PACKET NETWORK PROTOCOLS: X.25, X.32, X.3/X.28/X.29

THE OMNICOM INSTITUTE

OMNICOM, INC. • 115 Park Street, S.E. • Vienna, VA 22180 USA • TEL: (703) 281-1135 • FAX: (703) 281-1505 • TLX: 279678 OMNI UR

OMNICOM®

THE OMNICOM INSTITUTE

Course Schedule

PACKET NETWORK PROTOCOLS - X.25, X.32, X.3/X.28/X.29

DAY 1

9:00-10:10	**Concepts and Terminology**
10:10-10:30	**Morning Coffee**
10:30-11:30	**Physical Layer**
11:30-12:00	**Data Link Layer**
12:00-1:15	**Lunch**
1:15-3:00	**Data Link Layer** - continued
3:00-3:20	**Afternoon Refreshments**
3:20-4:45	**Packet Layer**
4:45-5:00	**Open Discussion**

DAY 2

9:00-10:10	**Packet Layer** - continued
10:10-10:30	**Morning Coffee**
10:30-11:00	**Packet Layer** - continued
11:00-12:00	**Additional Terminal Considerations**
12:00-1:15	**Lunch**
1:15-2:15	**Network Service Scenario**
2:15-3:00	**X.25 Dial-Up Access**
3:00-3:20	**Afternoon Refreshments**
3:20-4:30	**Packet Assembly/Disassembly**
4:30-4:45	**Open Discussion and Conclusion**

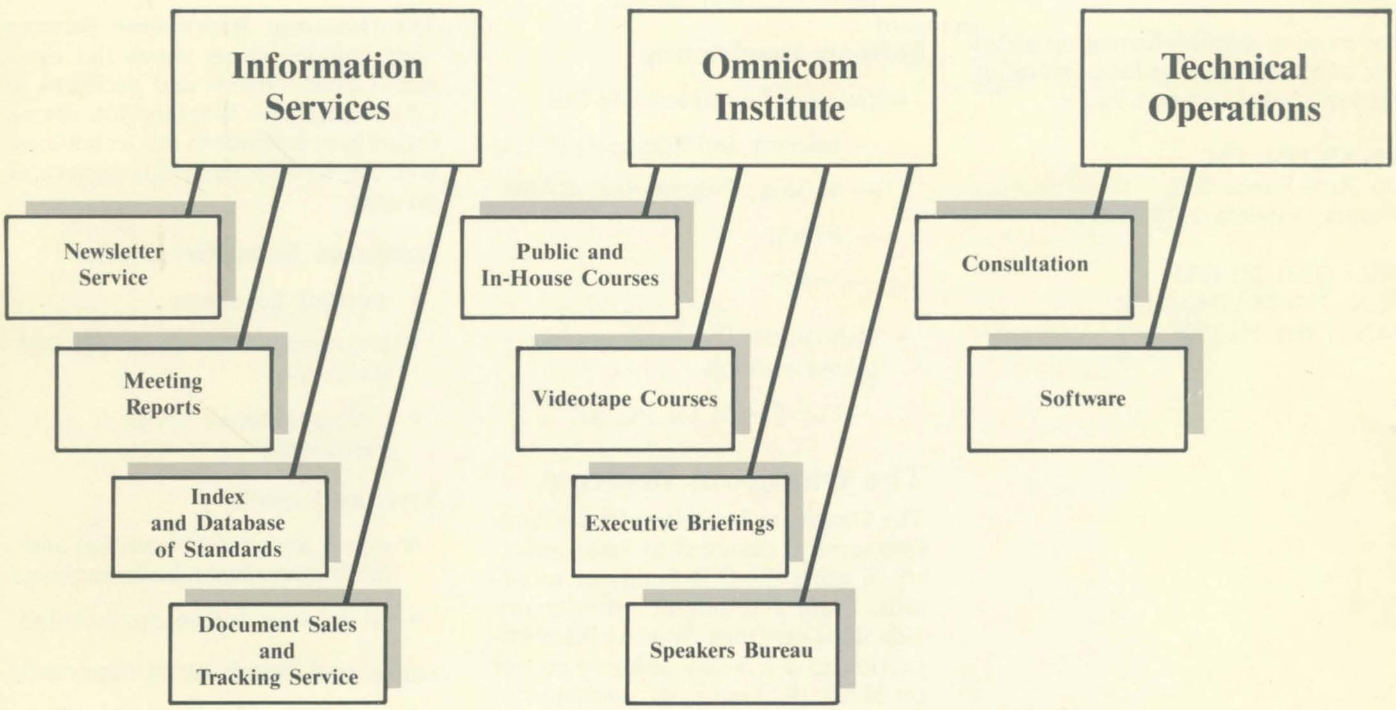
KATHLEEN L. DALLY

Kathy Dally is an active participant in the X.25 Rapporteur's collaborateurs group and is serving as the editor for the new X.32 dial-up procedures for packet network access. She is a Senior Consultant on the staff of Omnicom, Inc. and also serves as chairman of the ANSI Task Group on Public Digital Network Access. Previously she was with Burroughs designing several implementations of X.25, including product verification with various networks. Kathy has extensive experience in developing data communications facilities of business computers.

She received a Bachelor of Science with Honor and Distinction in Computer Science from the University of Delaware.

Make the Connection . . .
OMNICOM, INC.

OMNICOM—can help you connect to the latest developments in Open Systems Interconnection technology. In one place, you can find up-to-date courses, information, documents, advice on, and software in this advancing area of distributed information systems.



Depend on us to help you:

- save time and money with our expert guidance on Open Systems Interconnection (OSI) developments and implementation
- stay informed about this rapidly developing and important technology
- assess decisions and trends in standards organizations

Our staff are:

- professional, internationally recognized experts
- active in Open Systems Interconnection standards organizations
- contributors to the technological developments we report to you

Omnicom, Inc., founded in 1982, informs, educates, and gives technical support to professionals interested in Open Systems Interconnection technology for distributed information systems. Because Omnicom gives no endorsement or promotion of any particular manufacturer's product or technical solution, our information is unbiased and comprehensive. Omnicom's services are invaluable to anyone wanting accurate, objective information about this area of technology, which advances quickly with input from many sources.

For more in depth information about one of our services, or for a full information packet, contact us at:

OMNICOM, INC.
115 Park Street, S.E.
Vienna, Virginia 22180 USA

TEL: (703) 281-1135
TLX: 279678 OMNI UR
FAX: (703) 281-1505

Technical Operations

The Omnicom Technical Operations gives you expert guidance in OSI implementation at every stage. If you would like to implement OSI standards but need technical support from experts in this technology, we will provide you with the best advice on and software for your requirements.

Consulting Services

- requirement analysis
- design
- implementation
- performance evaluation

Software Development

- Osilogie™—implements OSI
  - — Internet and Transport (0,2,4)
  - — Session, Presentation, CASE
  - — FTAM
  - — X.400
- Osilogie/PC™—hardware integrated solution
  - — Full FTAM for PC AT

The Omnicom Institute

The Omnicom Institute offers education services designed to assist industry in using the OSI family of standards. From a 15-minute introductory videotape on Open Systems Interconnection to a five-day in-house course on MAP, the Omnicom Institute can meet your training needs.

Public and In-House Courses

- over 15 continually updated courses given by experts for working professionals
- include workbooks that become valuable reference tools

Videotape Courses

- self-paced
- introductory or in-depth courses on OSI
- include complete manuals minimizing notetaking

Executive Briefings

- tailored to your company's special needs
- video or live presentations

Speakers Bureau

- choose from a variety of symposia topics relating to OSI technology—all discussed by experts

Information Services

The Omnicom Information Services keep you informed about the most recent developments and decisions in OSI technology. Whether you are an expert in or a novice to this technology, you can benefit from our variety of services.

Omnicom Newsletter Service

- monthly newsletter
- bi-monthly tutorials on the OSI standards
- Omnicom Open Systems Handbook

Meeting Reports

- expert analyses of national and international standards meetings
- all meeting documents included

Index and Database of Standards

- over 1900 indexed standards
- published annually as the Omnicom Index of Standards
- access the Omnicom Database of Open Systems Standards from your own PC

Document Sales & Tracking Service

- individual document sales
- identification of documents pertaining to your specific interests

THE OMNICOM INSTITUTE

Table of Contents

PACKET NETWORK PROTOCOLS - X.25, X.32, X.3/X.28/X.29

SECTION PAGE

Concepts and Terminology 1

To set the stage for the 2-day intensive presentation, the concepts of Open Systems Interconnection are reviewed. The related vocabulary of standards as well as the standards development activities are introduced to facilitate an understanding of the material. In addition, important related standards are treated to establish the complete framework of the operating environment that will be covered.

X.25 Physical Level 49

Indentified as the Physical Level of X.25, the electrical, mechanical, functional, and procedural characteristics of the Physical Layer provide the physical interface with the transmission medium. X.25 provides these specifications by reference to other standards.

X.25 Link Level 73

X.25 specifies the Link Level for reliable transfer of data over the physical link, including synchronization, error detection, error recovery, and flow control. The Link Access Procedure B (LAPB) is a compatible subset of ISO's HDLC. In addition, new multilink procedures have been added.

X.25 Packet Level 141

The Packet Level of X.25 is now consistent with the OSI Network Layer. It provides the procedures for interaction between the subscriber and the network for establishment of virtual circuits, transfer of data, error recovery, and clearing of calls. A great number of special service features are specified to provide a comprehensive operating capability.

Additional Terminal Considerations 241

X.25 has been specified by CCITT to focus on the network aspects of the interface and protocol. ISO has developed two companion standards to cover a number of considerations about the Data Terminal Equipment (DTE) that have been left open by CCITT.

Network Service Scenario 265

The three layers of protocol that have been described must function in harmony while performing their defined tasks. Primitive requests or responses from a layer above cause protocol actions to be initiated. In turn, protocol actions cause primitive indications or confirmations to be passed to the layer above. The dynamics of operation of the three lower layers in cooperation will be demonstrated to show the total system operation of the Network Service in the OSI environment.

X.32 Dial-Up Access 291

X.25 basically specifies dedicated access between a subscriber and the network. The X.32 Recommendation specifies the procedures for establishing access between a terminal and a network via dial-up lines.

Packet Assembly/Disassembly 317

CCITT Recommendations X.3, X.28, and X.29 specify the parameters and procedures for simple asynchronous terminals to communicate through packet networks to other terminals connected directly or via a PAD.

CT000X25.095

INTRODUCTION TO X.25

In 1968, the International Telegraph and Telephone Consultative Committee (CCITT) established a study effort directed toward the establishment of international standards to meet the rapidly evolving data communications technology. A special working party spent the next four years trying to determine the technologies to be employed and the types of standards that would be needed for the new Public Data Networks.

At the Sixth Plenary Assembly of the CCITT in 1972, several Recommendations (the CCITT term for standard) were approved. These were little more than outlines of standards for interfacing with networks and interconnecting between networks of different nations. All of these were based on the conventional circuit-switching technology as commonly employed by telephone networks. At that time, however, the CCITT did recognize the spark of a more advanced technology. Therefore a minor question was established for study over the next four years (1973-1976) to determine if use of packet switching was appropriate for public data networks, and if so, what appropriate standards would need to be developed.

