ISDN

Currently, most control and industrial operations are carried out using remote data transmission schemes. Because the integrated services digital network (ISDN) has a digital nature and protocol architecture, ISDN-based secure transmission processing offers an excellent choice for industrial controls, teleconferencing, and distributed processing. Furthermore, several design and control environments require network-based virtual and design centers. Moreover, with emerging technologies such as primary rate interface (PRI) ISDN, the bandwidth of data transmission can be adjusted dynamically using bandwidth-on-demand bonding schemes.

In this article, we discuss the scope of digital switching with reference to data communications and networking, advanced bandwidth schemes, data security and encryption schemes, interconnectivity, and associated methodologies. In addition, concepts of bandwidth-on-demand will be introduced.

WHAT IS ISDN?

Integrated services digital network (ISDN) is a high-speed data transmission technology that allows users to simultaneously transfer voice, video, and data at speeds much faster than today's fastest analog modems. ISDN uses the existing phone line and provides up to 128 kbyte/s of bandwidth for information transfer. Compared with a 14.4 kbyte/s analog modem, it becomes clear how much easier ISDN can provide for bandwith-intensive applications—such as uploading or downloading large files, video conferencing, and surfing the World Wide Web. ISDN uses the digital binary language of computers, ones and zeros, to transmit voice, data, and video over existing copper wire telephone lines. By replacing much larger and slower analog signals with faster integrated digital packets, ISDN squeezes much more potential out of the computer and phone line. ISDN also allows us to use a single phone line for data transfer as well as voice or fax calls at the same time. For example, we can talk on the phone and send a fax simultaneously at speeds of up to 64 kbyte/s. If we are not engaged in a voice call, however, the entire bandwidth (128 kbyte/s) can be dedicated to a high-speed data connection for video conferencing or transfer of files to and from a remote database. ISDN uses the same standard phone jack as current technology. It is an inexpensive, convenient, reliable way to speed data communications and provide high-speed access to the Internet.

FUNDAMENTALS OF ISDN TECHNOLOGY

Announced in the early 1980s, ISDN progressed from standards committees to technology trials to successful applications. Using a standard interface, ISDN provides high-speed simultaneous digital transmission of voice, data, and video, which allows for universal connectivity to the public telephone network.

Each ISDN line is made up of 64 kbyte/s separate "channels" that send and receive calls. In addition, it provides a channel that is used primarily for signaling. Standard ISDN basic rate interface (BRI) lines have 2 B-channels, and more powerful ISDN PRI lines have 23 B-channels. Each channel can be used separately for any communications task, including voice calls, faxes, and data transmission. The channels can also be combined for information-intensive applications like video conferencing. There are two basic types of ISDN service:

- Basic rate interface (BRI)—(2 B-channels)
- Primary rate interface (PRI)—(23 B-channels)

Basic Rate Interface (BRI) Technology

ISDN BRI service is the easiest and most inexpensive way to use superfast technology to dramatically increase data transmission capabilities and be able to transmit data or faxes and talk on the phone at the same time. ISDN BRI, also called 2B+D, provides simultaneous integration of voice, data, and video over ordinary twisted-pair telephone wiring. BRI supports two bearer (B) channels at 64 kbyte/s, each for transmission of voice and data. These B-channels can be used individually; two voice or data calls can be made or received simultaneously. The B-channels can be combined into one superfast channel for high bandwidth applications like video conferencing. BRI also has a D-channel for signaling between the ISDN equipment and the phone company at 16 kbyte/s. The D-channel can also be used for packet switched data. With a total communications capacity of 144 kbyte/s, a single ISDN line can transmit information almost 10 times faster than a standard 14.4 kbyte/s modem. BRI provides service to Centrex multiple customers.

BRI Applications. Some of the typical ISDN BRI-based applications include:

- High-speed access to the Internet or online services
- Telecommuting/work at home
- Desktop video conferencing
- Businesses needing the voice capabilities of Centrex and the speed and bandwidth of ISDN

Technical Capabilities. The technical capabilities of ISDN BRI are:

- End-to-end digital transmission over ISDN-compatible network facilities
- Standard interface open systems interconnection (OSI model levels 1–3)
  - D-Channel (OSI L1-L3)
  - B-Channel (OSI L1)
  - Supports up to eight ISDN terminals on a single ISDN BRI line
- Circuit-switched B-channel data at speeds up to 64 kbyte/s
- Standard rate adaption (V.120) for sub-64 kbyte/s speeds
- Packet-switched data over B- or D-channels
- D-channel at 9.6 kbyte/s
- X.25 packet multiplexing over B-channel, for example, multiple virtual D packet sessions on a single B-channel
- Calling party number delivery on incoming calls
- Dynamic service selection over B-channels
- Out-of-band D-channel signaling

Primary Rate Interface (PRI) Technology

ISDN PRI service is well suited to meet the needs of small and large companies. PRI has 23 B-channels with a capacity of 64 kbyte/s, each for simultaneous transmission of voice and data, and one 64 kbyte/s channel that is used only for network management functions.

The 23 B-channels can be used for any mix of voice, virtual private lines, packet-switched data, circuit-switched data, or video. B-channels can be combined for increased bandwidth when higher speeds are required.

ISDN PRI uses four-wire T1 technology to provide reliable, high-speed switched connections to the public network. PRI allows call-by-call selection for access to a variety of communication facilities, potentially reducing trunking requirements by as much as 33%. Used as a tie line, PRI provides feature transparency between like-vendor Centrexes/private brands exchanges (PBXs).

Signaling System 7 (SS7) is the standard that provides the virtual network services for ISDN PRI. It delivers the information used with customized call identification and selection features as well as high performance call-setup features. SS7 is associated with ISDN because it plays an increasingly important role in inter- and intracarrier communications. The portability of 800 numbers among service carriers, for example, is an SS7 application.

PRI Applications. Some of the typical ISDN PRI-based applications include:

- Data, video, and voice network integration
- PBX-to-PBX connectivity for ISDN feature commonality
- PBX-to-Central Office (CO) connectivity for trunking
- Inverse multiplexer-to-inverse multiplexer connectivity for video conferencing
- LAN-to-LAN bridging or routing
- Imaging, for both client/server and computer aided design (CAD) application
- Video conferencing
- Connecting PBX systems to the public switched telephone network (PSTN) for voice transmission
- Connecting cluster controllers to PSTN for data transmission
- Connecting LANs and hosts
- Connecting multiplexers to PSTN

Technical Capabilities. The technical capabilities of ISDN PRI are:

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- D-channel at 9.6 kbyte/s
- X.25 packet multiplexing over B-channel, for example, multiple virtual D packet sessions on a single B-channel
- Calling party number delivery on incoming calls
- Dynamic service selection over B-channels
- Out-of-band D-channel signaling
- A very flexible mechanism for call control, network management, security, and so on

INTERFACE

In the United States, the telephone company will be providing its BRI customers with a U interface. The U interface is a two-wire (single pair) interface from the phone switch. It supports full-duplex data transfer over a single pair of wires; therefore, only a single device can be connected to a U interface. This device is called a network termination 1 (NT1). The situation is different elsewhere in the world, where the phone company is allowed to supply the NT1, and thereby the customer is provided an S/T interface. The NT1 is a relatively simple device that converts the two-wire U interface into four-wire S/T interface. The S/T interface supports multiple devices (up to seven devices can be placed on the S/T bus) while it is still a full-duplex interface; there is now a pair of wires to receive data, and another to transmit data. Today, many devices have NT1s built into their design. This design contains inexpensive and easier-to-install devices, but often reduces flexibility by preventing additional devices from being connected.

