

ISDN Design for Global Markets

Karen H. Dorato
Lisa J. Klau

Integrated Services Digital Network (ISDN) promises end-to-end, high-speed digital connectivity in a multivendor environment. Over the past several years, applications—such as high-speed data transfer and tele-marketing enhancements—have expanded, and the deployment of ISDN customer-premises equipment has increased. However, applications that are available in some countries are not available in others, in part, because standards for the ISDN primary-rate interface (PRI) and the deployment rates of this interface vary from country to country (and carrier to carrier). Thus, true global portability of the protocol is not feasible at this time. However, it is possible to design and develop a PRI implementation that aligns with these varying standards in a single software and hardware base. The implementation requires flexibility and leniency in handling certain protocol elements and may rely on system administration to allow explicit control over some country-specific options of the protocol. This paper reviews the differences found worldwide in the ISDN PRI standards, and describes the flexibility that can be designed into an ISDN PRI implementation to accommodate these inconsistencies.

Introduction

Service providers and equipment vendors throughout the world see the Integrated Services Digital Network as the network of the future. Designed to provide an end-to-end digital network, ISDN also promises multivendor connectivity and a wide range of integrated services that are based on an open set of standards. However, these promises are being realized slowly in the marketplace. A main reason for this lag in the availability of ISDN applications is the large variance in ISDN standards that have emerged throughout the world since CCITT began the initial standardization effort in the early 1980s. (CCITT is the International Telegraph and Telephone Consultative Committee.) Although the goal of ISDN is to have a common protocol that can be used anywhere, each country has applied various interpretations and changes to the international recommendations and currently has, in effect, its own version of the ISDN standard. (Panel 1 defines acronyms and terms.)

The ISDN primary-rate interface is the digital “pipe” used to connect a private branch exchange (PBX) or multiplexer to the public network, or to connect two PBXs to form a private network. To accommodate country-specific (or carrier-specific) differences and conform to each country’s standard, a vendor normally might be forced to produce several software releases for the same equipment. However, the flexible architecture used in the design of both the hardware and software components of the AT&T DEFINITY® telecommunications system enables AT&T to avoid the multiple release problem.¹ Hence, a single software release of this system’s ISDN PRI implementation is compatible with various networks around the world.

Key Terminology. It is critical that readers understand the difference between a recommendation and a specification (or standard). In the context of defining a protocol such as ISDN, a *recommendation* is all-inclusive; that is, it defines many

configurations and operations—some critical to the protocol, in general, and some relevant only in some applications of the protocol. A *specification* (or *standard*) is more selective than a recommendation. In particular, a specification defines only those aspects of the protocol that are necessary for the application being addressed by the specification.

For example, the CCITT recommendations define both a 1.544-Mb/s (megabits per second) interface and a 2.048-Mb/s interface. In contrast, the ETSI specifications, with their focus on the European market, define only a 2.048-Mb/s interface because use of the 1.544-Mb/s digital interface has, in general, been confined to North America and Japan. We will provide more detail shortly about the CCITT recommendations and the ETSI specifications. (ETSI is the European Telecommunication Standards Institute.)

Evolution of Global ISDN Standards

CCITT initiated the ISDN standardization effort with the publication of its “Red Books” in 1984.² The Red Books contained recommendations for the implementation of both the primary-rate interface and the basic-rate interface. However, the 1984 recommendations were not complete. Since then, CCITT has issued a more complete set of recommendations for ISDN. These recommendations were published as the CCITT “Blue Books” in 1988.³ The CCITT “White Books,” which replaced the Blue Books in 1992, added further clarifications and functionality to the Blue-Book recommendations.⁴

In addition to the efforts under way in CCITT, various national standards bodies have undertaken the task of applying the CCITT recommendations to form implementable, national ISDN standards. Among these standards bodies are the American National Standards Institute (ANSI) in the United States, the Telecommunications Technology Committee (TTC) in Japan, and the Australian Telecommunications Authority (AUSTEL).

Similar work is also under way in regional standards bodies. One such effort is going on in ETSI, which began publishing ISDN standards in the late 1980s for implementation throughout Europe. However, even these standards will have country-specific options, which are determined at the national level.

The specifications defined by the national and regional organizations are further refined by users groups, such as the National ISDN Users Forum (NIUF)

Panel 1. Abbreviations, Acronyms, and Terms

- ANSI — American National Standards Institute
- AUSTEL — Australian Telecommunications Authority
- B channel — bearer channel; carries voice or data
- Blue Books — CCITT recommendations for ISDN, published in 1988
- CCITT — International Telegraph and Telephone Consultative Committee, based in Geneva, Switzerland
- CS — codeset, a grouping of information-element identifiers for a particular type of network or user
- D channel — data channel; carries signaling for the bearer channels
- ECMA — European Computer Manufacturers Association
- EIUF — European ISDN Users Forum
- ETSI — European Telecommunication Standards Institute
- IE — information element
- IPNS — ISDN Private Network Specification Forum, a consortium of PBX manufacturers
- ISDN — Integrated Services Digital Network; CCITT-defined digital network
- ISO — International Organization for Standardization, based in Geneva, Switzerland
- NIUF — National ISDN Users Forum, a user group in North America
- PBX — private branch exchange
- PRI — primary-rate interface
- Red Books — initial CCITT recommendations for ISDN, published in 1984
- tandem — a PBX is a tandem for a particular call if the call neither terminates nor originates on that PBX and if the incoming and outgoing legs are both an ISDN PRI. Messages of end-to-end significance received for this call on one interface are sent out—i.e., tandemed—on the other interface.
- TTC — Telecommunications Technology Committee in Japan
- White Books — CCITT recommendations for ISDN, published in 1992
- X.25 — a packet-switching protocol at the link and packet layers; defined by CCITT

in North America, and the European ISDN Users Forum (EIUF) in Europe.