Study Group VII was formed permanently by CCITT in 1972 to carry out the work of developing standards for the new Public Data Networks. All commercial implementations (except Tymnet in the USA) were going in the direction of circuit-switching - ATT and DATRAN in the USA, NTT in Japan, and many European Countries. But Study Group VII assigned a Special Rapporteur to undertake the question of packet-switching. Mr. Bothnerby of Norway, who accepted the task, held several meetings that were attended by record numbers of participants. Although the interest was intense, there was considerable controversy about the concepts that should be employed. Most of the four years was taken up by long debates. In the meantime, commercial interest started to grow and, with the frustration of the slow progress in CCITT, a small ad hoc group was formed informally to attack the problem head-on. This group consisted of Telenet (USA), Bell Canada (Datapac), the French PTT (Transpac), and the United Kingdom Post Office (now British Telecom). With the study period near conclusion in 1976, this group submitted a proposal to the final meeting of Study Group VII. That was the birth of what has become known as CCITT Recommendation X.25.

Over the next four years, 1977-1980, the imagination of the world was captured by X.25 and widespread implementation began. This practical experience was fed back to the CCITT so that X.25 could be polished, enhanced, and expanded to become a technically sound, practical standard. The new 1980 version of X.25 was approved by the CCITT Seventh Plenary Assembly in November 1980. X.25 has now come of age.

The first section of this workbook is intended to provide an introduction to the basic principles of data communications and the terminology of the standards world. It will serve as a refresher for those who have an extensive background, while it will bring up to speed those who are newer to the field. A good foundation is important to gain the maximum benefit from the material that is to be presented. REMEMBER, THIS IS YOUR COURSE; YOUR PARTICIPATION IS AN IMPORTANT INGREDIENT.

CT014.095

DATA COMMUNICATIONS STANDARDS DEVELOPMENT ORGANIZATIONS

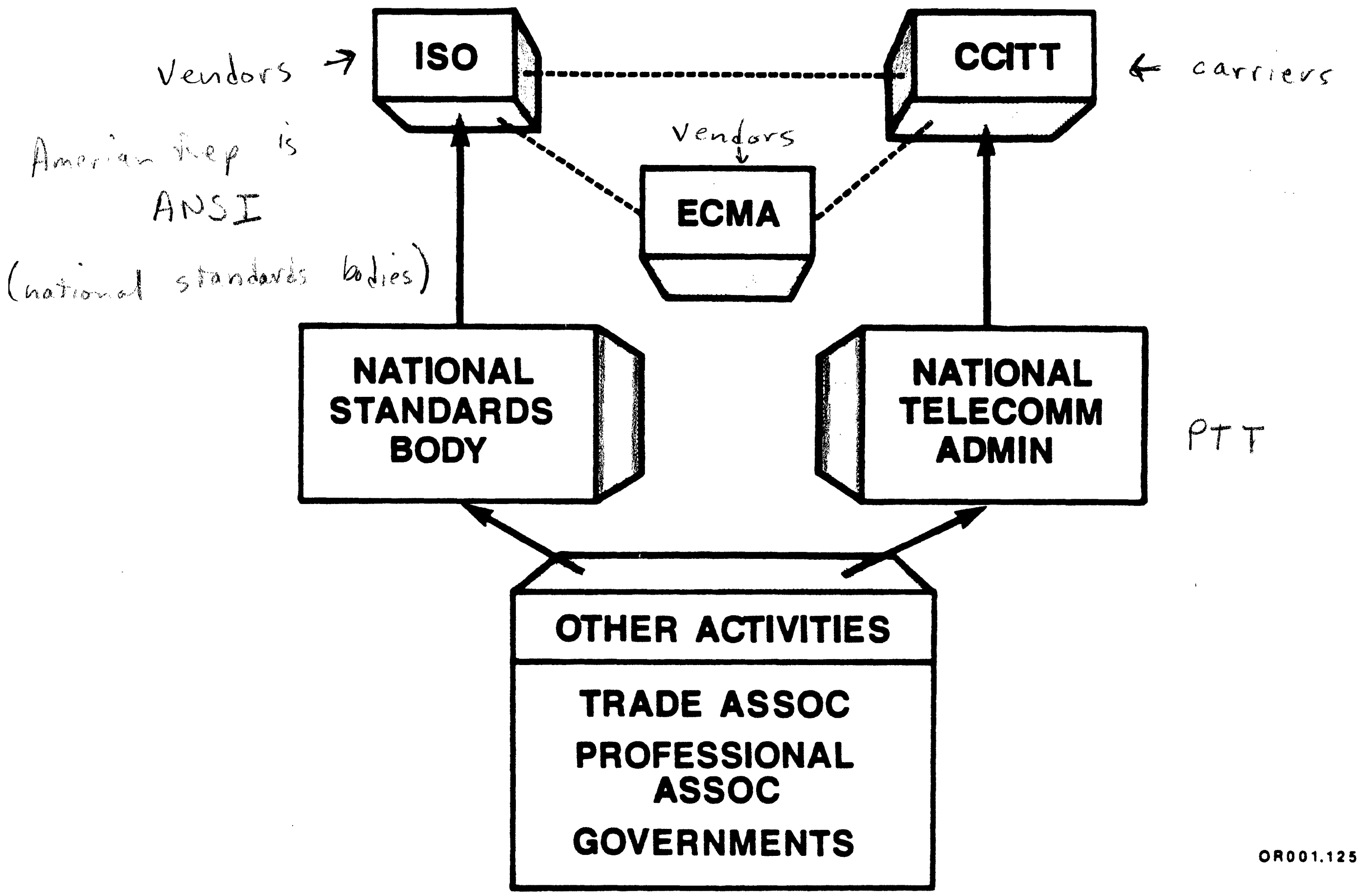
CCITT - The International Telegraph and Telephone Consultative Committee (CCITT) is under the International Telecommunications Union (ITU), which is a treaty organization formed in 1865. It is now a Specialized Agency of the United Nations and is dedicated to establishing effective and compatible telecommunications among the member nations of the world. The telecommunications administrations and carriers are the principal participants. Scientific and Industrial Organizations are also allowed to participate as observers. The results of the work of the CCITT are published every four years as Recommendations for interworking of public telecommunications systems. In the USA, the State Department is the principal member with the common carriers, such as AT&T and GTE Telenet, serving as Recognized Private Operating Agencies (RPOA). Omnicom, Inc. is a Scientific and Industrial member. In most countries the telecommunications service providers are government agencies - these serve as the principal members for these nations.

ISO - The International Organization for Standardization (ISO) is a voluntary activity of the national standardization organizations of each member country. Participation is principally from manufacturing and user communities as compared to the telecommunications carriers in CCITT. The ISO has been leading the way in the development of a universal architecture for Open Systems Interconnection and the communications of future distributed information systems. Close liaison is maintained with the CCITT to provide a well-rounded input for the final standards and Recommendations that are developed.

ECMA - The European Computer Manufacturers Association (ECMA) was formed specifically to develop standards for the computer industry. It is not a conventional trade organization. ECMA is presently very active in many areas, particularly in the development of higher layer protocols for Open Systems Interconnection.

National Standards Bodies - Most of the industrialized countries of the world have a national standards activity to serve as a clearing house and coordinate the work for voluntary and mandatory standards. Such an organization also serves as the country's member body to the international development activities of ISO.

DATA COMMUNICATIONS STANDARDS ORGANIZATIONS



CITT Four year cycle for study periods.

1984 Red books

1980 Yellow books

ISO Five year cycles TC 97 for Comms

CT015.095

OPEN SYSTEMS INTERCONNECTION

Telecommunication services provide the electrical means for interconnecting users so that they can deliver or exchange information with other desired parties. The familiar telephone call is such an example. Today there is a great need for the interconnection of computers and operating processes to facilitate delivery or exchange of information among appropriate parties. If the user equipment and interconnecting systems are of all the same manufacture or design, communication is generally realized.

In today's competitive world, however, there is a need for interconnection of operating equipment and systems from a wide range of designs and implementations. When user systems communicate internally, they are CLOSED systems, but when user systems must communicate externally with other systems, they must become OPEN systems.

The user is actually an application process (AP), which can be any sort of task from a simple program to a very complex operation. In performing their tasks, APs may need to communicate with other APs to obtain information or to accomplish other parts of a larger task. In order to be able to communicate outside the local environment of the system performing the AP, a set of conventions is needed to provide an Open Systems Interconnection Environment that will facilitate communication among heterogeneous user end-systems. Within the OSI Environment, a standard architecture with associated interfaces and protocols is employed to provide the widest range of applications with the flexibility required for effective and economical communication.

ISO has developed the basic Reference Model that defines the standard architecture of an **Open Systems Interconnection**. The model will:

* Provide a universally applicable structure

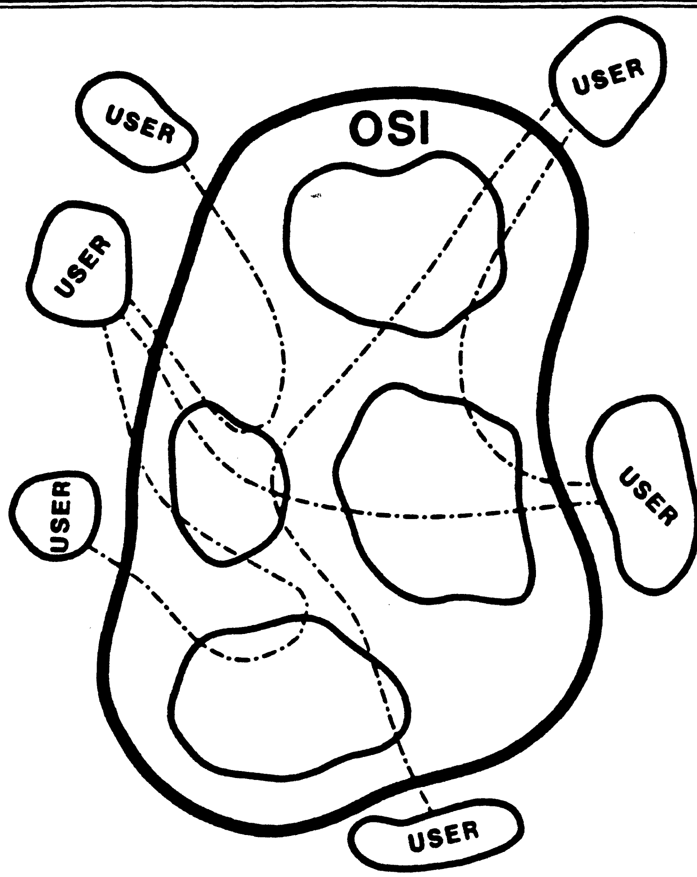
* Serve as a reference to position existing standards and compare requirements

* Facilitate compatible interconnections for communicating APs

* Enable an evolution of advancing technology.

The ISO specification for the OSI architecture is International Standard 7498 and the CCITT equivalent is Recommendation X.200. Both are identical.

OSI ENVIRONMENT



RM001.095

RM002.095

LAYERS OF OSI REFERENCE MODEL

The Open Systems Interconnection (OSI) Reference Model consists of seven independent layers which perform the following functions:

APPLICATION LAYER - Directly serves the end-user, which is the application process (AP), by providing the distributed information service to support the AP and manage the communication.