Technically, ISDN devices must go through a termination 2 (NT2) device, which converts the T interface into the S interface. (*Note:* The S and T interfaces are electrically equivalent.) Virtually all ISDN devices include an NT2 in their design. The NT2 communicates with terminal equipment and handles the layer 2 and 3 ISDN protocols. Devices most commonly expect either a U interface connection (these have a built-in NT1) or an S/T interface connection. Devices that connect to S/T (or S) interface include ISDN capable telephones and fax machines, video teleconferencing equipment, bridges/routers, and terminal adapters. All devices that are designed for ISDN are designated terminal equipment 1 (TE1). All other communications devices that are not ISDN capable, but have a standard telephone interface (also called the R interface), including ordinary analog telephones, fax machines, and modems, are designated terminal equipment 2 (TE2). A terminal adapter (TA) connects a TE2 to an ISDN S/T bus.

Going one step in the opposite direction takes us inside the telephone switch. Remember that the U interface connects the switch to the customer premises equipment. This local loop connection is called line termination (LT function). The connection to other switches within the phone network is called exchange termination (ET function). The LT function communicates via the V interface.

Layer 1—Physical Layer

The U interface for BRI is a two-wire, 160 kbyte/s digital connection. Echo cancellation is used to reduce noise, and data encoding schemes (2B1Q in North America, 4B3T in Europe) permit this relatively high data rate over ordinary single pair local loops.

2B1Q. 2B1Q (2 binary 1 quaternary) is the most common signaling method on U interfaces. This protocol is defined in detail in 1988 ANSI spec T1.601. In summary, 2B1Q provides:

- Two bits per baud
- Transfer rate of 160 kbyte/s
- Baud rate of 80 kbaud/s

Bits	Quaternary Symbol	Voltage Level
00	−3	−2.5
01	−1	−0.833
10	+3	+2.5
11	+1	+0.833

This means that the input voltage level can be one of four levels. (*Note:* Zero volts is not a valid voltage under this scheme.) These levels are called quaternaries. Each quaternary represents 2 data bits, since there are four possible ways to present 2 bits, as in the table above.

Frame Format. Each U interface frame is 240 bits long. At the prescribed data rate of 160 kbyte/s, each frame is therefore 1.5 ms long. Each frame consists of:

- Frame overhead—16 kbyte/s
- D-channel—16 kbyte/s
- 2 B-channels at 64 kbyte/s—128 kbyte/s

Sync	12* (B_1 + B_2 + D)	Maintenance
18 bits	216 bits	6 bits

- The sync field consists of nine quaternaries (2 bits each) in the pattern +3 +3 −3 −3 −3 +3 −3 +3 −3.
- (B1 + B2 + D) is 18 bits of data consisting of 8 bits from the first B-channel, 8 bits from the second B-channel, and 2 bits of D-channel data.
- The maintenance field contains cyclic redundancy check (CRC) information, block error detection flags, and "embedded operator commands" used for loopback testing without disrupting user data.

Data are transmitted in a superframe consisting of eight 240 bit frames for a total of 1920 bits (240 octets). The sync field of the first frame in the superframe is inverted (i.e., −3 −3 +3 +3 +3 +3 +3 −3 +3).

Layer 2—Data Link Layer

The ISDN data link layer is specified by the ITU Q-series documents Q.920 through Q.923. All of the signaling on the D-channel is defined in the Q.921 specifications.

LAP-D. Link Access Protocol–D-channel (LAP-D) is the layer 2 protocol used. This is almost identical to the X.25 LAP-B protocol. Here is the structure of a LAP-D frame:

Flag	Address	Control	Information	CRC	Flag

Flag (1 octet)—this is always $7E_{16}$ ($0111\ 1110_2$).

Address (2 octets)

1	2	3	4	5	6	7	8
SAPI (6 bits)						C/R	EAO
TEI (7 bits)							EA1

SAPI (service access point identifier), 6 bits.

C/R (command/response) bit indicates if the frame is a command or a response.

EAO (address extension) bit indicates whether this is the final octet of the address or not.

TEI (terminal endpoint identifier) 7-bit device identifier.

EAI (address extension) bit, same as EAO.

Control (2 octets)—the frame level control field indicates the frame types (information, supervisory, or unnumbered) and sequence numbers [N(r) and N(s)] as required.

Information—layer 3 protocol information and user data.

CRC (2 octets)—cyclic redundancy check is a low-level test for bit errors on the user data.

Flag (1 octet)—this is always $7E_{16}$ ($0111\ 1110_2$).

SAPI. Service access point identifier (SAPI) is a 6 bit field that identifies the point where layer 2 provides service to layer 3.

SAPI0	Description
0	Call control procedures
1	Packet mode using Q.931 call procedure
16	Packet mode communications procedures
32–47	Reserved for national use
63	Management procedures
127	Reserved for future use

TEIs. Terminated endpoint identifiers (TEIs) are unique IDs given to each (TE) on an ISDN S/T bus. This identifier can be dynamic; the value may be assigned statistically when the TE is installed or dynamically when activated.

TEI	Description
0–63	Fixed TEI assignment
64–126	Dynamic TEI assignment (assigned by the switch)
127	Broadcast to all devices

Establishing the Link Layer. The layer 2 establishment process is very similar to the X.25 LAP-B setup.

1. The TE (terminal endpoint) and the network initially exchange receive ready (RR) frames, listening for someone to initiate a connection.
2. The TE sends an unnumbered information (UI) frame with a SAPI of 63 (management procedure, query network) and TEI of 127 (broadcast).
3. The network assigns an available TEI (in the range 64–126).
4. The TE sends a set asynchronous balanced mode (SABME) frame with a SAPI of 0 (call control, used to initiate a SETUP) and a TEI of the value assigned by the network.
5. The network responds with an unnumbered acknowledgment (UA), SAPI = 0, TEI = assigned.

At this point, the connection is ready for a layer 3 setup.

Layer 3—Network Layer

The ISDN network layer is also specified by the ITU Q-series documents Q.930 through Q.939. Layer 3 is used to establish, maintain, and terminate logical network connections between two devices.