Besides these standards for public networks, standards for private networks in Europe are also being written by the European Computer Manufacturers Association (ECMA) and the ISDN Private Network Specification Forum (IPNS, a consortium of PBX manufacturers). The International Organization for Standardization (ISO) is writing worldwide standards for private networks.

Many options are left open by the CCITT recommendations and, to a lesser extent, by the regional standards. Because various national standards bodies have selected different options in defining their country-specific ISDN standards, these standards have diverged. However, the differences among the ISDN standards will become less evident as the countries move (at different paces) toward common implementations.

ISDN PRI Deployment Status. ISDN PRI service is now available in at least 14 countries,^{5,6} including the United States, Australia, Japan, Germany, Italy, France, and the United Kingdom.

In addition, 26 European countries signed the Memorandum of Understanding on April 6, 1989, which targeted 100-percent deployment of ETSI-compliant ISDN for 1992. However, this date has slipped somewhat in several countries.⁵ Italy and Germany now claim 100-percent deployment will occur by 1993, and the Netherlands has shifted its date to 1995. By the end of 1991, initial ISDN trials and services were available in most European countries (but for the most part, these trials and services do not yet comply fully with the ETSI standard).

Some countries waited until the CCITT Blue Books were published to begin implementing ISDN PRI in their national networks. However, most of the ISDN PRI networks currently deployed use implementations that were based on the CCITT Red Books. When ISDN PRI was introduced into these pre-Blue-Book networks, each country's national standards organization extended the CCITT protocol where necessary. Often, these extensions were not compatible. For example, in the United States, AT&T first introduced ISDN service in 1986 with a protocol that was based on the Red Books but used maintenance messages, which were not defined by the CCITT recommendations.

Migration to a Common Protocol. Today, vendors who participate in several ISDN PRI trials face another problem. Because more countries are moving to support the common European-wide or worldwide standards, the

protocol that is being used in a trial may not be the one that will be used in that country in the future. Therefore, vendors in Europe will have to build a special interface for their pre-ETSI trials and, then, provide an ETSI-compatible interface (presumably with country-specific modifications) for use in the future.

For example, the trial that Societa Italiana Per L'esercizio Telefonico is running in Italy uses a protocol that predates the Blue Books and is not consistent with the ETSI standards. But after the trial, the service to be offered will be ETSI compatible. Similarly, France and Germany have service offerings that follow non-ETSI-compatible specifications. For France, the migration path from its RNIS Numeris VN2 protocol (which is based on the Red Books) to its RNIS Numeris VN5 protocol (which is fully ETSI compliant) involves two "stepping stone" specifications: RNIS Numeris VN3 and VN4. (RNIS is the French acronym for ISDN.)

Vendors may need to support, at least in the short term, both an ETSI (or other global) version of the ISDN protocol and an older implementation for another reason. Years before the ETSI standard or the CCITT Blue Books existed, many vendors and countries had implemented ISDN-based networks, which have evolved since then to a state of feature richness. Until the ETSI implementations can catch up to this full-feature support, vendors obviously will be motivated to maintain the old standards for the sake of their existing customer base.

In the long term, as the trend toward globalization of the ISDN protocol continues, this multitude of country- and carrier-specific differences will eventually be a thing of the past. The progress made by ETSI in defining a standard that the European technical community, at large, has embraced is a sign of this trend. But until the migration to these common, regional or worldwide standards is complete, the proliferation of various country-specific standards and implementations will continue (in the short term) and, probably, will get worse before it gets better. Clearly, vendors who want to compete in today's global marketplace while this migration is in progress need to design systems that can easily accommodate this host of differences.

World-Class DEFINITY System

As discussed earlier, if customer-premises equipment is to operate in the global marketplace, then it must meet many standards, government regulations, and customer expectations that often conflict.

