ISDN STANDARDS EVOLUTION

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The evolution of the Integrated Services Digital Network (ISDN) from a primarily analog telephony network includes the evolution of standards that define the ISDN framework and services, as well as signaling and management functions. The International Telegraph and Telephone Consultative Committee (CCITT) has already defined many of the necessary standards. For example, circuit-switched, packet-switched, and private-line capabilities have been standardized, as well as two types of interfaces to connect customer premises equipment to the network. Standards need to be extended to cover, for instance, the integration of video into the ISDN framework, including the definition of a new wideband customer interface. New technologies such as wideband packet and fiber also need to be considered. This article describes the existing ISDN standards and presents an evolutionary scenario for future standards.

The Integrated Services Digital Network (ISDN) is defined by the International Telegraph and Telephone Consultative Committee (CCITT) as an end-to-end digital network that supports a wide range of services accessed by a limited set of standard multipurpose user-network interfaces. In general, ISDN will evolve from a telephony network as the network implements digital switching and connectivity. Some shortcomings of today's communications network and the services it provides are rectified by the fundamental concepts that ISDN introduces. Today's services are characterized by dedicated access to separate network services such as voice, packet data, digital data, etc. ISDN uses a single user-network interface and attempts to integrate voice, data, and image in this interface. Consequently, a single interface provides integrated access to all services. By necessity the access interface is digital to allow end-to-end digital connectivity. Another important characteristic of ISDN is the separation of information transfer (speech, data, image) from signaling and management functions. Conceptually, therefore, these could be viewed as logically separate channels in the digital-access interface. The ISDN architecture that encompasses these concepts is diagramed in the panel on page 21, and the standards necessary for their implementation are discussed below.

Standards Process and Forums

CCITT Study Group XVIII of Plenary VIII (1980-84) was primarily responsible for ISDN services standards. This group defined the ISDN framework and services in the international forums. The United States was an active participant in this standards-setting process as a member country, represented by a number of telecommunications companies. CCITT Study Group XI was responsible for defining the signaling protocol for both user-network access and the interexchange signaling based on Signaling System No. 7.

Currently the Exchange Carrier Standards Association T1 Committee is the national forum for defining ISDN standards within the United States. In addition, this forum is used as a means of preparing United States contributions to CCITT study groups for international standardization processes. The importance of ISDN has permeated CCITT to the extent that practically all study groups have technical questions dealing with ISDN.

1984 ISDN Standards

This section highlights the overall ISDN framework and the ISDN protocols. The ISDN framework covers the reference configuration, the interface structure, and the bearer services supported. The ISDN protocol addresses both the information transfer and signaling protocols for voice and data. A complete set of ISDN standards is given in CCITT 1984 I Series Recommendations.

The ISDN reference configuration is described in the panel on page 24. The other features of the ISDN framework are described below.

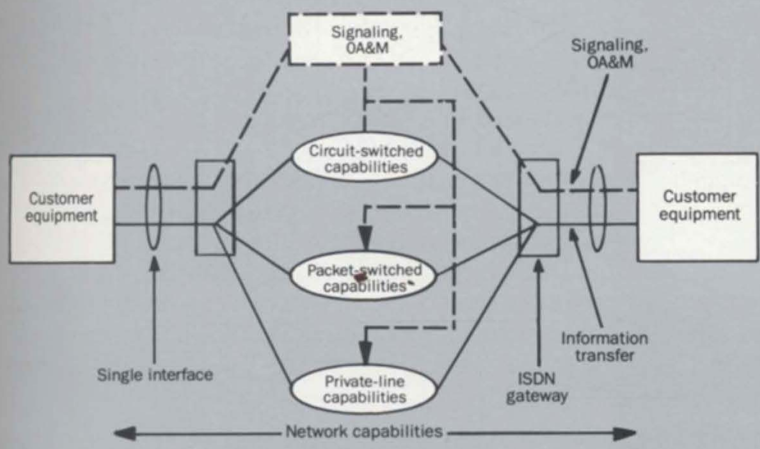
ISDN Interfaces—ISDN supports two standard interfaces to connect customer premises equipment to the network: the primary-rate interface (PRI) and the basic-rate interface (BRI). Both have been defined by CCITT, and both involve the multiplexing of customer information and signaling onto a physical medium such as loop or T carrier facility.