SPIDs. Service profile IDs (SPIDs) are used to identify what services and features the telco switch provides to the attached ISDN device. SPIDs are optional; when they are used, they are accessed only at call setup time. The format of the SPID is usually the 10 digit phone number of the ISDN line, and a suffix that is sometimes used to identify features on the line. If an ISDN line requires a SPID, but is not correctly supplied, then layer 2 initialization will take place but layer 3 will not, and the device will not be able to place or accept calls.

Information Field Structure. The information field is a variable length field that contains the Q.931 protocol data.

Information field							
1	2	3	4	5	6	7	8
Protocol discriminator							
0	0	0	0	Length of CRV			
0	Message Type						
Mandatory and optional information elements (variable)							

These are the fields in a Q.931 header:

Protocol discriminator (1 octet) identifies the layer 3 protocol. If this is a Q.931 header, this value is always 0816.

Length (1 octet) indicates the length of the next field, the CRV.

Call reference value (CRV) (1 or 2 octets) is used to uniquely identify each call on the user–network interface. This value is assigned at the beginning of a call, and this value becomes available for another call when the call is cleared.

Message type (1 octet) identifies the message type (e.g., SETUP, CONNECT). This determines what additional information is required and allowed.

Mandatory and optional information elements (variable length) are options that are set depending on the message type.

Layer 3 Call Setup. These are the steps that occur when an ISDN call is established. In the following example, there are three points where messages are sent and received: (1) the caller, (2) the ISDN switch, and (3) the receiver.

1. Caller sends a SETUP to the switch.
2. If the SETUP is OK, the switch sends a CALL PROCeeding to the caller, and then a SETUP to the receiver.
3. The receiver gets the SETUP. If it is OK, it then rings the phone and sends an ALERTING message to the switch.
4. The switch forwards the ALERTING message to the caller.
5. When the receiver answers the call, it sends a CONNECT message to the switch.
6. The switch forwards the CONNECT message to the caller.
7. The caller sends a CONNECT ACKnowledge message to the switch.
8. The switch forwards the CONNECT ACKnowledge message to the receiver.
9. Complete. The connection is now up.

Dynamic Allocation of B-Channels in a PRI. For practical purposes, combining multiple channels in a PRI for large videoconferences, data transfers, and the like is most often programmed into the digital switch serving the location. However, new bandwidth-on-demand controllers have begun to enable a network manager to combine larger bandwidths in real time to meet specific needs. They can also monitor quality and traffic on both corporate leased-lines and ISDN networks and perform dynamic allocation of B-channels to relieve bottlenecks or backup error-prone or damaged lines.

CONNECTING TO ISDN

There are three ways ISDN can be "delivered" from an ISDN-ready digital switch:

Through a Direct BRI Connection from an ISDN Switch. One or more standard BRI (2B+D) connections can be used to link a company directly to an ISDN-ready switch in a central office. These lines can connect directly to ISDN equipment in a small office or residence or can be connected through an outside connection.

Through ISDN Centrex Service. One or more BRIs can also be linked to ISDN Centrex service. This arrangement offers several advantages for an individual or company. Since the ISDN switch functions as the switching system, the company does not have to own or maintain a PBX or key system. It also offers a low-cost, virtually unlimited growth path.

Through a PRI Connection. A PRI delivers 23 B-channels plus one D-channel from the telephone company to the PBX or other control device, which then distributes the B-channels as needed throughout an organization. How this configuration is set up can vary greatly. Users with heavy data traffic, for example, might configure the connection through an ISDN router, multiplexer, or controller rather than PBX, reducing the chance of congestion through the switch.

ISDN AS A NETWORK CONTROLLER

ISDN offers a command-and-command structure that can actually mold the public phone network to individual need. In effect, the D-channel command language can transform the network itself into:

1. A virtual PBX that has no boundaries, creating what is truly a virtual office
2. An automatic call distributor, or more accurately a call optimizer, that logically directs incoming calls to agents worldwide
3. A user-controlled link between computers and voice applications anywhere

There are several companies today offering computer-based systems that allow users to communicate with the telephone network in the actual command language used by the network itself. The practical result is that companies with many offices statewide or even nationwide can link them all into a single, responsive telephone center. Calls can be routed to the best person, regardless of location. At the same time, calls to a local office where everyone is busy can be seamlessly forwarded to the nearest site with someone available, or even to agents working at home. A distributed call center gives users an enormous ability to shape and manage the network itself through the D-channel. A regular customer, for example, can be routed to a specific sales agent, while someone needing specialized assistance, as entered in initial prompts, can be directed to an appropriate specialist. Distributed calls centers can also balance work loads, centralize after-hour calling, and work around service interruptions at any site. A range of customer options can program call redirection.

THE POWER OF PACKET SWITCHING

Many users need to be continually connected when they are working from home. They require e-mail notification so they can quickly respond. They need regular updates of changing information such as stock quotes or news headlines. Or, they want to be available for an on-line conference that might be initiated by co-workers at another location. *Always On/Dynamic ISDN* (AO/DI) satisfies these requirements by providing a continual connection to the corporate network (Intranet) or Internet for telecommuters, remote workers, and independent professionals who require *Always On* connectivity for e-mail and data. Building on the feature-rich ISDN platform, which permits simultaneous voice, data, video, and e-mail on a single ISDN connection, D-channel *Always On* offers a cost-effective way of maintaining a real-time link without having a "dial-up" connection to the corporate network or Internet service provider (ISP). *Always On/Dynamic ISDN* offers the best of all worlds—an *Always On* digital platform with scalable connections that is paid for only as it is used.

How *Always On* Works

Always On uses the packet data capability that is an integral part of the ISDN international standard. Over the D (signaling) channel of the ISDN line, the user establishes a packet connection (virtual circuit) to a remote local area network (LAN) or an ISP. A user creates this bidirectional connection when logging on to a work-at-home computer and e-mail package. Once the connection is established, the user is on-line and can exchange information (packets) with a remote network as required, for example, to send and receive e-mail.

This packet connection can operate at 9.6 kbyte/s and if a higher bandwith is required, a circuit-switched connection (telephone call) is placed using one or both of the ISDN B-channels. This connection can be made automatically without user intervention, and permits data to move at speeds up to 128 kbyte/s (512 kbyte/s with compression). Once the data transfer is complete, the circuit-switched connection is dropped and the user remains on-line via the D-channel. For example, a user who receives an e-mail message with a large or lengthy file attachment employs this application. The initial notification of the e-mail will come via the D-channel. To transfer the large attached file, a B-channel connection is initiated automatically. When the file transfer is complete, the B-channel(s) call(s) end(s).

