



ISDN Overview

What is ISDN?

The Integrated Services Digital Network (ISDN) is a set of international standards for access to advanced, all-digital public telecommunications networks. The key elements of this definition are:

- Integrated Services
 - Voice
 - Video
 - Image
 - Data
 - Mixed media at a number of standard data rates
- Digital
 - Digital terminal equipment
 - Digital local loops
 - Digital trunks
 - Digital switching
 - Digital signaling
- Network
 - Worldwide, interoperating communications fabric under distributed control using common standards

ISDN standards have been defined by the ITU-T, a branch of the United Nations' International Telecommunications Union (ITU), in the series I and Q recommendations.

Integrated Services . . .

The current telephone network uses a mixture of analog and digital transmission methods and diverse access techniques and standards to provide different services:

- Switched voice telephony
- Centrex
- Dedicated point-to-point data carrier
- Packet-switched data carrier
- Dedicated point-to-point digital carrier

Future telephone networks will also provide full-motion video, voice/video/graphics conferencing, high-speed facsimile, and electronic mail.

ISDN integrates all these services by providing a small set of standard interfaces and access protocols that apply to all services. Because ISDN is an international standard, the same interfaces

and access protocols should be available anywhere in the world, across international boundaries, and among equipment from any set of vendors.

. . . Digital . . .

ISDN provides all of its services over an entirely digital transmission system. In pre-ISDN telephony, only interoffice trunks and certain high-capacity dedicated customer circuits use digital transmission.

ISDN employs digital transmission from the customer-premises equipment (CPE; i.e., telephones, data terminals, fax machines, etc.), through the local access loop, and across the carrier's trunk network. All central- and end-office switching is performed by digital switches, and all signalling (call establishment, "dial tone," ringing, on-hook/off-hook, service requests) occurs through digital protocols.

. . . Network

Finally, ISDN defines a NETWORK, not a loose collection of standards for private-line services. Ultimately, ISDN defines a single worldwide fabric of transmission and switching services operating under a common set of standards, with control distributed among all the various operating companies and national telecommunications authorities.

Components of ISDN

While individual operating companies and ministries will define the specific services, within the ISDN architecture the ITU standards define a number of component parts and functions:

- ISDN CHANNELS
- ACCESS TYPES
- DEVICES
- INTERFACES
- PROTOCOLS

ISDN Channels

A CHANNEL is the basic unit of ISDN service. The ISDN Standards define three basic types of channels:

- Bearer channels (B channels)
- Delta (or "Demand") channels (D channels)
- High-capacity channels (H channels)

B Channel

A B channel is a 64-Kbps unit of clear digital bandwidth. Based on the data rate required to carry one digital voice conversation, a B channel can carry any type of digital information (voice, data, or video) with no restrictions on format or protocol imposed by the ISDN carrier.

D Channel

A D channel is a signalling channel. It carries the information needed to connect or disconnect calls and to negotiate special calling parameters (i.e., automatic number ID, call waiting, data protocol). The D channel can also carry packet-switched data using the X.25 protocol.

The D channel is not a clear channel. It operates according to a well-defined pair of layered protocols:

- Q.921 (LAPD) at the Data Link Layer (Layer 2)
- Q.931 at the upper layers (Layers 3 and above)

The data rate of a D channel varies according to the type of access it serves: a Basic Rate Access D channel operates at 16 Kbps and a Primary Rate Access D channel operates at 64 Kbps.

Signalling on the D Channel

The ISDN D channel carries all signalling between the customer's terminal device and the carrier's end switching office.

Signalling information with end-to-end significance (i.e., which must be received by the terminal device at a call's destination, such as Automatic Calling Number Identification information) travels between the carrier's switching offices on the carrier's common-channel signalling network and on to the destination terminal through the receiving user's D channel.

H Channel

An H channel is a special, high-speed clear channel. H channels, designed primarily for full-motion color video, are not yet in common use. There are currently three kinds of H channel:

- H0 ("H-zero")
- H11 ("H-one-one")
- H12 ("H-one-two")

An H0 channel operates at 384 Kbps (roughly one fourth of a North American Primary Rate Access or one fifth of a European Primary Rate Access). An H11 channel operates at 1.536 Mbps and occupies one whole North American Primary Rate Access. An H12 channel occupies an entire European Primary Rate Access.