These two interfaces support all currently defined services accessed at transmission rates of up to 1.5 Mb/s (North America) and 2.0 Mb/s (Europe). They are defined to be service independent and can simultaneously support voice and data traffic. The data traffic can be packet or circuit mode. Moreover, switched services as well as permanent leased services "private lines" can be supported concurrently on an interface.

Channel Types—The ISDN architecture supports various information-bearing channel types on the two interfaces BRI and PRI. The D channel is 16 kb/s for the BRI and 64 kb/s for the PRI. The B channel is 64 kb/s for both interfaces.

The D channel supports a packet-mode layered protocol for call-control signaling, user-to-user signaling, and packet data. In addition, it can be used for operations, administration, and maintenance messages. The packet-data access on the D channel is currently based on the CCITT protocol X.25.

The B, H0, H11, and H12 channels support clear access at transmission rates of 64, 384, 1536, and 1920 kb/s respectively, and signaling control and maintenance messages are supported on the separate D channel. These channels are used to access circuit-mode and packet-mode services. ISDN subrates of 8, 16, and 32 kb/s and other common subrates of 2.4, 4.8 kb/s, etc. may be rate-adapted and multiplexed on a B channel.



ISDN Architecture

The ISDN architecture allows transmission of integrated voice, data, and image from customer to customer through a single user-network interface. Information transfer, represented in the diagram by solid lines, is separate from signaling and from operations, administration, and maintenance (OA&M), shown by dashed lines.

The circuit-switched network does not need to be wholly digital; however, end-to-end digital connectivity must be supported for clear digital transmission. ISDN does not preclude the use of analog facilities in the network for speech or voice-band data applications that do not require transparent digital end-to-end capability.

Interface Channel Structures—The North American PRI channel structure is composed of 24 slots. The most common arrangement in North America is 23B + D, where the B and D channels are provided at 64 kb/s. The D channel, when included in the interface, must be in the twenty-fourth slot. The PRI may also contain any combination of B and H0 channels as well as a single H11 channel. The maximum information transfer rate in the PRI is 1.536 Mb/s and the electrical rate is 1.544 Mb/s. The D channel need not be in the same interface as the B channels it controls. One D channel has sufficient capacity to control the B channels of 20 or more interfaces, depending on customer traffic characteristics. The PRI is expected to be used for major traffic sources such as digital PBXs, Local Area Networks (LANs), and computer hosts.

The European version of the PRI is 32 slots. One slot is used for framing and other layer 1 functions; another is always reserved for a D channel. The maximum information transfer rate in the European PRI is 1.920 Mb/s (for 30 slots) and 1.984 Mb/s (for 30 slots and one slot for a D channel). The electrical rate is 2.048 Mb/s.

The BRI channel structure is 2B + D where the B channels are provided at 64 kb/s and the D channel is provided at 16 kb/s. The BRI is expected to be used principally between network or premises switches and terminals.

ISDN Bearer Services—In ISDN a service is defined as a telecommunications capability available to the user. Bearer services are defined as services available at the ISDN customer interface whose information transfer capability invokes layer 1 and possibly layers 2 and 3 protocols. The ISDN bearer services are defined by standardized attributes such as transfer mode (circuit or packet), transfer rate (64, 384, 1536, 1920 kb/s), transfer capability (speech, 3.1-kHz audio), etc.