Network Congestion

When a user dials in the Internet or Intranet via an analog modem, a set of telephone network resources are reserved for that user's exclusive use during the call, whether or not any data are being transmitted. Those facilities include *talk paths* within the telephone switches at the originating and terminating ends of the call, *trunks* that interconnect the telephone switches, a port at the ISP or corporate location that the user has called, and, of course, the user's own phone line.

With ISDN and *Always On* the packet network maintains a set of pointers directing the flow of packets to and from the user. However, no other network resources are used except when data are actually being transmitted; thus, the network can easily support many simultaneous users with the same facilities. The user can actually use two B-channels for other telephone calls while the Internet or Intranet connection is maintained over the D-channel. Many *Always On* users can be simultaneously funneled into the same port at the ISP or corporate location.

Standards

The D-channel packet capability is defined in the international standards governing ISDN. Packets are formatted according to X.25, another international standard. The point-to-point protocol (PPP) and the multilink point-to-point protocol (ML-PPP), which are in widespread use today for Internet access and remote dial-up, are also used with *Always On.* Moreover, the newer bandwidth allocation control protocol (BACP) will also work with *Always On.* In addition, Internet protocol (IP), IPX, and NetBEUI can also operate with *Always On.* The user's ISDN terminal adapter must have an X.25 packet capability and the Internet/Intranet location into which the user is dialing must have a network connection to the packet network in order for the user to establish the *Always On* link.

A Concise History of Packet Switching

Defined in the early 1970s, X.25 packet-switch protocols are accepted as a worldwide communications standard. Information is divided into small packets, each of which contains a complete address as well as codes to put it in proper sequence with other packets being sent. A packet assembler/disassembler (PAD) at the sending end accomplishes this packetizing. At the receiving end, another PAD accepts the transmission, puts it in correct order (packets can travel many routes through the network and may not arrive in the order they were sent), and forwards it intact, in proper sequence, to its destination.

X.25 Packet Switching

Through X.25 interconnections, it is possible to link directly to services or locations on packet networks around the world. Since the X.25 protocol was originally designed for often noisy and interference-prone analog lines, it also performs a broad range of error-checking and error-correction functions. If any packet is not received correctly, the receiving PAD signals for retransmission until the packet comes through correctly. The result is exceptional accuracy through lines that were, and in many areas of the world still are, less than perfect for data transmission.

A Virtual Transaction Network

In effect, ISDN with X.25 D-channel packet switching offers the benefits of a private network, yet uses standard telephone lines and the public telephone network. These advantages are being put to use in a growing number of applications.

- A credit card service company has linked thousands of point-of-sale card readers to its computerized database for credit card authorization and transaction processing. Credit processing time has been reduced from an average of more than 30 s to less than 2 s. Credit processing costs have been reduced to less than a penny per transaction.
- Several major oil companies have linked gas pumps, cash registers, and even vending machines into nationwide data networks. Central computers authorize credit purchases, control inventory, and schedule just-in-time replenishment of everything from gasoline and oil to candy and potato chips.
- A number of health maintenance organizations use point-of-sale card readers and ISDN with X.25 D-channel packet switching telephone lines to authorize medical insurance benefits and issue payment requests to a range of healthcare insurers.
- Many state agencies are using food stamp credit to reduce the probability of fraud in the use and collection of paper food stamps. A magnetic card is inserted into the standard card-swipe terminals now appearing in many supermarkets. They quickly authorize a purchase and automatically deduct the amount from the cardholder's account.
- A growing number of banks are now linking remote automatic teller machines to a central computer through ISDN with X.25 D-channels packet switching. The D-channel connections eliminate the need for dedicated lines to the ATM and make it economical to serve many more locations.
- Several state lottery agencies are experimenting with ISDN-based approaches to playing the state lottery and a number of games. The attraction of ISDN with X.25 D-channel packet switching is that it uses existing telephone lines and thus reduces the current dependence on dedicated connections to these statewide systems. It would make lottery terminals much more widely available, to almost any location that had forms of telemetry.

Note that in many of these applications the ISDN call sets up a connection in milliseconds. Therefore, the use of a dialed modem on an ordinary telephone line is simply not practical because call-by-call connection times are far longer than a customer is willing to wait.

Putting ISDN to Work

Currently, many central office switches have been upgraded to either AT&T 5ESS or Nortel DMS-100 systems, both designed specifically for full range digital services such as ISDN. In the few areas where a digital switch has not been installed yet, ISDN can still be made available through a special remote arrangement. The end result is that many customers can now get ISDN BRI. Telephone companies also give seamless connections to the long-distance ISDN services of the major interchange carriers (IECs) such as AT&T, MCI, or Sprint, just as they do for all types of voice (and many data) services. Many of these IECs offer access to their own ISDN PRI services as well.

For international applications, many European and Pacific Rim countries offer ISDN connections to overseas commercial centers, and several of these systems are actively used by customers and hubs for overseas networks. Worldwide ISDN interconnections are available through major IECs, with local connections provided by regional telephone companies.

While some limitations do still remain, enormous progress has been made in nationwide availability and transportability of ISDN. One problem, which is quickly being solved, is that present equipment working on one particular carrier's ISDN service may not function properly on ISDN from another source. The reasons for this problem, and the evolving solution, are discussed in the following section.

National ISDN

The problem of lack of national standards has received ample attention and is being corrected. In February 1991, Bell Communications Research (Bellcore) issued a technical specification for what is called National ISDN. Planned in three phases, National ISDN attempts to standardize the ISDN services offered by the seven regional operating companies and serves as recommendation to other communications companies in the United States. National ISDN-1 was finalized and adopted by the large Bell companies late in 1996 and early 1997. Its major thrust is the promotion of terminal probability—so those customers who move can take their ISDN equipment with them and be assured it will work at the new ISDN location. Switch interoperability ensures that various ISDN network service providers will all communicate seamlessly via a standard signaling language.

Several interchange carriers, however, such as AT&T, MCI, and Sprint do not adhere exclusively to these recommendations, since National ISDN-1 specifications do not include a number of features and equipment connections that these companies believe are more important. They all offer separate versions of what is generically called *Custom ISDN N-1.* In many cases, telephone, terminals and other devices for these services do work with the ISDN systems offered by regional and other carriers.

The Movement Toward Worldwide Unity

Nevertheless, much of the difficulty of interconnections is being overcome by the telephone companies, and by digital switch and ISDN equipment manufacturers. Specifications for National ISDN-2 and ISDN-3 have also been defined and were targeted for nationwide implementation in the 1998–1999 time frame. These versions, which progressively add service and equipment capabilities, should ultimately make all ISDN services in the United States closely compatible. In addition, the open standards environment will spur the creation of an enormous variety of services and equipment at lower costs.