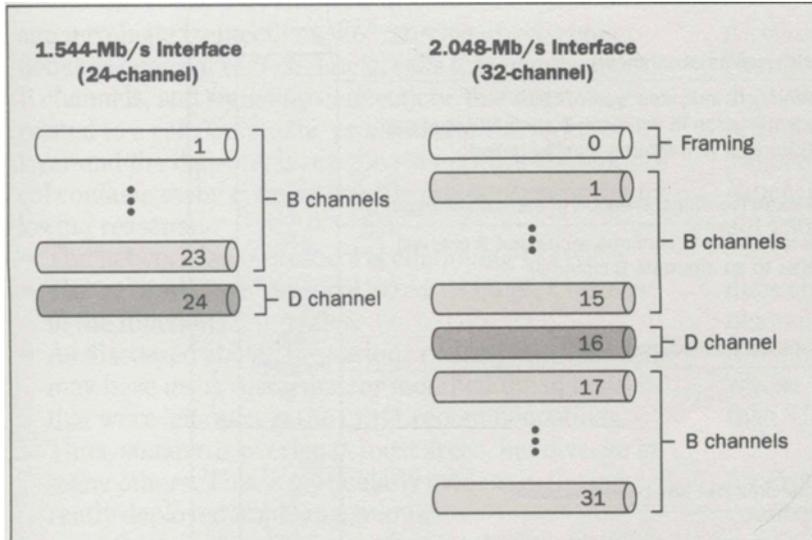


Figure 1. The CCITT recommendations for the ISDN primary-rate interface support both a 1.544-Mb/s interface (which is used in North America and Japan) and a 2.048-Mb/s interface (which is used in Europe and elsewhere). The 1.544-Mb/s recommendations on the left define a 193-bit frame consisting of twenty-four 8-bit time slots, plus one framing bit. The 2.048-Mb/s recommendations on the right define a 256-bit frame consisting of thirty-two 8-bit time slots.

AT&T's DEFINITY system readily adapts to these needs. For example, within the 18 months after AT&T introduced the DEFINITY system in the United States, it was also able to introduce the system in more than 20 countries. This rapid deployment was possible largely because of the strengths of the DEFINITY system's architecture, which allow the system to be adapted easily to meet the technical differences faced in each country.⁷ This flexible architecture includes the ISDN PRI implementation on the DEFINITY system, which is currently available in the United States and Australia. AT&T plans to introduce ISDN PRI on the DEFINITY system in Italy, the United Kingdom, Japan, France, Germany, the Netherlands, Spain, and other countries.

Although the issues discussed in this paper are relevant for any customer-premises equipment that connects to an ISDN PRI, we will focus on the specific implementation choices that were made for the DEFINITY PBX.

Physical Layer—Layer 1. In general, the specifications for the physical layer (i.e., layer 1) of a communications channel define details of the bit-stream transmission, including:

- Electrical characteristics (bit rate, voltage, line coding, and so on)
- Frame structure (time slots per frame, time-slot assignment, and so on)
- Operational issues (normal and fault-condition signals and states).

For ISDN PRI, the CCITT recommendations support both a 1.544-Mb/s interface (which is used in North

America and Japan) and a 2.048-Mb/s interface (which is used in Europe and elsewhere). As the diagrams in Figure 1 show:

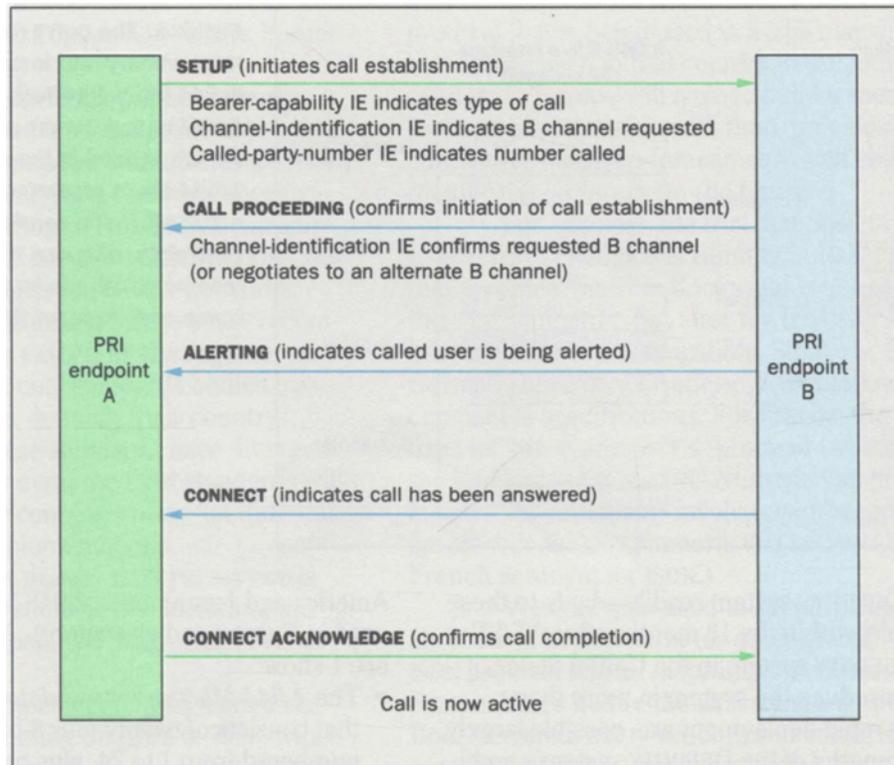
- The 1.544-Mb/s recommendations define a 193-bit frame that consists of twenty-four 8-bit time slots, which are numbered from 1 to 24, plus one framing bit. Time slots 1 through 23 are assigned as B channels (i.e., bearer channels that carry voice or data). Time slot 24 is assigned to the D channel (i.e., the data channel, which carries signaling for the bearer channels).
- The 2.048-Mb/s recommendations define a 256-bit frame that consists of thirty-two 8-bit time slots, which are numbered from 0 to 31. Time slots 1 through 15 and 17 through 31 are assigned as B channels, and time slot 16 is assigned to the D channel. Time slot 0 carries framing information.