ISDN Access Types

ISDN offers two general types of access:

- BASIC RATE ACCESS (BRA)
- PRIMARY RATE ACCESS (PRA)

These differ from one another by the amount of information they can carry.

Basic Rate Access

Basic Rate Access is based on new technology conceived especially for ISDN. Designed to provide service to individual users or small businesses, Basic Rate Access provides two 64-Kbps B channels and one 16-Kbps D channel (referred to as 2B+D). In other words, it provides transmission facilities for one voice conversation (one B channel), one medium-speed data session (the other B channel), and the signalling exchanges needed to make them work (the D channel).

Two B channels at 64 Kbps plus one D channel at 16 Kbps equals 144K bps. The ISDN Basic Rate transmission protocol uses an additional 48 Kbps of bandwidth for maintenance and synchronization, so an ISDN Basic Rate Access actually uses 192 Kbps.

Primary Rate Access

Primary Rate Access, which is based on pre-ISDN digital carrier technology, is designed to provide high-capacity service to large customers for applications such as PBX-to-PBX trunking. There are two kinds of Primary Rate Access: 23B+D and 30B+D. Each depends on the kind of digital carrier available in a given country.

In North America and Japan, 23B+D Primary Rate Access operates at 1.544 Mbps and offers 23 B channels plus 1 64-Kbps D channel (usually located in time-slot 23), or 4 H0 channels, or 1 H11 channel. In most of the rest of the world, 30B+D Primary Rate Access operates at 2.048 Mbps and offers 30 B channels plus 1 64-Kbps D channel (located in time-slot 16), or 5 H0 channels, or 1 H12 channel.

ISDN Devices

In the context of ISDN standards, STANDARD DEVICES refers not to actual hardware, but to standard collections of functions that can usually be performed by individual hardware units. The ISDN Standard Devices are:

- Terminal Equipment (TE)
- Terminal Adapter (TA)
- Network Termination 1 (NT1)
- Network Termination 2 (NT2)
- Exchange Termination (ET)

Terminal Equipment (TE)

A TE is any piece of communicating equipment that complies with the ISDN standards. Examples include: digital telephones, ISDN data terminals, Group IV Fax machines, and ISDN-equipped computers.

In most cases, a TE should be able to provide a full Basic Rate Access (2B+D), although some TEs may use only 1B+D or even only a D channel.

Terminal Adapter (TA)

A TA is a special interface-conversion device that allows communicating devices that don't conform to ISDN standards to communicate over the ISDN.

The most common TAs provide Basic Rate Access and have one RJ-type modular jack for voice and one RS-232 or V.35 connector for data (with each port able to connect to either of the available B channels). Some TAs have a separate data connector for the D channel.

Network Termination (NT1 and NT2)

The NT devices, NT1 and NT2, form the physical and logical boundary between the customer's premises and the carrier's network. NT1 performs the logical interface functions of switching and local-device control (local signalling). NT2 performs the physical interface conversion between the dissimilar customer and network sides of the interface.

In most cases, a single device, such as a PBX or digital multiplexer, performs both physical and logical interface functions. In ISDN terms, such a device is called NT12 ("NT-one-two") or simply NT.

Exchange Termination (ET)

The ET forms the physical and logical boundary between the digital local loop and the carrier's switching office. It performs the same functions at the end office that the NT performs at the customer's premises.

In addition, the ET:

1. Separates the B channels, placing them on the proper interoffice trunks to their ultimate destinations
2. Terminates the signalling path of the customer's D channel, converting any necessary end-to-end signalling from the ISDN D-channel signalling protocol to the carrier's switch-to-switch trunk signalling protocol

ISDN Interfaces (Standard Reference Points)

The ISDN standards specify four distinct interfaces in the customer's connection to the network: R, S, T, and U.