The availability of local ISDN BRI and PRI services is growing rapidly throughout the nation. Full digitization of many regional networks has been scheduled, and ISDN interconnections to the backbone networks of the IECs are now proceeding at a rapid pace. It is also possible today to establish ISDN-compatible data links to out-of-state locations not served by ISDN, by using Switched 56 services. The major interexchange carriers, all regional operating companies, and many specialized international carriers offer Switched 56 services. These are single-channel, dialed, data-only connections, capable of speeds up to 56 kbyte/s. Virtually all are connected to the interexchange carriers nationwide digital networks.

ISDN EQUIPMENT

Now that we have looked at some of the more popular applications of ISDN, we will look at what types of equipment best implements these applications, including NT1s, TAs, NICs, bridges, and routers.

NT1s

ISDN abides by a set of standards that define the layers of contact between the central office and the user's equipment. Each point of contact has a specific function and communicates using a different layer of protocols according to the needs of the user's equipment. The different points are as follows: NT1, NT2, TE1, and TE2. NT1 represents the actual termination of the ISDN circuit to the site and handles the communication to the telephone switch for the devices that it connects via TDM. That is why a device accordingly called a network termination (NT1) must reside between the switch interface (called the U interface) and each ISDN-compatible equipment interface. This interface is called an S interface for equipment such as TAs and/or a T interface for other switching devices such as PBXs; often both are implemented NT1 units, hence the S/T label of the interface. Other devices that do not abide by the ISDN standards, such as analog phones, can be accounted for by another interface (R interface) that is not usually implemented into simple NT1 units but is commonly incorporated into small office/home office (SOHO) oriented ISDN devices or more complex NT1 devices.

NT1 units typically connect ISDN-compatible devices to the ISDN line. More complex NT1 units connect noncompatible devices such as analog phones and fax machines as well as ISDN-compatible devices. NT1 units can be purchased as external devices or can be purchased as built-in components to ISDN equipment being connected. Every ISDN component needs an NT1 to operate. There are advantages and a disadvantage to having a built-in NT1 unit. The built-in NT1s are usually less expensive than external ones and the user does not have to deal with finding a place to put it. The simplest external NT1s are usually about two-thirds the size of a standard modem, and they cost around $100 to $150. The disadvantage of internal NT1s is that the user must leave the equipment powered up to use the other devices connected to the NT1 device. This often involves leaving the entire computer running, so it can power the TA card, and the TA card can power its NT1, so the phone connected to the NT1 can operate. This is often unacceptable to companies trying to conserve on electricity bills and equipment wear. Most vendors offer their equipment with NT1 units, so the user has a choice.

ISDN TAs and NICs

ISDN TAs work essentially the same as standard modems. They look the same physically and have the same applications for data transfer. Like standard modems, there are all types of TAs: internal, external, and PC cards (PCMCIA).

One thing, however, must be considered when deciding to go with an external TA, even though it is not as much of a problem as it used to be. The user equipment must have the serial chip set that can handle the higher speeds of ISDN. Nothing less than a 16550UART will do for full ISDN speeds via external TAs. If possible, having an advanced serial card and driver is ideal to eliminate any problems and take full advantage of the ISDN speeds. However, most PC 486, Mac 68040, and later models will handle the serial speeds without any problems.

When choosing a modem, it is important to make certain that the modem supports 2 B-channel operation and the vendor supplies drivers that will allocate the B-channels. It is imperative to allocate the channels so that the user can take advantage of ISDN's channel allocation features. Some older modems do not allow use of the second B-channel.

ISDN NICs carry many of the same attributes as TAs but function as regular LAN cards would on a 10BASE-T network. Just as a TA appears as another modem to the application, an ISDN NIC fools its application into believing that it is talking to a regular NIC. The vendor usually provides special NDIS or ODI drivers for the ISDN NIC that replace traditional ones used for Ethernet. These drivers handle the ISDN functions of the card as well as the translations from the network to the next layer of protocols such as IPX and IP. ISDN NICs are essentially an interface to another network, ISDN.

Which one is better? That naturally depends on user needs and implementation. TAs can be made to perform the same functions through software and can serve many other simple roles such as plain terminal connections. NICs are often, but not always, more transparent to the user when initiating and terminating connections and can function as a NIC. TAs are typically more popular than ISDN NICs.

ISDN Bridges

ISDN bridges do just that. They bridge data from LAN to remote LAN transparently to the user, just as if the data were on the destination LAN. Like TAs, ISDN bridges come in internal and external varieties and offer built-in NT1 unit options. They are essentially TAs or NICs with bridging firmware that will transfer LAN traffic regardless of protocol between remote sites. Bridges are a good choice for sites that run many protocols and operate over relatively short distances. Bridges offer some packet filtering to help reduce traffic but do not filter out most of the packets generated by routers and servers that could keep an expensive long distance link up.

Users must plan carefully before deciding to implement a bridged solution as opposed to routing and choosing which product to use. Many bridges take full advantage of standard ISDN channel allocation protocols and compression algorithms to help manage the connection and minimize the usage of the ISDN line, reducing the cost of operation. It is important to find out which product supports the filtering and line management features that are needed for the network.

ISDN Routers

Among the more complex of the ISDN devices, routers allow remote sites to take full advantage of ISDN link and traffic moving between the various locations. Complex LAN configurations can be made simple and effective using ISDN routers. Packets can be routed and filtered according to protocol and packet type and can be intelligently routed quickly to various sites using either a single BRI connection, multiple BRIs, or PRI connections.

The router vendors have been hard-pressed over the past few years by standards for remote access and LAN-to-LAN routing connections and link management. Standards such as multilink PPP and STAC compression are among the most popular of router solutions. These standards define common protocols for ISDN devices to establish an ISDN link, route specific protocols, allocate bandwidth on demand, and compress data between different vendors' equipment. ISDN interoperability among various vendors has proved to be a nightmare in the past. This is important when scalability is a factor in choosing a routing solution or when third parties are to be integrated into the network solution such as ISPs.

Many of the routers can link remote dial-in users as well as linking LANs to LANs. Many also offer bridging capability for the protocols that they do not route. There are standards for each. As a result of the standards effort, many ISDN routers now offer the most cost-effective solution to linking branch offices that need the bandwidth and low cost. Good ISDN routers will tend to cost more than any of the other ISDN devices already mentioned but will soon pay for themselves in cost of operation when linking central LANs and remote LANs.

Aside from single BRI routers, higher-end solutions are available that work with these lower-end BRI routers. Some vendors offer routers with multiple BRIs with the option to add more. Users must weigh the cost of multiple BRI connections against a PRI and related equipment. Large companies with many remote users and ISPs typically use PRI circuits and routers to best manage many users dialing in from many destinations. PRI is very expensive, but ideal in these situations. For the rest, BRI can be scalable and cost effective if planned right.

ISDN AS THE ONLY LINE OR AS A SECOND LINE

While ISDN is specifically designed to deliver digital connections through existing copper twisted-pair lines, many smaller locations (and many larger ones as well) will have to decide whether or not to use ISDN as the only telephone connection, or to install it as separate, second line.

