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Teleservices

High-level services that include computer processing of user data by the communication network.

Telex

A one-way information retrieval service

2B+D

Basic Rate Interface, referring to the two B channels (supporting 64 Kbps) and a single D channel (16 Kbps).

U (Reference Point U)

An ISDN reference model designator corresponding to the full-duplex data signal of the subscriber line.

Videotex

Time-sharing access to databases such as travel, consumer products, and electronic mail.

X.400

The CCITT standard for electronic message handling, known as electronic mail (email).

RJ-45

A modular cable connector standard, utilized with consumer telecommunications equipment, including Sun SPARCstation systems equipped for ISDN connectivity.

S (Reference Point S)

An ISDN reference model designator referring to the interface between the user's ISDN devices and network-related equipment.

SS7 (Signalling System #7)

The protocol scheme utilized by AT&T for internetworking with other communications switches in its own state, outside its service state, and outside its service country

Supplementary Services

Services that work in conjunction with bearer services, extending or adding value to them.

T (Reference Point T)

An ISDN reference model designator that corresponds to the division between the network provider's equipment and that of the user.

T1

A communications service providing leased-line support for 1,544,000 bits/second on twisted copper wire.

TA

Terminal Adapter, used to connect TE2 (non-ISDN) equipment to an ISDN network.

TCP/IP

Transport Control Protocol/Internet Protocol, a DARPA-defined network protocol suite featuring a connection-less network layer.

TE1

Devices that support the standard ISDN interface, including digital phones, digital facsimile, and integrated voice/data terminal devices.

TE2

Non-ISDN equipment, including serial (RS-232) communications devices such as computers and terminals.

PBX

Private Branch Exchange, an integrated telephone switching system located on customer premises.

POS

Point of Sale, referring to the generally computerized systems utilized in most businesses for transacting and tracking sales.

POTS

Plain Old Telephone Service, a term referring to basic voice services provided by the telephone company.

Primary Rate Interface (PRI)

The ISDN interface designed for volume requirements such as trunk links for PBX systems and large-scale computer connections and consisting of 23 B channels and a single D channel, or 23B+D.

OSI

Open Systems Interconnection, an activity of the ISO for standardization of communications.

Out-of-band Signalling

The method of communications where signalling information and data are carried on different channels.

PTT

An acronym for Post, Telephone and Telegraph agencies, which in many countries are a nationalized entity set up to administer communications.

Q.930

The definition of the call control and signalling protocol for ISDN. Also referred to as I.450.

Q.931

The specification for the call control and signalling protocol for ISDN. Also referred to as Q.451.

R (Reference Point R)

An ISDN reference model designator representing the interface between non-ISDN equipment and adaptor equipment connecting it to ISDN.

RBOCs

The Regional Bell operating companies formed as a result of the divestiture of AT&T.

ISO

International Organization for Standardization, an international group defining standards in a variety of technology areas including computing and communications.

IVR

Interactive Voice Response, provides a user-friendly computer interface wherein the caller can make requests of an applications (such as database, control, and so on) via voice.

LAP-B

Link Access Protocol - Balanced, the data link procedure used in CCITT Recommendation X.25 and ISO7776.

LAP-D

Link Access Protocol - D Channel, an HDLC family data link layer protocol used on ISDN D Channels, defined in CCITT Recommendation Q.921.

Multiplexing

The method of combining separate data signals together on one channel such that they may be decoded again at the signal destination.

Network Layer

Layer 3 of the OSI Reference Model, responsible for routing data through a communication network.

NT

An interface designation indicating integrated Network Termination 1 (NT1) capabilities.

NT1

A device responsible for the physical and electrical termination functions of ISDN on user premises.

NT2

Equipment capable of performing intelligent operations such as switching and concentration functions, including devices such as digital PBXs, terminal controllers, and local area networks.

Packet Switching

A communications architecture in which data is transferred across the network in variable-length packets using a scheme called store and forward.

Facsimile

Electronic transmission of image-based data, usually originating in printed format.

FCC

Federal Communications Commission, a US federal agency responsible for the regulation of telecommunications.

Groupware

An application that is collaborative in nature, such as a shared white board, network-based appointment scheduling, and interactive video conferencing.

I.430

A definition of the Layer 1 characteristics of the Basic Rate Interface.

I.431

A definition of the Layer 1 characteristics of the Primary Rate Interface.

I.440

A CCITT recommendation defining the general aspects for the data link layer of ISDN. Also referred to as Q.920.

I.441

A definition of the Layer 2 characteristics of the D channel, defined as the LAP-D protocol. Also referred to as Q.921

I.450

The definition of the call control and signalling protocol for ISDN. Also referred to as Q.930.

I.451

The specification for the call control and signalling protocol for ISDN. Also referred to as Q.931.

IEC

Inter-Exchange Carrier (for example AT&T, MCI, and Sprint) providing long distance communications between local phone companies.

Inband Signalling

A method of telephone communications where the signaling functions are combined with the voice communication on the same wire.

CCITT

The International Telephone and Telegraph Consultative Committee, an arm of the International Telecommunications Union (a United Nations agency).

Centrex

A service offered by telephone companies that provides functions similar to those of the PBX, from the telephone company office.

Circuit Switching

The exclusive allocation of a specific channel for the duration of the connection. Each individual link in the circuit is dedicated to the connection.

CO (Central Office)

The central office location, sometimes called an exchange, where the communications switches reside that provide for connection to the network.

Codec

Coder-decoder, transforming analog data into digital, and digital into analog.

CSMA/CD

Carrier Sense Multiple Access Collision Detection, a scheme for network control where a carrier signal (sent by more than one node) is detected and data is subsequently re-sent at a randomly selected time delta.

CSMA/CR

Carrier Sense Multiple Access Collision Resolution, a scheme for network control where data (sent by more than one node) is detected and, upon collision, is re-sent. This scheme is used on the passive bus defined as part of the ISDN Layer 1 characteristics.

D Channel

Delta Channel, a component of the ISDN access arrangement that handles signalling.

Data Link Layer

Layer 2 of the OSI Reference Model, providing framing, error detection, and other services.

DBRI

Dual Basic Rate Interface, a Sun-designed integrated circuit providing both NT and TE interfaces.

ISDN Terminology

ACD

Automatic Call Distribution, an intelligent application that can route calls automatically to the appropriate individual or location based upon recognition of callers identity, location, and so on.

B Channel

Bearer Channel, a component of the ISDN access arrangement used to carry subscriber information.

Basic Rate Interface (BRI)

The ISDN interface designed to support simple applications like telephony and basic computer communications and consisting of two B channels and one D channel, or 2B+D.

Bearer Services

A particular communications capability, such as the ability to carry speech, audio, and digital data.

Broadband ISDN (B-ISDN)

A type of ISDN based cell-switched delivery of bearer services with access rates over 150 Mbps.

CASE

Computer-Aided Software Engineering, the use of computer application design, development, testing, and documentation software. CASE is an ideal candidate for network-oriented groupware technology.

W. Gifford *ISDN User-Network Interfaces*, IEEE Journal on Selected Areas of Communications, May 1986

J. Griffiths *ISDN Explained*, Wiley, 1990

International Organization for Standardization, Basic Reference Model for Open Systems Interconnection, ISO 7498, 1984

Stallings, William *Computer Communications: Architectures, Protocols and Standards*, IEEE Computer Society, 1991

W. Wu and A. Livine *ISDN: A Snapshot*, Proceedings of the IEEE, February 1991

ISDN Reference B

Fred Goldstein, *ISDN in Perspective*, Addison-Wesley, 1992

Verma, Pramode *ISDN Systems: Architecture, Technology and Application*s, Prentice-Hall,1991

Stallings, William *ISDN and Broadband ISDN*, Macmillan, 1991

Angus, Ian *ISDN, A Manager's Guide to Today's Revolution in Business Telecommunications*, Telemanagement, 1990

Helgert, Hermann , *Integrated Services Digital Network*, Addison-Wesley, 1991

P. Bocker, I*SDN: Concepts, Methods and Systems*, Springer-Verlag, 1988

National Telecommunications Administration *Standards in Process: Foundations and Profiles of ISDN and OSI Studies*, National Telecommunications Administration,Report 84-170, 1984

J. Bellamy*, Digital Telephony*, Wiley, 1991

U. Black*, Computer Networks, Protocols, Standards and Interfaces*, Prentice-Hall, 1987

J Aschenbrenner *Open Systems Interconnection*, IBM Systems Journal Numbers 3 & 4, J Aschenbrenner, 1986

P. Chilton *X.400: The Messaging and Interconnection Medium for the Future*, NCC Publications, 1990

In the United States, ISDN services are available, but to a somewhat lesser extent than Europe. At present, networking is possible between AT&T's Switched Digital International (SDI) service and France Telecom and British Telecom ISDN services.

The following table shows the current projected deployment plans for the Regional Bell Operating Companies, or RBOCs, for the United States. These figures reflect the projected installation of ISDN lines and switches through 1994.

Table A-1 RBOC ISDN Projected Deployment Plans through 1994[1]

	Number of Lines (in thousands) by 1994			
RBOC	**Total**	**Digital Switch Service**	**SS7 Access**	**ISDN Access**
Ameritech	17,662	9,622 54%	11,790 67%	13,350 76%
Bell Atlantic	20,260	13,517 67%	18,853 93%	17,100 84%
Bell South	20,243	13,494 67%	19,333 96%	10,500 52%
NYNEX	17,489	12,282 70%	15,574 89%	5,470 31%
Pacific Telesis	16,218	6,990 43%	5,150 32%	7,500 46%
Southwestern Bell	13,290	5,970 45%	8,840 67%	2,200 17%
US West	13,799	6,068 44%	7,424 54%	8,000 58%

1. Based upon LEC Submissions in FCC Docket 89-624 and Bellcore Special Report SR-NWT-002102, ISDN Deployment Data, Issue 1, October 1991

ISDN and the Telephone Companies A

For emerging technologies to be successful, standards are essential. Standards enable software developers to avoid having to write multiple versions of their product for different vendors switches. The also enable applications to be portable using a single network protocol when running over different media.

Until recently, ISDN acceptance has been constrained by a number of factors, including switch standards, availability of ISDN lines, ISDN equipment costs and availability and user awareness. Recent agreements by the Regional Bell Operating Companies in the United States, as well as European telecommunications authorities and those of Japan and other countries has led to establishment of standards which make ISDN a plausible and compelling technology for deployment and use.

In Europe, the France Telecom Numeris service is currently available countrywide. British Telecom has a completely digital long distance network and is using it to rapidly deploy ISDN throughout Great Britain. The German PTT is similarly advanced in ISDN technology.

ISDN is available on a wide scale in Japan. Both NTT and KDD have implemented ISDN services.

Most of the European countries have signed the Memorandum of Understanding (MoU) which is an agreement to implement a common subset of ISDN services. The common recommendations are defined by the European Telephony Standards Institute (ETSI) and should be available by late 1993.

The Teleservices Interface

The CCITT defines the services of ISDN, in three categories: *bearer services*, *supplementary services*, and *teleservices*. The bearer services are the basic set of services provided by the communications carrier, and include circuit-switched and packet-switched voice and data transmission. Bearer services are selected at the initiation of a call.

The supplementary services work in conjunction with bearer services, and extend or add value to them. Supplementary services for traditional telephone service include call forwarding, call transfer, and call waiting. ISDN supplementary services add to those of traditional telephony with number identification, direct inward dialing, calling line identification and restriction, charging services, call completion, and others.