PRESENTATION LAYER - Provides the services to allow the AP to interpret the meaning of the information exchanged. The Presentation Layer identifies and negotiates the transfer syntax used for the communication. Adaptation or translation can then be done locally at each end-system.

SESSION LAYER - Supports the dialog between cooperating APs; binding and unbinding them into a communicating relationship.

TRANSPORT LAYER - Provides end-to-end control and information interchange with the level of reliability that is needed for the application. The services provided to the upper layers are independent of the underlying network implementation. The Transport Layer is therefore the user's liaison, acting as the go-between for the user and the network.

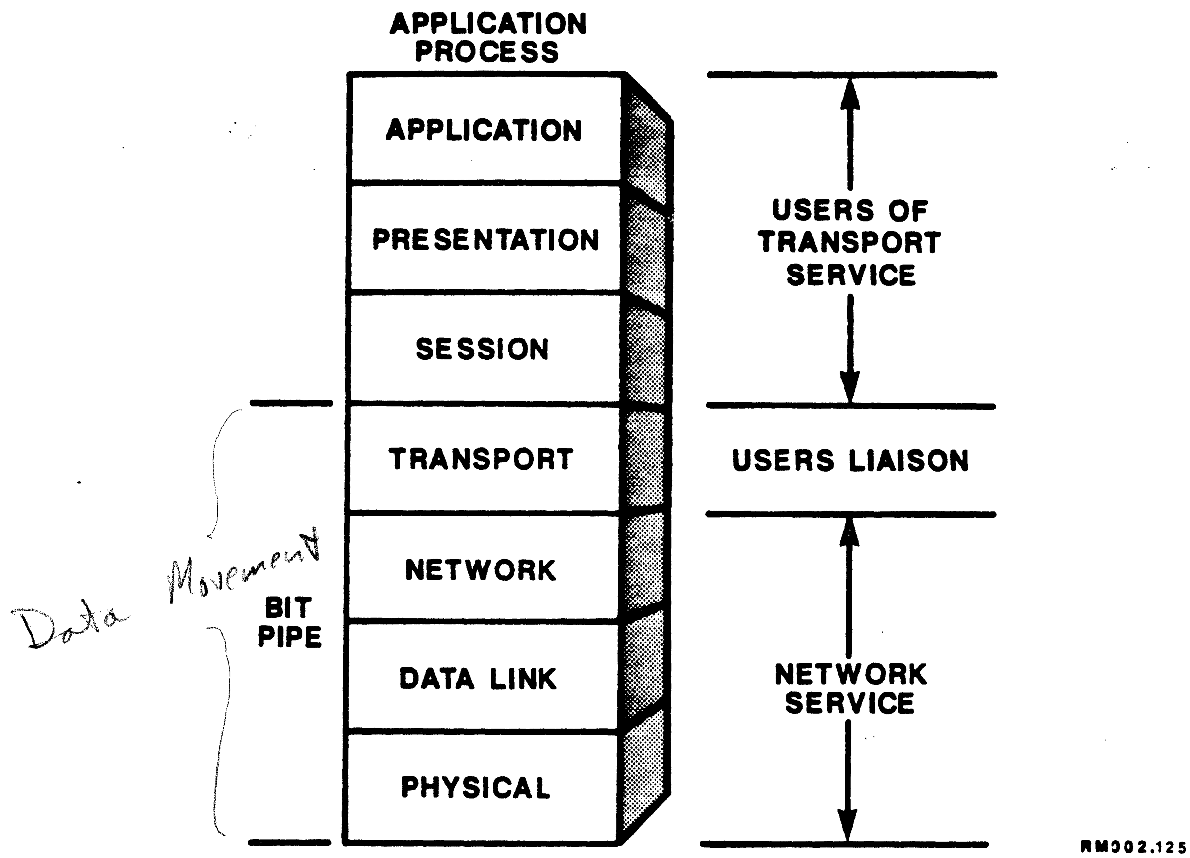
NETWORK LAYER - Provides the means to establish, maintain, and terminate the switched connections between end-systems. Addressing and routing functions are included. The interface between this layer and the transport layer provides services that are independent of the underlying media.

DATA LINK LAYER - Provides the synchronization and error control for the information transmitted over the physical link.

PHYSICAL LAYER - Provides the functional and procedural characteristics to activate, maintain, and deactivate the physical connection. The electrical and mechanical characteristics provide the physical interface to the external transmission media.

Collectively the lower four layers can be considered the "bit pipe" that transfers the information between the communicating end systems.

LAYERS OF MODEL



ARCHITECTURE OF X.25

* **PHYSICAL LEVEL** - includes the functional and procedural characteristics to activate, maintain, and deactivate a physical connection. Earlier definitions for the Physical Level also included the electrical and mechanical characteristics, but it was later determined that these elements represent the interface between the OSI environment and the physical transmission circuits. The commonly known physical interface is the EIA RS-232-C or CCITT V.24/V.28. The X.25 Physical Level is equivalent to the OSI Physical Layer.

* **LINK LEVEL** - provides for reliable transfer of data across the physical link. Typically, BSC and SDLC are well known proprietary data link protocols. X.25 implements LAP B, which is a subset of the ISO HDLC standard. The X.25 Link Level is equivalent to the OSI Data Link Layer.

* **PACKET LEVEL** - provides for the routing and switching of virtual circuits and data through network nodes and for interaction between the subscriber and the switched network. The CCITT Recommendation X.25 Packet Level protocol (1984) is one established standard that completely fulfills the OSI Network Layer functions.

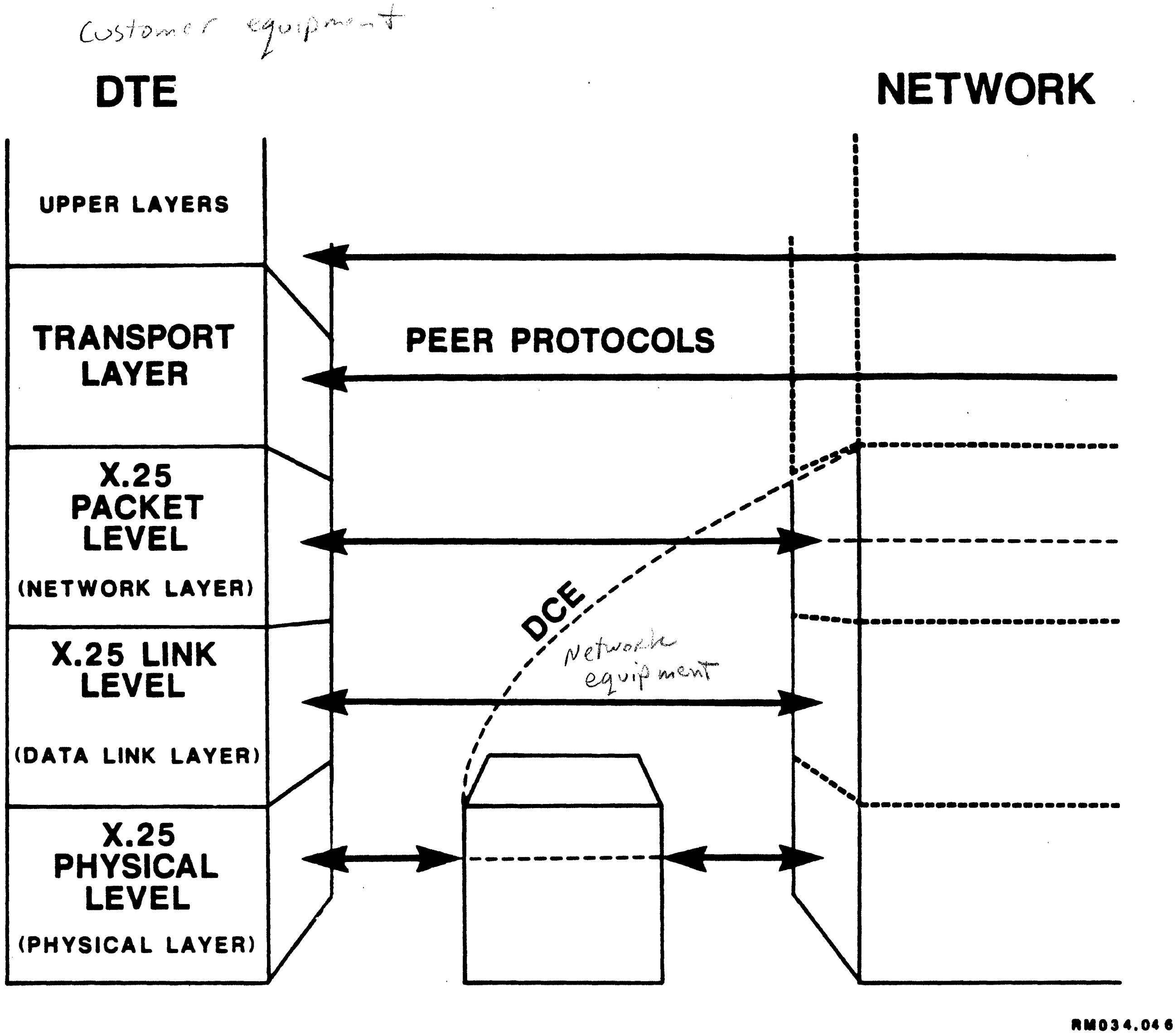
* **UPPER LAYERS** - provide the additional functionality needed to support the communicating application processes residing in the connected end-systems. The upper layers added to the lower three levels indicated above defines the new Open System Interconnection (OSI) architecture.

NOTE: The term "level" was first introduced in the original version of X.25 in 1976. Later, during the development of OSI, the term "layer" was adopted for a set of unique functions that facilitate an OSI communication. Although some purists disagree, the terms "level" in X.25 has the same meaning of "layer" in OSI.