It is important to know that in the United States, the Federal Communications Commission (FCC) chose to implement ISDN in a way that requires users to supply at their site a network terminating device (NT1) to which the line is connected and which must be powered at the customer site. This means that if the NT1 loses power, the ISDN line will not be usable. Traditional analog telephone service does not require any terminating equipment other than the phone, which usually does not require commercial power and therefore functions even when commercial power is absent. For this reason it is strongly recommended that ISDN be installed as a separate line unless customers agree to be responsible for providing their own power supply in the event of prolonged outage.

The Spectrum of Digital Technologies

ISDN is, in fact, one of a number of emerging technologies designed to exploit the power of the worldwide digital communications network. These technologies include asynchronous transfer mode (ATM), switched multimegabit data service (SMDS), and frame relay (all designed for high-speed network access through dedicated, leased lines) as well as ISDN and Switched 56 services (which offer both dedicated and dialed access).

The Unique Value of ISDN

To many users, especially individuals and those in smaller companies, ISDN is by far the most important of these technologies. To literally millions of users, it offers inexpensive dialed service, high-speed data transmission, and the ability to send and receive voice, data, and moving images through the same fully digital connections. Communications to most of the major business centers of Europe and the Pacific Rim can now be set up with a simple dialed call.

ISDN Closes Digital Loop

The real promise of ISDN, as noted earlier, is in replacing the dialed analog collection of the past with the dialed digital connections of the future. The ramifications for those who use computers are many.

- Digital-to-analog conversions will go away. Modems to covert the digital signals of PCs, LANs, and other devices to the analog signals needed for the analog network will be replaced. Instead, high-speed pulses will flow directly from one digital device to another through a totally digital network.
- Many digital connections will become dialed, not dedicated. It will no longer be necessary to lease expensive dedicated digital lines simply to link a high-speed data device to the network. The deciding factor will be the economics of how fast the line must be and how frequently it is used.
- Endless connectivity possibilities will open. It will become possible to link individuals, networks, and systems that are neither economical nor practical to link today.

Some obvious examples of these new applications are telecommuting, LAN-to-LAN or LAN-to-host interconnection, high-speed (greater than 28.8 kbyte/s modems) Internet access, remote image sharing and retrieval; inexpensive teleconferencing, combined voice and document or image collaborations, high-speed access to remote files or databases, and accelerated links to remote libraries and research systems.

While most of these applications are technically possible today without ISDN, very few are practical, either because costs are too high or transmission speeds are too slow. The purpose of this article, in fact, is to look at these innovative uses. Many are important breakthroughs, while others are merely helpful conveniences. But all in concert show beyond a doubt that an important new technology has begun to take its place on the stage of teleconferencing.

The Increase of User's Data Speeds

Logarithmic views show how transmission speeds available to individual users have accelerated in the past two decades. Digital speeds should continue to grow, while analog speeds begin to peak.

WORKGROUP CONNECTIVITY

Today, both large and small organizations are choosing ISDN to bring people, offices, and locations together in effective, easy-to-use, communications systems. ISDN, with end-to-end digital connections, offers giant steps forward in speeds up to 128 kbyte/s today, with the quantum leaps of digital data compression still to come. But that, in fact, its just the beginning. As more and more ultra-high-speed channels begin to bind the network together, and the broadband cables that will carry high-definition television begin to reach into more and more areas, the growth of dialed digital transmission speeds available to ISDN users should continue unchecked well into the future.

Telecommuting

Across the nation, legislative mandates are being put in place to reduce the number of cars commuting to and from an office each day. For example, the Clean Air Act affects all large and mid-sized companies, and limits the number of cars in a company parking lot based on number of employees. One immediate answer to this problem is telecommuting.

A Basic ISDN Setup for Home or Office

An important fact to remember is that an ISDN line does not provide its own power. Therefore, an independent power supply is always required.

The idea of ISDN telecommuting is simple: to "transport" as much of the functionality of the office as possible to a remote site through a single ISDN BRI connection. This functionality includes:

- Acceptably high-speed access to the user's LAN and file servers
- Full access to mailboxes, and the ability to send, receive, forward, and annotate both voice and written messages
- Reasonably fast interconnections to other company LANs or hosts, remote systems, and other networks, such as the Internet
- Teleconferenced meetings, or the full-color images of co-workers through a range of rapidly emerging PC video technologies

Note that often these dialed connections can be quite brief, which means that many at-home workers can share the same ISDN channels installed at a network or host, keeping up-front costs reasonable. Moreover, efficient LAN or host access can also be important to someone who is traveling, who is ill and at home, or who is spending the day at another location. With ISDN, they have not only better telephone contact with co-workers and messaging systems, but efficient laptop access to their LAN or file server.

LAN-to-LAN Links

A typical LAN-to-LAN configuration is used, and charges are incurred only when data are sent. One of the most immediately accepted and widely used applications of ISDN is in linking LANs to each other and to the outside world. Information in most local area networks travels through dedicated fiber-optic or coaxial cables at speeds of 10 Mbyte/s to 30 Mbyte/s, which means that, contrary to a common misconception, ISDN was not designated to replace these LANs or bridge them into larger local or wide area networks. Rather, it is ideal for the cost-effective, temporary linking of LANs to each other, to remote hosts, or to individual non-LAN users or locations for the timely transfer of specific information or files. In fact, the growing popularity of these applications has spurred manufacturers to offer comprehensive lines of ISDN LAN-bridging and file-transfer equipment.

Are data rates fast enough? The answer today is a solid yes. Current data transfer rates are typically characterized by users as acceptable; a rating that should improve quickly as B-channel speeds increase in the near future. Higher LAN-to-LAN speeds are also possible now by inverse multiplexing multiple B-channels into bandwidth connections.

A Typical LAN-to-Host Arrangement

Dialed connections offer enormous savings compared with dedicated links, ensuring fast, efficient file transfers. Most transfers of large files today take place through dedicated broad digital connections or on magnetic media physically transported by messengers and overnight couriers. The flexibility of ISDN PRI connections, in contrast, is that it expands a system manager's options. It enables the same dialed B-channels used for individual connections during the day to be combined into higher-speed links for after-hours transfers and from multiple points. Similarly, many remote sites that currently have only analog access content themselves with weekly revisions of pricing and inventory updates, manufacturing schedules, and the like. The time required to transfer these files from a central system to multiple satellite locations through analog connections simply takes too long to make more frequent transmissions practical. Similar limitations exist in many industries. Equity pricing services, for example, often use disks and tapes, messengers, and overnight couriers for weekly price updates to the thousands of trust departments, pension funds, and other money managers they serve.