From the standards viewpoint, these are not "real" physical interfaces, but simply STANDARD REFERENCE POINTS where physical interfaces may be necessary. However, in common practice, the names of reference points are used to refer to physical interfaces.

The R Interface

The interface at reference point R is the physical and logical interface between a non-ISDN terminal device and a terminal adapter (TA). The R interface is not really part of the ISDN; it can conform to any of the common telephone or data interface standards.

The S Interface

The interface at reference point S is the physical and logical interface between a TE (or TA) and an NT. The S interface uses four wires and employs a bipolar transmission technique known as Alternate Mark Inversion (AMI).

A special feature of the S interface is the "Short Passive Bus" configuration, which allows up to eight ISDN devices (TE or TA) to contend for packet access to the D channel in a prioritized, round-robin fashion. Only one device at a time can use a given B channel.

The T Interface

The interface at reference point T is the physical and logical interface between NT1 and NT2, whenever the two NTs are implemented as separate pieces of hardware. The specification for the T interface is identical to the specification for the S interface.

In most implementations, NT1 and NT2 exist in the same physical device, so there is no real T interface.

The U Interface

The interface at reference point U is the physical and logical interface between NT (or NT2) and the ISDN carrier's local transmission loop. It is also the legal demarcation between the carrier's loop and the customer's premises.

The U interface is implemented with two wires and uses a special quaternary signal format (i.e., four possible electrical states, with one pulse encoding a predefined combination of 2 bits) called 2B1Q. Quaternary encoding allows the U interface to carry data with a logical bit rate of 192 Kbps over a signal with a physical pulse rate of only 96 Kbps. The slower pulse rate is better suited to the less-predictable environment of the outside-plant loop carrier system.

ISDN Protocols

The ISDN protocols are signalling protocols that govern the exchange of data on the D channel. The two ISDN signalling protocols make up a layered protocol stack, with the Link Access Protocol for the D Channel (LAPD, also known as Q.921) providing Layer 2 data-link services and the Q.931 protocol providing higher-layer services.

LAPD is a simple, bit-oriented data-link protocol similar in structure and operation to HDLC and SDLC. The Q.931 signalling protocol is one of the most complex and feature-rich communication protocols ever designed.

LAPD (Q.921)

The LAPD protocol operates between TE and NT over the D channel of an ISDN S interface. In traditional data communications terms, the TE acts as DTE and the NT acts as DCE.

The unit of LAPD transmission is a FRAME. As in other bit-oriented protocols, frames are demarcated from an idle circuit and from other frames by a FLAG pattern. Like HDLC, LAPD can operate with either a Modulo 8 or a Modulo 128 frame window.

A LAPD frame contains the following fields:

- ADDRESS
- COMMAND/RESPONSE BIT
- CONTROL
- INFORMATION (only in frames carrying higher-layer data)
- FRAME CHECK SEQUENCE

Refer to the INTERVIEW Technical Manual for information about decoding LAPD frames.

LAPD vs. Other Bit-Oriented Protocols

The principal differences between LAPD and other bit-oriented protocols are the structure of the address field and the optional exchange of Sequenced Information (SIO and SI1) frames.

LAPD Address Field

A LAPD address is 16 bits long and contains two parts: the SERVICE ACCESS POINT IDENTIFIER (SAPI) and the TERMINAL ENDPOINT IDENTIFIER (TEI). The SAPI identifies the specific service (i.e., voice, circuit-switched data, network management, etc.) to which the frame refers. The TEI identifies the TE itself, especially in situations such as Primary Rate Access or the Basic Rate Access short passive bus, where a single physical link might terminate at more than one TE.

Sequenced INFORMATION Frames

For applications that require a quicker response to frame errors than the normal MOD 8 or MOD 128 sequence numbering offers, LAPD provides a Sequenced Information service which uses a MOD 2 "frame window." Sequenced Information frames traveling in the same direction alternate between SIO and SI1, reducing the LAPD frame window to one outstanding frame for special situations.