Both interfaces transmit 8000 frames per second.

The layer-1 standards are mature and stable, and the 1.544-Mb/s and 2.048-Mb/s interfaces are largely consistent worldwide. Nevertheless, we still have to consider the national options. To deal with these differences in a single software and hardware base, the country-specific options are selected through system administration, and the appropriate parameters are downloaded to the PRI board.⁷ These parameters include the ability to specify whether the board will run at 1.544 Mb/s or 2.048 Mb/s, so that a single board can be used for either standard.

In addition, the CCITT recommendations do not clearly define the physical-layer idle code (which is transmitted on every time slot that is not assigned to a

Figure 2. Most of the country-specific ISDN PRI specifications agree on the protocol exchange required to establish a call between ISDN PRI endpoints, as in this network-layer message exchange. However, the exact information-element (IE) encodings required at each country's endpoints may be different enough that no call attempts would succeed.



channel, and on every channel that is not allocated to a call). Therefore, this idle code can be administered for each PRI board, to allow alignment with the differing country specifications.

For voice transmission, CCITT defines two compression schemes: A-law and μ -law companding. As a system-administration option, either companding scheme can be selected for the switch as a whole, and either scheme can be selected for each PRI board. If the switch and the board are administered for different schemes, then the DEFINITY system does the conversion necessary between the two schemes.

Data-Link Layer—Layer 2. In general, the specifications for the data-link layer (i.e., layer 2) of a communications channel define procedures for converting an error-prone physical layer (layer 1) into an error-free transmission line for the network layer (layer 3).

For ISDN PRI, the protocol definition for the data-link layer is also relatively mature, because it is drawn mostly from the widely used X.25 packet-switching protocol. But as with the physical layer, certain country-specific differences exist, particularly in the areas of

error handling and error recovery. These differences are minor, and two layer-2 implementations that are built to align with two different country-specific standards might still be functional. (By *functional*, we mean a layer-2 link could be established and maintained between the two implementations.) However, if a country has specific testing requirements for the error-handling and error-recovery procedures, then an implementation might meet the CCITT recommendations yet, despite this functionality, not be able to pass the country's conformance-testing requirements.

The DEFINITY system currently supports a single layer-2 protocol, which aligns with both the CCITT recommendations and the ETSI specifications. Because of the potential need to accommodate country-specific error-handling and error-recovery procedures, the DEFINITY system's ISDN PRI was designed to allow easy expansion to support multiple versions of the layer-2 protocol simultaneously.

Network Layer—Layer 3. In general, the specifications for the network layer (i.e., layer 3) of a communications channel define procedures to establish, maintain,

and terminate connections. For ISDN PRI, these connections may consist of B channels, calls that use these B channels, and signaling connections that are not related to a call. Unlike the protocols for the physical layer and the data-link layer, the PRI network-layer protocol contains many country-specific differences for the following reasons:

- The network-layer protocol is continuing to evolve.
- The network-layer protocol is more complex because of the functions it provides.
- As discussed above, the various country specifications may have used, discarded, or modified the options that were left open in the CCITT recommendations. Thus, standards overlap in most areas, but diverge in many others. This is particularly evident in the currently deployed implementations.

Customer-premises equipment that attempts to provide even basic ISDN PRI service in several different countries or in a multicountry network faces a challenging task. Because the network layer also supplies the foundation for invoking and operating supplementary services (which continue to be defined), the task is even more difficult.

General differences. Most of the country-specific ISDN PRI specifications agree on the message exchange required to establish a call between two ISDN PRI endpoints. The layer-3 message exchange in Figure 2 illustrates this protocol.

However, a single, hard-coded implementation of even such basic aspects of the PRI protocol at layer 3 would not be functional in all countries. The information-element (IE) encodings that the various country PRI specifications require for a basic call-setup message exchange differ enough that the exact encoding required in one country may be unusable in another country. (*Unusable* means that no call attempts would be successful.)

For example, the *Type of Number* field of the called-party-number IE is used to identify the type of the number whose digits follow in the information element. Possible encodings include 'Unknown', 'International Number', and 'National Number'.

In the U.S., for example, the AT&T switched network expects the PBX to do some digit manipulation. That is, if the *Type of Number* field indicates that this is a 'National Number', the AT&T switched network expects the digits that follow to be a 10-digit number in the North American numbering-plan format. But if the *Type of*

Number field indicates that this is an 'International Number', then the AT&T switched network expects the digits that follow to be an international number that begins with a country code. However, the AT&T switched network will not accept a call whose *Type of Number* field is encoded as 'Unknown', because it does not know how to handle the digits that follow.

On the other hand, the public network in Japan does not expect (or allow) the PBX to do any digit manipulation, and the *Type of Number* field must be encoded as 'Unknown'. This public network will not accept a call whose *Type of Number* field is encoded as anything other than 'Unknown'.

