

X.25 and related recommendations in IBM products

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This paper describes IBM's use of Recommendation X.25 and related recommendations of the International Telegraph and Telephone Consultative Committee. After reviewing the development history of X.25 and some of the motivations for using it, the paper gives an overview of packet-switched data networks. The reader is then given a brief technical description of Recommendation X.25 and some other recommendations used in conjunction with X.25. The architectural relationships between X.25 and IBM's Systems Network Architecture (SNA) are described for packet-switched X.25 connections between SNA nodes and for X.25 connections between SNA and non-SNA nodes. Specific elements of Recommendation X.25 used in SNA nodes are defined. After several IBM products that support X.25 and some of the related recommendations are described, IBM's equipment for testing the X.25 interface is discussed.

The X.25 recommendation approved by the International Telegraph and Telephone Consultative Committee (CCITT) at Geneva in 1976¹ created significant worldwide interest. It specifies the interface between packet-mode data-terminal equipment (DTE) and equipment that is generally referred to as the data circuit-terminating equipment (DCE). The early network implementations of the X.25 recommendation were by DATAPAC® in Canada and TRANSPAC® in France with service offerings beginning in 1977 and 1978, respectively.

It was soon recognized that interpretation of the X.25 recommendation (subsequently called "X.25")

was varied, in many cases resulting in implementations that are incompatible.²⁻⁶ This incompatibility puts a burden on DTE designers because a DTE designed for one packet network may not work on others even though their interfaces conform to X.25.

During the four years immediately following 1976, Study Group VII of the CCITT worked diligently to clarify and enhance X.25. In November 1980, the CCITT plenary assembly approved the current version of the interface.⁷ It is noteworthy that since first approved in 1976, the recommendation evolved in four years to what many believe is a well-defined interface.

Having participated in the development of X.25, IBM announced in 1977 an attachment capability of several DTE products for packet-switched data networks (PSDNs) in Canada and France. Since that early announcement, IBM has enhanced its X.25 product offerings and extended support to many additional countries. IBM products that have the X.25 interface comply with the 1980 version of X.25.

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Table 1 Public packet-switched networks using the X.25 interface

Location	Availability
Argentina	1983
Australia	1983
Austria	1982
Belgium	1982
Brazil	1984
Canada	1977
Chile	1981
Denmark	1983
Euronet*	1979
Finland	1983
France	1978
West Germany	1981
Ireland	1982
Israel	1982
Italy	1984
Japan	1980
Luxembourg	1982
Mexico	1982
Netherlands	1981
New Zealand	1982
Norway	1983
Peru	1984
Portugal	1983
Singapore	1982
South Africa	1982
Spain	1982
Sweden	1983
Switzerland	1982
United Kingdom	1981
United States	1980
Venezuela	1984
Yugoslavia	1985

*A network sponsored by the European Economic Community

IBM's X.25 products operate in accordance with Systems Network Architecture (SNA).^{8,9} SNA defines formats and protocols governing interactions among IBM products that are components of the SNA network.¹⁰ The implementation of X.25 in IBM products allows connectivity of SNA, and in some instances non-SNA, products through a PSDN.

Although the list continues to grow, Table 1 shows some of the countries with existing or projected public X.25-based packet-switched data networks. Many countries have recognized the need for international networks and connectivity between them; consequently, many PSDNs are now interconnected. Euronet is an international PSDN set up by PTT Administration with the financial cooperation of the European Economic Community (EEC) to enable

users to gain access to the Diane European data bank network.

The use of X.25 is not limited to the public sector. A number of businesses have already implemented private X.25 networks, and more are considering doing the same. Many X.25 hardware and software products are now available, allowing private networks to be implemented with relative ease. Since

IBM's X.25 products operate in accordance with SNA.

X.25 defines only an interface between a DTE and a DCE, the network designers are free to design the internal structure of their network independently. Thus, a network could be implemented using SNA as the backbone and X.25 as the network interface.

Typically, a user of an X.25 public offering is faced with a somewhat more complex rate structure than for more traditional services. Packet network tariffs usually consist of four or more different charges such as an installation charge, an access charge, a connect-time charge, and a charge per packet that is, in many cases, independent of distance and connect time. In order to determine what is most attractive for a particular application, a careful analysis of all the costs must be completed. Packet switching appears most attractive for applications with low- to mid-range volumes as depicted in Figure 1. Note also that for a few short transactions each day, circuit-switched facilities appear to be more attractive than packet-switched networks and that for large volumes of data, nonswitched facilities are still the most cost-effective.

Packet-switched data networks

A DTE attached to a PSDN can be a host processor, cluster controller, or terminal that is sending and receiving data. Figure 2 shows how two DTEs communicate via two DCEs and a packet network.¹¹ The DCE is provided by the carrier and located near the

DTE. However, the intelligence for the termination that constitutes the DCE usually originates further within the network, at the switching node. The situation with telephones is similar, where the dial tone emanates from the handset but the intelligence responsible for it is elsewhere.

The packet-switched data network consists of switching nodes and high-speed transmission links between these nodes. Data is formatted into packets of fixed maximum length. Some PSDNs offer dynamic routing so that data packets may be rerouted along a different path if the current path

Packets are the basic information unit transmitted through a packet network.

through the network is not working or becomes too crowded. Dynamic routing of packets along any one of several alternative paths can minimize delays and increase system reliability. Such networks recover from transmission errors, eliminate duplicated packets, and order packets arriving out of sequence.

Virtual circuits are superimposed on the X.25 access links, which are either nonswitched or switched real circuits. However, at this time, IBM and most networks support only nonswitched real circuits for X.25 access to packet-switched networks. The virtual circuits also can be permanent or switched. Switched virtual circuits (virtual calls) are set up by sending the "calling digits" identifying the remote DTE within a control packet.

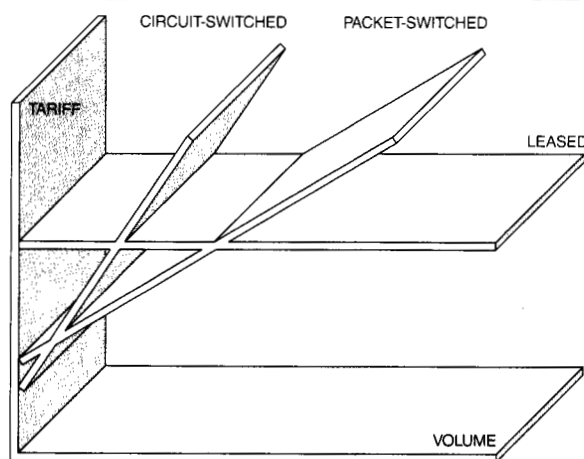
A logical channel identifier in the packet header associates the packet with a permanent or switched virtual circuit, allowing the network to control the routing of the packet through the network to the receiving DTE. The identifier is used as a shorthand address to obtain the complete DTE address. Packet

interleaving, which involves assigning several logical channels to the same physical circuit, allows one DTE to communicate simultaneously with many others.

One of the significant differences between real and virtual circuits is the multiplexing across the DTE/DCE interface. Architecturally, a single real circuit can accommodate up to 4095 virtual circuits; thus, host computers that typically require connections to multiple remote DTEs may require far fewer communication adapters and network interfaces (Figure 3). By multiplexing the packets from a number of users, packet switching can improve the utilization of transmission facilities. Each user is allocated transmission time only as needed.