Teleservices are higher-level services that include computer processing of user data by the communication network. Teleservices on SPARCstation ISDN are achieved through the use of an integrated environment known as the Teleservices Platform. The platform enables multiple applications to share access to multiple telephony devices on a workstation. The platform also provides the framework to integrate the system components for ISDN datacom and the future components for fax and other teleservices.

The Teleservices Server is a collection of integrated components that provide the functionality required in supporting a multi-client, multiple-device environment. Multi-client support includes system-wide access controls to prevent unauthorized access to restricted telephone devices attached to the workstation. Other security features provide control over which applications may control or monitor calls. Multiple-device support permit applications to access any of several switch or telephony devices that are connected to a workstation. The multiple device components use a database describing the configuration and capabilities of each of the switches and call appearances assigned or connected to the workstation. The Teleservices Server is a central point that monitors requests for these resources and tracks utilization and availability of each device.

The Teleservices APIs enable applications to have consistent high-level access to telephony and networking facilities via ISDN. Applications using these APIs can perform normal telephony operations within the application. For example, an automatic call distribution application might answer a call and transparently obtain the calling number. The application could then refer to its database, and extract details on the caller, forwarding the information, and possibly the call itself, to a service representative responsible for the caller's account.

Another application, designed to manage conference calls, could refer to individual network calendars, and set up a time for a call. At the appointed time, the application could execute the conference call automatically for each user.

Wide Area Network Architecture

The Wide Area Network (WAN) architecture for ISDN is based on support for TCP/IP protocols over ISDN. The 64Kbit/second performance of ISDN B-channels provides a viable alternative to leased lines for extending local area networks to remote locations. Applications that can effectively use such an architecture include telecommuting, remote X Windows, remote backup and servicing, and real-time access to large databases or information services.

Applications using TCP/IP today will run transparently on TCP/IP over ISDN. The TCP and IP protocols are written on top of the Point-to-Point Protocol (PPP) defined as part of the TCP/IP standard. Additional network and distributed computing interfaces, such as sockets and TLI, and the applications that use them would also be transparent over ISDN. Figure 6-2 illustrates the architecture of WAN software on ISDN.

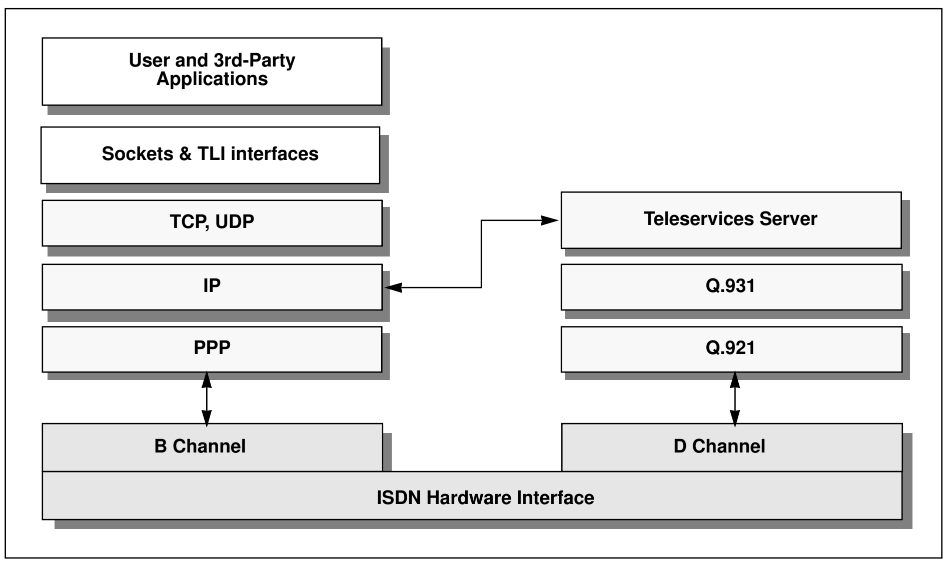

Figure 6-2 ISDN WAN Architecture

The TCP/IP protocol suite under ISDN provides for routing of data between local and remote systems on a ISDN network. A workstation running TCP/IP over ISDN can also act as a gateway to the ISDN network for other non-ISDN equipped systems residing on the same Ethernet network. Applications using TCP/IP over Ethernet networks should also run without modification over TCP/IP on ISDN.

Device driver access provides a defined interface for developers who need ready access to Sun Dual Basic Rate Interface chip. Application developers seeking greater control and system integration within ISDN might use this interface.

The teleservices APIs would provide support for 3rd-party applications such as audio applications, P*64 video compression for video conferencing, Group 3 and 4 Facsimile capabilities, and interactive collaborative applications.

Figure 6-1 illustrates the software architecture of Sun's ISDN implementation.

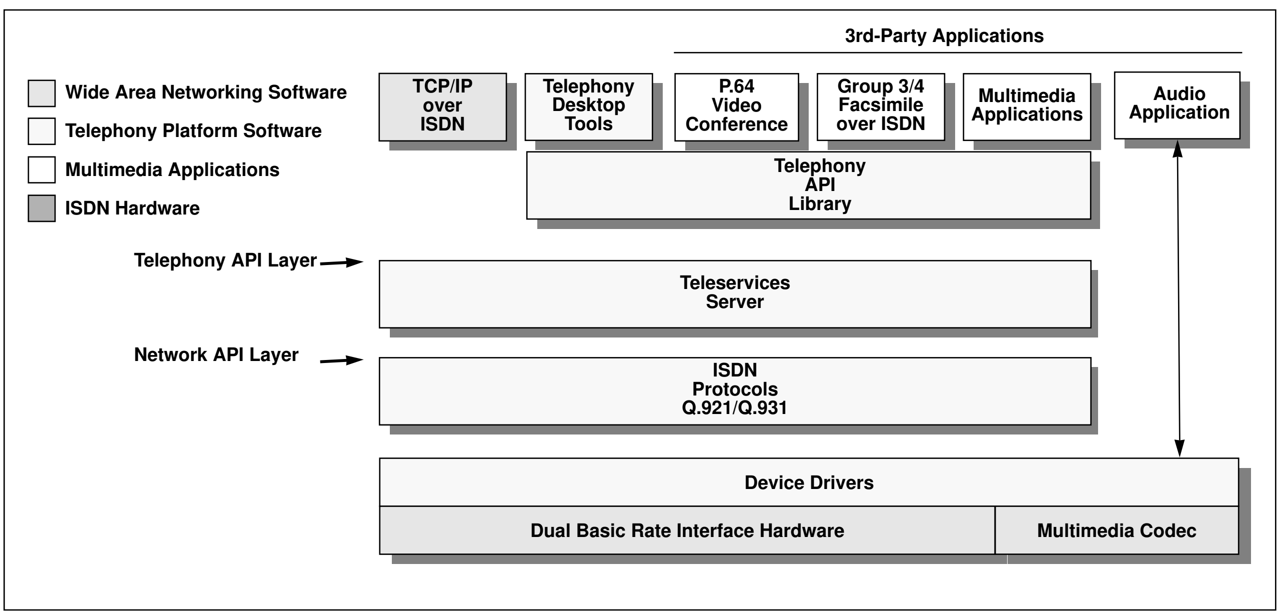

Figure 6-1 ISDN Software Architecture

ISDN Software Architecture 6

Architecture of Sun's ISDN

ISDN on Sun SPARCstation systems is accessed through a multi-layered architecture known as the Teleservices Platform. This approach provides a teleservices application program interface, and a library for applications programmers, system processes that manage ISDN protocol interactions, and services that control Sun's ISDN hardware device drivers and the underlying devices.

Access to the ISDN network is provided through ISDN software interfaces broken down into three components: the Sun ISDN APIs (telephony and network), the TCP/IP protocols, and the ISDN drivers for Sun's hardware implementation of ISDN. Sun's ISDN product is designed to support data communications and integrated multimedia (audio and data).

Application integration and multimedia product interaction is achieved through a separate server process called the Teleservices Server, for which independent application program interfaces (APIs) are provided. The Telephony API provides basic creation, answering, and release of a call, as well as transfer, hold, and conference capabilities. Additionally, the API permits applications to answer an incoming call based upon the connection type (that is, fax, data, or voice), and the origination or destination directory number. The Network API provides a foundation for network protocols that may be layered above ISDN.

The Sun audio interface provides 12.2 Mbps for output to an attached Sun speaker box device. Developers who currently use the /dev/audio device may continue to do so, or they may enhance their applications by using the telephony API. A new device, known as /dev/dbrit0ted, provides file system logical device assignment to the ISDN interface. The Sun audio interface has higher-level functionality than /dev/audio, including the handling of all ISDN traffic, routing voice/audio and data appropriately.

The architecture of providing audio Codec support on the SPARCstation system ISDN permits a microphone and SpeakerBox device to be used as a substitute for a telephone in some countries. This approach is dependent on local regulations regarding telephone equipment, so the additional use of headphones attached to the SpeakerBox is advised. Headphones have the additional benefit of handling echo cancelling of the audio output.

Integration with ISDN through the telephony API enables the application to take full advantage of the environment, including call control and handling, interaction with other audio and multimedia applications, and networking.

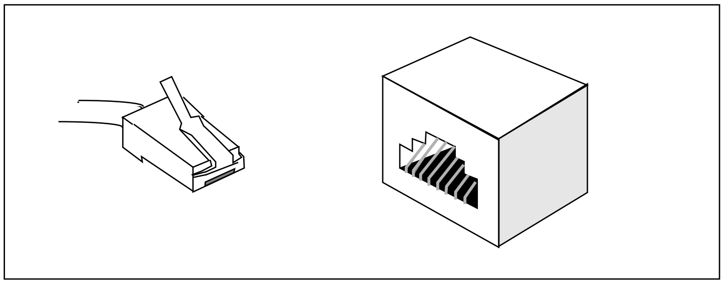

Figure 5-3 ISDN Physical Connectors–RJ-45 Modular Jack and Socket

HDLC Framing

The DBRI chip also supports a built-in HDLC Transceiver that provides data framing on-chip for higher performance at lower cost. Having HDLC framing on the chip reduces cost by obviating the need for additional off-chip components or the need to frame data via software.

Besides HDLC framing of B channel data, HDLC framing for D channels is also possible. This enables D channel communications for applications that don't require the bandwidth provided by the B channels. D channel-only services would cost less than 2B+D ISDN communications.

B channel framing includes HDLC packets, µ-Law compressed audio data, and raw data (unencoded).

The HDLC transceiver also provides Cyclical Redundancy Checking (CRC) of errors for frame mode data.

Audio/ISDN Integration

The speaker box interface integrates audio capability on the Sun SPARCstation system with ISDN through an audio coder-decoder (Codec) that handles the digital-to-analog conversion. Because audio is routed through the ISDN interface, it requires no CPU cycles for audio processing. This approach is especially attractive for conferencing applications where real-time audio is desirable.

Initial software support for ISDN on SPARC systems addresses the TE interface only. Following certification of the SPARCstation ISDN NT interface, SPARC systems will be capable of supporting NT as well. Please consult country-specific ISDN documentation for details on connecting ISDN in your area.

With certification, the NT connection could enable an ISDN telephone to be attached to the workstation, and configured through software to provide integrated telephony. The Sun ISDN connectors supply power across the interface, such as might be required for robust support of basic telephony, in the event the attached workstation is down. Figure 5.2.1 illustrates the ISDN connectors on the back of the SPARCstation 10 system.