LEGEND:

DTE = Data Terminal Equipment

DCE = Data Circuit-terminating Equipment: this term is used figuratively in X.25 and it really means the logic at the switch on the network side of the subscriber access circuit.


customer equipment
DTE
NETWORK
UPPER LAYERS
TRANSPORT LAYER
PEER PROTOCOLS
X.25 PACKET LEVEL
(NETWORK LAYER)
DCE
Network equipment
X.25 LINK LEVEL
(DATA LINK LAYER)
X.25 PHYSICAL LEVEL
(PHYSICAL LAYER)
RM034.046

RM013.095

PEER-TO-PEER PROTOCOLS

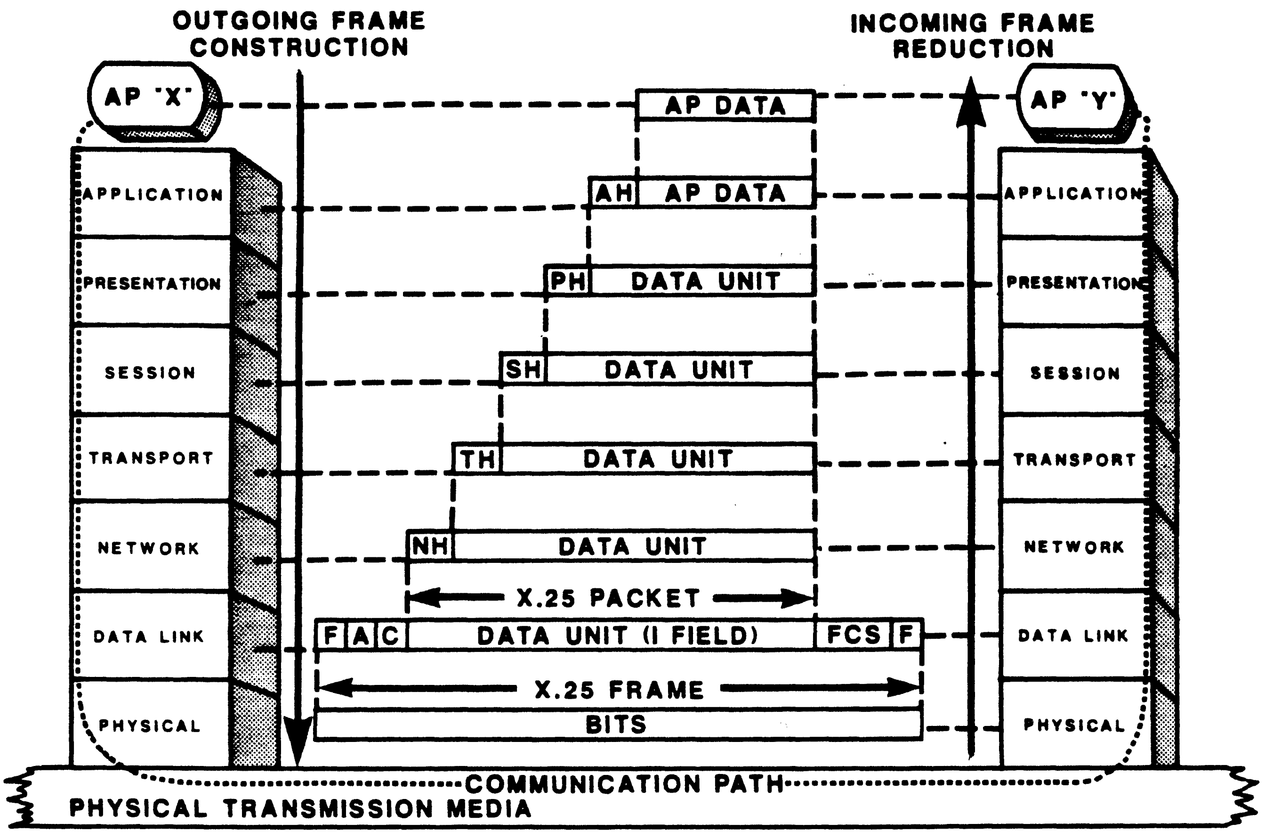
At each end of an interconnection for each layer, there is a peer entity that represents the functional unit of the layer. To facilitate communication between the APs, the peer entities must communicate with each other by peer protocols.

The message, or data, from the originating AP passes vertically down through each layer, where the respective header control information is appended for the horizontal peer-to-peer control communication. At the receiving end, the header information is removed at the respective layer, processed by the functional unit of that layer, and the remaining data unit is then passed up to the next layer, where a similar operation takes place. The information continues to be passed vertically up through each layer and then finally is delivered to the destination AP.

In this example, CCITT Recommendation X.25 defines the peer protocols for the lower three layers of the model. Protocols active at the upper layers are specified by other OSI standards.

LEGEND:

AP = Application Process
AH = Application header (PCI)
PH = Presentation header (PCI)
SH = Session header (PCI)
TH = Transport header (PCI)
NH = Network header (PCI)
F = Flag
A = Address
C = Control
FCS= Frame Check Sequence


OUTGOING FRAME CONSTRUCTION
INCOMING FRAME REDUCTION
AP "X"
AP "Y"
AP DATA
AH AP DATA
PH DATA UNIT
SH DATA UNIT
TH DATA UNIT
NH DATA UNIT
X.25 PACKET
F A C DATA UNIT (I FIELD) FCS F
X.25 FRAME
BITS
APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL
COMMUNICATION PATH
PHYSICAL TRANSMISSION MEDIA

RM013.125

CT005.095

SWITCHED NETWORKS

For a majority of applications, the use of dedicated transmission circuits between communicating end-points is costly and inefficient. The circuits are in place permanently whether or not the users are transmitting information. If there is a large or continuous amount of data to be transferred, then the use of dedicated circuits can be justified. On the other hand, many applications only need to communicate intermittently. As a result, there is a large amount of idle time when the circuits are not in use. This unused time still costs the user.

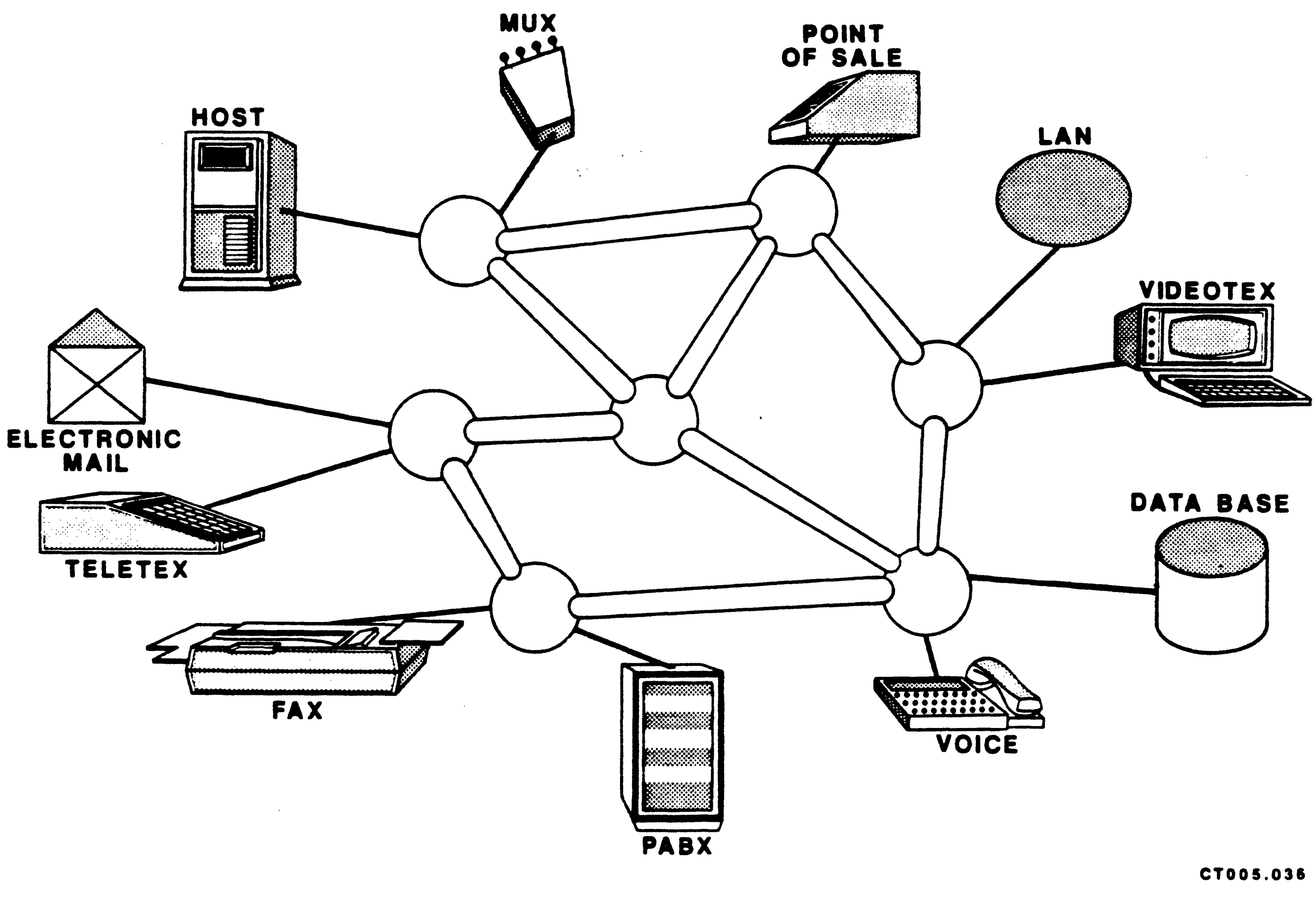
If the user can share telecommunication transmission resources, then only the cost for the time of actual use of a communication is realized. Switched telecommunications networks provide this benefit. The user, or subscriber, has a dedicated access circuit only to the first node of the network. This node is where the switching functions are performed. All of the transmission media among the nodes of the network are then provided on a shared, on-demand basis.

The nodes (circles in the figure) in telecommunications networks are called Data Switching Exchanges (DSEs). The access circuits from the user to the DSE and the trunks between DSEs are individual physical links (data links) that are connected in tandem to build up a given end-to-end communication path.

The trunks among the DSEs can be shared in a number of ways. They may support only one communication at a time as they are called up for a connection; they may be time division multiplexed to support a number of narrow-band connections over the wide-band circuit; or they may use statistical multiplexing where the information is into the transmission stream as it becomes available. Each mode of operation can effectively satisfy a certain population of applications. A continuous large amount of data at a high rate would likely use single wide-band trunks, while a continuous block of data at a lower rate would use a time division multiplexed trunk. Finally, burst-type communications would more effectively utilize a statistical mode of operation.

A variety of connected users are shown in the figure, which could represent a worldwide distributed information system of the future. This is also representative of the operation environment for OSI.

DISTRIBUTED INFORMATION SYSTEM



CT006.095

CIRCUIT-SWITCHED NETWORKS

In a circuit-switched network, a dedicated path is set up between the two communicating users. The path is held for the duration of the call whether or not any data is being transmitted. Normally, the trunks between DSEs are time division multiplexed on a wideband medium; and they are duplex, which provides for simultaneous transmission of information in both directions.

Some access circuits using the telephone networks are only two-wire and will only support half-duplex operation at the higher data signalling rates (above 2400 bit/s). This means that data can be transmitted in only one direction at a time or alternatively changing directions.

A circuit is set up through a network using a conventional call establishment procedure: call request - dial tone - dial number - call (non)progress signals - incoming call, ringing - answer - proceed with communication. Generally, with a circuit-switched connection, there is a fully transparent communication path, as there is with a dedicated leased circuit; but it is held only for the time necessary to complete the communication. It is then released and the switch resources and interswitch trunks are made available for service to others.