Q.931: The ISDN D-Channel Signalling Protocol

In fulfilling the ISDN goal of Integrated Services over common facilities, the Q.931 D-channel signalling protocol does much of the integrating. The principal job of Q.931 is to carry signalling information about the nature of the ISDN service required for specific calls (or data sessions) between the end user's terminal equipment and the ISDN carrier's end office.

The following is a short list of some critical information the Q.931 protocol MUST convey:

SERVICE INFORMATION

Information on the nature of the service requested for the call: voice, D-channel packet switched data, B-Channel packet switched data, circuit-switched data, electronic mail, facsimile, video, or others

TERMINAL CAPABILITIES

Information on the capabilities of the terminal equipment originating and receiving the call: the type of signalling required (i.e., stimulus signalling for simple digital telephones or functional signalling for full- featured ISDN terminals) and the terminal's ability to handle special features and services [e.g., Automatic Number Identification (ANI), ANI blocking, 800-service, call screening, call forwarding, data rate adaptation, conference calling]

HANDSHAKING

Negotiations between the originating and receiving terminals on the nature of information to be exchanged

In addition to these mandatory features, the Q.931 protocol must support the wide range of OPTIONAL features offered by all possible vendors of ISDN terminal and switching equipment. While ISDN provides a standard architecture and common interfaces, it necessarily leaves much room for invention, innovation, and just plain market differentiation among the products and services that implement the standard.

No single device supports the whole range of possible Q.931 messages. The ITU Q.931 standard provides only a minimally functional subset that allows different manufacturers and ISDN carriers to provide a rich variety of features and services.

To support this variety of features and functions, the Q.931 has several features of its own that make it a uniquely complex protocol:

- OPTIONAL FIELDS
- VARIABLE-LENGTH FIELDS
- CODESET SHIFTING
- PROTOCOL SHIFTING

OPTIONAL FIELDS

Most protocols offer some options in the structure of a message to allow for efficiency in ordinary operation (i.e., short packets for common functions). The Q.931 protocol provides a broad hierarchy of OPTIONAL fields whose appearance in a given message depends on the nature of the service requested, the nature of the terminal device, and sometimes even the specific application being served.

VARIABLE-LENGTH FIELDS

Most optional fields in Q.931 messages can vary in length. A Q.931 message can contain a large amount of information designed simply to allow terminal equipment to find specific fields in the message.

CODESET SHIFTING

Different national ISDNs, equipment vendors, and private carriers require special ways of encoding signalling information. The Q.931 protocol allows for shifting among several CODESETS to accommodate this variation.

PROTOCOL SHIFTING

Because the ISDN standards require that the D channel be able to carry packet-switched data as well as signalling information, the Q.931 protocol contains features that allow shifting

into an entirely different protocol from message to message. These features take the form of a shift indicator that states that the rest of the current message should be interpreted as X.25 (or another alternative protocol).

Q.931 AND SS#7

The Q.931 protocol operates only on the D channel of the ISDN interface between the customer's terminal equipment and the ISDN carrier's Exchange Termination (ET). It does not provide end-to-end signalling over the public telephone network, although certain features of the protocol (such as terminal handshaking) do have end-to-end significance.

The carrier's ET locates those Q.931 messages that have end-to-end significance and translates them onto the carrier's own common-channel signalling network, which uses ITU Common Channel Signalling System Number 7 (SS#7) for signalling among end-office and central-office switches. At a call's destination end office, the ET retranslates end-to-end signalling information and adds it to the local signalling in the Q.931 data stream between the ET and the terminal equipment on the receiving end of the call.

Testing ISDN

Like any digital communications facility, ISDN can be tested at any of several levels. ISDN tests can operate strictly at the physical level, at the level of the logical transmission path, and at the higher levels of logical protocol. All of these tests can provide valuable information in testing ISDN circuits and equipment.

Physical Testing

PAIR QUALIFICATION is the most common reason for testing ISDN at the physical level. ISDN circuits must often use pre-ISDN local-loop facilities designed to carry more-robust analog transmissions. A high-speed digital transmission technique is sensitive to signal degradation from such common local-loop features as bridge taps and echo cancellers.

Before installing ISDN, carrier craftspeople must qualify the wire pairs to handle the ISDN signal. Purely physical parameters such as continuity, impedance, and electrical loading are especially important.