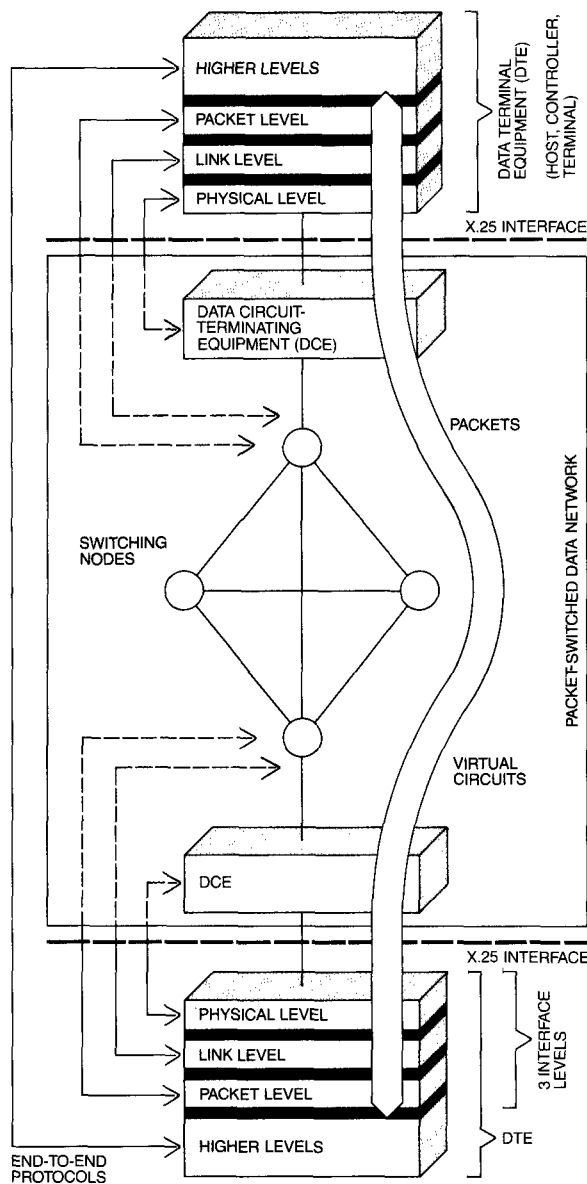
In addition to the sending and receiving of packets via permanent and switched virtual circuits, X.25

Figure 1 Tariff parameters affecting data communication services



	DISTANCE	VOLUME	DURATION	TIME OF DAY	FIXED RESPONSE TIME	SPEED	ATTACHMENT CHARGE
LEASED	X				X	X	X
CIRCUIT-SWITCHED	X		X	X	X	X	X
PACKET-SWITCHED		X	X	X		X	X
ALL PARAMETERS VARY BY COUNTRY AND SERVICE AND TIME							

Figure 2 Packet switching with X.25



also includes rules for communicating via "datagrams." These are self-contained packets that include all the control information required by the network and the complete address of the intended receiver. This is in contrast to virtual-circuit service where the source and destination addresses are

retained by the network. There is no apparent relationship between datagrams, and each may be routed independently of the others. Thus, datagrams are comparable to letters or telegrams. Datagrams may arrive in a different order than sent, and their receipt at the delivery point is not acknowledged. Because of these disadvantages, there has been very little interest in the datagram service.

X.25 and related recommendations

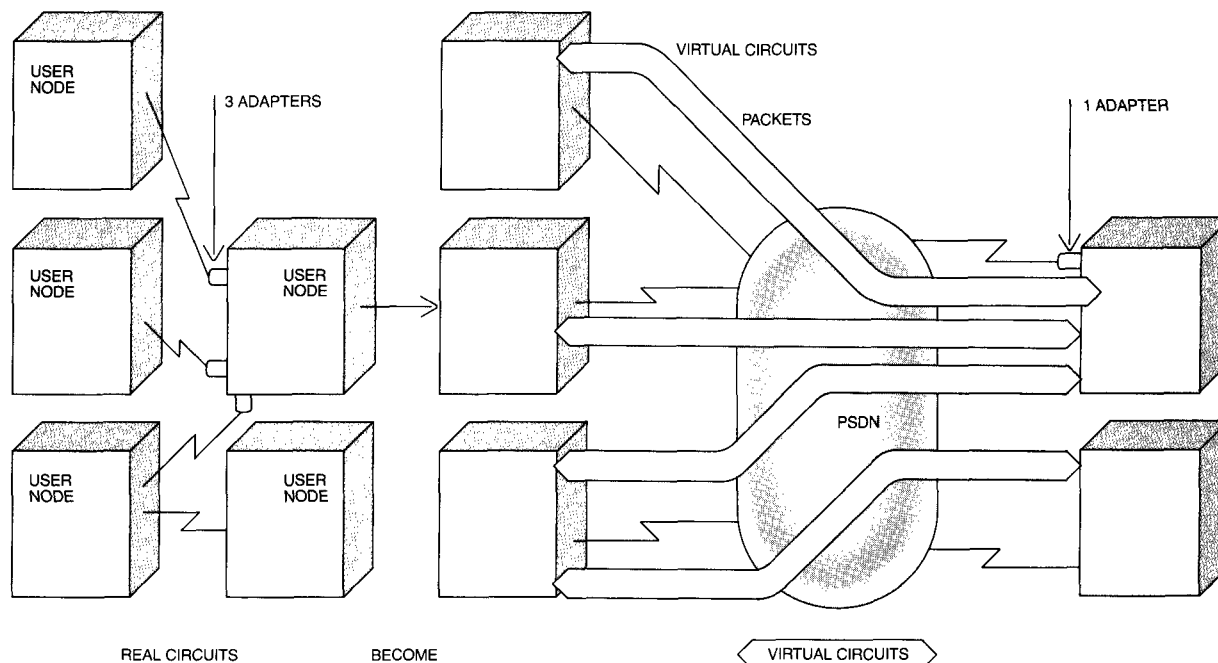
Recommendation X.25 defines three different levels—physical, link, and packet—and lays down guidelines for packet-switched network services. (See Figures 2 and 4.) The physical level (Level 1) governs the mechanical, electrical, functional, and procedural characteristics of the interface required to activate, maintain, and deactivate the physical circuit between the DTE and DCE.

X.25 defines an interface between a user's equipment and the packet network.

Although the preferred physical-level element conforms to CCITT Recommendation X.21,^{7,12} Recommendation X.21 bis⁷ (which includes CCITT Recommendation V.24¹³ and RS-232-C of the Electronic Industries Association¹⁴) may be used for an unspecified interim period.

Two link-level (Level 2) procedures are defined in the recommendation: Link Access Procedure (LAP) and Link Access Procedure—Balanced (LAPB). LAP procedures were used in such early networks as DATAPAC and TRANSPAC and are supported in some IBM products. LAP procedures provide symmetrical data transfer and maintain the distinction between primary and secondary stations for control. LAP does not conform with High-Level Data Link Control (HDLC)¹⁵ of the International Organization for Standardization (ISO). In LAPB, the HDLC-conforming procedure preferred by the CCITT, con-

Figure 3 Multiple links can be replaced by multiplexed virtual circuits



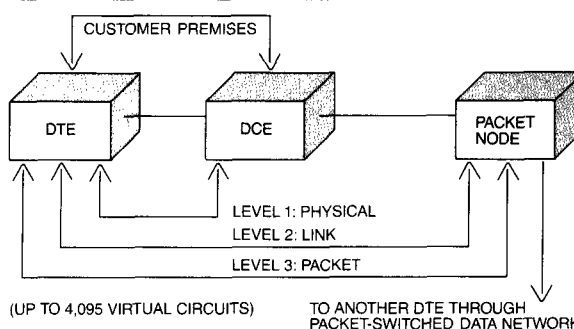
control as well as data transfer is symmetrical, and recovery rules are simpler. Both LAP and LAPB provide efficient data transfer (no polling) on a duplex, point-to-point link.