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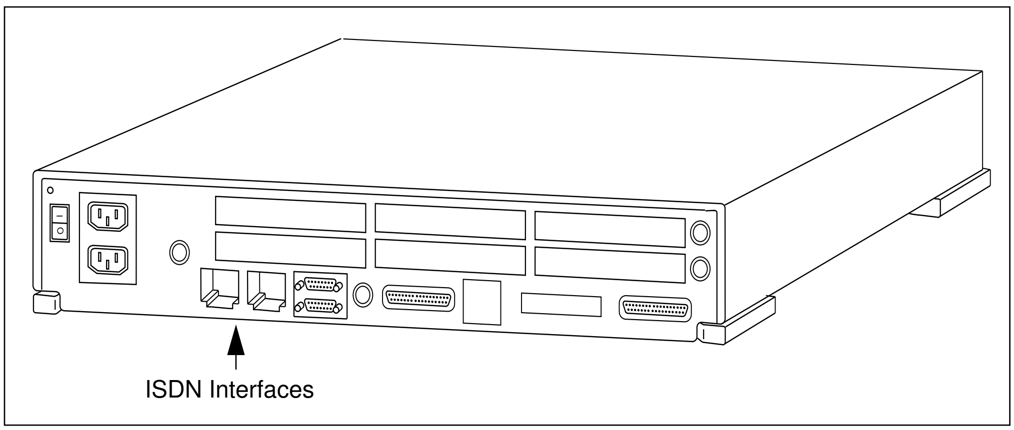

Figure 5-2 SPARCstation 10 ISDN Back Panel Connections

ISDN Connectors

The connection between TE and NT for the basic access interface is defined by ISO 8877 as an 8-pin physical connector, also known as an RJ-45.

Two pins in the connector are required for transmission in each direction (for a total of four), and are used to connect to twisted-pair leads coming from TE and NT devices. The ISO specification also provides for power to be supplied across the interface, such as might be required for robust support of basic telephony in the event of loss of local power. Figure 5-3 illustrates the male and female ISDN connectors.

SPARCstation ISDN External Ports

The SPARCstation system supports the Basic Rate Interface through a pair of ISDN RJ-45 ports on the back of each system. Each RJ-45 modular connector supports full ISDN communications.

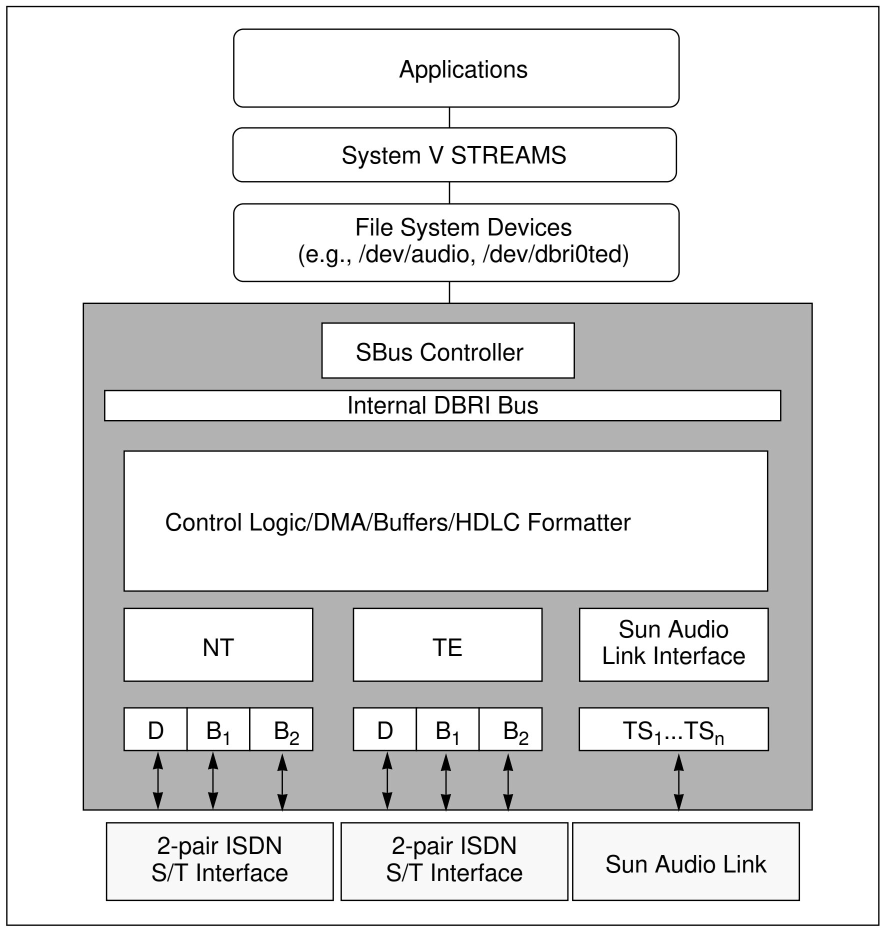

Figure 5-1 ISDN Dual Basic Rate Interface

SPARCstation ISDN Hardware Architecture 5

ISDN on the SPARCstation System

ISDN on the SPARCstation™ system is available either as a standard feature on the motherboard or as an optional SBus card. In both cases, the Sun™ SPARCstation ISDN interface uses a custom chip known as the Dual Basic Rate Interface (DBRI) chip, which provides support for TE and NT connections. SPARCstation systems are capable of supporting multiple ISDN interface boards via the SBus. The philosophy behind the design of a custom ISDN chip is based upon providing an optimized, low-cost ISDN interface capable of being placed on all future SPARC[σπεακερ βοξ]-based systems. A dual interface enables the chip to support additional ISDN devices connected to the NT port, such as an ISDN telephone or terminal.

The DBRI implementation supports CCITT I.430 and ANSI T1.605 standards for 4-wire 2B+D ISDN Basic Access at the S or T Reference Point.

The DBRI enables flexible routing between four interfaces: TE, NT, the Sun audio interface, and the SBus. Additionally, DBRI can concatenate the two B channels to enable 128 Kbps operation. HDLC formatting to memory is provided on both D channels, and may be used on up to six other channels or subchannels. Figure 5-1 illustrates the Sun ISDN DBRI chip architecture.

Besides the D and B channel interfaces, the DBRI supports an on-chip built-in SBus interface, providing a lower cost audio connection for external devices such as the Sun speaker box device.

Signalling System # 7

Just having the telephone company offer ISDN service is not enough. For ISDN services to be useful, a user should be able to communicate with the rest of the world. In order for the telephone company to offer that connectivity, it must implement a common protocol scheme for internetworking with other switches in its own state, outside its service state, and outside its service country.

Signalling System # 7 (SS7) is the result of a long evolution of signalling protocols by AT&T, which have largely attempted to follow and enable the transmission and control technology that makes up the phone system. SS7 is a complete protocol suite, occupying all seven layers of the OSI Reference Model (though not all OSI layers are included).

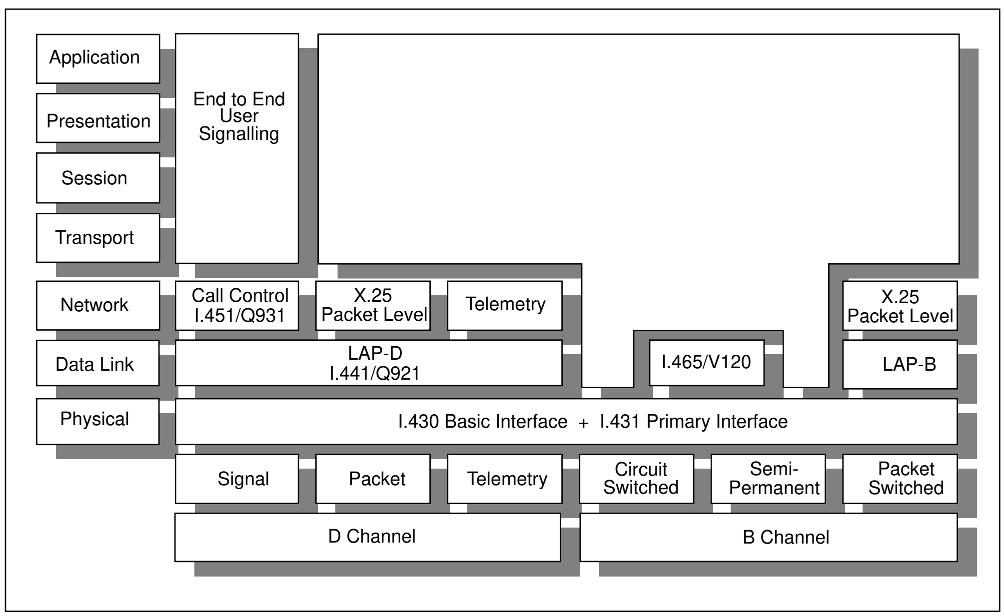

Figure 4-2 ISDN Protocol Architecture

Layer 2

Layer 2 is transparent to the B channel, while the D channel uses a protocol called LAPD. LAPD I.441/Q931 provides a specification for the LAP-D protocol (or *Link Access Protocol*, *Channel D*). LAP-D is the result of a long history of protocol evolution, beginning in the 1970s. Originally, IBM and Digital Equipment Corporation provided proprietary protocols for terminal access to their equipment. As a result of standards efforts by ISO (purveyor of the OSI model), the *High-Level Data Link Control* (HDLC) protocol was defined. LAP-D is actually closely related to the Link Access Protocol-Balanced (LAP-B) protocol, which meets the ISO HDLC standard.

LAP-D deals with statistical multiplexing of telemetry, signalling, and packet information as well as traditional HDLC protocol functions such as flow control and error control. The I.440 recommendation defines the general aspects for the data link layer while I.441 provides its detailed specification.

Layer 3

At Layer 3, the B channels continue to be transparent, while the D channel is divided into three different protocols, depending upon their function. The call control and signalling protocol is defined by the I.450 and I.451 (identical to Q.930 and Q.931) recommendations. Packet switching relies on the X.25 protocol.

Telemetry such as control and monitoring has been left to individual countries to implement.

Layer 3 protocols are the user's methodology for not only requesting a connection, but for defining the parameters of that connection. I.450 and I.451, in defining the signalling functions, deal with issues such as call setup, acknowledgment, disconnection, and status. Minor differences remain in implementations of I.451 among various countries, though standards at this level will likely emerge in a few years.

ISDN Protocols

Development of ISDN protocols includes both the interaction of ISDN users with the network as well as between one another. Recognizing the benefits in mapping ISDN protocols to the OSI model, the standards committees have worked toward this goal. ISDN adds to the OSI model with additional requirements including support for multimedia calls permitting the flow of multiple types of data (voice, text, facsimile, and appropriate control signals), multipoint connection support (useful for conference calls), and multiple related protocols (where the D channel controls the B channel).

While some of these features are defined outside of the OSI model, ISDN does match the 7-layer model to a large extent. Figure 4-2 illustrates the ISDN layers relative to the OSI reference model.

Layer 1

Layer 1 (the *Physical Layer*) of ISDN provides more functions than Ethernet because it handles both user and the central office (CO) switch side of NT1 connections. It also manages the 2B+D channels and allows up to eight terminal devices on a passive multidrop bus.

The I.430 of the I-series recommendations defines the Layer 1 characteristics of the Basic user-network interface as applied to the S (system) or T (terminal) reference points; in essence, the Basic Rate Interface. The I.431 recommendation defines equivalent characteristics for the Primary Rate Interface.