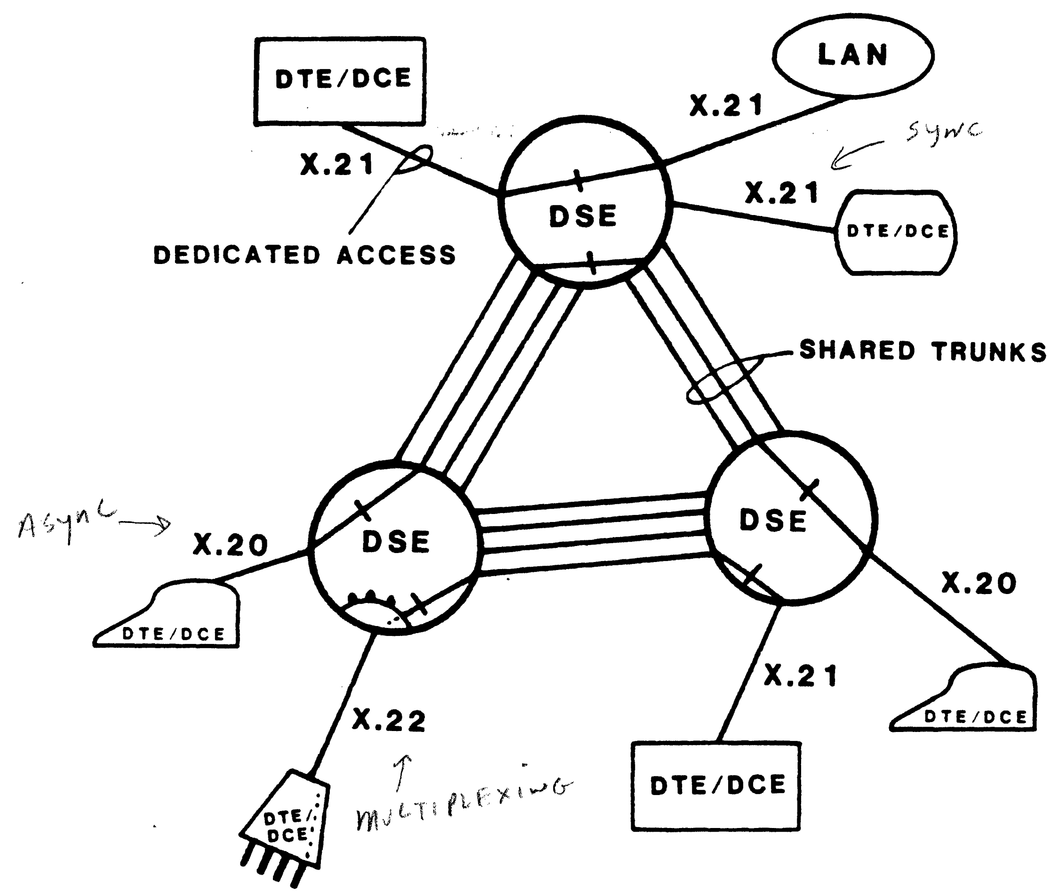
Public Data Networks provide duplex operation. In this configuration of circuit-switched service, good efficiency and cost benefit is optimized only when there is nearly continuous transmission of data in both directions for the duration of the call. The transparent connections provided enable the transmission of data in any format and using any code that is mutually agreed upon among the communicating parties. They may also use any mutually agreed upon Data Link Protocol during data transfer. During data transfer there is only one data link, which is between the communicating ends. Multipoint as well as point-to-point connections are possible through a circuit switched network. The Public Data Network standards are:

X.20 - Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for start-stop transmission services on public data networks - X.20 defines the procedures and physical interface for access of asynchronous start-stop terminals of 300 bit/s and below.

X.21 - Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for synchronous operation on public data networks - X.21 defines the procedures and general purpose interface for access to synchronous networks for data rates from 600 bit/s to 48 kbit/s.

X.22 - Multiplex DTE/DCE interface for user classes 3-6- X.22 is a time-division multiplexed interface for a number of X.21 accesses over a single physical 48 kbit/s line.

CIRCUIT-SWITCHED NETWORK



CT006.055

CT007.095

PACKET-SWITCHED NETWORKS

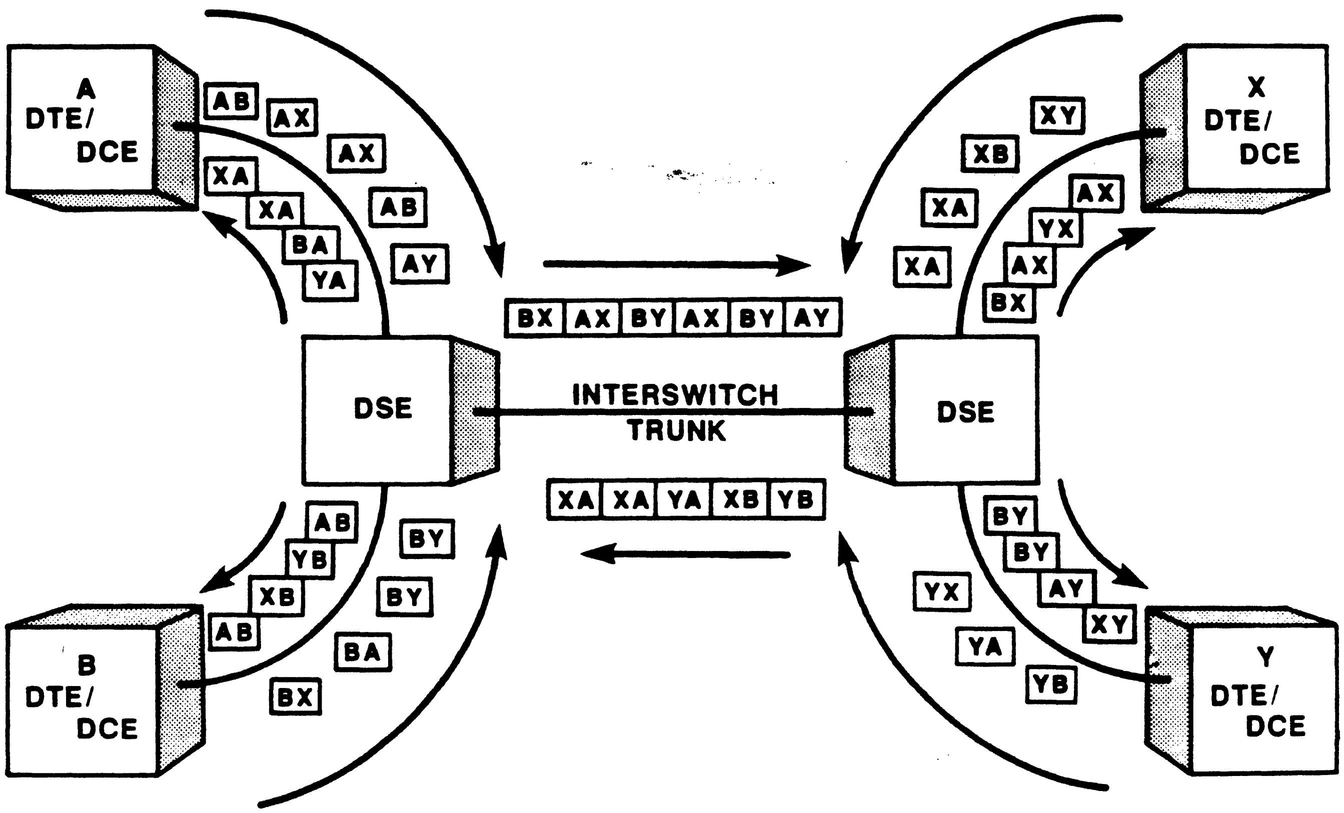
The transmission medium has generally been the most costly part of a communication. Although the cost of digital transmission is rapidly decreasing, efficient use will still be essential as the demand for bandwidth increases. Packet-switching offers the benefit of statistical multiplexing on the transmission media to minimize the idle periods in which no useful information is being passed.

A packet is a fixed, maximum-length unit of data and control information that is sent from the source to the destination. A packet may be fully self-contained, with all the necessary control information to be routed to the destination. A packet may also be one of a series of packets that contain the data and control for a complete communication and are transported across a pre-established logical path.

Packets received by the DSE from a subscriber are interleaved with other packets as they are routed through the network to their destinations. The interleaving is done on a statistical basis as the packets become available. With proper network design and grading for the trunks between DSEs, a very high usage of bandwidth can be realized. This efficient use of shared resources will then provide significant economic benefits to the users.

Two basic modes of operation that have been defined for packet-switched networks are datagram (connectionless) and virtual circuit (connection-oriented) packet switching.

PACKET-SWITCHED SERVICE



CT009.095

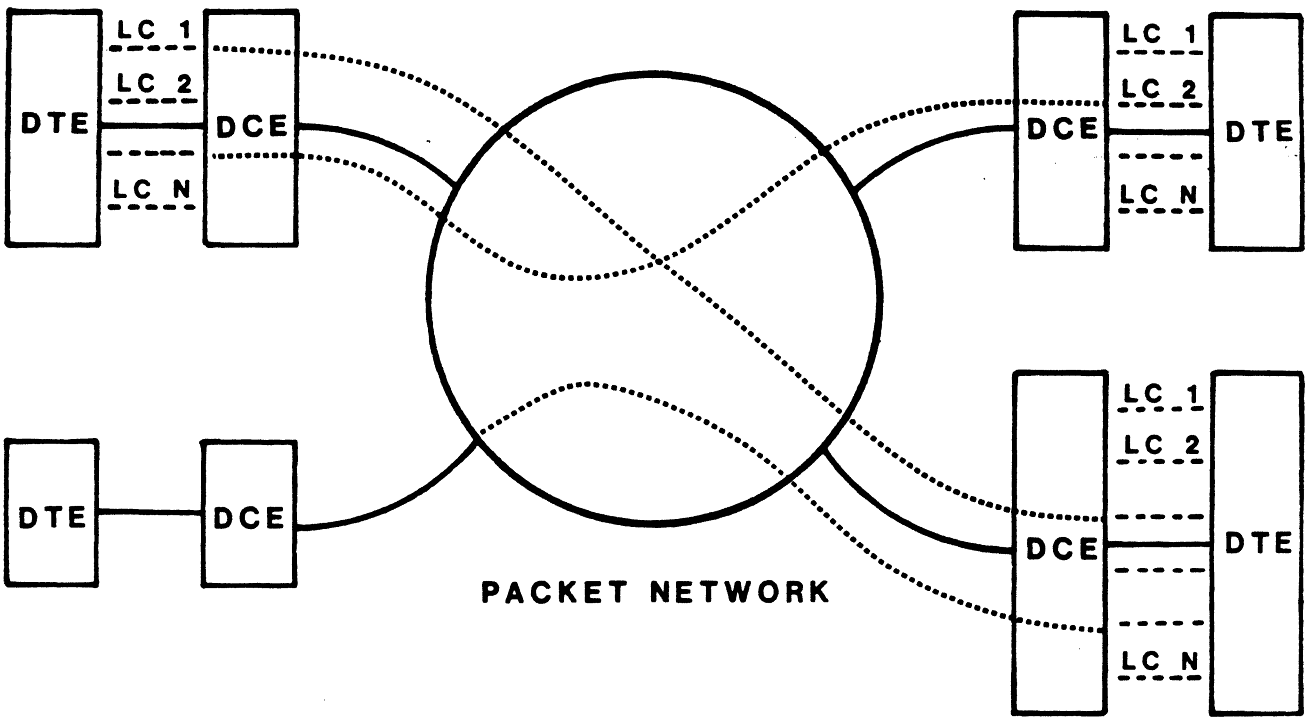
VIRTUAL CIRCUIT SERVICE

A virtual circuit provides a connection-oriented service similar to that of circuit switching but with the advantages of statistical multiplexing. An end-to-end communication path is provided through the logical allocation of network resources. This logical path may be provided either on a permanent basis by a Permanent Virtual Circuit (PVC), or on a request or dial-up basis by a Virtual Call (VC). Once the logical path is established, the packets are transferred between connected ends as desired. They are statistically multiplexed with packets of other communicating users to optimize the utilization of the transmission media.