Level 3 (packet level) of X.25 defines the packet formats and such control procedures as establishing and clearing calls, data transfer, flow control, and error recovery. Packets are the basic information unit transmitted through a packet network. In addition to data packets, various types of control packets can be sent between a DTE and the adjacent DCE, or vice versa.

Although a definition of X.25 was given previously, it is important to understand that X.25 defines an *interface* between a user's equipment and the packet network. It does not define the essential end-to-end networking architecture for users or for packet networks.

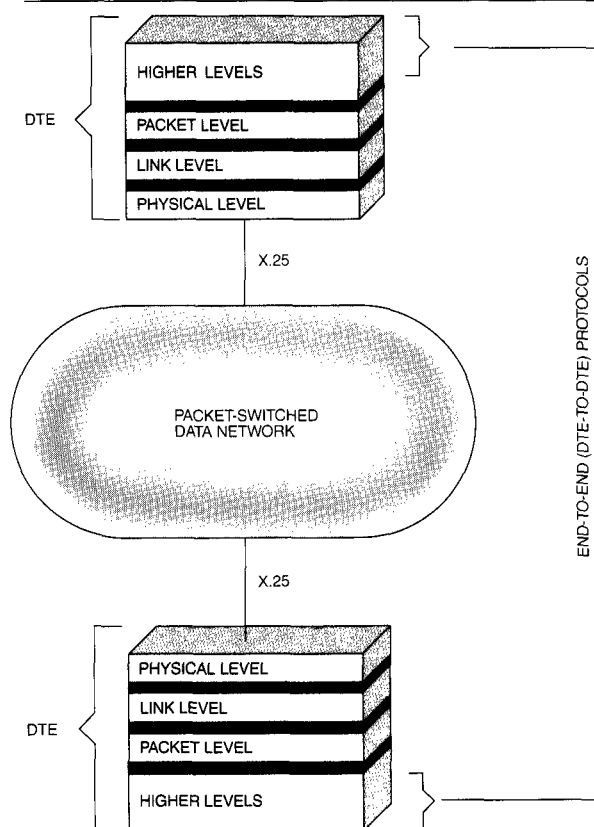
Effective communication between DTEs requires additional protocols at one or more levels above the

Figure 4 The three levels of X.25



packet level of the X.25 DTE/DCE interface (see Figure 5). Efforts are currently being made within the standards community to develop standard networking protocols, referred to as Open Systems

Figure 5 Higher-level protocols for DTE-to-DTE communications



Interconnection (OSI), to accomplish communication at the higher levels. These efforts are taking place within the ISO,¹⁶ the CCITT,¹⁷ the European Computer Manufacturers Association (ECMA),¹⁸ and other organizations.

The ISO has published a Provisional Architecture Model for OSI.¹⁶ The protocols that allow effective communication between diverse IBM SNA X.25 DTEs such as data processing, distributed computing, and office systems are provided by the higher levels of SNA. Reference 19 describes the relationships that exist between SNA^{8-10,20-25} and the ISO Provisional Architecture Model.

Some other CCITT recommendations used by public packet-switched data networks in conjunction with X.25 are X.1, X.2, X.3, X.28, X.29, X.75, X.96, and X.121,

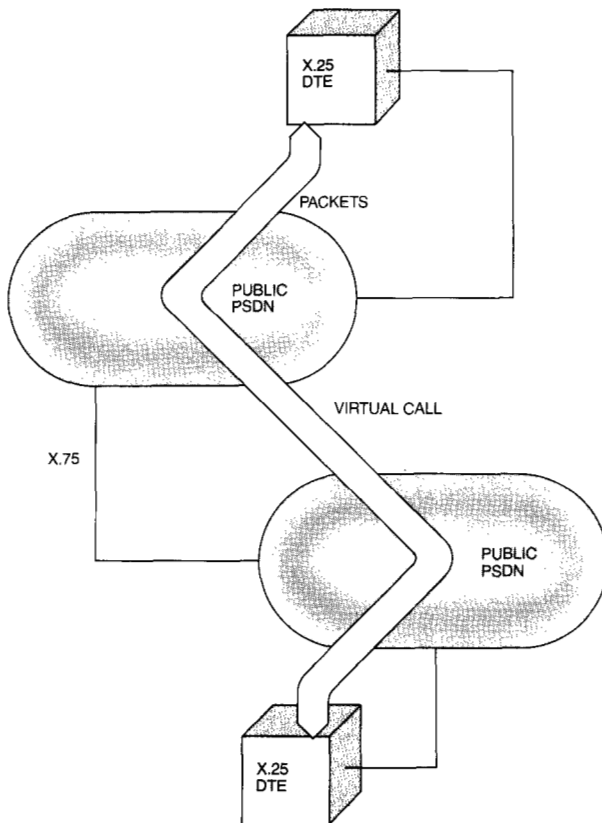
which are summarized in Table 2. Two DTEs can make international connections through two or more national public packet-switched networks that are interconnected using X.75²⁶ as shown in Figure 6. Recommendation X.75 defines the CCITT interface for interconnecting public packet-switched data networks. Based on Recommendation X.25, Recommendation X.75 defines interconnection for virtual calls (only), allows X.25 user facilities to span networks, includes internetwork accounting procedures, and provides certain technical enhancements, such as multiple links, between networks.

Nonpacket-mode terminals can attach to packet networks via protocol converters implemented as separate units or contained within a packet-

Table 2 Summary of other CCITT recommendations used in conjunction with X.25

X.1	International user classes of service in public data networks.
X.2	International user services and facilities in public data networks.
X.3	Packet assembly/disassembly facility (PAD) in a public data network.
X.21	Interface between DTE and DCE for synchronous operation on public data networks.
X.21 bis	Use on public data networks of DTE which is designated for interfacing to synchronous V-series modems.
X.28	DTE/DCE interface for a start/stop mode DTE accessing the PAD facility in a public data network situated in the same country.
X.29	Procedures for the exchange of control information and user data between a PAD facility and a packet mode DTE or another PAD.
X.75	Terminal and transit call control procedures and data transfer system on international circuits between packet-switched data networks.
X.96	Call progress signals in public data networks.
X.121	International numbering plan for public data networks.

Figure 6 Network interconnection using X.75



switched data network node. These conversion units are called PADs (packet assembler/disassemblers). They allow an attached non-X.25 DTE to communicate over virtual circuits with an X.25 DTE. Three specific CCITT recommendations—X.3, X.28, and X.29⁷—define communication between a start-stop (asynchronous) DTE and an X.25 DTE, as shown in Figure 7. X.28 defines how the start-stop terminal communicates with the PAD; X.29 defines how the X.25 DTE uses X.25 qualified data packets to control the PAD; and X.3 defines the operation of the PAD.

Some packet-switched data networks have implemented PADs for which there are no CCITT recommendations. For example, several networks attach binary synchronous communication (BSC) devices²⁷ to PADs for communication with X.25 DTEs.²⁸ There is also a proposal, called Single Channel DTE,²⁹ for attaching high-level data link control (HDLC) DTEs to PADs for communication with X.25 DTEs. These

nonstandard PAD configurations are shown in Figure 8. The specifications of nonstandard PADs are analogous to X.3, X.28, and X.29.

Recommendation X.1⁷ defines start-stop, synchronous, and packet terminal classes of service for public data networks. Recommended data signaling rates, start-stop code structures, and call control signals are given in X.1. Recommendation X.2⁷ defines international user services and facilities in public data networks, namely for circuit-switched services, leased-circuit services, and packet-switched services. With respect to packet switching, X.2 defines X.25 and PAD services and facilities that are essential for all public packet-switched data networks to implement. Recommendation X.2 also describes services and facilities that networks can additionally implement, and those whose classification is for further study in the CCITT.