CCITT has standardized the circuit-mode and packet-mode bearer services. The standardized circuit-mode services are

- 64-kb/s clear
- Speech with μ-law or A-law pulse-code modulation (PCM) coding and the network transport (analog, digital, low bit-rate voice, etc.) provided within voice-quality requirements
- 3.1-kHz audio voice-band data bearer service where the network meets the current modem-quality requirements
- 384-kb/s clear
- 1536-kb/s clear
- 1920-kb/s clear.

Bearer services 4, 5, and 6 above are currently defined only for reserved or permanent nonswitched applications; however, extension of these bearer services to switched capability has been accepted recently and will be included in the subsequent updates of the standards.

The ISDN packet-mode services are currently based on the X.25 protocol at layer 3, with link-access protocols (LAPs) B and D at layer 2. The standardized packet-mode services are

- B channel with LAPB layer 2 and X.25 layer 3
- D channel with LAPD layer 2 and X.25 layer 3.

ISDN Protocol Reference Model and Specification—This model is based on the open system interconnection (OSI) layered communication model (see Figure 1) adopted by the International Standards Organization (ISO). The ISDN protocol reference model generalizes the OSI model and applies it not only to information transfer but also to signaling and maintenance functions. The OSI model needs to be

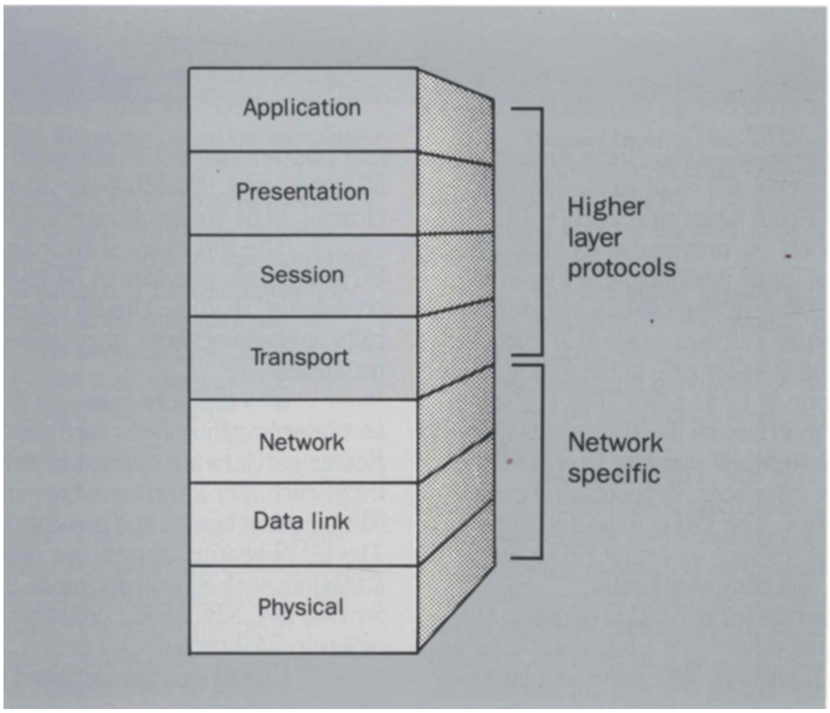


Figure 1. The open system interconnection (OSI) reference model is the basis for the ISDN protocol reference model. The seven layers represent seven distinct groupings of protocol functions. A given layer presents a specific service to layers above it.