Clearly, the differences at layer 3 can be critical for even basic call setup. If a PBX is to align with several country PRI specifications at the same time, then it must provide more than a single, hard-coded implementation of the protocol. Critical protocol differences must be accommodated in some way, so that various standards can be supported simultaneously.

If a vendor is to build a common ISDN PRI, these general areas of differences need to be addressed:

- Messages supported
- Information elements supported
- Message-encoding rules to be used (e.g., which information elements are mandatory or optional)
- IE-encoding rules to be used (e.g., which octets are mandatory or optional; what do the different encodings mean)
- Call states supported
- State transitions expected
- Basic call services supported (e.g., wideband channels, or overlap send or receive)
- Procedures to be followed for ISDN to non-ISDN interworking
- Maintenance procedures to be followed for the B channels
- Error-handling rules to be used.

DEFINITY System Handles Diverging Protocols

The DEFINITY system approaches the differences between the many ISDN PRI specifications for layer 3 in three main ways:

- The software that supports layer 3 is designed to be flexible and lenient. (That is, the implementation does not enforce all elements of the protocol, and yet provides a fully functional and compatible interface.)

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- The software is driven by switch administration. (This means that administrative parameters are provided to control the protocol and feature options.)
 - Some areas, such as B-channel maintenance, use a combination of approaches. For these areas, an *intelligent maintenance architecture* is provided. Thus, switch administration drives the software, but the software is also flexible to allow for unexpected differences in other vendors' networks.

The rest of this section discusses these approaches in detail.

Lenient Software. Flexibility and leniency in the layer-3 software is especially beneficial when we consider message validation. The DEFINITY system's software is able to process incoming layer-3 messages that conform to many different country-specific ISDN PRI standards. Wherever possible, the DEFINITY system accepts incoming message encodings that may or may not conform to the PRI specification that is in effect for the network or switch from which the layer-3 message was sent.

To allow as many calls as possible to be completed, the basic philosophy is for the software to be lenient about potentially minor protocol violations from another switch. However, all outgoing messages are encoded in a format that is accepted by the PRI specification supported on the outgoing interface. (By *outgoing* messages, we mean both those messages that originated from the DEFINITY system and those in a networked call that originated from another switch and are sent out again—that is, *tandemed*—on another PRI.)

For example, although the CCITT recommendations require that messages be encoded with the information elements in a particular order, the DEFINITY system (as permitted by the CCITT recommendations) does not require the far end to do so. All information elements in an incoming message are processed, regardless of their order of appearance. However, outgoing messages are always encoded with the information elements in the correct order.

In addition to message validation, flexibility and leniency in the layer-3 software is beneficial for message-encoding practices that are supported in some PRI standards, but not in others. Again, the DEFINITY system's philosophy is to be lenient about the *incoming* message encodings for the sake of maximum call completion. But it strictly follows the globally accepted message-encoding practices in all *outgoing* messages sent from the switch.

Support for the locking-shift and nonlocking-shift IES serves as a good example. CCITT defines eight codesets—that is, groupings of IE identifiers—that are numbered 0 through 7. For example, codeset 0 IES are defined by CCITT for the basic protocol, while codeset 6 is reserved for IES that are specific to the local network. The *nonlocking-shift IE* provides a temporary shift from the current codeset to a different codeset, but the new codeset applies only to the next IE in the message. The *locking-shift IE* provides a more permanent shift to a different codeset. Here, the indicated codeset applies until another locking or nonlocking shift is received, or until the end of the message is reached.

Although defined in the CCITT recommendations, some PRI standards do not require that the nonlocking-shift IE be supported. Instead, these standards allow the recipient of a nonlocking-shift IE to ignore the nonlocking-shift IE and the information element that follows it. Thus, PBXs that comply with these standards may not be able to process all the information elements in a message.

The DEFINITY system supports locking-shift and nonlocking-shift IES. If it receives an incoming message that contains nonlocking-shift IES, the DEFINITY system processes all information elements in the message in the correct codeset, including the information elements that immediately follow the nonlocking-shift IES. To allow full-feature operation with networks that do not support the nonlocking-shift IE, the DEFINITY system always uses locking-shift IES to encode its outgoing messages (even the *tandemed* messages), with all the information elements in codeset 0 first, followed by the information elements in other codesets in numerical codeset order. This approach also enables networks that process only the information elements in codeset 0 to provide the correct functionality for basic features (i.e., codeset 0).

Figure 3 illustrates the message conversion that can take place, using the examples noted in the above paragraphs (that is, placing information elements in numerical order, and relying on the globally accepted locking-shift mechanism for changing codesets). Of course, additional conversions at the IE-content level may also take place (e.g., modification of the digits of the called-party number, based on system-routing administration).