There is an additional level of multiplexing that provides for the eight terminal support on the passive bus mentioned above. To achieve multiplexing and provide equal access to the D channel by all terminals, a scheme similar to that used by Ethernet's *carrier sense multiple access/collision detection* (CSMA/CD) is employed. Instead of sensing the carrier; however, the contention scheme looks for data, and hence is known as CSMA/CR, for collision resolution.

On the loop side (the side that connects to the CO) of the NT1, the data rate is 160 Kbps (2B+D+overhead of 16Kbps). However, sending 160 Kbps on telephone cable that was designed for a 4 KHz analog signal is difficult. Various schemes were proposed for the U interface, and the FCC adopted an *echo-cancelling with decision feedback equalization* technique. Additionally, a 2 Binary, 1 Quaternary (2B1Q) line coding scheme was adopted, since it allowed for reduction of the line rate to 80 Kbps.

R (for rate) represents the interface between non-ISDN equipment and adaptor equipment connecting it to ISDN.

- Reference Point U (U)

  U (user) corresponds to the full-duplex data signal of the subscriber line. U is defined at the individual country level.

Figure 4-1 illustrates the various types of equipment described above, together with their respective reference points.

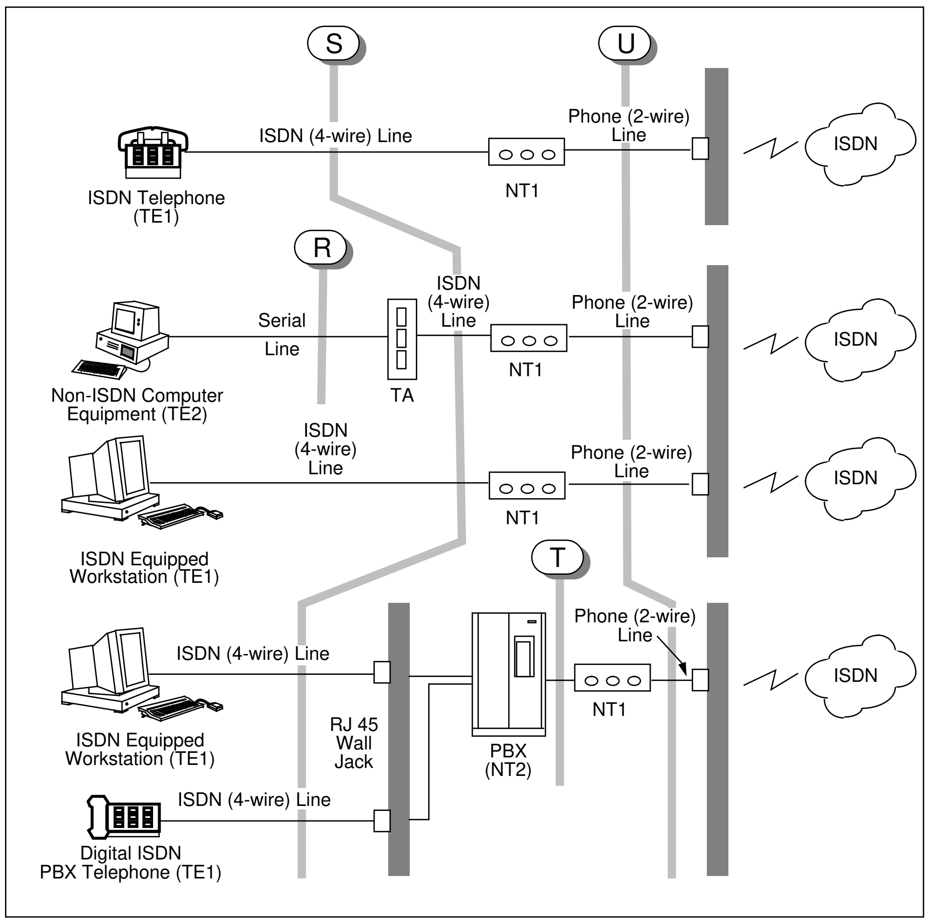

Figure 4-1 ISDN Reference Points

and conversion from 4-wire customer premise wiring to the 2-wire local loop connection required by ISDN. NT1 is considered to belong to OSI layer 1 (Physical Layer).

- Network Termination 2 (NT2)

  NT2 can perform intelligent operations such as switching and concentration functions. NT2 includes devices such as digital PBXs, terminal controllers and local area networks. NT2 includes features that span layers 1 through 3 of the OSI model (physical, data link, and network).

- Terminal Equipment 1 (TE1)

  TE1 refers to devices that support the standard ISDN interface, including digital phones, digital facsimile, and integrated voice/data terminal devices. TE1 devices provide 2B+D channel interfacing to ISDN.

- Terminal Equipment 2 (TE2)

  TE2 includes non-ISDN equipment, including serial (RS-232) communications devices such as computers and terminals. TE2 also refers to X.25 interface-equipped computing equipment. TE2 devices follow CCITT recommendations for non-ISDN equipment connecting to ISDN. As such, they require a terminal adapter (TA) to interface.

- Terminal Adapter (TA)

  TAs are used to connect TE2 (non-ISDN) equipment to an ISDN network. TA devices must adapt a traditional CCITT interface to the S or T interface with respect to physical connection, signalling, and speed.

By definition, the functional groupings for ISDN also include the reference points that delineate them:

- Reference Point T (T)

  T (for terminal) corresponds to the division between the network provider's equipment and that of the user.

- Reference Point S (S)

  S (system) refers to the interface between the user's ISDN devices and network-related equipment. S is defined as a worldwide standard.

- Reference Point R (R)

ISDN Technology Model and Implementation 4

Like the emerging OSI standard reference model, the ISDN model takes a layered approach. The principal benefit of layering is that it provides a framework for standardization. Once the functions performed in each layer are defined, protocol standards can be developed. Standards work can thus be organized, which in turn provides guidelines to equipment manufacturers and software developers.

The development of ISDN is governed by a set of recommendations issued by CCITT, called the I-series of recommendations.

The ISDN Reference Model

The ISDN reference model is broken down into functional groupings, separated by *reference points*. Interfaces are defined for each reference point, providing a stable standard, which enables open availability of equipment.

The most effective way to examine the ISDN model is in comparison to the OSI model, hence references to the OSI layers are made. The functional groupings for the ISDN model are:

- Network Termination 1 (NT1)

  NT1 includes the physical and electrical termination functions of ISDN on user premises. The NT1 may be controlled by the ISDN provider. It represents the boundary to the network, isolating the user from the specific transmission details. NT1 can support multiple devices (such as computer, fax, phones) via a multi-drop arrangement. It also provides power transfer

Connecting to PBX Systems

Many businesses today use proprietary PBX systems and digital phones for their internal phone systems. ISDN has the potential to create and open standard for PBX systems, enabling telephone sets from different vendors to be interchanged on PBX systems, and thereby leading to lower prices. Customers using ISDN will have the flexibility to purchase ISDN switches from one company, and ISDN telephone sets from another.

Most PBX systems in use today are capable of being upgraded to ISDN. PBX vendors such as AT&T, Rolm, Siemens, Northern Telecom, and Toshiba all provide upgrade paths to ISDN for their systems. The upgrade costs vary from vendor to vendor, but are sometimes quite expensive. Only non-ISDN customer equipment would require a TA. Any ISDN-ready equipment would connect directly to the PBX network. Figure 3-2 illustrates ISDN connection to PBX systems.

To gain access to ISDN, the customer must purchase, or subscribe to an ISDN line. The tariffs on basic rate ISDN run about one to two times that of a single analog line in most countries. The customer would need to obtain the ISDN line (as well as an ISDN phone if voice communications are desired) from the local telephone service provider. A residential customer will also need to buy or lease a device called an *Network Terminator 1* (NT1). The NT1 converts the 4-wire signal into a 2-wire system currently available to the central office. In addition to 4-to-2 wire conversion, the NT1 also performs the required multiplexing and echo cancelling.

In the United States, NT1 devices typically costs $200 - $300 dollars today, and prices are likely to fall to $100 by the end of 1992. In Europe,NT1 devices are available free of charge with ISDN service. In Japan, NT1 devices are called DSUs, and are available via lease from NTT, the telecommunications provider. Figure 3-2 illustrates an ISDN residential connection.

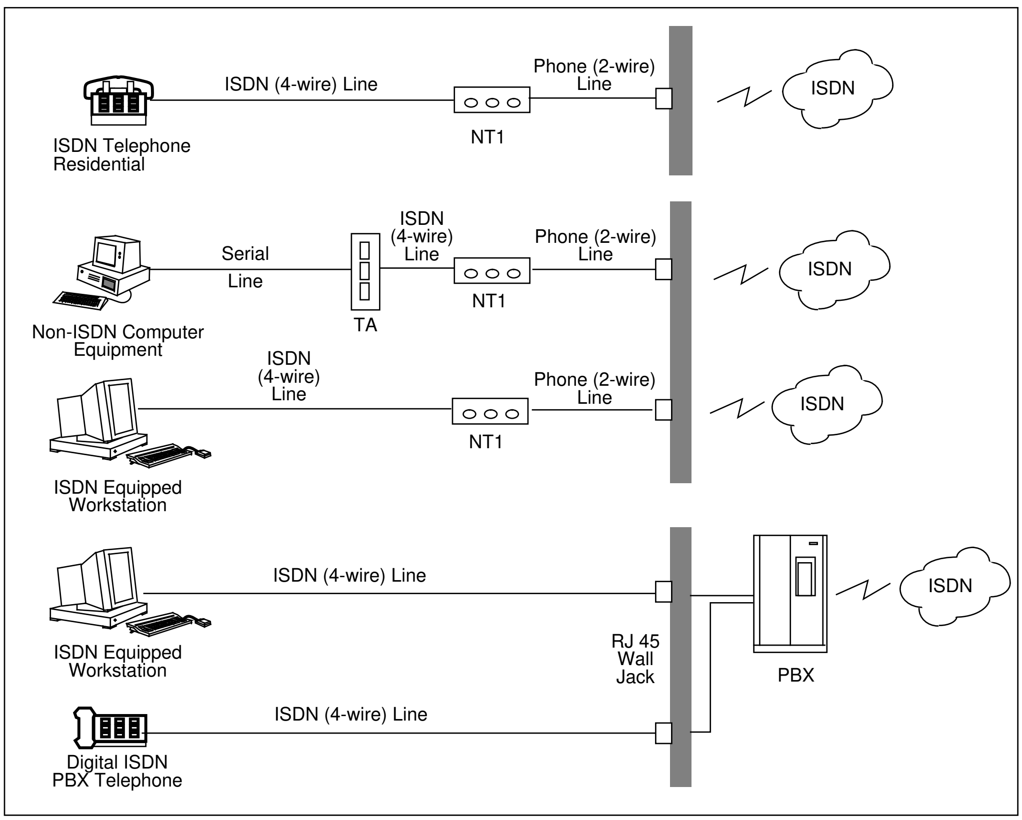

Figure 3-2 ISDN Connections

The largest immediate benefit, and hence the likely application area to be addressed first by ISDN, is integrated voice and data. BRI has sufficient bandwidth to support both interactive computing applications and high-quality voice communications.

In the BRI scheme, the D channel is can be used for more than just the control signalling it assumes from telephony. The D channel's 16 Kbps data rate equates to about 9600 bps in computer communications (after overhead and signalling functions are performed). Hence the D channel is simultaneously capable of supporting low-bandwidth applications such as videotex, remote control and monitoring, and a large range of interactive computer applications.

A cost savings from the basic rate is likely for applications where D channel bandwidth is satisfactory.