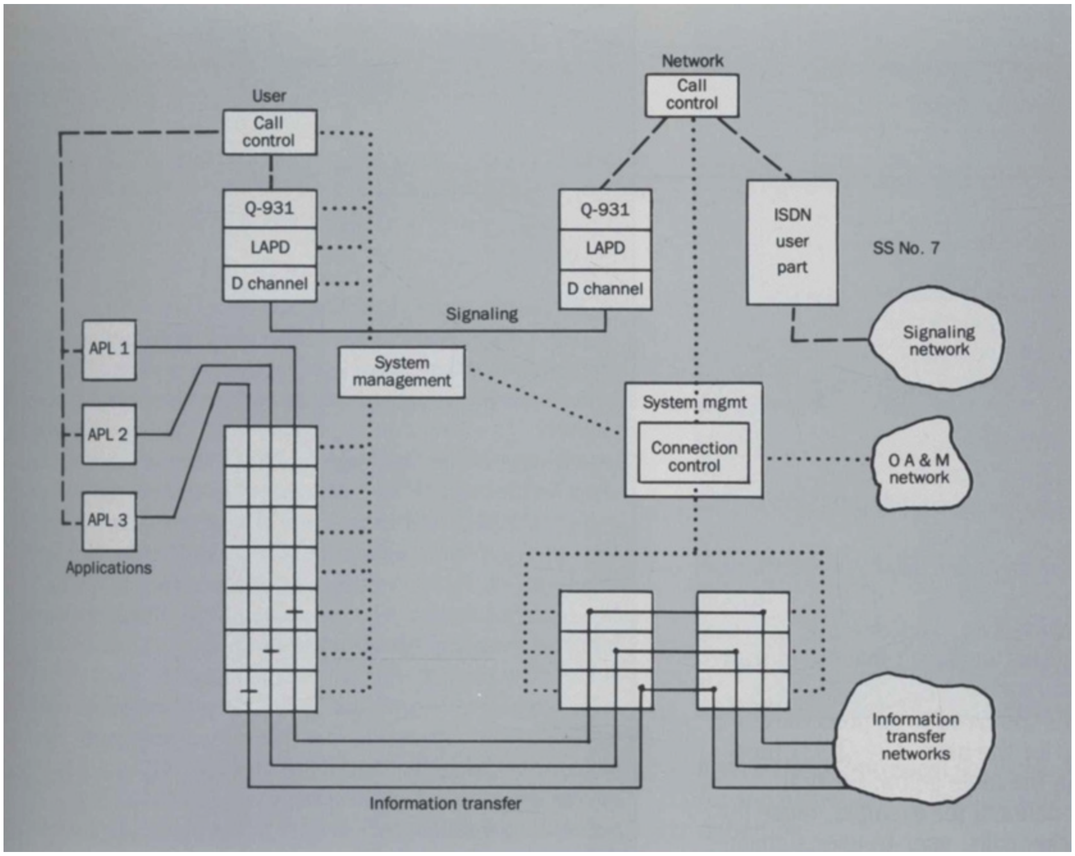


Figure 2. This diagram shows the relationship between signaling and information transfer. The upper part represents the ISDN signaling reference protocol, composed of Q.931 in the user-to-the-exchange network and Signaling System No. 7 in the interexchange network. The bottom part represents information transfer and the seven-layer protocol model. Under the command of the signaling channel, network resources are made available in the information transfer network through the call control and connection control capabilities of the network.

interpreted carefully and future modifications adopted to address several new issues the ISDN protocol reference model requires, such as information flow for multimedia calls, renegotiation of connection characteristics, etc. As indicated earlier, information transfer, signaling, and management are functions supported on logically separate channels, and each is governed by a seven-layer ISDN protocol reference model, as shown in Figure 2.

The physical layer protocol supports all the functions supported by the other higher layers. The BRI physical layer interface requires a balanced metallic transmission line for each direction capable of supporting 192 kb/s. This layer provides bit streams to support two B channels at 64 kb/s and a D channel at 16 kb/s. It also provides the maintenance, timing, and synchronization functions and allows the activation/deactivation of terminals connected to the network. The protocol accommodates two modes of operation: point-to-point, in which only one terminal transmitter and one receiver are active at any one time, and point-to-multipoint, in which multiple terminals are active at any one time.