Call progress signals in public circuit-switched and packet-switched data networks are used to inform the caller about the progress of his call. Types of call progress signals and whether a type is mandatory

Figure 7 X.3, X.28, and X.29 recommendations for start-stop PADs

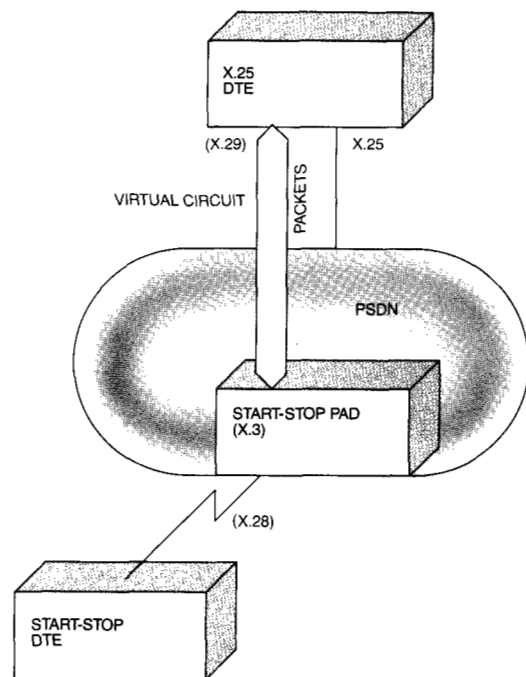
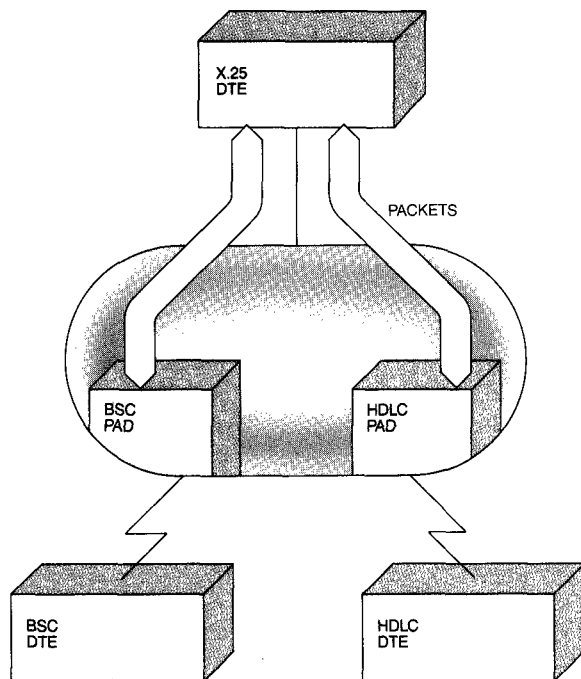


Figure 8 Nonstandard BSC and HDLC PADs



are defined in Recommendation X.96.²⁶ Some call progress signals indicate circumstances that prevent connection with a called number; other signals indicate progress made towards establishing the call.

The international numbering plans and procedures for public data networks are given in Recommendation X.121²⁶ to facilitate interworking on a worldwide basis. Code formats for identifying countries, public networks inside countries, and network terminal numbers of data terminals attached to a given network are specified in X.121. The director of the CCITT assigns country codes. It is a country responsibility to coordinate assignment of network codes inside the country.

Architectural relationship to SNA

Public packet network services provide an alternate method for transporting user information. However, application requirements, geographical considerations, and applicable tariffs often dictate the choice of services and facilities for transporting

information. Therefore, virtual circuits are managed in SNA in a manner consistent with the management of real circuits. Such management allows concurrent use of other services and facilities offered by telecommunication administrations, recognized private operating agencies, and companies providing common carrier or value-added telecommunications services around the world. Relationships between SNA and X.25 are defined for two types of connection:

- SNA-to-SNA connections that allow SNA X.25 DTEs to be connected to one another by permanent virtual circuit services or virtual call services, or both.
- SNA-to-non-SNA connections that allow SNA X.25 DTEs to be connected to non-SNA X.25 DTEs by permanent virtual circuit services or virtual call services, or both.

Use of X.25 for SNA-to-SNA connections. Consider the use of the X.25 interface for communicating between SNA nodes through packet-switched data networks. SNA defines a layered structure for communication networks that enables network end users, such as operators and application programs, to communicate without regard for the operational details of the telecommunications media and data transmission services employed. This architectural direction has facilitated the development of a set of communication adapters that permits designers of individual SNA products to offer a wide variety of telecommunication capabilities to their users; therefore, an SNA network can employ the most advantageous data transmission service for a given application based on the cost and availability of the various alternatives. Although X.25 packet-switched data services may be chosen in many circumstances, leased-circuit or circuit-switched services are often preferred. Some of the data transmission services and facilities that can coexist in SNA networks are shown in Figure 9.

The information transmitted between end users in an SNA network may traverse several data links and intermediate nodes. Each pair of nodes directly connected by a data link is termed "adjacent" within SNA. The data link control (DLC) elements provide the lowest level of management for data transmission between these adjacent nodes. In addition to its data transmission function, the DLC also handles other tasks such as initialization, identification exchange, and link tests between adjacent nodes.

These adjacent node functions are readily implemented over point-to-point and multipoint links, in which one station acts in a control or primary role and the other stations act as secondaries. (Since secondary stations on a multipoint circuit cannot communicate directly with one another, they are not adjacent in the SNA sense.) When a public packet-switched data network serves as the medium connecting SNA nodes, the requirement for adjacent

wise, permanent virtual circuits are managed like nonswitched real circuits.

One popular form of multiplexing that predates X.25 is the multipoint configuration of nonswitched real circuits. The secondary stations on a multipoint circuit are adjacent to the primary station but not to one another. In effect, point-to-point logical circuits connect the primary with all of the secondaries. Consequently, multipoint real circuits are analogous to packet-switched services that provide a separate virtual circuit from the primary to the secondary. Again, depending on the application and tariffs, either virtual call or permanent virtual circuit services can be used.

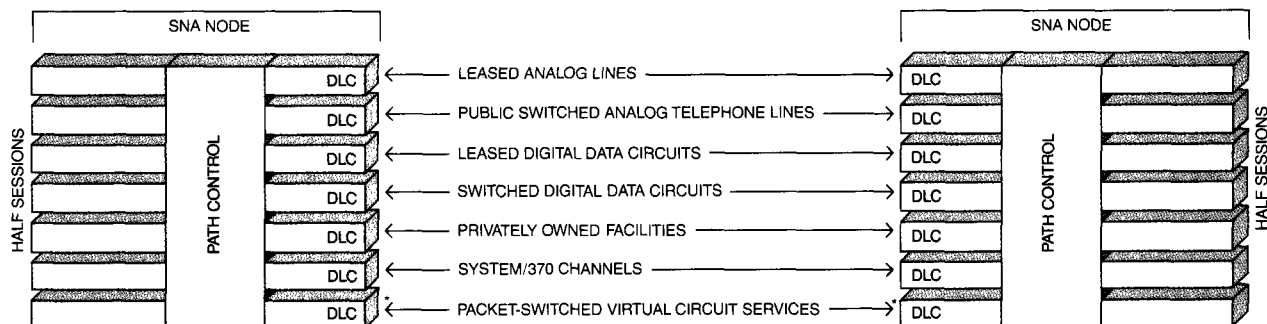
To permit concurrent use of data link control and virtual circuit protocol services, all of the properties of the former must be available in the latter. SNA X.25 DTEs employ a Logical Link Control (LLC) protocol to provide certain adjacent node services in environments where SNA nodes are connected through one or more packet networks. This protocol, known as Qualified Logical Link Control (QLLC), uses "qualified" data packets to transfer data link control information between the two SNA nodes. For example, Synchronous Data Link Control (SDLC) functions such as exchange identification (XID), set mode, TEST, and disconnect (DISC), among others, are passed through the PSDN using qualified data packets. Once data link connectivity has been established, SNA Path Information Units (PIUs)^{10,20} are transferred in normal, unqualified data packets. PIUs that exceed the maximum user data area of the data packet are transferred as packet sequences concatenated by the More Data Mark (M-bit).