In addition to multiplexing the packets on the trunks between DSEs in the network, the same statistical multiplexing technique can also be used on the access circuit between the user and the DSE. In effect, this enables multiple virtual circuits to be set up with a DTE. For example, a host computer may have the capacity to hold simultaneous communications with a number of distant subscribers. This is done by allocating a number of logical channels between the subscriber and the DSE over the access circuit. A virtual circuit (either permanent or dialed) can be established on each logical channel. Each packet is associated with a logical channel, which is mapped to the appropriate destination of the virtual circuit. This enables a more effective utilization of the access circuit for the available bandwidth and the traffic density for each logical channel.

The procedures for setting up a virtual call are functionally identical to establishing a circuit-switched connection. Once the logical path is established, the data packets are automatically routed to the appropriate destination.

VIRTUAL CIRCUIT SERVICE



CT009.115

CT011.112

INTERNETWORKING

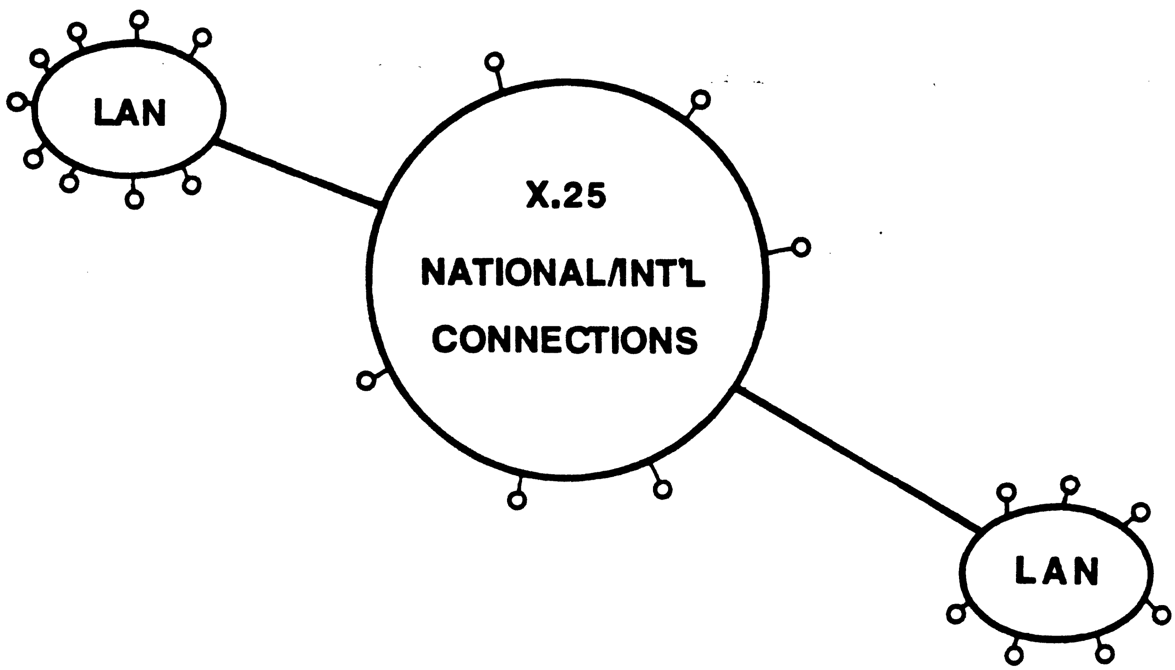
There is much discussion regarding the interconnection of networks to support communications over a large distributed area. This is not only desirable, but absolutely essential if truly global distributed information systems are to be realized.

The considerations boil down to what is possible and practical to do. Many academics like to think of unlimited interconnection of networks in tandem; but the quality of service and routing considerations constrain this approach considerably. Unless there is a common world-wide numbering plan that can be shared by all, full interconnection will not be a practical proposition.

As things stand today, X.25 packet switched networks are becoming the dominant offering for public networks, and will be widely used for private networks as well. Over limited distances, local area networks (LANs) will also be in wide use. The interconnections of local area networks with other local area networks will primarily be done through public networks because of the economics of transmission media.

Accordingly, it is expected that the typical configuration for future distributed information systems will be as shown in the figure - local area networks and subscribers interconnected via the national and international public data networks using the X.25 interface protocol. Dedicated circuit or other alternate means will also be used for certain requirements, but they will be in the minority.

A TYPICAL INTERNETWORK CONFIGURATION



CTO11.055

CT010.026

CCITT PACKET SWITCHING STANDARDS

X.25 - Interface between Data Terminal Equipment and Data Circuit-terminating Equipment for Terminals Operating in the Packet Mode on Public Data Networks - X.25 specifies the procedures for operation with packet networks providing Virtual Call (VC) and Permanent Virtual Circuit (PVC) services. The standard defines the operations for the three lower layers of the OSI Reference Model - Physical, Data Link, and Network. It provides for multiple logical channels across the access circuits between the DTEs and the DSEs. X.25 is also used for interconnecting public packet networks and private networks.

X.75 - Terminal and Transit Control Signalling System on International Circuits between Packet-switched Data Networks - X.75 specifies the procedures for connecting public X.25 packet networks through a gateway interface. It uses the same three-level architecture and is very nearly the same as the X.25 procedures. There is only one added field at the packet level (Network Layer), which is for utility information between networks. It does not apply to connection of private networks.

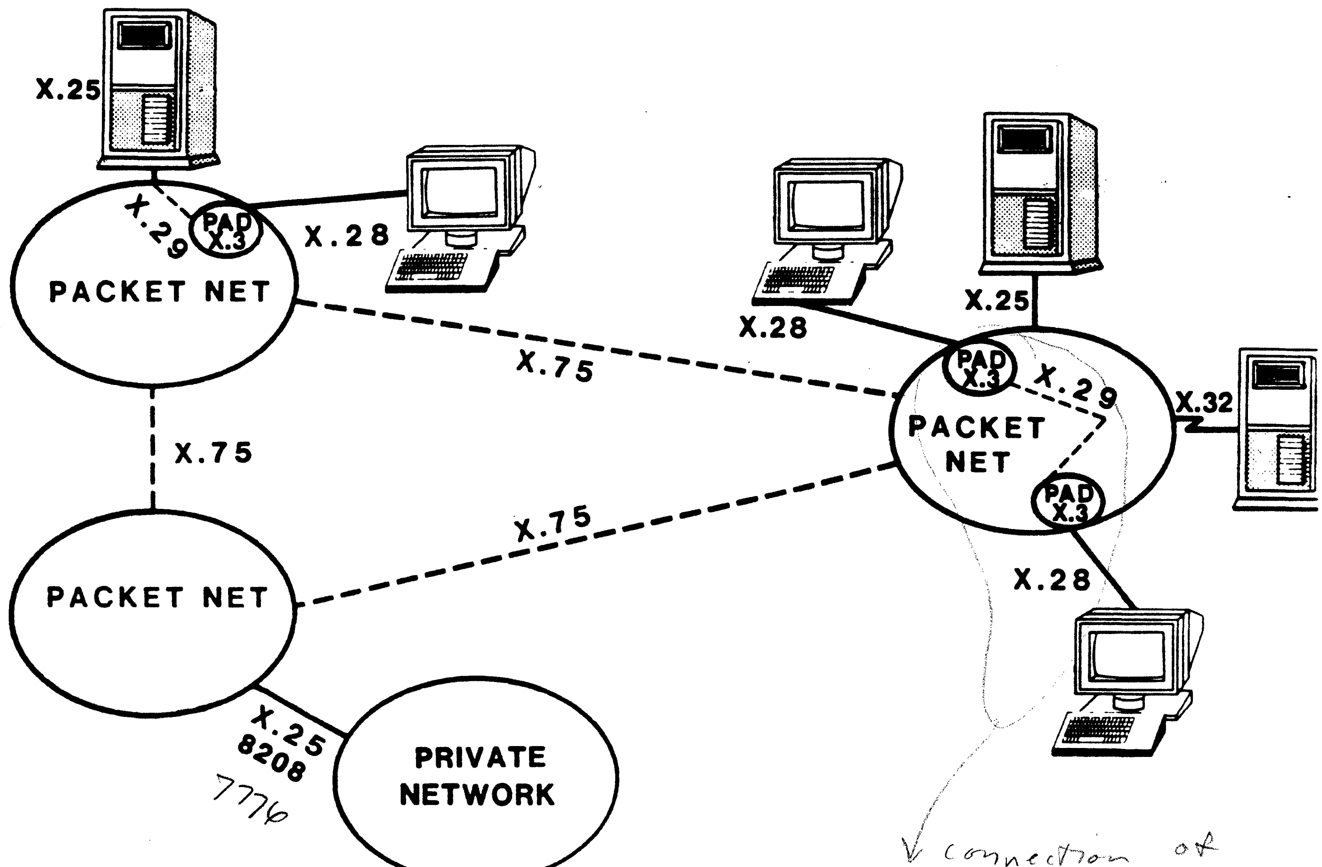
X.3 - Packet Assembly/Disassembly Facility (PAD) in a Public Data Network - X.3 describes the functions of the PAD, defines the operating parameters, and the control commands for conversion between serial streams of data with a start-stop terminal and packets with an X.25 terminal.

X.28 - DTE/DCE Interface for a Start-stop Mode Data Terminal Equipment Accessing the Packet Assembly Disassembly Facility (PAD) in a Public Data Network in the same Country - X.28 describes the procedures for connection and operation of simple asynchronous DTEs with X.25 packet networks. The PAD performs the function of converting serial streams of information from the asynchronous DTE into X.25 packets for transit in the network and vice versa.

X.29 - Procedures for the Exchange of Control Information and User Data between a Packet Assembly/Disassembly Facility (PAD) and a Packet Mode DTE and another PAD - X.29 specifies the procedures for an X.25 DTE to control the operation of the PAD during a communication with an asynchronous DTE through the PAD.

ISO 8208 - X.25 Packet Level Protocol for Data Terminal Equipment - This is a companion to X.25 that further specifies parameter values for DTE implementation. It also provides additional features that facilitate internetworking with private networks.

PACKET SWITCHING STANDARDS



CT010.016

connection of character Async equipment mode / to PSDN

CS001.095

COMPANION PUBLIC DATA NETWORK STANDARDS

In the CCITT interface Recommendations, such as X.25, X.28, X.75, etc., there are references to other companion Recommendations on specific details for certain items. Most of these Recommendations do not stand on their own, but rather provide supplemental details that apply to many other Public Data Network Recommendations. These are covered only briefly in order to identify what they are and what information they provide.

X.1 - recognized data signalling rates for public network access.

X.2 - optional service features--such as quality of service parameter negotiation, closed user groups, reverse charges, etc.

X.96- information signals provided to subscribers from the switched telecommunication services.

X.121- Public Data Network addressing schemes.

COMPANION PUBLIC DATA NETWORK RECOMMENDATIONS

- T.50 - INT'L ALPHA. NO. 5 (FORMERLY V.3)
- X.1 - USER CLASSES
- X.2 - USER FACILITIES
- X.96 - CALL PROGRESS SIGNAL
- X.121 - INT' L NUMBERING PLAN

CS001.104

CS002.026

INTERNATIONAL ALPHABET NUMBER #5

T.50 - International Alphabet Number 5 (IA5) - defines the 7-bit code for the alphanumeric and control characters in character-oriented applications.