The PRI physical layer requires a standard 1.544-Mb/s interface with Extended Super Frame (ESF) format and Bipolar Eight Zero Substitution (B8ZS) line coding format. (B8ZS is a coding format for maintaining ones density on a PRI physical link.) Each frame is 193 bits and consists of 24 eight-bit time slots and one framing, error checking, and data link bit. The interface provides bit streams to support 24 time slots that can be assigned to a 64-kb/s D channel, 64-kb/s B channel, 384-kb/s H0 channel, or 1536-kb/s H11 channel. The signaling D channel, if present, must be in time slot 24.

Signaling Protocol—The signaling protocol uses the first three layers of the OSI reference model. The physical layer is described above; layers 2 and 3 are described below.

The D channel data link layer (layer 2) protocol is based on the X.25 LAPB layer 2 protocol and is called

LAPD. The LAPD frame format is shown in Figure 3. This protocol provides the following functions:

- Multiple logical links in the D channel
- Detection and recovery of transmission errors
- Flow control
- Sequence numbering and control
- Transparency.

Layer 3 signaling protocol, called Q.931, provides the following functions:

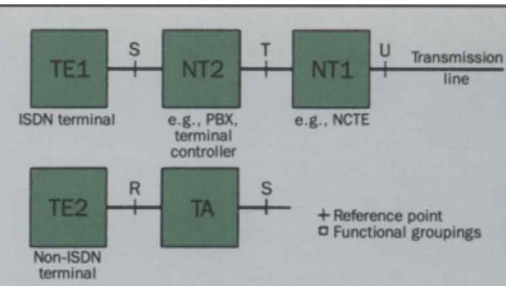
- Signaling relationship for multiple calls between the user and the network
- Call establishment, maintenance, and clearing
- Access protocol for a packet-mode service called user-to-user signaling.

The sequence of messages (referred to as procedures) effects different functions for the user. The Q.931 message structure is shown in the table below. Several procedures are currently defined, for example, those for circuit-switched calls, packet calls, user-to-user signaling.

Q.931 Message Structure

Message	Function
Protocol discriminator	Identifies the packet type
Call reference	Identifies the call
Message type	Identifies the message e.g., DISconnect
Mandatory information elements	E.g., bearer capability in SETUP
Additional information elements	E.g., channel identification

The call reference field in the message identifies the call to which the message pertains. Additional information associated with a call is provided by the information element fields, such as the bearer capability requested: speech, 64-kb/s clear data, etc.



ISDN Reference Configurations

The ISDN reference configuration includes the interface reference points and the functional groups between these reference points in the ISDN user-network interface. The Network Termination 1 (NT1) terminates the loop-transmission electronics at the U reference point, provides for maintenance functions and performance monitoring, and isolates the transmission-line technology from the T interface reference point. The S and T interface reference points are where the ISDN interface specifications apply. The Network Termination 2 (NT2) provides for a terminal controller function (for example, PBX) for a number of ISDN terminals called Terminal Equipment 1 (TE1). NT2 provides for multiplexing and for switching, concentration, and maintenance functions. Non-ISDN terminals are referred to as Terminal Equipment 2 (TE2) and are connected at the interface reference point R. TE2 requires a terminal adaptor (TA) to connect to the ISDN interface reference point S or T. It is envisaged that a number of TAs will be available to allow the connection of non-ISDN terminals to the ISDN network.

Information Transfer Protocol—The information transfer protocol spans all layers of the OSI model. Different protocol layers are required for different applications. For example:

- Voice-application layer 1 provides a coding scheme such as μ-law. All other layers are null.
- Circuit-switched data layer 1 provides for synchronous data transfer at 64, 384, and 1536 kb/s. The end user is free to use any protocol above layer 1. For example, high-level data link control (HDLC) may provide an improved bit error rate or multiple streams of data.
- Packet-switched data layer 1 provides for synchronous data transfer at 16 kb/s (D channel) and 64 kb/s. On the B channel, layer 2 uses the LAPB X.25 protocol. On the D channel, layer 2 uses the LAPD protocol. Layer 3 uses the standard X.25 layer 3 protocol.