ISDN Connectivity and the Workstation

Currently, most residential customers in the United States have analog phones, while businesses have a mixture of analog and proprietary digital phones purchased from PBX vendors, or an analog Centrex system purchased from the telephone company. Today, digital phones typically cost in the range of $400 to $800. ISDN telephones generally about the same, and prices are dropping. As demand for ISDN develops, particularly in Japan and Europe, pricing for telephone sets will drop even further.

In some countries, the PTT that provides telephone service will often lease the telephone equipment, and hence may provide an ISDN phone for the same base rate as its analog counterpart.

Connecting to Non-ISDN Computer Equipment

Users of non-ISDN computing equipment may want to connect their systems directly to ISDN lines. To do so, the user must install a device called a terminal adapter (TA), which provides a conversion from ISDN to the serial (RS-232) interface on most computers. The TA provides voice and data terminal interfaces for connection to user equipment and an ISDN media interface for connection to the ISDN line. Because RS-232 serial connections are generally limited to 19.2 Kbps, the TA would only provide that data rate, and not utilize the full ISDN bandwidth. TAs cost approximately $600 - $1200 dollars and are available from the telephone companies or through computer communication equipment vendors. Figure 3-2 illustrates an ISDN connection to non-ISDN computer equipment.

ISDN Standardization

Many segments of the telecommunications industry are engaged in a concerted effort to make nationwide ISDN deployment a reality. Problems that haunted ISDN in the past, including lack of standard hardware and software protocols (and the corresponding gaps in interoperability), are being addressed by *National ISDN-1*. National ISDN-1 is a joint effort of the Bell companies, interexchange carriers, and telephone switch manufacturers. The effort (led by Bellcore, a research arm of AT&T) is solving the major standards problems by establishing a single hardware standard, for deployment by late 1992.

Similar efforts on standardization are underway in Europe, through the leadership of the European Telecommunications Standards Institute (ETSI). ETSI, together with major equipment vendors and switch manufacturers, has established a plan for implementing EuroISDN, providing essentially the same level of compatibility as National ISDN-1. The common standard was defined as part of the Memoranda of Understanding (MoU) reached between all the EC countries, and is expected to be generally available across Europe by 1993.

ISDN standardization is an evolutionary process, accelerated by currently established standards, and product and service availability. Over time, all countries, product manufacturers, and service providers will meet ISDN standards.

Features of the Basic Rate Interface

The basic rate interface is likely to be the most popular of ISDN connections. A single ISDN-capable system on a network can provide access to ISDN for other systems as well. However the subscription costs for BRI are likely to be low enough to motivate independent connections from each user.

BRI has some attractive characteristics, including the ability to use existing twisted-pair wiring. Because BRI does not require rewiring, most companies with modular twisted-pair wiring are essentially ISDN-ready, once they have ISDN equipment (phones, PBX, and so on) and have secured ISDN service from the telecommunications provider, or run ISDN internally, independent to the telephone company.

the available ISDN types, some number of bearer channels is provided, together with a *delta channel* (D channel), that handles signalling (via out-of-band).

ISDN interfaces are defined as one of three types:

- Basic Rate Interface (BRI)

  The basic rate interface is designed to support simple applications like telephony and basic computer communications. BRI consists of two B channels and one D channel, or 2B+D.

- Primary Rate Interface (PRI)

  The primary rate interface is designed for volume requirements such as trunk links for PBX systems and large-scale computer connections. PRI consists of 23 B channels and a single D channel, or 23B+D. (In Europe, PRI is defined as 30 B channels instead of 23.)

- Broadband ISDN (B-ISDN)

  B-ISDN offers significantly higher communication rates (as much as 150 Mbps), and hence would surpass BRI and PRI in managing high-bandwidth applications including video, HDTV, and graphics-oriented services.

Both BRI and PRI are limited to 64 Kbps per B channel. However, some telecommunications providers (depending on their switching technology) may permit access to the aggregate connection, allowing for 128 Kbps for BRI. PRI access always permits access to the aggregate bandwidth of 1.544 Mbps (2.048 Mbps in Europe).

The D channel is capable of 16 Kbps for the BRI interface and 64 Kbps for PRI.

PRI will be used as a connection between servers, similar to a leased-lined usage.

Broadband ISDN (B-ISDN) is still in development and widespread use will not occur for manay years. B-ISDN is dependent on the deployment of a complete optical fiber network (including from the central office to the home or business), which will clearly be expensive during the early years of its availability. In time, however, B-ISDN will likely succeed ISDN, while providing newer, more powerful capabilities, possibly including HDTV service.

For ISDN to meet the requirements of the CCITT and be feasible for the telecommunications providers, flexibility in configuration has proven important. Indeed, a large part of the potential of ISDN lies in future services and capabilities.

Figure 3-1 illustrates the general architecture of ISDN, based on CCITT recommendation I.325.

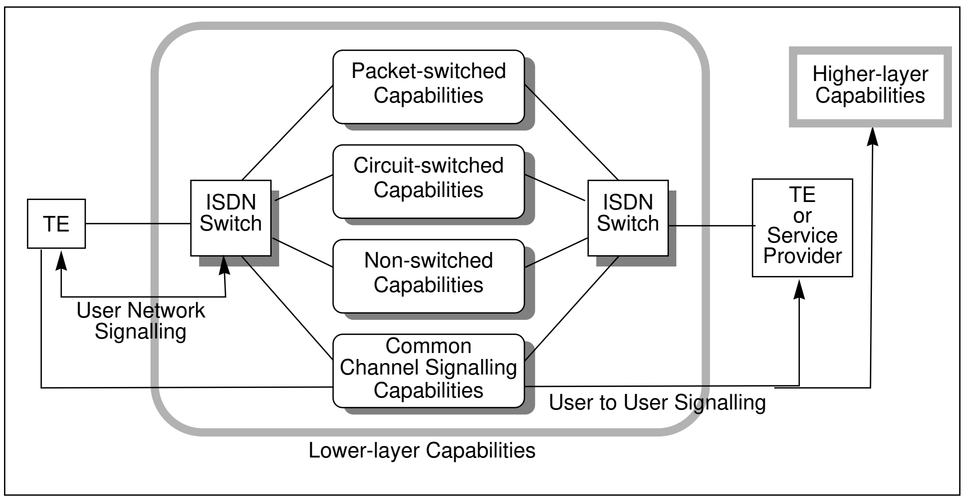

Figure 3-1 ISDN Architecture

ISDN Types

There are several types of ISDN, each of which addresses slightly different user and application requirements. In contrast to the existing telephone system, all ISDN services offer *out-of-band signalling*, where signalling information and data are carried on different channels. This architecture provides greater flexibility in network control, operations, and in the possible services provided by ISDN.

With ISDN, voice and data are carried on a *bearer channel* (B channel) occupying a bandwidth of 64 Kbps. Higher-capacity bearer channels, called H channels (consisting of a group of B channels), may also be available. In each of

ISDN Fundamentals 3

As defined by the CCITT, ISDN is intended to provide a set of characteristic services for applications using it. In particular, ISDN should provide:

- Support for switched and nonswitched applications

  ISDN will accommodate both circuit-and packet-switched technologies as well as dedicated connections.

- Support for both voice and non-voice applications

  Telecommunications capabilities such as voice connections and digital data transfer will be included.

- Support for 64 Kbps connections

  In providing circuit-and packet-switched services, ISDN will support 64 Kbps connections.

- Layered architecture

  The protocols developed (and in preparation) for user access to ISDN are implemented in a layered architecture, which is mappable to the *Open Systems Interconnect* (OSI) network model.

- Network intelligence

  ISDN is designed as an intelligent network, capable of sophisticated network management, maintenance, and a broader array of services well beyond circuit-switched connections.

Global use of ISDN can also provide a more flexible working environment, enabling engineering, design, manufacturing, and marketing teams to be separated geographically. Response teams could also be called together to manage problems and resolve issues without the necessity of travel. Figure 2-4 illustrates worldwide collaboration via ISDN.

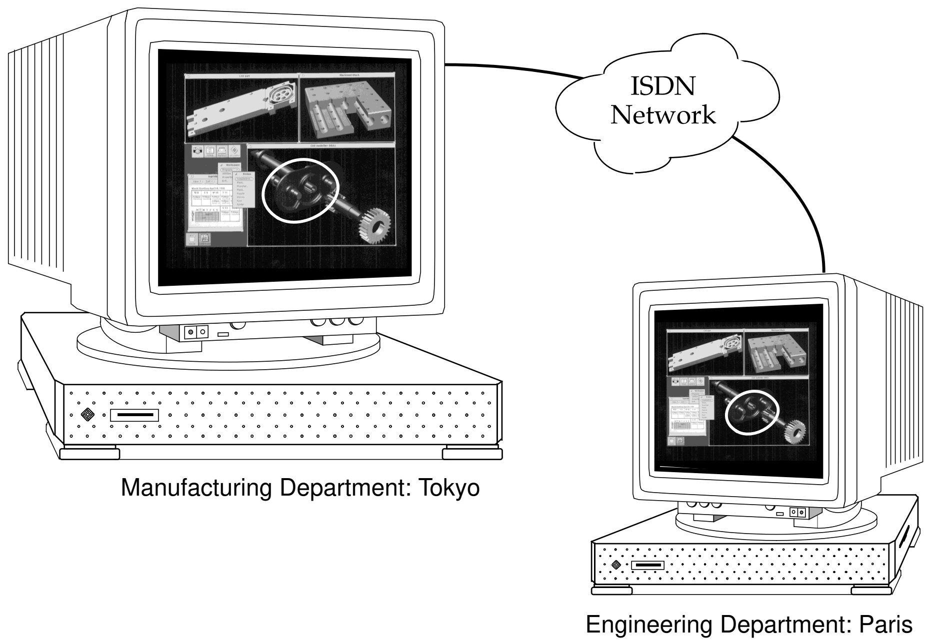

Figure 2-4 ISDN Network-based Interactive Collaboration

Video teleconferencing, once the domain of expensive proprietary systems located in boardrooms and corporate offices, will likely move to the individual user's desktop. Users separated geographically will be able to interact, sharing and annotating information interactively. Network-based whiteboards will enable users to share ideas while emphasizing both verbal and nonverbal communication through video-based face-to-face interaction. Besides interactive collaborative computing benefits, ISDN provides a single connection for both voice and data, which is more flexible and often less expensive than leased lines.

Wide Area Networking

Communication services providers such as the telephone companies have a significant interest in expanding the telecommunications market. So do vendors of telecommunications equipment. The availability of an advanced, unified network offering a wide range of services is compelling for vendor and user alike.

One of the broadest application markets for ISDN, and the basis for many others, is wide area networks (WANs). Today, most companies using a WAN subscribe to one or more T1 connections, or use the packet-switched services of the telecommunications provider. These services are sold as dedicated connections for which the customer may pay significant fixed fees, regardless of their usage. For lower-bandwidth requirements, ISDN will provide somewhat lower performance at significantly lower cost.

To use ISDN as a replacement or adjunct to existing WAN services, standard internetwork protocols such as TCP/IP will likely be offered by communications and computer equipment vendors.

The most significant benefit to developers is the transparency of ISDN applications that operate over TCP/IP connections without a tariff charge. Further, an ISDN workstation could act as a gateway to the ISDN network for other workstations on the local Ethernet network.

ISDN may be used to provide a monitoring connection directly into residential and business locations. Sensors connected to an ISDN interface could provide surveillance and alarm systems, including audio and video display from the remote location.

Benefits to the ISDN user of wide area networks include extending the local computing environment to remote locations, including home (telecommuting) and smaller branch offices. This would provide greater information access and flow, and more flexibility in working location.