X.25 virtual circuits are managed in SNA much like real circuits.

node functions still exists, but the actual physical adjacency is absent.

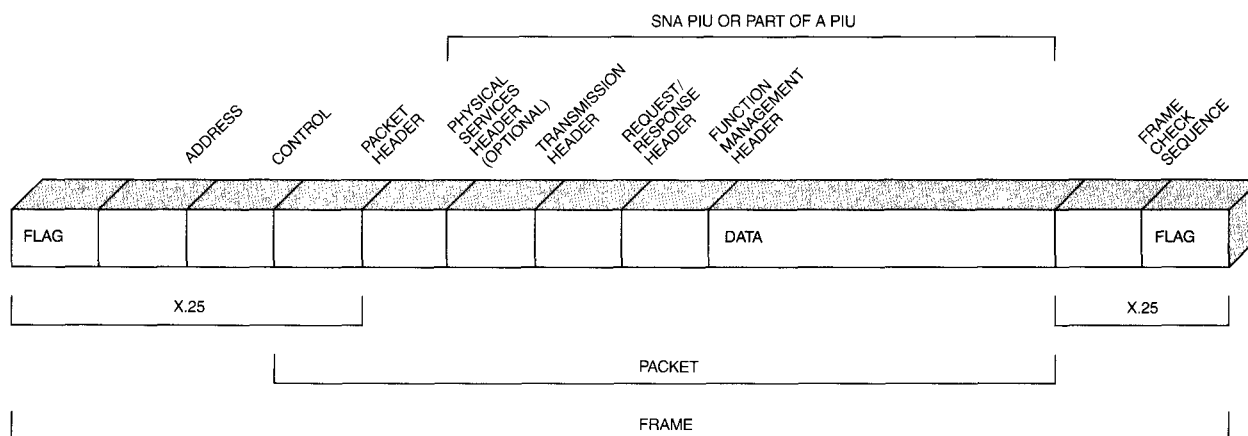
Prior to the introduction of public packet-switched data services with their X.25-based virtual circuits, only real circuits were available to interconnect SNA nodes. These included both circuit-switched services and nonswitched circuit services. Through the provision of a variety of communications adapters, SNA products are able to employ a wide range of speeds over both telephone-type facilities and public data networks. In order to minimize the operational impact on end users and the duplication of function in the products, virtual calls (switched virtual circuits) are managed like switched real circuits. Like-

Figure 9 Coexistence of data transmission services and facilities within SNA



*THE DLC (DATA LINK CONTROL) INCLUDES LOGICAL LINK CONTROL (LLC) AND X.25 PACKET-LEVEL COMPONENTS AS DESCRIBED IN THE TEXT.

Figure 10 Packet and frame formats



[Note that some initial SNA X.25 DTE implementations do not support the QLLC and M-bit procedures. They perform adjacent node services and packet segmentation/concateration using a Physical Services Header (PSH).^{30]}

Figure 10 shows the format of the frame and included packet for SNA-to-SNA virtual circuits. The frame carries either link-control information only or control information and a single packet associated with a particular virtual circuit.

Use of X.25 for SNA-to-non-SNA connections. The X.25 interface can be used in SNA nodes to make connections to non-SNA nodes through packet-switched data networks. SNA-to-non-SNA connections provide a mechanism for transporting data between an application program that resides in an SNA node and a remote non-SNA terminal, such as a non-SNA X.25 DTE or a start-stop terminal attached to a PAD facility. The three types of operation defined for SNA-to-non-SNA connections are mapped, transparent, and hybrid. No standard protocol is provided above the packet level of Recommendation X.25 for SNA-to-non-SNA connections. These higher-level protocols remain a matter to be agreed upon between the individual non-SNA terminal and the supporting customer-supplied application program within the SNA node. Figure 11 shows virtual-circuit connection of non-SNA equipment to an SNA node.

In mapped operation, all of the X.25 protocols can be mapped to and from similar SNA protocol subsets directly at the SNA X.25 DTE/DCE interface; thus, virtual circuits are associated with SNA sessions on a one-to-one basis. An application in the host can therefore communicate with the non-SNA node without any X.25 sensitivity. However, the application and the remote node must have a common understanding of the data streams being exchanged and must process them accordingly.

In transparent operation, the packet level of X.25 can be implemented in a host application program. In this case, the packet-level protocols are transported, transparently, within the structure of SNA between the application and the X.25 interface. In hybrid operation, X.25 packet-level functions are neither fully mapped nor fully transparent. An application does some X.25 functions as in transparent operation; the remaining X.25 functions are performed at the X.25 interface.

Multiple DTE/DCE interfaces. Some SNA X.25 DTEs can support multiple X.25 DTE/DCE interfaces. To do so is a product-specific choice based on traffic requirements or the need to directly access two or more networks concurrently, or both. Some products also permit SNA-to-SNA and SNA-to-non-SNA connections to co-reside at the same X.25 DTE/DCE interface.

X.25 elements in SNA nodes

The elements of X.25 selected for use in SNA nodes at the physical level, link level, and packet level are described in this section. SNA-to-SNA and SNA-to-non-SNA connections differ only at the packet level. Therefore, descriptions of the physical level and the link level elements are common to both types of connection. The reader is referred to References 12 and 30 for more detail.

Physical level. The physical level employs a duplex (two-way simultaneous) transmission facility. During an interim period, described in Reference 7, some SNA X.25 DTEs support X.21 bis instead of X.21 at the physical level.

IBM X.21 bis implementations for nonswitched access conform to

- CCITT Recommendation V.24¹³ with V.28¹³ electrical characteristics at speeds of 19.2 kilobits per second (kbit/s) and below.
- CCITT Recommendation V.35¹³ at signaling speeds in excess of 19.2 kbit/s.

Switched-circuit access to packet networks is not supported because essential DTE and DCE identification and characterization functions are still being defined by the CCITT. As of this writing, most packet-switched data networks do not support X.25 switched-circuit access.

Transmission speed is product-specific; however, all SNA X.25 DTEs support at least one of the X.25 speeds (2.4, 4.8, 9.6, or 48.0 kbit/s) and some may support one or more additional speeds (e.g., 1.2, 19.2, 56.0, and 64.0 kbit/s).

Link level. Recommendation X.25 defines a symmetrical link access procedure (LAP) and a balanced link access procedure (LAPB) for use as the link-level element. Except for certain early implementations, SNA X.25 DTEs use only the LAPB procedure since the CCITT has adopted it as the preferred link-level procedure to be supported by all public packet networks.

SNA X.25 DTEs transmit and receive only frames containing a single packet consisting of an integral number of octets and are sequenced using modulo 8 sequence numbering. They employ recovery mechanisms that conform fully with LAPB. Packets trans-

ferred across the DTE/DCE interface are contained within the link-level information field.

Packet level. Packet types transmitted and received and their uses with the various services are shown in Table 3. These packets are used as described in Reference 30. Except for certain early implementations, the qualifier bit is set ($Q = 1$) in data packets to transfer Logical Link Control (LLC) information. Packet sequences are generated using the more-data bit. The delivery confirmation bit ($D = 1$) in data packets is allowed only on SNA-to-non-SNA connections because SNA has its own end-to-end mechanisms at levels above X.25.