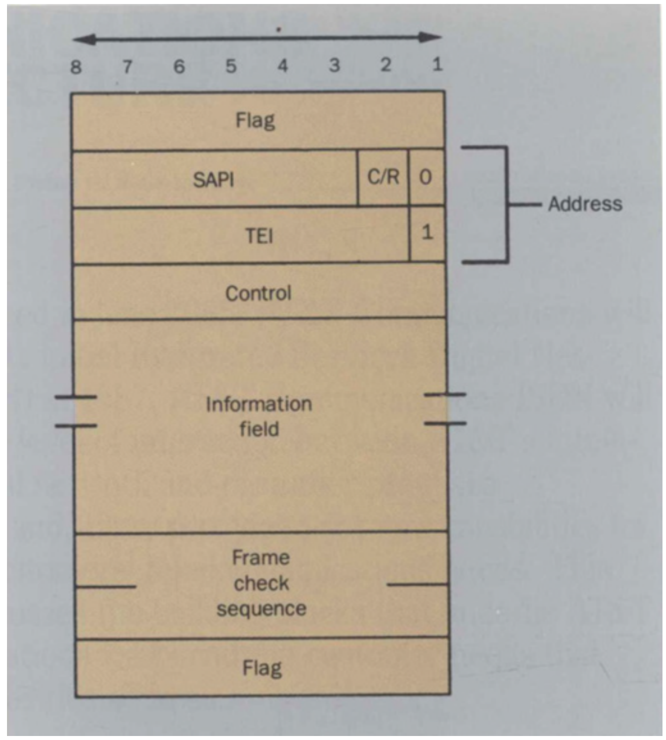


Figure 3. In the LAPD frame format the address field contains a service access point identifier (SAPI) and a terminal endpoint identifier (TEI) to identify the data link connection endpoints. SAPI is the endpoint identifier from layer 2 to layer 3, and TEI identifies a specific connection endpoint within a service access point. Currently SAPI 0 is assigned to call-control procedures, SAPI 63 to management procedures, and SAPI 16 to packet-mode communication.

Future Extensions

The current ISDN CCITT plenary is considering a number of questions in order to clarify the 1984 I Series Recommendations to expand services and network capabilities. Broad areas of work that require standardization are described below.

In services, ISDN needs to address high quality video and its integration into the ISDN framework. This requires a new wideband interface that provides a high bandwidth (30 to 200 Mb/s) capability at the user-to-network interface. The definition of a wideband ISDN interface will allow the provisioning of video capabilities to the end users. In addition, this wideband interface would open the door to the interconnection of LANs to ISDN.

The extended ISDN framework needs to include promising new technologies, such as wideband packet and fiber, currently being tested by communications engineers.

The existing family of ISDN bearer services will likely be enlarged to include new circuit-mode and packet-mode services. These services will create the need for a single call-control mechanism capable of supporting all services (voice, data, and image) in order to avoid costly proliferation of signaling types and procedures for different services.

Another important activity of CCITT during the next few years will be work on protocols for signaling, management, and information transfer. The supplementary services protocol needs to be specified based on the basic call-control capabilities of Q.931. The advantage of a signaling protocol common to all services and connections is a desirable characteristic that requires the definition of signaling for packet-mode services in a logically separate channel. A common signaling protocol would allow the definition of a common packetized protocol for the information transfer channel that supports a number of end-to-end service needs, such as packet data and ultimately packet voice.

The area of management and operations has been identified as a separate logical control capability that uses layers 1 and 2 protocol services. However, the protocols for the higher layers require careful attention and definition.

Finally, in information transfer, protocols for higher layers of the OSI model will facilitate communication between end-user applications and allow diverse coding and formatting protocols to communicate with each other. Another important area of future extension is definition of new protocols for LANs that interconnect naturally with wideband ISDN interfaces without costly gateway devices that degrade performance and reduce throughput.

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