At a slightly higher level, digital tests such as Bit Error Rate and Error-Free Seconds Rate can be used to qualify the local loop.

Protocol Testing

There are four basic reasons for performing protocol tests on ISDN circuits:

- CONFORMANCE TESTING
- INTEROPERABILITY TESTING
- PERFORMANCE TESTING
- TROUBLESHOOTING

Conformance Testing

Conformance testing is designed to prove whether a given device, service, feature, or implementation of ISDN conforms to a specific standard. The standard may be the ITU I- and Q-series references or may be a carrier's or manufacturer's own technical reference.

Conformance tests are usually run automatically in long series of short, very specific tests with pass/fail results provided in stages along the way. Many ISDN providers, especially telecommunications ministries, require conformance testing before a given product or service can be operated on their networks. A given product or service is usually tested once for conformance.

Interoperability Testing

Interoperability testing is designed to prove whether two ISDN products or services (i.e., one vendor's terminal and another vendor's switch) can perform together according to specification. Any ISDN product needs to be tested for interoperability with any other ISDN product with which it may communicate.

A maxim in interoperability testing is that, "The commutative law does not apply." In other words, if A interoperates with B and B interoperates with C, A does not necessarily interoperate with C. ISDN products must be tested for conformance and interoperability at every major revision.

Performance Testing

Performance testing requires the gathering and display of statistics on the numbers of protocol units (i.e., frames, packets, messages) transmitted and received over time between units. The goal of performance testing is to discover deviations (from a specification or from normal operation) that point to underlying problems in the terminal or switching equipment or in the operation of the protocols themselves.

For ISDN, degrading performance of the D channel protocols (such as longer and longer Call Setup times) can indicate a number of protocol problems that ranges from user error at the terminal to traffic overloading on the carrier's network. Degrading data communications performance on a B channel might point to a failure to negotiate Calling parameters on the D channel.

In general, performance testing uncovers operational problems that might otherwise pass interoperability testing.

Troubleshooting

Once the user has determined that a problem has occurred on a circuit, troubleshooting finds the problem's cause. For ISDN circuits to date, the principal cause of circuit problems has been user error.

ISDN defines many new ways of performing familiar tasks (e.g., making a telephone call). Practices that were once common sense can now cause protocol problems.

Failure of terminal and switching equipment to interoperate properly despite passing interoperability tests is another major ISDN worry, especially in end-to-end signalling between similar but not identical terminals.

ISDN also adds a new layer of complexity to straightforward protocol testing of data communications over the B channels. Users must now look for subtle effects of D-channel Call Setup procedures, such as failure to complete the call over the D channel before link startup begins on the B channel.

Multichannel Protocol Monitoring

These descriptions of ISDN problems and testing techniques illustrate the need for multichannel protocol testing on ISDN circuits. Protocols on the D channel control much of what happens on the B channels, and events on the B channels can highlight protocol problems on the D channel.

In order to test ISDN properly, a protocol analyzer must be able to monitor at least the D channel and one of the B channels simultaneously. It should also be able to correlate events in time on the separate channels.

Monitoring and Emulation

An ISDN protocol analyzer should also be able to monitor on one channel and emulate on another.

Monitoring a B channel while simulating a Call Setup on the D channel allows an operator to see the intended (or unintended) results of D-channel actions on the B channel under control. Monitoring the D channel while emulating on a B channel can illustrate important signalling events, such as how the D channel responds to an abnormal termination on the B channel.

Multichannel Emulation

Emulating a switch or terminal device on both the D channel and a B channel allows the protocol analyzer to control an ISDN communication completely, both to verify normal operation and to test the effects of abnormal conditions. All conformance and interoperability testing of ISDN protocols should be performed as dual-channel emulations.

Additional Information

This document only gives a general overview of Integrated Systems Digital Networks. For more detailed information on ISDN standards and technologies, see the documents available from the [International Telecommunications Union \(ITU\)](#). For information on specific implementations, consult the manufacturers' or carriers' reference documents and technical advisories.