Other X.25 data packet characteristics include packet sequence numbering modulo 8 or, optionally, 128; maximum user data fields of 128 or, optionally, additional sizes of 16, 32, 64, 512, or 1024 octets; and window sizes (W), $1 \leq W < 8$ for modulo 8 packet sequence numbering or $1 \leq W < 128$ for modulo 128 packet sequence numbering.

Figure 11 Virtual circuit connections of non-SNA to SNA nodes

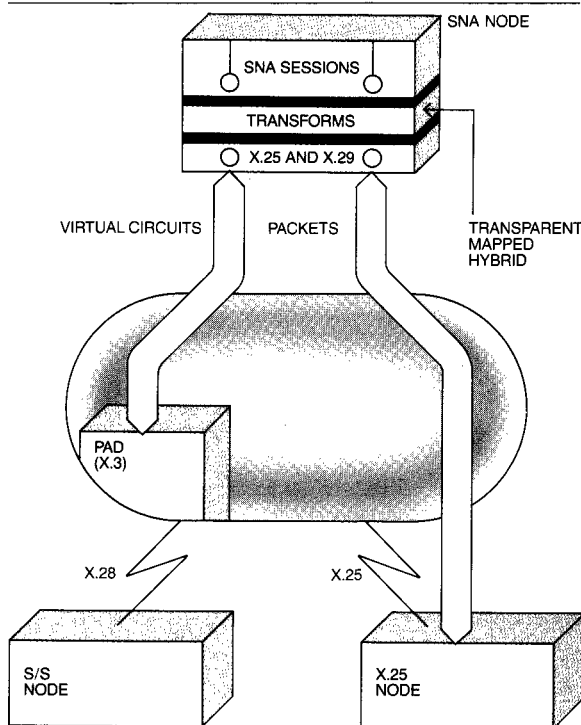


Table 3 Packet types and their uses with various services

Packet type		Service		
From DCE to DTE	From DTE to DCE	VC	PVC	I/F
Call setup and clearing				
Incoming call	Call request	X		
Call connected	Call accepted	X		
Clear indication	Clear request	X		
DCE clear confirmation	DTE clear confirmation	X		
Data [and interrupt]				
DCE data	DTE data	X	X	
[DCE interrupt]	[DTE interrupt]	[X]	[X]	
[DCE interrupt confirmation]	[DTE interrupt confirmation]	[X]	[X]	
Flow control and reset				
DCE receive ready	DTE receive ready	X	X	
DCE receive not ready	DTE receive not ready	X	X	
Reset indication		X	X	
	Reset request		X	
DCE reset confirmation	DTE reset confirmation		X	
Restart				
Restart indication	Restart indication			X
DCE restart confirmation	DTE restart confirmation			X
Diagnostic*				X

VC = Virtual Call

PVC = Permanent Virtual Circuit

I/F = Entire DTE/DCE interface

[] = For SNA-to-non-SNA connections only

*Not necessarily available on all networks

Note: DTE REJECT and DATAGRAM packets are not used

In addition to the specific significance specified in X.25 for bits 8 and 7 of the first octet of the user data field in CALL REQUEST and INCOMING CALL packets, the remaining bits of this octet are used to distinguish between SNA-to-SNA and SNA-to-non-SNA connections that may coexist at the same X.25 DTE/DCE interface.

When subscribed optional user facilities are indicated in INCOMING CALL packets, SNA X.25 DTEs do one of the following:

- Accept the call with no further negotiation.
- Attempt parameter negotiation using the facilities field in the CALL ACCEPTED packet.
- Reject the call using the CLEAR REQUEST packet with an appropriate diagnostic indication.

Table 4 shows optional user facilities for SNA DTEs. Some X.25 optional user facilities require that explicit support functions be provided by the DTE; others, designated "User Choice," do not; they are

designated to the packet carrier when the X.25 interface is subscribed.

During the data transfer phase, SNA X.25 DTEs process error notification information contained in RESET, CLEAR, RESTART, or DIAGNOSTIC packets. On SNA-to-SNA connections, all DTEs use a consistent set of diagnostic codes that flow end-to-end as the result of clearing, resetting, or restarting. Whether an error is detected by the DTE or by the DCE, the DTE notifies the SNA higher levels of the error condition so that recovery procedures can be initiated.

IBM X.25 product support

The X.25 recommendation provides DTE-to-DTE connectivity through a packet-switched network. Additional, higher-level functions are required to accomplish communications. This procedure can be com-

pared to the public switched telephone network that provides the connection, but the parties connected must speak the same language to accomplish communication. As discussed earlier, SNA in circuit-switched and nonswitched environments provides the higher-level communication functions once connectivity is attained.

When IBM began implementation of X.25 in some of its products, two alternatives were considered:

When IBM began implementation of X.25, two alternatives were considered.

1. Provide a capability that requires no customer-supplied programming because SNA provides the required communication capability.
2. Provide a packet-level (Level 3) user programming interface that allows a user to write the code necessary to provide his own communication function.

Early emphasis was given to the first alternative because the impact to IBM customers requiring X.25 support would be minimal. However, today a packet-level user programming interface is available in certain IBM products.

Consideration also had to be given either to integrating the X.25 support into a given product or to providing an adapter external to the product. Such an external adapter provides protocol conversion between X.25 and the product link-level protocol, Synchronous Data Link Control (SDLC).

The major benefits of integrating the X.25 function into a product are generally the following:

1. Elimination of unique electrical power supplies and physical packaging; therefore, implementation costs may be less.
2. Elimination of additional user equipment.
3. Elimination of the extra store-and-forward delay caused by an external adapter.
4. Reduced maintenance.

Even with these benefits, if a large number of products must be retrofitted with X.25 support, the external adapter approach for X.25 attachment is considerably more attractive.