Remote Telemetry and Security

ISDN connections can also let machines talk to each other. At a leading California biotechnology company, an ISDN system initially installed for LAN-to-LAN connectivity, telecommuting, and other uses now links computers to a growing number of monitoring devices for room and liquid temperature control, fluid disbursements, animal feeding, and the like. For each, the system helps maintain virtually flawless control. Several other companies are also using ISDN for physical security in warehouses, receiving docks, and other similarly vulnerable sites. Both B- and D-channels can be used as inexpensive conduits for remote TV cameras and to monitor locks, alarms, and strategically placed sound, movement, heat, and other sensors.

Two Conversations on the Same Line

As we know, ISDN enables two separate voice conversations to take place, at the same time, through the same single twisted-pair telephone wire that traditionally, in an analog environment, carried only one conversation. What is more, since ISDN delivers two separate channels through the wire, it is also possible to conduct a conversation on one channel and simultaneously use the other for a data device such as a PC or facsimile machine. These multiple conversations could also take place while the speaker or someone else uses the D-channel for a third simultaneous transmission.

The Advantages of ISDN Voice

It is also possible to attach up to eight devices—telephones, computers, faxes, and more—on every BRI connection and to give these devices as many as 64 call appearances of the same telephone number, or virtually any combination of different numbers. This feature alone offers enormous advantages. A few examples will show why:

1. In a busy sales location, several representatives who are frequently out of the office might share a series of numbers on a single ISDN line. Each incoming call can be answered correctly ("Jane Green's office" or "Dan Brown's line"); theoretically as many as 64 representatives served by up to eight telephones, faxes, or PCs require only one ISDN line, not the many lines currently needed.
2. A busy individual might have two or more appearances of a single number on an ISDN telephone, as well as different numbers linked to a PC and/or a fax, so that the appropriate device can answer incoming calls. At any time, a voice conversation on one call appearance can be put on hold, and another voice call made or received on another call appearance. These calls can even be conferenced into a three-way conversation. Yet all of this takes place through a single ISDN, not the three or four phone lines required today.

The Economics of ISDN

In an office equipped with ISDN, two conversations, or PC or fax transmissions, or any combination of these could take place at the same time, and all devices share the same line. Furthermore, multiple data devices such as credit units, PCs, remote sensors, and the like can all contend for and use the packet-switched D-channel at the same time that two conversations take place on the B-channels.

Easy-to-Use Call Management

ISDN also offers better call management. Not only is the range of features extended, but the telephone's liquid-crystal display (LCD) is linked to the ISDN D-channel so that useful telephone functions are no longer buried in a complicated system of double presses and two-second holds.

Rather, they become as quickly available as when pressing a button on an automatically displayed menu. Normal ISDN BRI links include the most widely used features:

1. *Hold.* For anyone who has inadvertently disconnected a caller rather than put them on hold, the easy use of this capability will make it the important tool it should be.
2. *Three-Way Conference.* Adding another voice to the conversation is a powerful feature, yet one rarely used.
3. *Call Transfer.* An important feature frequently used by receptionists and operators, who use it enough to remember, but rarely by anyone else. ISDN makes it almost automatic.

Extended Call Management

For those who take advantage of an ISDN Centrex service, or those in a large organization or campus served by their own comparably equipped digital switch, the range of call management features can be greatly extended. Some of these include:

1. *Call Forwarding.* Forwards calls to a preselected number when the called number is busy, after a preset number of rings, or permanently.
2. *Call Pickup.* Allows an incoming call to be picked up at another station where the line is busy, after a preset number of rings, or permanently.
3. *Directed Call Pickup.* Allows calls to a specific line, to be answered only by another specified line.
4. *Message-Waiting Indicator.* Shows with a light or lamp on the set that a voice message has been received.
5. *Direct Inward Dial to Direct Outward Dial (DID/DOD) Transfer.* Allows a call answered at the Centrex location to be transferred to any other number with the caller staying connected as though the call were only being transferred across an office.

ISDN Telephones

Softkeys offer quick, effortless access to features and functions. The "inspect" button displays additional features. Sometimes called a "virtual key system," Centrex ISDN features make a formidable competitor to premises-based PBX or key systems. The centrex switch becomes, in effect, the PBX serving a location. It offers extended functionality and the potential for unlimited growth and enhancement, with much reduced capital investments and little risk of obsolescence.

When Centrex locations are scattered yet still served by the same central office (a requirement on all Centrex systems), the unifying features of the Centrex combine with the ISDN capabilities to create a powerful and versatile system.

In this case all calls between Centrex stations (voice or data, even if they are located at different addresses) are free, being "in system" or intercom calls. For telecommuters located near their offices, or businesses with multiple locations served by the same telephone company's central office, this capability, which extends big system features to the remote user, is unmatched.

Hi-Fi on the Digital Highway

Throughout the world radio stations now use ISDN for clear, quiet sound transmissions from baseball, basketball, and other games, concerts, news conferences, political conventions, and similar events. At most locations, temporary ISDN lines are installed, although at more venues, permanent ISDN lines have been put in place by both broadcasters and entrepreneurs who leased them to others for major functions. Modern sound studios are also using ISDN for remote recording of announcers' voices, live music, or other components of a firm's video, advertising, or audiovisual presentations. The latest digitizing equipment can compress the highest-quality audio signals (CD quality stereo), which would ordinarily require 1,411,200 bits/s to transmit into bit streams of 56, 64, and 128 kbyte/s. Many studios also download stereo tracks recorded elsewhere for mixing and enhancement on their more sophisticated equipment, or for incorporation into a film or television presentation. Many voiceover and automatic dialog replacement (ADR) sessions are now done with talent and the mixers and directors all in different locations. Today, many voice samplings for dubbing into foreign language films are recorded and then transmitted over ISDN.

ISDN lines and state-of-the-art compression equipment have been used to link singers in San Francisco, Hollywood, and Hawaii into a simple real-time concert. It is believed that the technology opens many possibilities, from remote concerts, talent auditions, and collaborative jam sessions, to telejukeboxes in which customers link their stereo systems to a compact disk library to hear and perhaps even buy new releases or hard-to-find classics.

ISDN in Marketing and Service

Telemarketing call centers and telephone service centers are voice installations that also give representatives access to data stored in a computer. These sites have flourished in the past decade, especially for answering incoming sales calls from advertisements or catalog service calls for parts, repair, or assistance.

Basic Telemarketing

The PBX prompts for an account number and delivers both the call and customer records to the next available agent. Using a range of computers, from small PCs to mainframes, these systems automatically answer each call, prompt the caller for an account number (or read the incoming caller-ID number when available), and simultaneously deliver both the call and the caller's computerized record to the next available agent. ISDN adds a new dimension to these facilities, because through a single telephone connection, ISDN offers not only a voice connection to the caller but a simultaneous high-speed data connection to a computer.