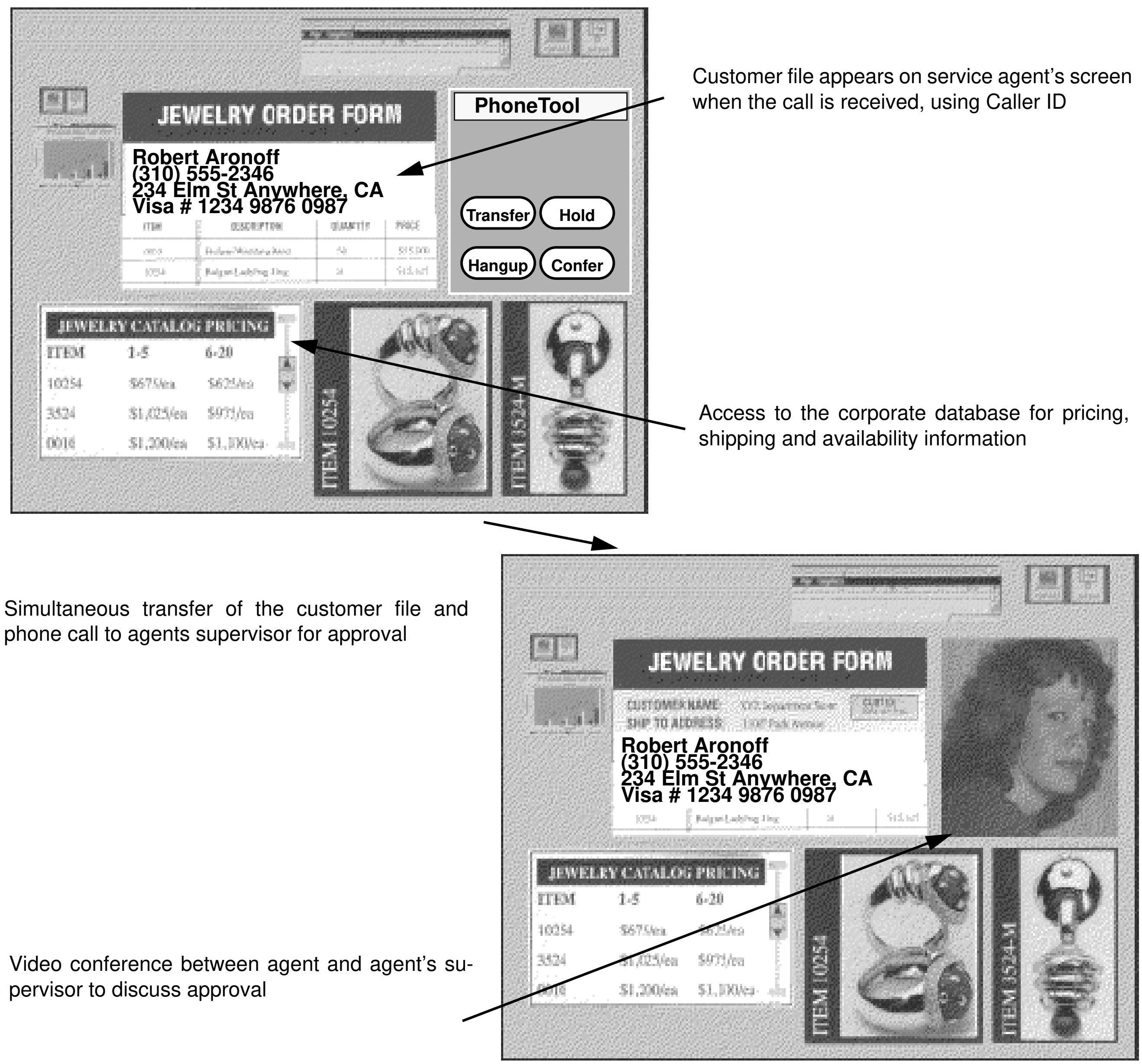

Figure 2-3 Integrated Corporate Telephony Application

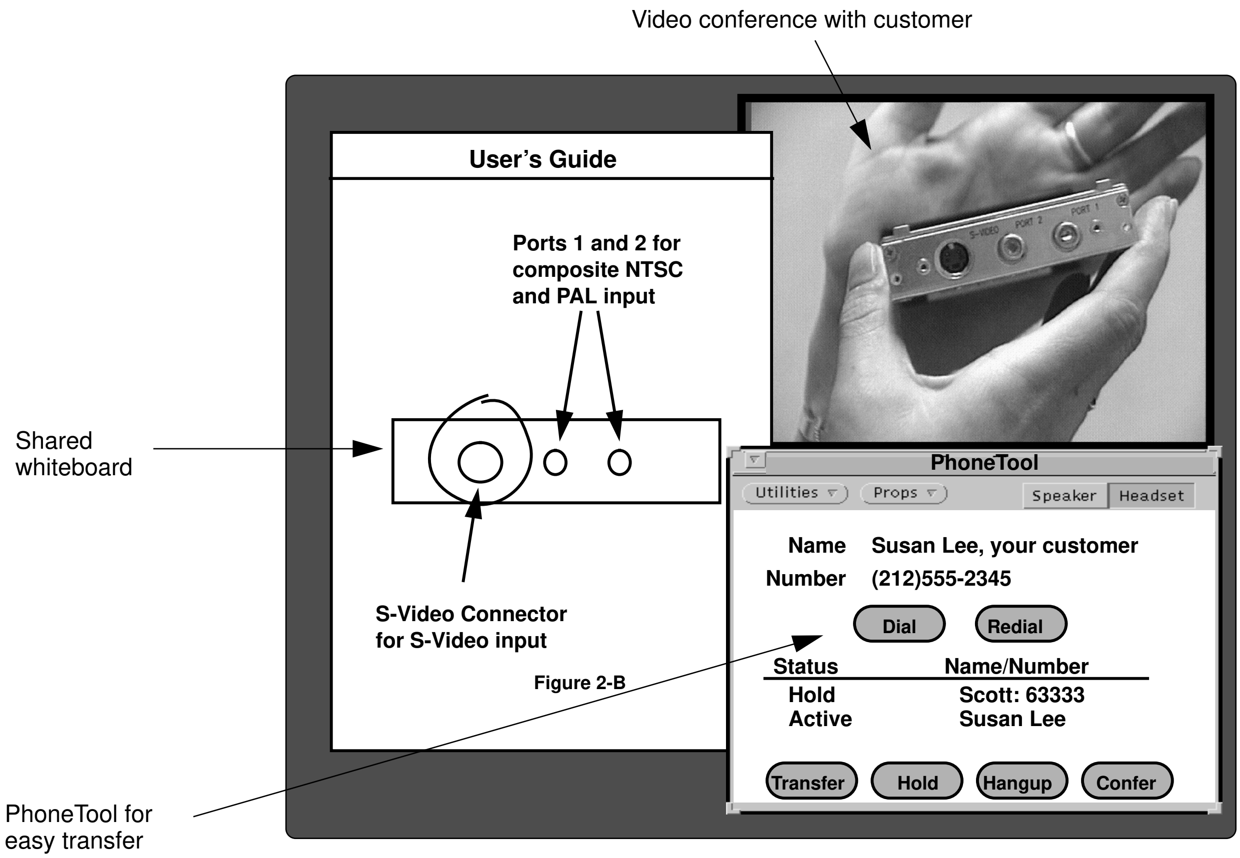

Figure 2-2 Problem Diagnosis via Remote Access on ISDN

ACD applications may intelligently route calls automatically to the recipient's location, based on the nearest ISDN phone. Or, the ACD application may interpret the origin of the call to connect it to a service or sales representative responsible for the calling area.

Advances in voice recognition and text-to-speech conversion may also provide a more flexible and user-friendly environment for remote information access. Using Caller ID services, applications may interrogate databases for information regarding the caller's account status or medical history, displaying the information for the recipient prior to answering the customer's call. Figure 2-3 provides an example of an integrated corporate telephony application.

Remote Access

Additional telephony applications will include the integration of PBX and computer systems via ISDN and distributed teleservices using *interactive voice response* (IVR) and *automatic call distribution* (ACD).

IVR systems employed via ISDN could provide applications that enable direct user interaction with computerized databases through voice control, and include customer service, financial, control and monitoring, and general information applications (such as weather, traffic, messages). Users could access email and voicemail messages remotely by calling in to their system. Voice mail could be played back through normal audio, while electronic mail converted from text to speech. And IVR systems could read facsimile and email applications (text to speech), prompt for recipient response, and enable voice annotation of the return electronic mail.

Finally, remote access could assist in problem resolution with customers at distant locations, via video conferencing or shared whiteboards. Such facilities might broaden the support capabilities available from product vendors and offer more economical maintenance services to customers. Figure 2-2 illustrates such an application.

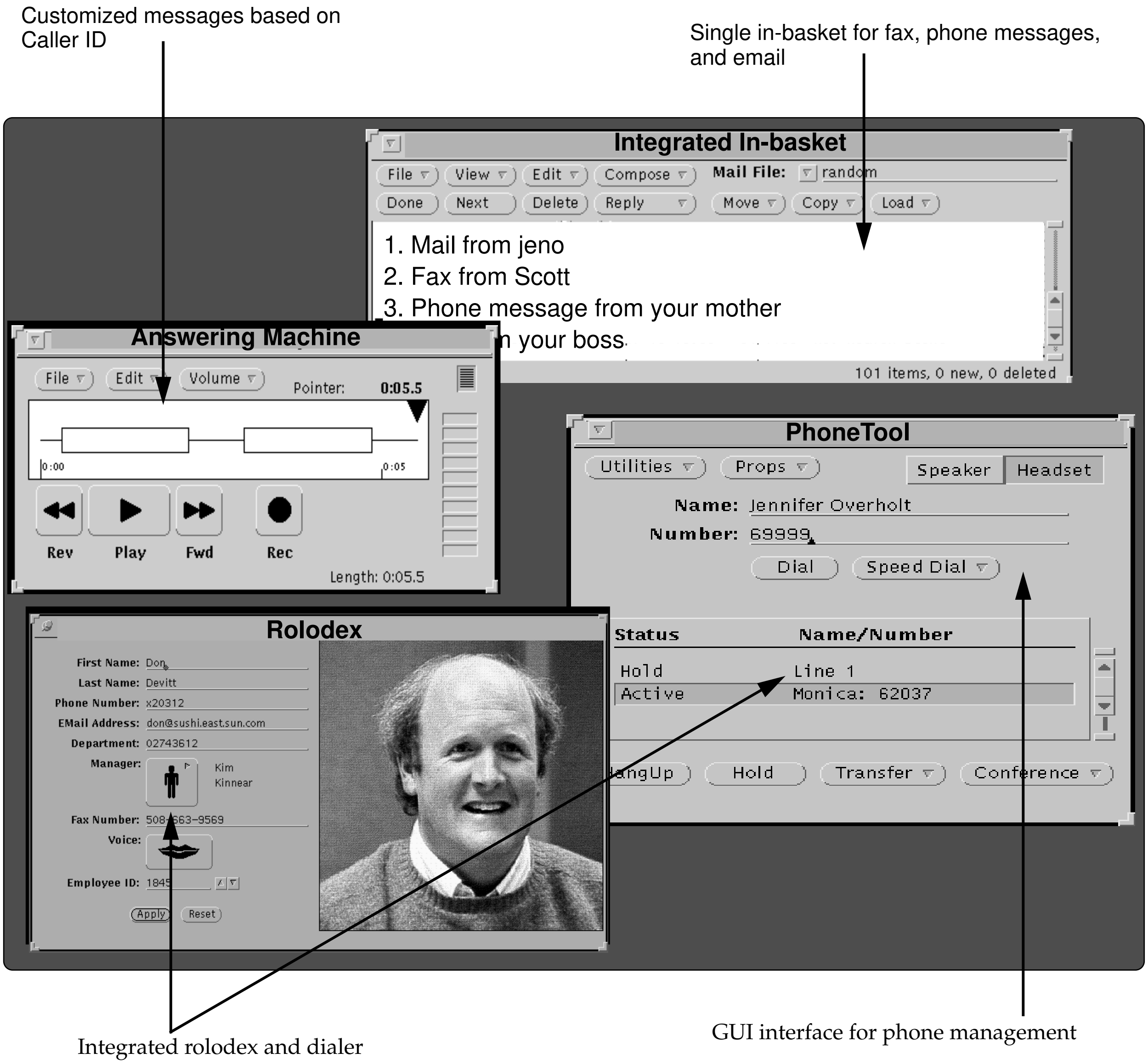

Figure 2-1 Integrated Telephony Application (Rolodex, VoiceMail, Telephone)

Desktop Telephony

Typically, when making a phone call today, a person will dial out of their internal PBX system to obtain an outside carrier, and then dial the intended party. If the phone number is unknown, a call to directory assistance in the calling area is made to obtain the party's number.