In addition to the flexibility already described, the software is also designed to be lenient when

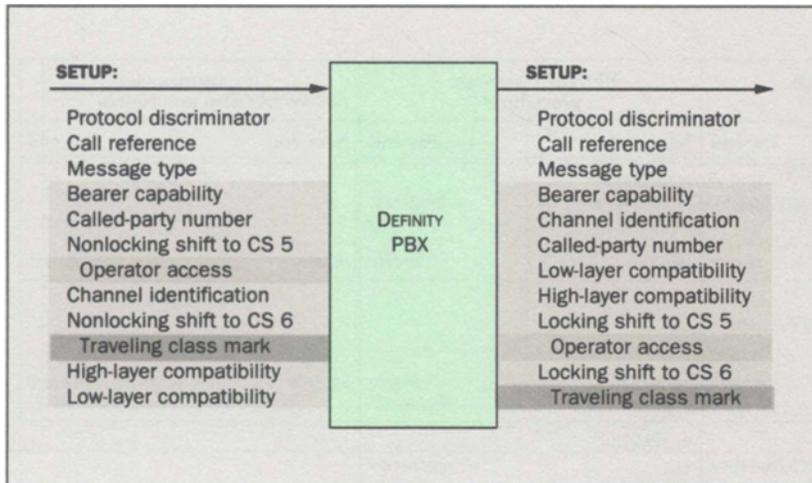


Figure 3. In a call-setup message exchange, message conversions in the PBX place the outgoing information elements in numerical order based on the IE identifier (e.g., channel identification before called-party number). These conversions also rely on the globally accepted locking-shift mechanism to change codesets (CSs).

terminating and tandeming calls that contain information it cannot process. For example, if an incoming call is to be switched to another PBX or ISDN endpoint, the DEFINITY system will transparently tandem all unknown information elements in codeset 0 (i.e., CCITT), codeset 5 (i.e., national), codeset 6 (i.e., local network), and codeset 7 (i.e., user-specific). This action accomplishes two goals:

- It provides forward compatibility by not rejecting information elements in codeset 0 that may be added to the CCITT recommendations after the switch is deployed. These information elements may be important for call completion at the terminating end.
- In a networked environment, an information element that the DEFINITY system does not recognize is passed to the next switch, where it may be used to provide an enhanced service for the call. Again, these information elements may be critical to a supplementary service that otherwise would not be provided at the terminating switch.

Administrative Parameters. Two types of administration parameters drive the DEFINITY system's ISDN PRI software. One type, which we refer to as *protocol administration*, drives country-specific (or standard-specific) software for country-specific (or standard-specific) options or parameters. The other type, which we call *feature administration*, drives software that is common to all interfaces because it drives switch features.

Protocol administration. The DEFINITY system requires that a *country protocol* be administered for each ISDN primary-rate, user-network interface. In addition, the DEFINITY system requires that a *peer protocol* be

administered for each ISDN primary-rate peer interface (i.e., the ECMA peer protocol).

These administered protocols are used to drive layer-3 protocol decisions in the software where those decisions are purely the result of differences in the PRI specifications, such as error procedures, and not related to a particular feature. The use of this administration parameter allows nonstandard aspects of the protocol to be implemented on a particular interface, without affecting the protocol used on another interface.

For example, Australia's ISDN PRI specification defines a nonstandard method for the assignment of B-channel numbers to time slots on the interface. Therefore, if the Australian protocol is selected for a particular interface, then the channels are numbered according to this method. Also, although most specifications require that the *Numbering Plan Identification* field in the called-party-number IE be encoded as 'ISDN Telephony', Japan requires that this field be encoded as 'Unknown'. Therefore, when the country protocol selected is the Japanese protocol, 'Unknown' is used to populate the *Numbering Plan Identification* field of the called-party-number IE. For all other protocols, 'ISDN Telephony' is used in this field.

Feature administration. Several information elements can be populated with various encodings that are based on the feature or service being requested. Thus, the different encodings are determined in common software using the conditions that surround a particular call, and not the protocol that has been administered for the interface.

For example, the *Type of Number* field in the called-party-number IE is populated using system-

Table I. Comparison of B-channel Maintenance Strategies

Scenario	SERVICE message procedures		RESTART message procedures		No maintenance message procedures	
	Near end	Far end	Near end	Far end	Near end	Far end
1. Initialize near-end B channel; far end is ready <i>B-channel state</i>	SERVICE/in-serv→ ←SERV-ACK/in-serv		RESTART→ ←REST-ACK			
	<i>in-serv</i>	<i>in-serv</i>	<i>in-serv</i>	<i>in-serv</i>	<i>in-serv</i>	<i>in-serv</i>
2. Near-end B channel is removed from service (e.g., port-hardware failure; manual intervention) <i>B-channel state</i>	SERVICE/out-serv→ ←SERV-ACK/out-serv					
	<i>out-serv</i>	<i>out-serv</i>	<i>out-serv</i>	<i>in-serv</i> (but see 4)	<i>out-serv</i>	<i>in-serv</i> (but see 4)
3. Near end tries to restore B channel to service; far end is not ready <i>B-channel state</i>	SERVICE/in-serv→ ←SERV-ACK/out-serv		RESTART→ ←ignored>			
	<i>out-serv</i>	<i>out-serv</i>	<i>out-serv</i> (eventually)	<i>out-serv</i>	<i>in-serv</i> (but see 4)	<i>out-serv</i>
4. Near-end DEFINITY system infers, via call-control messaging, that far-end B channel is out of service (e.g., repeated channel negotiation by far end away from that B channel; receipt of cause 82 "identified channel does not exist") <i>B-channel state</i>	N/A	N/A				
			<i>in-serv</i> → <i>out-serv</i> (without RESTART)	<i>out-serv</i>	<i>in-serv</i> → <i>out-serv</i>	<i>out-serv</i>
5. Near-end DEFINITY system infers, via call-control messaging, that far end has restored the B channel to service, or that its out-of-service inference was incorrect (e.g., far-end call origination for that B channel; far-end B-channel negotiation to that B channel) <i>B-channel state</i>	N/A	N/A				
			<i>out-serv</i> → <i>in-serv</i> (without RESTART)	<i>in-serv</i>	<i>out-serv</i> → <i>in-serv</i>	<i>in-serv</i>