Examples of ISDN applications that can be effectively extended through Switched 56 services are those that:

- Do not depend on voice transmission
- Do not use several channels simultaneously for multimedia transmission
- Do not need data speeds greater than 56 kbyte/s
- Do not depend on the call-by-call intermixing of circuit-switched data
- Do not depend on out-of-band D-channel signaling

NETWORK SECURITY CONCEPTS

ISDN is a public network and, as such, data security mechanisms need to be implemented to make the network secure for the exchange of confidential information. Also, test and evaluation methodologies need to be implemented to properly characterize the level of security that is being implemented. For that reason, high data security applications such as transfer of confidential medical, industrial, commercial, and banking information require private, dedicated network configurations. Due to the large number of applications and lack of standardization, it is very expensive and difficult to implement standard tests and maintenance procedures for private networks. An alternative, less expensive, and more appropriate solution would be to use a public network such as ISDN, with standard security mechanisms and encryption schemes to make it equivalent to a private network. However, end users such as hospitals, laboratories, and other organizations would be ready to accept the public network as secure as the private network only if they can test, evaluate, and characterize those secure schemes themselves. Unfortunately, those standards are not available for ISDN-based data encryption schemes.

Sources of Threats to the Public Switched Network

Recently, several government documents have reported the growing vulnerability of the public switched network (PSN) and the government's concern about maintaining the integrity of the PSN against intruders. Specifically, a report by the President's National Security Telecommunications Advisory Committee (NSTAC) concluded that "until there is confidence that strong, comprehensive security programs are in place, the industry should assume that a motivated and resourceful adversary, in one concerted manipulation of the network software, could degrade at least portions of the PSN and monitor or disrupt the telecommunications serving [government] users." Unfortunately, users of expensive leased lines pay for a false sense of security, since these lines are sometimes subject to the same threats as the PSN. Furthermore, the new open systems telecommunications environment has been characterized as one with: a large number of features; multimedia, multiparty services; partial knowledge of the feature set by service designers; lower skill and knowledge levels of some service creators; multiple execution environments from different vendors; and distributed intelligence. A Bellcore investigation reports that "while the advent of open systems interfaces has assisted the acceptance and international deployment of networking technology, it has also seen a down side in that it has become easier to intrude on networks designed with such open features." The Telecommunications Security Guideline ranks the most significant threats to the PSN as listed in Table 1.

In this research, we are interested, in particular, in how to mitigate the impact of malicious hackers and sabotagers on the public ISDN. Some of the safeguards against malicious hackers are:

1. Install mechanisms that will validate network software and check for and remove malicious software . . .. Encrypt sensitive data or protocol information that may be transmitted by wireless or other unprotected channels.
2. Use security-oriented access technologies such as dial-back modems, dial-in passwords, and validation of incoming calling number against an authorization database.
3. Develop and implement an overall network security architecture. Computers should mediate access to network software through appropriately applied user identification and authentication mechanisms. Biometric, token-based, and third-party authentication systems should be used.

Also, threats to the PSN that could be mitigated by system (or customer) based software include:

1. *Masquerade.* Refers to a user posing as another authorized user. A user will effectively masquerade as another user through replay of data or insertion of data, which appears genuine, into the communication path. This threat can come from outside users accessing the application from the PSN, locally connected users, or system administrators through direct-connected or dial-up control.
2. *Disclosure of Information.* Refers to data disclosed without authorization.
3. *Unauthorized System Access.* Refers to a user accessing system software information. An example of this threat is a user accessing and modifying the password table.
4. *Denial of Service.* Refers to a degraded performance of the application. An example of this threat is a malicious hacker trying to repeatedly log into the application, which might prevent an authorized user from accessing it.
5. *Traffic Analysis..* Refers to a hacker observing traffic in the PSN and makes an inference using the source and destination addresses. This concern can only be addressed by a switch software modification, perhaps through the encryption of the D-channel information. This, if done properly, would maintain the required throughput but render this information useless to a malicious hacker listening on the D-channel. Furthermore, idle times on the lines could be padded in such a way that it would be impossible to discern when the channels are not used. As it is now, there is always some activity (handshaking between the switch and the CPE) on the D-channel even when the corresponding B-channels are idle; therefore the required changes are technically feasible.

Table 1. Most Significant Threats to the Public Switched Network

Threat	Likelihood	Principal Impact on Network
Employees	50%	Availability and integrity
Natural disasters	20%	Availability
Hackers	15%	Availability, integrity, privacy
Sabotage	15%	Availability

One advantage the ISDN has over the PSN is out-of-band signaling versus in-band signaling for network control. In-band signaling, the tones to signal switches could be introduced by users through their telephone instruments to defraud network service providers. ISDN uses out-of-band signaling through the separate D-channel for network control. But, out-of-band signaling in itself does not make ISDN public networks secure from fraud.

A detailed guideline for the eight high-level security requirements includes:

1. *Identification.* Pertains to the process whereby the application system recognizes a user's unique and auditable, but not confidential, identity, such as the user ID.
2. *Authentication.* Refers to the process of verifying the identity claimed by the user. Authentication can be provided by a password or "smart card" and must be kept confidential.
3. *System Access Control.* Refers to allowing access to the applications only to those users who have been identified and authenticated.
4. *Resource Access Control.* Pertains to guaranteeing users only the least privileges required to perform their job function.
5. *Data and System Integrity.* Refers to the reliability of the application and its resources.
6. *Audit.* Refers to a trail for investigating security-relevant events.
7. *Security Administration.* Refers to the tools for managing security-relevant tasks.
8. *Documentation.* Describes how the security features of the application should be provided.

ISDN is a public network and, as such, data security mechanisms need to be implemented to make the network secure for the exchange of confidential information. Also, test and evaluation methodologies need to be implemented to properly characterize the level of security that is being implemented. High data security applications such as transfer of confidential medical, industrial, commercial, and banking information require private, dedicated network configurations. Due to the large number of applications and lack of standardization, it is very expensive and difficult to propose standard tests and maintenance procedures for private networks. An alternative, less expensive, and more appropriate solution would be to use a public network such as ISDN, with standard security mechanisms and encryption schemes to make it equivalent to a private network. However, end users such as hospitals, laboratories, and other organizations would be ready to accept the public network as secure as the private network only if they can test, evaluate, and characterize those secure schemes themselves.

BIBLIOGRAPHY

http://www.bellcore.com/BC.dynjava?ADSIVMWISvcsPDGeneralProductDescription

http://www.bellcore.com/NIC/

http://www.bellcore.com/CILS/

http://www.bellcore.com/ISDN/

http://www.bellcore.com/ISDN/digest.htm

http://www.bellcore.com/ISDN/dcm-1.htm

http://www.bellcore.com/NIC/links.htm

http://www.bellcore.com/BC.dynjava?BTECCatalogCHPGeneralContentHomePage

IRMA BECERRA-FERNANDEZ
SUBBARAO V. WUNNAVA
Florida International University