IA5 is the international equivalent of the American National Standard ASCII for character coding of data. This is an example of close cooperation between CCITT and ISO as a joint standard. The ISO version, International Standard 646, is essentially the same as ASCII except for characters 2/3 and 2/4 representing currency signs.

IA5 or ASCII provides a commonly used method of encoding for data communications applications. It is used in Public Data Network applications such as X.20, X.21, X.3, and X.28. It is also the basis for the character oriented data link control protocols commonly known as BSC, or Basic Mode, internationally.

TABLE 11/T.50

International Reference Version (IRV)

				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
					0	1	2	3	4	5	6	7
b_4	b_3	b_2	b_1									
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	¤	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	IS4	,	<	L	\	l	|
1	1	0	1	13	CR	IS3	-	=	M	]	m	}
1	1	1	0	14	SO	IS2	.	>	N	^	n	‾
1	1	1	1	15	SI	IS1	/	?	O	_	o	DEL

CCITT-12432

Position is different

Int'l monetary symbol

Only Differences from ASCII

CS002.026

CS003.112

USER CLASSES OF SERVICE

X.1 - International User Classes of Service in Public Data Networks - provides the list of recognized data signalling rates for various modes of operation.

These are considered to apply internationally, but there are some differences from the practices in the USA. For example, the 48 kbit/s signalling rate is not used in N. America where 56 kbit/s is the normal practice, and there are other rates that are commonly used in the US that are not included in X.1. The CCITT desires to limit the proliferation of rates as much as possible, but is willing to recognize those that can be justified.

It is expected that in the future an expansion to include 1200 and 2400 bit/s start-stop will also be included because of its wide use and newly standardized modems supporting those rates.

TABLE 1/X.1

International user classes of service in public data networks and ISDNs
(see Notes 1 to 17)

a) Circuit switched and leased circuit data transmission services for data terminal equipment operating in start-stop mode, using X.20 or X.20 bis interfaces (see Note 1)

User class of service	Data signalling rate and code structure in the data transfer phase (see Notes 7 and 8)	Call control signals in the call control phase (see Note 6)
1	300 bit/s, 11* units/character start-stop (see Note 2)	300 bit/s, International Alphabet No. 5 (11 units/character) start-stop
2	50 to 200 bit/s, 7,5 to 11* units/character start-stop (see Notes 3 and 5)	200 bit/s, International Alphabet No. 5 (11 units/character) start-stop (see Note 4)

* Usage in accordance with Recommendation X.4.

b) Circuit switched and leased circuit data transmission services for data terminal equipment operating in synchronous mode, using X.21 or X.21 bis interfaces

User class of service	Data signalling rate in the data transfer phase (see Notes 8 and 10)	Call control signals in the call control phase (see Note 9)
3	600 bit/s	600 bit/s, International Alphabet No. 5
4	2 400 bit/s	2 400 bit/s, International Alphabet No. 5
5	4 800 bit/s	4 800 bit/s, International Alphabet No. 5
6	9 600 bit/s	9 600 bit/s, International Alphabet No. 5
7	48 000 bit/s	48 000 bit/s, International Alphabet No. 5

c) Packet switched data transmission service for data terminal equipment operating in synchronous mode, using X.25 interface (see Note 11)

User class of service	Data signalling rate (see Note 13)
8	2 400 bit/s
9	4 800 bit/s
10	9 600 bit/s
11	48 000 bit/s
12	1 200 bit/s (see Note 12)

d) Packet switched data transmission service for data terminal equipment operating in start-stop mode, using X.28 interface (see Note 11)

User class of service	Data signalling rate and code structure
20	50-300 bit/s, 10 or 11 units/character
21	75/1200 bit/s, 10 units/character (see Notes 14 and 15)
22	1200 bit/s, 10 units/character (see Notes 16 and 17)

CS003A.026

Note 1 – There is no user class of service for the data signalling rate of 50 bit/s, the transmission mode of 7.5 units/character start-stop and address selection and call progress signals at 50 bit/s, International Telegraph Alphabet No. 2. However, several Administrations have indicated that their telex service (50-baud, International Telegraph Alphabet No. 2) will be provided as one of the many services carried by their public data network.

Note 2 – Taking account of the existence of data terminal equipments operating in the start-stop mode at a data signalling rate of 300 bit/s and with a 10 unit/character code structure, some Administrations have indicated that their public data networks will accommodate such terminals. Other Administrations, however, have indicated that they cannot guarantee acceptable transmission if such terminals are connected to their networks.

Note 3 – Class 2 will provide, in the data transfer phase, for operation at the following data signalling rates and code structures:

50 bit/s (7.5 units/character)
100 bit/s (7.5 units/character)
110 bit/s (11 units/character)
134.5 bit/s (9 units/character)
200 bit/s (11 units/character)

Call control signals would be at 200 bit/s, International Alphabet No. 5 (11 units/character) as indicated in a) of Table 1/X.1.

Note 4 – Some Administrations have indicated that, for certain of the data signalling rates listed in Note 3 above, they will permit users in class 2 to operate the same signalling rate and code structure for both data transfer and address selection and to receive call progress signals at these signalling rates and code structures. Where International Alphabet No. 5 is used for the call control signals, the appropriate parts of Recommendation X.20 shall apply.

Note 5 – For international user class of service 2, it should be noted that some public data networks may not be able to prevent two terminals working at different data signalling rates and code structures from being connected together by means of a circuit-switched connection.

Note 6 – Only applicable for the circuit-switched data transmission service.

Note 7 – The support of user classes 1 and 2 in ISDN is for further study.

Note 8 – Some Administrations are planning to offer a circuit-switched asynchronous service for terminal operating at the data signalling rate of: 600 bit/s, 1200 bit/s, 2400 bit/s, 4800 bit/s, 9600 bit/s. 10 units/character, start-stop in the data transfer phase and respectively 600 bit/s, 1200 bit/s, 2400 bit/s, 4800 bit/s, 9600 bit/s, International Alphabet No. 5, 10 units/character, start-stop in the call control phase. This service would be supported by synchronous network bearer channels.

Note 9 – Only applicable for the circuit-switched data transmission service, using the Recommendation X.21 interface.

Note 10 – The support of user classes of service 3 to 7 in the ISDN is provided by means of a terminal adaptor (in accordance with Recommendation X.30). The concept of terminal adaptor functional grouping is defined in Recommendation I.411.

Note 11 – The packet-switched data transmission service allows for communication between Recommendations X.25 and/or X.28 data terminal equipments operating at different data signalling rates.

Note 12 – The user class of service 12 is only provided via PSTN access. It might also be offered in the maritime satellite data transmission system.

Note 13 – The support of user classes of service 8 to 11 in the ISDN is provided by means of a terminal adaptor (in accordance with Recommendation X.31). The concept of terminal adaptor functional grouping is defined in Recommendation I.411. The support of user class 12 in the ISDN is for further study.

Note 14 – 75 bit/s from DTE to DCE, 1200 bit/s from DCE to DTE.

Note 15 – This user class of service will not be supported by all Administrations.

Note 16 – The support of user classes of service 20 to 22 in the ISDN may be provided by means of a terminal adaptor providing PAD functions. Other means to support these user classes of service in the ISDN are for further study.

Note 17 – Some Administrations may offer higher speeds.

CS003B.026

NOTES

CS004.112

USER SERVICES AND FACILITIES

X.2 - International User Services and Facilities in Public Data Networks - specifies the special and optional service features (facilities) that can be provided by Public Data Networks.

X.2 provides only the basic shopping list of features with an indication of whether they are essential (E), additional option (A), or for further study (FS). Also included are the various types of service to be provided. The specific details of operation of the facilities is provided by the particular interface protocol. In addition, Recommendation **X.300** - **Principles and Procedures for Realization of International User Facilities and Network Utilities in Public Data Networks** - provides a good description of the different facilities provided.

TABLE 1/X.2

International data transmission services and optional user facilities in public data networks

a) Circuit switched data transmission service

Optional user facility (see Note 6)	All user classes of service
1. *Optional user facilities assigned for an agreed contractual period*	
1.1 Direct call	A
1.2 Closed user group	E
1.3 Closed user group with outgoing access	A
1.4 Closed user group with incoming access	A
1.5 Incoming calls barred within a closed user group	A
1.6 Outgoing calls barred within a closed user group	A
1.7 Calling line identification	A
1.8 Called line identification	A
1.9 Bilateral closed user group	A
1.10 Bilateral closed user group with outgoing access	A
1.11 Incoming calls barred	A
1.12 Reverse charging acceptance	A
1.13 Connect when free	A
1.14 Waiting allowed	A
1.15 Redirection of calls	A
1.16 On-line facility parameter registration/cancellation	A
1.17 DTE inactive registration/cancellation	A
1.18 Date and time indication	A
1.19 Hunt group	A
2. *Optional user facilities requested by the DTE on a per-call basis*	
2.1 Direct call	A
2.2 Abbreviated address calling	A
2.3 Multi-address calling (see Note 7)	A
2.4 Reverse charging	A
2.5 RPOA selection	A
2.6 Charging information	A
2.7 Called line identification	A

Additional — essential

b1) Packet switched data transmission services (see Notes 1, 2, 3 and 4)

Services	User classes of service	
	8-11	20-22
Virtual call service	E	E
Permanent virtual circuit service (see Note 8)	E	FS

CS004A.026

TABLE 1/X.2 *(cont.)*

b2) Facilities of packet switched data networks

Optional user facility (see Note 6)	User classes of service			
	8-11		20-22 (see Note 5)	
	VC	PVC	VC	PVC
1. *Optional user facilities assigned for an agreed contractual period*				
1.1 Extended packet sequence numbering (module 128)	A	A	–	–
1.2 Nonstandard default window sizes	A	A	–	–
1.3 Nonstandard default packet sizes 16, 32, 64, 256, 512, 1024, 2048, 4096	A	A	FS	FS
1.4 Default throughput classes assignment	A	A	FS	FS
1.5 Flow control parameter negotiation	E	–	FS	–
1.6 Throughput class negotiation	E	–	FS	–
1.7 Packet retransmission	A	A	–	–
1.8 Incoming calls barred	E	–	A	–
1.9 Outgoing calls barred	E	–	A	–
1.10 One-way logical channel outgoing	E	–	–	–
1.11 One-way logical channel incoming	A	–	–	–
1.12 Closed user group	E	–	E	–
1.13 Closed user group with outgoing access	A	–	A	–
1.14 Closed user group with incoming access	A	–	A	–
1.15 Incoming calls barred within a closed user group	A	–	A	–
1.16 Outgoing calls barred within a closed user group	A	–	A	–
1.17 Bilateral closed user group	A	–	A	–
1.18 Bilateral closed user group with outgoing access	A	–	A	–
1.19 Reverse charging acceptance	A	–	A	–
1.20 Fast select acceptance	E	–	FS	–
1.21 Multilink procedure	A	A	–	–
1.22 Charging information	A	–	A	–
1.23 Direct call	FS	–	A	–
1.24 Hunt group	A	–	A	–
1.25 On-line facility registration	A	–	FS	–
1.26 D-bit modification	A	A	FS	–
1.27 Local charging prevention	A	–	FS	–
1.28 Call redirection	A	–	FS	–
1.29 Network user identification	A	–	A	–
1.30 Extended frame sequence numbering	A	A	–	–
1.31 RPOA selection	A	–	A	–
2. *Optional user facilities on a per-call basis*				
2.1 Closed user group selection	E	–	E	–
2.2 Bilateral closed user group selection	A	–	FS	–
2.3 Reverse charging	A	–	A	–
2.4 RPOA selection	A	–	A	–
2.5 Flow control parameter negotiation	E	–	–	–
2.6 Fast select	E	–	FS	–
2.7 Throughput class negotiation	E	–	–	–
2.8 Abbreviated address calling	FS	–	A	–
2.9 Charging information	A	–	A	–
2.10 Transit delay selection and indication (see Note 10)	E	–	–	–
2.11 Call redirection notification	A	–	FS	–
2.12 Called line address modified notification	A	–	FS	–
2.13 Network user identification	A	–	A	–
2.14 Closed user group with outgoing access selection	A	–	FS	–

CS004B.026

NOTES

CS005.112

CALL PROGRESS SIGNALS

X.96 - Call Progress Signals in Public Data Networks - defines the information that can be provided by the network to the DTE in advising on the status of the network and the connection or communication. The title is really a misnomer, because the great majority of the signals have a negative connotation, advising why the communication is not possible. "Call Nonprogress Signals" would be a more appropriate title. In X.25 these signals appear in the Cause Fields of the various packets.