When sending and receiving facsimiles today, the user must manually attend to the fax machine to dial the number for the destination. On the other end, someone would likely read the (manually prepared) cover sheet and send the fax to the correct party through departmental mail.

Where ISDN services are used on a large scale together with desktop computing, they are likely to significantly influence the tools available to the user. For example, graphical user interfaces will make information lookup such as rolodex referencing and telephone dialing more automated. Use of a speaker and microphone attached to the workstation would enable the user to make a call without needing a telephone handset.

Figure 2-1 illustrates an application providing integrated telephony capabilities on a workstation.

- Natural language processing and voice recognition can make information access easier.
- As these technology areas deliver applications in the 1990s, information will become increasingly easier to access and manage.
- Information media is moving to digital.

  Whether through CDs, telephones, computing, or high-definition television, information is more and more often presented digitally.

As the amount of information individuals work with continues to increase, greater emphasis will likely be placed on methods to increase the bandwidth of communication between computers and users. This will include processing the information, extracting the relevant details, and formatting it in compelling ways. Additionally, global corporations and markets are placing new demands on workers in terms of sharing information and developing new ideas.

Examples of collaborative, context-sensitive applications include traditional tools such as text processors, CAD drafting systems, and virtually any single-user application where information and access should be shared.

Other interesting applications include networked whiteboards, multimedia and hypermedia tools, computer-based training, and concurrent engineering.

ISDN promises to affect desktop computing in a variety of ways, from increasing information access through new media to complete integration with telephony technology. A large number of applications are possible with ISDN, ranging from video teleconferencing, multimedia email, and wide area networking to PBX network and trunk support.

Computer-integrated Telephony

Telephone, facsimile, and answering machine capabilities will be integrated into desktop computer workstations, in some cases augmenting voice and facsimile services through application programs and database information access.

ISDN Applications 2

A number of major technology and market trends are contributing to driving ISDN into common usage:

- Computers are increasing connected together instead of standing alone.
- More than 30% of all personal computers have communications capabilities, and the majority of business computers are networked. Access to information, both internally and externally, is becoming a principal factor in staying competitive.
- People want to communicate with one another, regardless of location.
- Global corporations, cellular technology, telecommuting, and remote access applications are all contributing to the emergence of integrated digital communications. The availability of digital communication will increasingly be assumed.
- The amount and variety of information is increasing dramatically.
- The amount of information is doubling every two years. In order to process and utilize this information, personal workstations must present it in an efficient and intuitive manner. Applications relying on high-bandwidth networks are essential for the management of ever-increasing information flow.
- Cellular communications is redefining access to information.
- Automobiles and airplanes no longer represent barriers to information access. Eventually, anywhere you go, you'll have access to the global network.

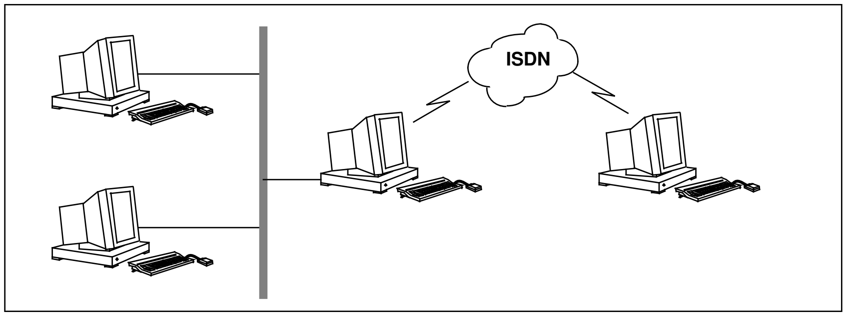

Figure 1-5 Local and Wide Area Networks

In both Ethernet coaxial and twisted-pair networks, a network protocol suite must run to allow the individual computers to communicate. The most common protocol is *Transport Control Protocol/Internet Protocol* (TCP/IP), but there are many other protocols.

With the migration of telecommunication systems toward an increasingly all-digital network, the emergence of ISDN as the industry standard for digital telephone service is not surprising.

If the line is a dial-up connection, the telephone company assigns a dedicated channel at random in its network. If the line is a leased connection, it is active and dedicated at all times, so the communication is generally continuous. In the case of dial-up connections requiring long distance connections, services are provided differently in the United States than elsewhere:

In the United States: The local telephone service provider must connect to an *Inter-Exchange Carrier* (IEC), such as AT&T, MCI, or Sprint, to provide the long distance connection. On the far end, the IEC passes the call to the local telephone service provider who completes the connection.

In Europe, Australia, Japan and many other countries: The local telephone service provider is also the provider of long distance service. Hence there is no inter-exchange for local to long distance connections. However, the telephone company does assign different billing rates to the calls.

Both leased-line and dial-up communications via modem are relatively inefficient because data is converted from analog to digital form numerous times between source and destination. Additionally, the network is under utilized because a 56 Kbps (thousand bits/second) connection is assigned to the digital transmission, and the modems in current usage are typically 2400-9600 bps, and hence use only 4%-17% of the network bandwidth.

Within the local business environment, *Ethernet* networks are common for connecting computers to one another. Ethernet is a local area network standard developed by Xerox in the 1970s, initially based on coaxial cable media. Ethernet is the architecture upon which many company-wide networks are based. Twisted-pair Ethernet has also recently emerged as a popular network media due to low cost and the ability to capitalize on wiring identical to that used by the companies internal telephone facilities. Figure 1.5.2 illustrates a local and wide area network configuration.

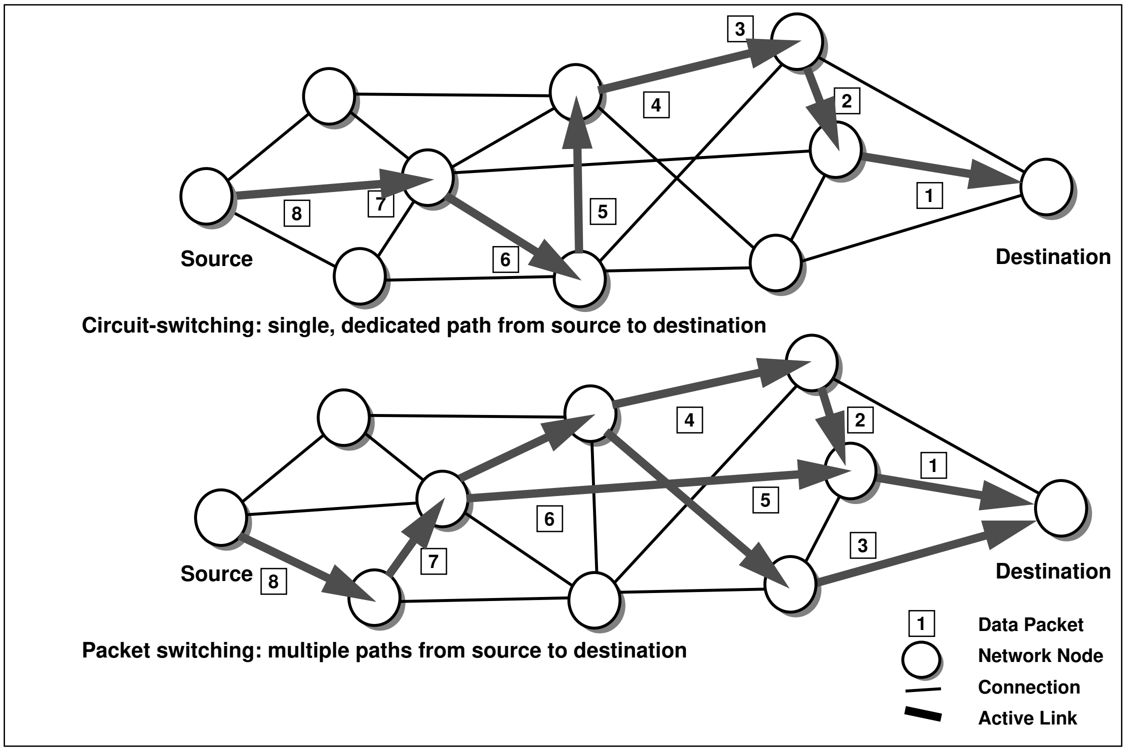

Figure 1-4 Circuit-and Packet Switched Networks

Circuit-switched networks assume a dedicated channel between source and destination, with messages arriving in precisely the same order they were sent. Packet-switched networks are based upon the idea that all network nodes are aware of the status of all other nodes. As packetized messages are sent from the source node, they may take many different routes to the destination, and are placed in their correct order as they arrive. Both circuit and packet-switched networks are provided by the telecommunications company, with the user fees based upon usage.

If the user requires a dedicated channel due to the nature of an application, dial-up or leased-line facilities may be appropriate. Connections to either leased-line or dial-up services are usually performed either digitally or through serial modem devices that convert the digital computer signals to analog prior to being sent through the telephone network.

Europe has been relatively advanced in implementing ISDN. France now provides basic ISDN services virtually everywhere. Germany is installing ISDN at a rapid pace, expecting widespread national coverage by mid-1993. Britain is installing ISDN in major metropolitan areas now, expecting to achieve complete coverage of those areas by the end of 1992. Most other European countries have begun installing ISDN or have plans for doing so, generally by 1994. The European Community has provided considerable influence and impetus for the modernization of the European telecommunications infrastructure, and has been a key factor in the progressive deployment of ISDN.

ISDN is already available throughout Japan and in many other Asian and Pacific Rim communities including Hong Kong, Singapore, and Australia.

Computer Communications and Network Technology

Examining current communications and network technology in gaining an understanding of ISDN and its role in the computing environment is useful. Historically, requirements for distributed computing environments relied on data communications links provided through dial-up or leased-line services of the telecommunications provider. These services include *circuit-switched* and *packed-switched networks*, T1 carrier systems, and a variety of others.

Circuit switching is the exclusive allocation of a specific channel for the duration of the connection. For long distance connections, each individual link in the circuit is dedicated to the connection. Circuit switching is the dominant technology today for both voice and data communications and will likely remain so during much of the ISDN era. Circuit switching is frequently used in PBX systems and private *Wide Area Networks* (WANs).