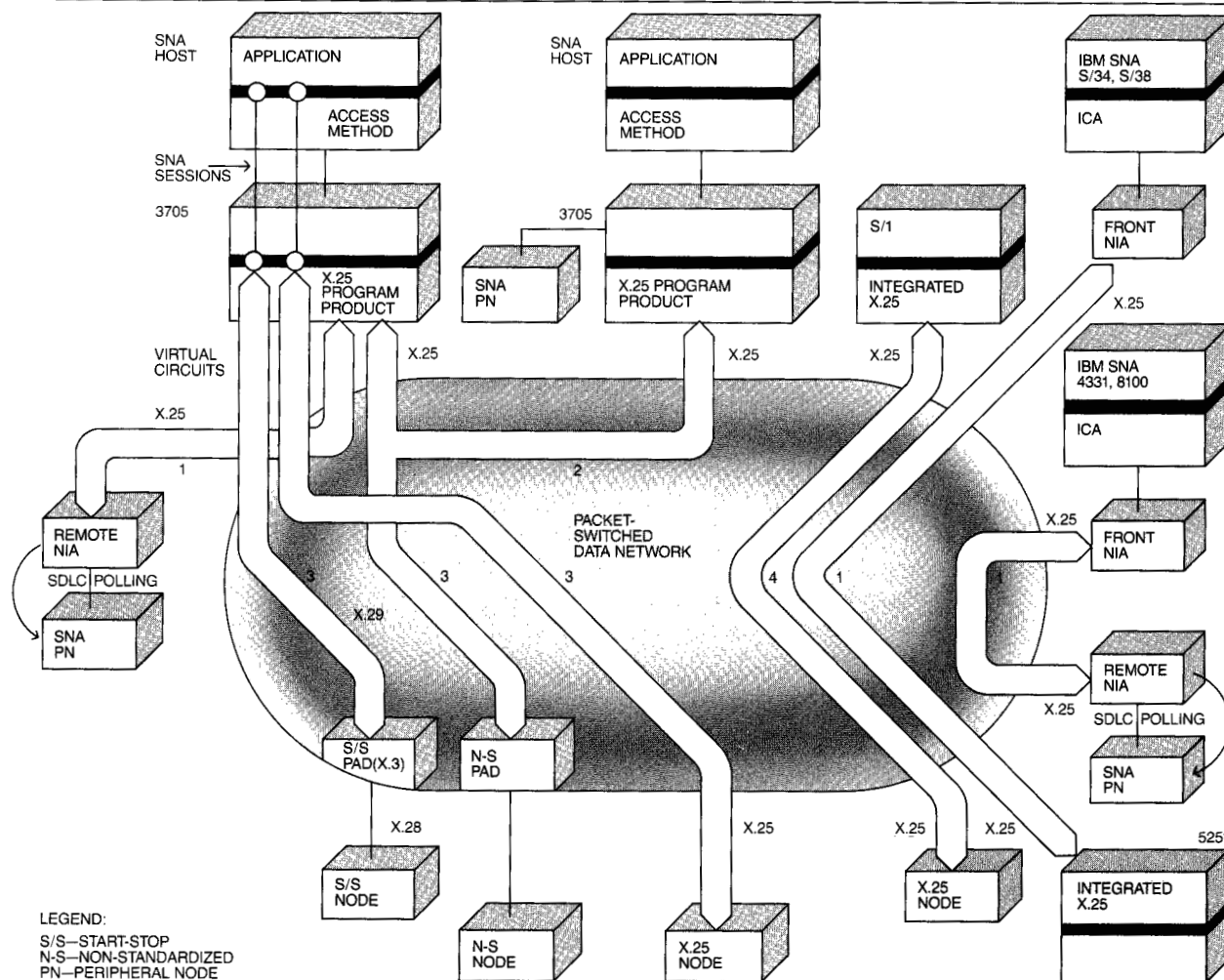
The IBM product implementations conform to the 1980 CCITT X.25 recommendation subset defined in Reference 30. Among the X.25 products offered by IBM are the 5973 L02 Network Interface Adapter (NIA),^{31,32} which is an external protocol converter, and the X.25 program product that operates in the 3705 Communications Controller in conjunction with the Network Control Program (NCP). The X.25 program product is called the NCP Packet Switching Interface (NPSI).³³ Other products include X.25 features for the Series/1 processor^{34,35} and the 5251 Data Entry Display.³⁶ Four different types of packet-switched communication can be described for the IBM products, but not all are supported by each product:

Table 4 Optional user facilities for SNA DTEs

X.25 optional user facilities provided	IBM SNA X.25 DTEs
Nonstandard default window size	All
Default throughput class assignment	User choice
Incoming calls barred	User choice
Outgoing calls barred	User choice
Single closed user group (CUG)	User choice
Single CUG with outgoing access	User choice
Single CUG with incoming access	User choice
Incoming calls barred within a CUG	User choice
Outgoing calls barred within a CUG	User choice
One-way logical channel outgoing	Some
One-way logical channel incoming	Some
Reverse charging	Some
Reverse charging acceptance	Some
Nonstandard default packet size	Some
Flow control parameter negotiation	Some
Throughput class negotiation	Some
Multiple closed user groups	Some
Multiple CUG with outgoing access	Some
Multiple CUG with incoming access	Some
Extended packet sequence numbering	Some
RPOA selection	Some
Fast select	Some
Fast select acceptance	Some
Packet retransmission	None
Bilateral closed user group	None
Bilateral CUG with outgoing access	None

All = facilities always provided
 Some = facilities that may be optionally provided
 None = facilities not normally provided
 User choice = facilities provided solely by packet networks

Figure 12 Examples of IBM X.25 support



1. SNA-host-to-SNA-peripheral node
2. SNA-host-to-SNA-host/peripheral node
3. SNA-host-to-non-SNA DTE
4. Non-SNA-processor-to-non-SNA DTE

The four types are shown in Figure 12; the numbers beside the arrows represent the type.

SNA-host-to-SNA-peripheral node. The IBM X.25 product offerings make possible several different configurations of this type. One configuration uses the NPSI program product in conjunction with the

NIA. The NPSI program product places SNA messages into packets. After the packets are transported through the packet-switched data network, the NIA removes the SNA messages from the packets and sends them over an SDLC link to the peripheral node. In this configuration the NIA is referred to as a remote NIA.

In a second configuration for SNA-host-to-SNA-peripheral node communication, another version of the NIA replaces the NPSI program product. Here the NIA is known as the front-end NIA; it can be used

to attach an IBM 4331 processor, 8100 processor, 3705-80 controller, System/34, or System/38 to a packet-switched data network. The front-end NIA can communicate through the network to a remote NIA. Both NIAs function as an SDLC/X.25 protocol converter.

Another instance of SNA-host-to-SNA-peripheral node communication occurs using the IBM 5251 Integrated X.25 Attachment to communicate with a System/34 or System/38 attached to the network using a front-end NIA.

Although a remote NIA can control only a single permanent or switched virtual circuit, a front-end NIA can control four permanent virtual circuits or one switched virtual circuit. With either NIA, virtual calls can be initiated from an attached keypad. In order to avoid sending an excessive number of nondata packets through the network, the host polls the front-end NIA which responds to the host but does not pass the poll to the network. Instead, the front-end NIA lets the remote NIA do the polling of the attached peripheral node.

Although there are some country-by-country restrictions, the list of SNA products attachable to the NPSI and NIAs as of this writing is shown in Table 5.

SNA-host-to-SNA-host/peripheral node. The NPSI (Release 3) program product supports packet-switched communication via two 3705 Communications Controllers using X.25 permanent virtual circuits. This support provides the capability of having an application in one host communicating through an X.25 network either to an application in another host or to an application in an X.25 peripheral node attached to the different host or its associated communications controller.

SNA-host-to-non-SNA DTE. As shown in Figure 12, the NPSI program product can support three types of communication to non-SNA DTEs (represented by arrows with the number three adjacent to them):

- SNA-host-to-X.25-native DTE
- SNA-host-to-start-stop-PAD device
- SNA-host-to-nonstandard-PAD device

The X.25 interface for SNA-to-SNA and SNA-to-non-SNA communication differs only at the packet level. For SNA-to-non-SNA communication there are no end-to-end SNA formats or protocols. Necessary higher-level protocols must be agreed upon between the individual non-SNA X.25 terminal and the supporting customer-supplied application in the SNA host.

Table 5 SNA peripheral node support

SNA peripheral nodes attachable through remote NIA	SNA host X.25 access			
	NPSI System/370, 303X, 4341, 3081	4331	8100 System	Front-end NIA System/34 System/38
3271	X	X		
3274	X	X	X	
3275	X	X		
3276	X	X	X	
3601, 3602	X	X	X	
3605/5995	X	X		
3651	X	X	X	
3680	X	X	X	
3771, 3774, 3775, 3776, 3777	X	X		
3791/3730	X	X	X	
5251				X X
5285, 5288	X	X		
Series/1	X	X		
System/32	X	X		
System/34	X	X		X
System/38	X	X		
8100 System	X	X	X	
8775	X	X	X	

SNA-host-to-X.25-native DTE. Communication between an SNA host and a non-SNA X.25 DTE is controlled either by a portion of the NPSI program product known as the Protocol Converter for Non-SNA Equipment (PCNE) or by a user application program in the host. The transformation in the PCNE function between SNA and X.25 is referred to as a mapped operation in which the X.25 DTE is represented to SNA as a known peripheral node. The

Non-SNA equipment may be a terminal or a CPU.

