconnected via Signaling System No.7 link.

If the calling terminal equipment places the outgoing call with enblock dialing, the SETUP message includes the bearer capability, low level compatibility, high level compatibility, and called party number. If, however, the call is made with overlap dialing, then each of the individual digits of the called party number is sent as INFORMATION packets.

The exchange examines the called party number in the SETUP message and returns a CALL PROCEEDING message when the number is complete and valid. If the called party number received is incomplete, the exchange will send the SETUP ACK and ask the user for additional called party number information.

The Originating Exchange sends the call setup request via Signaling System No. 7 to the Terminating Exchange, which in turn sends a SETUP message at the user-network interface to the Called TE. On receipt of the SETUP message, the Called TE will check the SETUP message to see if it is compatible with the bearer capability, low and high level compatibility specified in the SETUP message.

Next, the Called TE will return with the ALERTING message to confirm compatibility. This generates the alerting tone at the Originating TE. Once the call is answered, the Called TE sends a CONNECT message. The Terminating Exchange acknowledges the CONNECT message with the CONNECT ACK to the answering TE, and also relays this message to the originating party. The Calling TE may or may not return with an optional CONNECT ACK. At this time, the designated B-channel path is connected. This completes the Call Setup phase and the User Data Transfer phase begins.

On completion of the User Data Transfer, one of the parties, either the Calling TE or the Called TE, can

initiate a Call Clear-down. In Figure 10, the Calling TE initiates the Clear-down by sending a DISCONNECT message which includes the cause and location of the Call Clear-down and clears-down the B-channel connection.

In response to the DISCONNECT message, the Originating Exchange will return to the Originating TE a RELEASE message. The Originating TE completes the Call Clear-down phase by sending a RELEASE COMPLETE message.

This Call Clear-down guest is also forwarded by the Originating Exchange to the Terminating Exchange, which in turn sends a DISCONNECT message to the

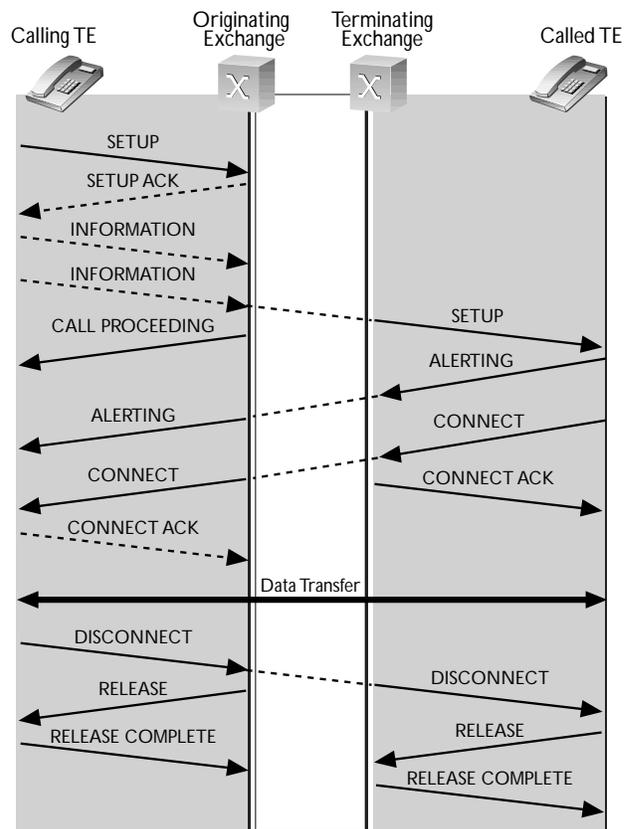


Figure 10 Basic Call Sequence

Called TE. The Called TE responds with the RELEASE to the request. The Terminating Exchange completes the Call Clear-down phase with the RELEASE COMPLETE message.

In the Call Setup phase, if the Called TE is not compatible with the service request, the incoming call must be cleared. The network shall include the cause of failure in the RELEASE message sent to the Originating TE.



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