Packet switching is a service in which data is transferred across the network in variable-length packets using a scheme called "store and forward". Packet-switched networks were developed to overcome a basic limitation of circuit-switching, which provides a fixed amount of bandwidth to the communications channel. While this approach makes sense for voice communications, data communications is typified by bursts of traffic. Packet switching addresses this type of flow by providing communication bandwidth on a demand basis, as it is needed. Packet switching has been used successfully in both public and private data networks with X.25 as the most common protocol. Figure 1-4 illustrates circuit-and packet-switched networks.

1. Source: Bellcore 1991.

ISDN Acceptance and Availability

Like any complex technology developed through a standards process, ISDN has taken time to be developed, refined, and deployed. Many organizations are actively involved in encouraging ISDN, including the CCITT, the International Telecommunications Union (ITU), the International Organization for Standardization (ISO), and national standards organizations such as the American National Standards Institute (ANSI) and the European Computer Manufacturers Association (ECMA).

In 1968, the CCITT established a study group to explore a variety of issues related to the use of digital technology in telecommunications networks. Over the course of the following two decades, the group made general recommendations regarding digital technology standardization including switching and signalling. Several successive study periods examined ongoing developments of digital technology, ultimately leading to the definition of an integrated services digital network. During the latter periods from 1981-84 and 1985-88, the study group developed and refined a set of recommendations that defines ISDN. Figure 1-3 shows the structure of the I-series recommendations.

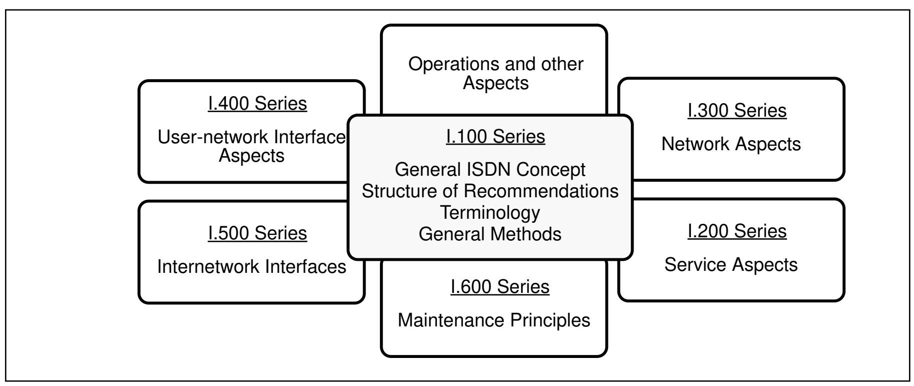

Figure 1-3 Series Recommendations

Most developed countries have already begun widespread installation of ISDN services. In the United States, the regional Bell operating companies and most of the independent telephone service providers offer ISDN service to some areas today. By the end of 1992, 40% of all access lines will be in ISDN-equipped areas. And by 1994, over 60% will be. In metropolitan areas, coverage will be 70%-80% by 1994.[1]

The trend toward digital communications has been driven by three principal factors: *equipment costs*, *sharing of long distance lines*, and *network control*.

Although the low costs of analog switching and transmission technology brought about the widespread acceptance of telecommunications, digital technology has quickly outpaced it in terms of cost and reliability. Additionally, continued reduction in the size of digital components is leading to greater levels of integration with resulting cost reduction.

Network control of telecommunications via computer has obvious benefits in terms of call routing, load balancing, and error detection. There are clear advantages to using the digital nature of the signals that monitor status and provide control of networks.

Emergence of ISDN

During the course of the last two decades, telecommunications providers have marketed a considerable array of digital communications services, principally to address high-bandwidth applications such as video teleconferencing and computer communications. While these services have addressed many of the needs of industry, they were largely driven by the applications requirements, rather than designed to fit into a coherent whole.

Recognizing that the range of services provided could be better addressed by a completely digital environment, coupled with acknowledgment that information processing would likely become a consumer market, the telephone companies began exploring a way to integrate services into a single networking scheme. The resulting effort became a standards movement driven by the *International Telephone and Telegraph Consultative Committee (CCITT)*, the United Nations organization that coordinates international telecommunications.

ISDN refers to a specific set of services provided through a limited and standardized set of interfaces. The interfaces make possible an unencumbered consumer equipment market while services (the business of the telephone companies) are available on a subscription basis, much as basic telephone service is today.

ISDN is an architecture for digital communications that can provide a number of integrated services currently provided by separate networks. Such services include voice, circuit-switched and packet-switched data, video conferencing, and telex.

With the advent of digital computers and the need to connect computers and terminals together between distant locations, a number of telecommunications equipment providers saw the opportunity to capitalize on emerging digital switch technology. They by incorporated it into integrated telephone systems that they sold to companies for their internal switchboards. These systems, known as *private branch exchanges* (PBX), were sold based on switch digital data as well as voice.

The mass appeal of telephone communications necessarily led to regulated industries to facilitate construction of the large communications networks required to serve a growing user base. The telecommunications authorities in many countries are nationalized and have broad responsibilities for a range of communication activities.

Evolution of Analog to Digital Communications

While analog switches are still in use today (particularly in rural areas or undeveloped countries), telephone providers began replacing them in the 1970s with computer-controlled *digital switches*. These switches initially converted analog voice to digital for internal switching and transport, and were later joined by fully digital central offices.

Prior to and during the conversion to digital switching and digital central offices, telecommunications providers began offering digital data services as well. The intention was to address the growing needs of digital data communications in areas such as banking, finance, government, and large corporations. In the United States, AT&T initially offered its *T1 carrier system* in the late 1960s, which provided 1,544,000 bits/second on twisted copper wire. Thus a T1 line can carry 24 simultaneous voice calls (64,000 bits/sec realizable from a 4 KHz wide voice band). Similar services are also available in other countries. Figure 1-2 illustrates the analog and digital components of today's phone systems.

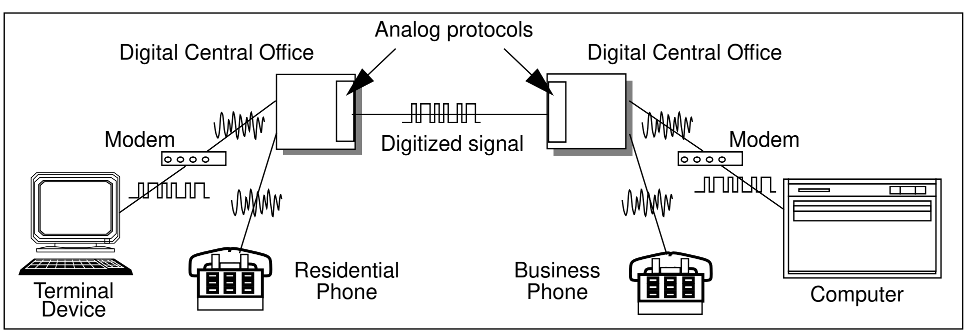

Figure 1-2 Digital and Analog Components of Most Telephone Systems Today

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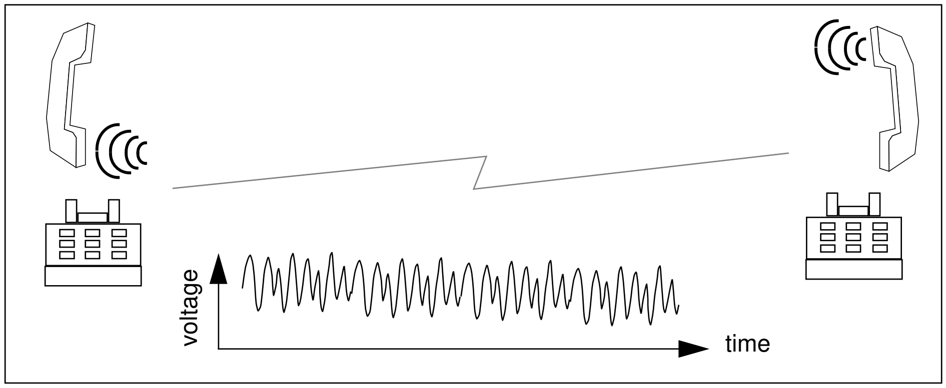

Figure 1-1 Analog Communication via Telephone

The development of long distance telephone communication relied heavily on characteristics of analog communication. By separating individual calls into *4 kilohertz* (thousand cycles per second) *bands*, engineers could superimpose, or *multiplex*, multiple calls on top of one another, and thereby share a single line among many users. The individual voice signals are assigned a frequency band, combined with other voice signals (assigned different bands) on the same wire, and finally decomposed at the far end, prior to being sent to the destination telephone.

In the early days of telephone, a human operator was necessary to direct a call to its destination. By the early 1920s however, *analog switches* replaced human operators and permitted direct dialing. To make this possible, automated switches sensing the dial movement of the initiating caller were interpreted and a connection was thus made. Both the human operator and the analog switch were located in a central location, (in the United States, called the *central office*), through which all circuits were routed. Today, this location is still significant in providing the local connection to the communications network, though the switching is fully automated and often digital.

The earliest telephones required many wires for their connection to the central office: wiring for the talk channels were distinct from those used to signal the switch (via the telephone dial). This proved to be so impractical that they were quickly replaced by a wiring scheme that combined the signaling functions with the voice communication on the same wire. The scheme, still in use today, is known as *inband signaling*, and explains why you can't dial while talking or talk while the phone is ringing.

Overview

Telecommunications is defined as the science and technology of sending messages by electrical or electronic means. While telephones are generally associated with telecommunications, the advancement of technology over the last few decades has redefined telecommunications to include such concepts as network routing, satellites, optical links, and broadband communication.

Since the initial development of the telephone system in the late 1800s, the impact of telecommunications has grown to a level where conceiving of the functioning of modern society without it is difficult. Over one billion telephones now serve the world, and the total continues to grow by more than 6% annually. In the most advanced countries, telephone service has reached a density of more than 95%[1].

ISDN came into existence through the necessity of providing a single integrated structure to accommodate a wide variety of services. Historically, applications have driven the design and implementation of application-specific networks. But as applications are defined and develop at an ever-increasing rate, an integrated structure that offered flexibility in providing new services as they evolved became essential.

ISDN represents both the logical evolution of communications technology and the convergence of interactive user computing, work environments spanning large geographies, and the need to process information at faster rates and in a more efficient manner.

Basic Telephony Concepts

The original telephone was an *analog* device. It carried voice by modulating an electrical current with a waveform, analogous to the acoustical wave that the ear can hear. Most telephones in use today still use analog modulation. Figure 1-1 illustrates analog communication.

1. IEEE Transactions on Communications, Val. COM-22, and Proceedings of the IEEE, Vol. 74.

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Introduction

The Integrated Services Digital Network, or ISDN, represents the logical evolution of digital networks to accommodate widespread voice and data communications on the broadest possible scale. Sun's vision of ISDN includes the creation of interactive enterprise collaboration in the workplace: anyone may communicate interactively with others, anywhere in the world.

This perspective, means that the computer workstation will become the new communication center, combining many existing communication media with new ones, while creating new paradigms for the expression and sharing of ideas. Information in the form of charts and pictures, schedules and plans, and audio and video will merge through application programs that provide a collaborative vehicle for decisions in the 1990s and beyond.

The desktop will become the platform for a new set of productivity tools, seamlessly integrated into the critical business activities and methodology of today's companies, and providing a competitive edge for facing the global challenges of tomorrow. Individuals will gain new freedom in where they work and how they access information. And ideas will be communicated in more expedient and creative ways.

Figures

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ISDN Technology

Technical White Paper

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