NPSI maps between X.25 protocols and IBM 3767 keyboard/display protocols, but no mapping occurs between the X.25 user data field and the SNA data stream. This is different from the conversion in the NIA, where SDLC protocols are converted to and from X.25 protocols and the higher-level, end-to-end protocols are passed through from the host to the DTE.

The non-SNA equipment may be a terminal or a CPU, as long as it supports the X.25 interface. This is especially useful when the user wants to use his own non-SNA protocols between an application program in the SNA network and the non-SNA DTE.

Two additional features of the NPSI program product can be used for communication to an X.25 native DTE. They are the General Access to X.25 Transport Extension (GATE) and the Dedicated Access to X.25 Transport Extension (DATE).^{8,33,37} "Transport extension" refers to an extension of the X.25 interface from the NPSI in the 3705 Communications Controller to an application in the host. With GATE and DATE, an application program signals the program product to send certain control packets to activate or deactivate virtual circuits. This allows the user's application to communicate through the network to non-SNA devices. The user defines his own higher-level protocols. DATE also can be used to provide SNA-host-to-SNA-peripheral-node communication, with the user providing a program to process X.25 control packets.

GATE and DATE are similar, but in GATE a single application program in the host communicates both control information and data to multiple non-SNA X.25 DTEs. In DATE, there are multiple application programs in the host, one of which is dedicated for communicating only control information. All other application programs using DATE communicate only data packets.

SNA-host-to-start-stop-PAD device. Communication between an SNA host and an asynchronous, start-stop DTE (conforming to CCITT Recommendation X.28) is accomplished by using a network-provided PAD. Integrated support in the X.25 NPSI program product allows start-stop terminals to communicate with an SNA host application. The program product controls the PAD using a set of qualified data packet functions defined in CCITT Recommendation X.29. CCITT Recommendation X.3 defines operation of the network PAD. An X.25 permanent virtual circuit or virtual call connects the NPSI to the PAD. The data transfer protocol must be predefined and understood by both the start-stop terminal and the host application.

SNA-host-to-nonstandard-PAD device. Some packet-switched data networks support attachment of devices for which CCITT has no recommendations. These include non-SNA devices such as the binary synchronous IBM 3270 display and the IBM 2780 remote job entry system. Since there is no built-in PAD control, an application program must process PAD control information, which is conveyed to the packet-switched network by nonstandardized PAD support in the NPSI program product.

The NPSI program product also supports a number of other program products (SNA-to-SNA only). Included are these data base, time-sharing, and communication network management program products: Customer Information Control System (CICS), Information Management System (IMS), Time Sharing Option (TSO), Network Communications Control Facility (NCCF), and Virtual Storage Personal Computing (VSPC). The Network Terminal Option (NTO) can co-reside with the NPSI program product, which can be used with multiple X.25 interfaces to the same or different packet-switched networks. Multiple interfaces to the same network can be configured to add link capacity for additional users.

Table 6 lists NPSI program product support functions that can co-reside on the same interface.

Non-SNA-processor-to-non-SNA DTE. The IBM Series/1 processor provides integrated X.25 support for a non-SNA environment. This support manages the X.25 protocols on behalf of a user application program. Applications are written to a macro level interface. The user-supplied application program must support end-to-end protocols above the packet

analyzer, as a protocol driver, and as a network simulator.

Functioning as a test-case-driven network analyzer, the tool can be used to manage one physical link at the HDLC level or one permanent or switched virtual circuit at the X.25 packet level. In this mode, the tool acts as a DTE. Its purpose is to determine how the X.25 DCE interface under test conforms to the 1980 CCITT X.25 recommendation. The test is performed by sending both normal and abnormal sequences across the interface and comparing the DCE response to the expected result.

The second mode of operation of the tool is that of a protocol driver. Here the tool acts as a DCE; a DTE under test can be attached to verify conformance to X.25. As in the network analyzer, the protocol driver is test-case-driven and allows the user to manage only one link at the HDLC level or one virtual circuit at the packet level. Again, the virtual circuit may be either permanent or switched. Normal and error procedures can be tested. When network differences are found using the network analyzer, special test cases can be written for the protocol driver that allow products to be tested for compatibility with unique network differences. An additional program operating in the protocol driver environment supports up to 16 virtual circuits, thus allowing some interaction and performance testing to be done. The major benefit of the protocol driver is that an X.25 DTE can be tested in the laboratory so that there is a high probability of its performing satisfactorily when attached to a specific set of X.25 networks.

The third and final mode of operation of the tool is as a network simulator. IBM has chosen to make the tool simulate a network with interfaces based on the 1980 CCITT X.25 recommendation. The purpose here is to allow end-to-end application testing in an SNA/X.25 environment, whereas the first two modes of operation of the tool allow testing only through

Verification of compatibility with a particular network becomes expensive and time-consuming.

level. An interface is also provided so that user programs can communicate over point-to-point links using LAPB, bypassing the packet level.

Testing products for X.25 attachment

Because of the increasing number of products that provide an X.25 interface, verification of compatibility with a particular network becomes expensive and time-consuming. Obviously, physical attachment testing of each product with the current and projected X.25 networks is not practical. Thus, the requirement to understand network differences and to verify that X.25 products will perform satisfactorily when attached to the many different networks has led IBM to develop special X.25 tools that are intended for internal use only. The tool is based on the Series/1 processor using the Real-Time Programming System (RPS) and its X.25 hardware and software^{34,35} features. Special software has been developed that provides for operation as a network

Table 6 Program product support functions that can co-reside (on the same X.25 interface)

	GATE	DATE	Integrated PAD	Transparent PAD	SNA	PCNE
GATE	/	No	Yes	Yes	Yes	Yes
DATE	No	/	No	Yes	Yes	Yes
Integrated PAD	Yes	No	/	No	Yes	Yes
Transparent PAD	Yes	Yes	No	/	Yes	Yes
SNA	Yes	Yes	Yes	Yes	/	Yes
PCNE	Yes	Yes	Yes	Yes	Yes	/

the packet level. The simulator allows multiple physical ports and thus multiple X.25 DCE appearances. Two DTEs can be attached and tested for normal end-to-end processing through the simulated X.25 network.

With this tool many of the existing and projected X.25 networks can be analyzed. As a result of the analyses, a comprehensive library of test cases can be compiled allowing products to be tested adequately in the laboratory environment.

Some administrations today require certification of products that attach to their X.25 networks. Certifi-

The X.25 functions used in SNA have been selected based on current user requirements.

cation is generally understood to mean link and packet level validation to ensure that the network is protected from harm caused by products that do not conform to the particular X.25 interface required by the network.

This certification process places a burden on the DTE supplier in terms of resources and time spent testing each product with each network. The process can also delay the availability of products in a given country with resultant impact to a user's system development schedules. Two alternatives to product-by-product certification would seem to be possible for the administrations:

1. Provide protective capability on the DCE side of the X.25 interface to disconnect DTEs that violate the protocols.
2. Certify both the DTE supplier's test tools (e.g., the Series/1 described above) and his product test process to ensure that products are fully tested at the supplier's development sites.

Since the first alternative may not be acceptable to all administrations, IBM will vigorously pursue the second with the X.25 administrations.

Summary comment

We have seen that many countries currently have or plan to have packet-switched data networks. Adherence to the 1980 version of Recommendation X.25 by the PSDNs is more important now than ever to allow development of compatible X.25 products. The implementation of the X.25 interface in IBM products provides an additional communication service that can co-reside in SNA nodes with a large array of other communication services, thus allowing the user more flexibility. The X.25 functions used in SNA have been selected based on current user requirements. Future requirements include direct DTE-to-DTE communication without an intervening packet network, and providing the DCE side of the interface in SNA nodes so that an SNA network can provide X.25 packet-switched services.

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