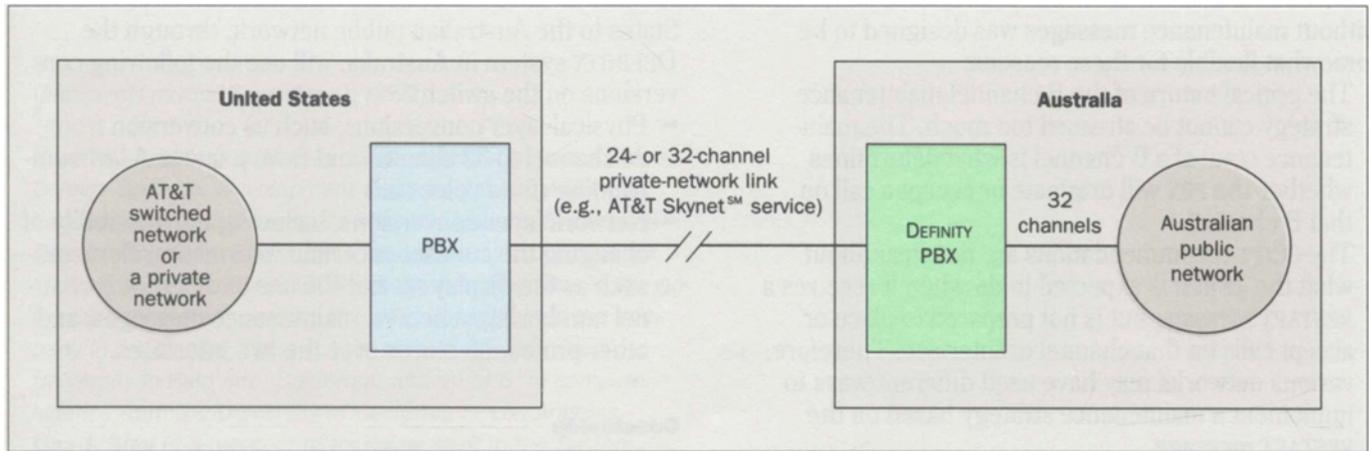
NOTE: in-serv = in service; out-serv = out of service; REST-ACK = RESTART ACKNOWLEDGE; SERV-ACK = SERVICE ACKNOWLEDGE;

administration information about the dialed-digit string. This gives the system administrator flexibility to fine tune the protocol, as needed. Also, the calling party's name and number may (or may not) be sent for each call, based on similar system administration.

In addition, system-administration decisions at the feature level provide backward or forward compatibility with other implementations by allowing the system administrator to choose the codeset in which certain information elements are to be sent. For example, for each trunk group, the system administrator can determine the codeset (i.e., 0, 6, or 7) in which the display IE is to be sent, based on the needs of the far-end switch.

Intelligent Maintenance Architecture. As mentioned earlier, the CCITT Red Books did not define a mechanism for maintaining the B channels (that is, for resetting the channels and returning them to an idle condition when a failure has occurred). Because of this omission in the original recommendations, several different paths have been taken in this area.

AT&T defined its own maintenance messages and procedures (i.e., SERVICE message procedures). Other country and carrier specifications followed the Red Books and left such procedures undefined; that is, no maintenance messages are defined or exchanged. The PRI specifications that were developed after the CCITT Blue



Books became available followed the Blue-Book definitions of maintenance messages and procedures (i.e., RESTART message procedures). Thus, we currently have three diverging methods for handling B-channel maintenance. The rest of this section discusses the differences between these procedures, and the approach taken by the DEFINITY system to accommodate these differences. Table I summarizes the differences.

Current CCITT recommendations for layer 3 define the RESTART and RESTART ACKNOWLEDGE messages, which are exchanged to force a B channel or an entire interface into an idle condition. Usually, a RESTART message is sent by the near end of the interface when the interface first comes into service, when the far end does not respond to other layer-3 messages, or when some other failure has occurred. No explicit method exists for the far end to tell the near end that, although it has received the RESTART message, the channel or interface is not ready for use (e.g., the B channel has a local, physical problem). In addition, the near end has no way to notify the far end explicitly of a near-end problem that will result in a trunk being unavailable for service.

In contrast, as mentioned above, the AT&T ISDN PRI specification⁸ defines additional maintenance messages (i.e., SERVICE and SERVICE ACKNOWLEDGE) that are exchanged by the two sides of a primary-rate interface to establish the maintenance state (i.e., in-service, maintenance, or out-of-service) of each B channel in the interface. Both messages explicitly indicate the maintenance state. Therefore, the far end now can inform the near end that it has, for example,

Figure 4. This multinational gateway application shows a private-network connection between a DEFINITY system in Australia and another PBX in the United States. By using the administrable protocol and the various administration options of its ISDN PRI board, the DEFINITY system can support different, perhaps incompatible, PRI implementations simultaneously.

received the request to transition the B channel to an in-service state but is unable to do so (e.g., because of a local, physical problem with the B channel).

Some country-specific ISDN PRI standards do not support *any* messages, such as RESTART or SERVICE, that can be used when a B channel is in a maintenance condition. Presumably, the B channels are to be considered always available. Even if an implementation is able to note a local problem and remove the B channel from service, it has no way to notify the far end explicitly of the problem. The near end also has no way to notify the far end explicitly that the problem has been rectified. (The ability to send such a message would be helpful if the far end were able to infer from the call-control messaging that the near end had a problem with that B channel.)

The DEFINITY system supports maintenance strategies that are based on the RESTART message, on the SERVICE message, and on no explicit exchange of maintenance messages. The strategy in effect on a particular ISDN primary-rate interface is determined by the protocol that was administered for the interface.

In addition, the DEFINITY system's strategy about maintaining PRI B channels via RESTART messages or

without maintenance messages was designed to be somewhat flexible for these reasons:

- The critical nature of the B-channel maintenance strategy cannot be stressed too much. The maintenance state of a B channel is what determines whether the PBX will originate or accept a call on that B channel.
- The CCITT recommendations are not clear about what the switch is expected to do when it receives a RESTART message but is not prepared to place or accept calls on that channel or interface. Therefore, various networks may have used different ways to implement a maintenance strategy based on the RESTART message.

The flexibility of the DEFINITY system about the maintenance strategy simply means that the state of the B channel is determined by methods other than just the exchange of RESTART messages. In particular, layer-3 call-control messages can override the maintenance state determined from the maintenance messages. A positive indication that the far end considers a B channel ready for call activity (e.g., the receipt of a SETUP message from the far end to request a B channel that the near end considers to be in a far-end, out-of-service condition) will cause the channel's state to be changed to in-service, and the call-setup activity will continue.

Table I summarizes several key differences between the three B-channel maintenance strategies. It shows the explicit exchanges of maintenance messages and also shows the DEFINITY system's ability to make proactive maintenance decisions based on various call-control scenarios.

Gateway Functionality. The architecture we have described in this paper gives the DEFINITY system the capability to act as a gateway switch between two incompatible ISDN PRI implementations. (See Figure 4.) By using the administrable protocol and the various administration options of the ISDN PRI board, the DEFINITY system can support different PRI implementations simultaneously.

For example, Figure 4 depicts a private-network connection between a DEFINITY PBX in Australia and another PBX (possibly a different vendor's PBX) in the United States. The DEFINITY PBX in Australia is also connected to the Australian public network, and the PBX in the United States is also connected to the AT&T switched network. A call that is placed from the United

States to the Australian public network, through the DEFINITY system in Australia, will use the following conversions on the switch:

- Physical-layer conversions, such as conversion from 24 channel to 32 channel and from μ -law to A-law companding (for a voice call)
- Network-layer conversions, including the possibility of changing the codeset of certain information elements—such as the display IE; and the use of different B-channel numbering schemes, maintenance messages, and other protocol features over the two interfaces.

Conclusion

The promise of ISDN—to provide high-speed digital connectivity in a multivendor environment—is being realized slowly because of differences in both the ISDN standards and the implementations currently deployed worldwide. If ISDN is to be supported in the global market, these differences could force the vendors of customer-premises equipment to develop multiple implementations of ISDN PRI.

However, this paper has discussed ways to address these divergent standards until the promise of a common, globally deployed standard is reached. AT&T's DEFINITY PBX addresses these differences with an architecture that provides leniency in the design and flexibility in the choice of certain interface parameters.

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Karen H. Dorato is a member of technical staff in the Global DEFINITY Software Development Department with AT&T Bell Laboratories/Global Business Communications Systems in Denver, Colorado. She is the lead engineer responsible for implementing the global ISDN primary-rate interface in the global DEFINITY system product line. Ms. Dorato joined the company in 1986. She has a B.A. in psychology from Stanford University in Palo Alto, California, and an M.S. in computer science from the University of California at Los Angeles.

Lisa J. Klau is a member of technical staff in the System Interworking Department with AT&T Bell Laboratories/Global Business Communications Systems in Middletown, New Jersey. She is responsible for the definition and deployment of the ISDN primary-rate interface on the global DEFINITY system product line. In addition, she is active in worldwide ISDN-standardization activities. Ms. Klau joined the company in 1985. She has a B.S. in electrical engineering from Rutgers, The State University of New Jersey, in New Brunswick, and an M.S. in electrical engineering from Columbia University in New York City.