TABLE 1/X.96

Call progress signal	Definition	Category	Applicable to: Circuit switching	Packet switching: VC	Packet switching: PVC	See Note
Terminal called	The incoming call was signalled to the DTE and call acceptance is awaited.	A	(M)	–	–	1
Redirected call	The call has been redirected to another number assigned by the called subscriber.	A	(M)	–	–	
Connect when free	The called number is busy and the call has been placed in a queue. The call will be connected when the called number becomes free if the caller waits.	A	(M)	–	–	
Registration/cancellation confirmed	The facility registration or cancellation requested by the calling DTE has been confirmed by the network.	B	(M)	(M)	(M)	11
Redirection facility active	The redirection facility is active.	B	(M)	–	–	2
Redirection facility not active	The redirection facility is not active.	B	(M)	–	–	2
No connection	Cause unspecified.	C1	M	–	–	
Selection signal transmission error	A transmission error has been detected in the selection signals by the first Data Switching Exchange (DSE).	C2	M	–	–	
Local procedure error	A procedure error caused by the DTE is detected by the DCE at the local DTE/DCE interface. Possible reasons are indicated in relevant Series X interface Recommendations (e.g.: incorrect format, expiration of a time-out).	D1	M	M	M	3
Network congestion	A condition exists in the network such as: 1) temporary network congestion, 2) temporary fault condition within the network, including procedure error within a network or an international link.	C2	M	M	M	
Network out of order	Temporary inability to handle data traffic.	C2	–	–	M	

CS005A.026

TABLE 1/X.96 *(cont.)*

Call progress signal	Definition	Cate-gory	Applicable to			See Note
			Circuit switching	Packet Switching		
				VC	PVC	
Invalid facility request	A facility requested by the calling DTE (circuit switching or packet switching services) or the called DTE (packet-switching service only) is detected as invalid by the DCE at the local DTE/DCE interface. Possible reasons include: – request for a facility which has not been subscribed to by the DTE, – request for a facility which is not available in the local network, – request for a facility which has not been recognized as valid by the local DCE.	D1	M	M	–	
RPOA out of order	The RPOA nominated by the calling DTE is unable to forward the call.	D2	(M)	(M)	–	4
Changed number	The called DTE has been assigned a new number.	D1	M	–	–	
Not obtainable	The called DTE address is out of the numbering plan or not assigned to any DTE.	D1	M	M	–	
Access barred	The calling DTE is not permitted the connection to the called DTE. Possible reasons include: – unauthorized access between the calling DTE and the called DTE; – incompatible closed user group.	D1	M	M	–	
Reverse charging acceptance not subscribed	The called DTE has not subscribed to the reverse charging acceptance facility.	D1	FS	(M)	–	
Incompatible user class of service	The called DTE belongs to a user class of service which is incompatible with that of the calling DTE.	D1	M	–	–	5

CS005B.026

TABLE 1/X.96 *(cont.)*

Call progress signal	Definition	Category	Applicable to: Circuit switching	Packet switching: VC	Packet switching: PVC	See Note
Fast select acceptance not subscribed	The called DTE has not subscribed to the fast select acceptance facility.	D1	–	(M)	–	
Incompatible destination	The remote DTE/DCE interface or the transit network does not support a function or facility requested.	D1	–	M	M	
Ship absent	The called ship is absent.	D1	–	M	–	13
Out of order	The remote number is out of order. Possible reasons include: – DTE is uncontrolled not ready; – DCE power off; – network fault in the local loop; – in packet switched services only: X.25 level 1 not functioning, X.25 level 2 not in operation.	D1 or D2	See Note 6	M See Note 7	M	8
Network fault in the local loop	The local loop associated with the called DCE is faulty.	D2	M Unless out of order is provided	See Note 7		9
DCE power off	Called DCE has no mains power or is switched off.	D1	M	See Note 7		9
Uncontrolled not ready	Called DTE is uncontrolled not ready.	D1	M	See Note 7		9
Controlled not ready	Called DTE is signalling controlled not ready.	D1	M	FS	FS	1
Number busy	The called DTE is detected by the DCE as engaged on other call(s), and therefore as not being able to accept the incoming call.	C1	M	M	–	
Call the information service	The called number is temporarily unobtainable. Call the network information service for details.	D1	M	–	–	

CS005C.028

TABLE 1/X.96 *(end)*

Call progress signal	Definition	Category	Applicable to: Circuit switching	Applicable to: Packet switching VC	Applicable to: Packet switching PVC	See Note
Remote procedure error	A procedure error caused by the DTE or an invalid facility request by the remote DTE is detected by the DCE at the remote DTE/DCE interface. Possible reasons are indicated in relevant Series X interface Recommendations.	D1	–	M	M	
Long term network congestion	A major shortage of network resource exists.	D2	M	–	–	10
Network operational	Network is ready to resume normal operation after a temporary failure or congestion.	C1	–	–	M	
Remote DTE operational	Remote DTE/DCE interface is ready to resume normal operation after a temporary failure or out of order condition (e.g. restart at the DTE/DCE interface). Loss of data may have occurred.	C1	–	–	M	
DTE originated	The remote DTE has initiated a clear, reset or restart procedure.	B or D1	–	M	M	12
PAD clearing	The call has been cleared by the local PAD as an answer to an invitation from the remote DTE (X.28 only).	B	–	M (X.28 only)	–	
Private/public network reached	See Annex F of Recommendation X.21.	A	–	–	–	14
DTE interactive	The called DTE has registered for being inactive until the date and time indicated.	D1	–	–	–	

– Not applicable.

M Mandatory in all networks.

(M) Mandatory where the relevant optional user facility is provided.

FS Further study.

CS005D.026

Notes concerning Table 1/X.96

Note 1 – The international implications of ***controlled not ready*** and ***manual answering*** are for further study.

Note 2 – Sent as confirmation/answer for the ***redirection activation/deactivation*** facility.

Note 3 – For circuit switching, applicable only to the calling DTE.

Note 4 – The ***RPOA out-of-order*** call progress signal will not be returned to a DTE which does not subscribe to the ***RPOA selection*** facility.

Note 5 – Some networks may use the ***not obtainable*** call progress signal to signal this condition.

Note 6 – Used as an alternative signal in networks where one or more of the conditions ***uncontrolled not ready, DCE power off*** and ***network fault in the local loop*** cannot be uniquely identified.

Note 7 – Although the basic ***out-of-order*** call progress signal is transmitted for these conditions, the diagnostic field in the ***clearing*** or ***resetting*** packet may give more precision.

Note 8 – The fact that a DTE is also out of order when the link access procedure level is not operating correctly is a subject for further study.

Note 9 – Should be provided where the network can identify the condition.

Note 10 – Activated by the operational staff of the network.

Note 11 – Applicable only to the DTE/DCE interface (***restart*** packets in case of packet switching service).

Note 12 – Possible reasons for this include ***reverse charging not accepted. Reset*** and ***restart*** are not applicable to the circuit-switching service.

Note 13 – Used only in conjunction with mobile maritime service.

Note 14 – Refer to Notes 3 and 4 of Annex F to Recommendation X.21.

TABLE 2/X.96

Category	Significance
A	Call not cleared. Calling DTE is expected to wait.
B	Call cleared because the procedure is complete.
C1 and C2	*Call cleared* The calling DTE should call again soon: the next attempt may be successful. However, after a number of unsuccessful call attempts with the same response, the cause could be assumed to be in Category D1 or D2. The interval between successive attempts, and the maximum number of attempts, will depend on a number of circumstances including: – nature of the call progress signal, – user's traffic pattern, – tariffs, – possible regulations by the Administrations. *Reset* (for packet-switched services only). The DTE may continue to transmit data recognizing that data loss may have occurred.
D1 and D2	*Call cleared* The calling DTE should take other action to clarify when the call attempt might be successful. *Reset* (for permanent virtual circuit only). The DTE should cease data transmission and take other action as appropriate.
C1 and D1	Due to subscriber condition.
C2 and D2	Due to network condition.

CS005E.026

CS006.095

INTERNATIONAL NUMBERING PLAN

X.121 - International Numbering Plan for Public Data Networks - defines the universal subscriber addressing scheme, which will enable the unique identification of each subscriber reached through the international public data network services.

Originally, X.121 applied only to the public networks; but it now accommodates connection of private networks as well through assignment of Data Network Identifier Codes (DNICs) to groups of private networks in each country. The individual countries administer the allocation of the numbers to private networks. International routing is done using the DNIC, while the final national routing would be done by the public network group that interconnects to the private networks.

The problem of developing universal numbering plans is very complex and will not be readily solved. Internationally, there are as many political problems as there are technical ones. With separate telephone, telex, and public data network plans, the problem is compounded.

CCITT RECOMMENDATION X.121

INT'L NUMBERING PLAN FOR PUBLIC DATA NETWORKS

UNIQUELY IDENTIFIES:

- WORLD ZONE
- COUNTRY OR GEOGRAPHICAL AREA
- NETWORK
- SUBSCRIBER

Maximum 14 Digits

CS006.055

CS007.114

ADDRESS FORMATS

INTERNATIONAL PREFIX - For outgoing international calls from a public data network the International Prefix (P) is an access code that identifies a call being made to a subscriber on a public data network in a different country. This digit is either a 1 or 0 depending on the specific network where the call originates.

DATA NETWORK IDENTIFICATION CODE (DNIC) - A basic 4-digit "area code" is used in this scheme. The first digit, "Z", provides an indication of the World Zones, such as North America, Europe, etc. It also provides an escape for interworking with the Telex and telephone networks. The "Z" together with the next two "X" digits provide identification of the country, or geographical area. The last "X" digit is used to identify the specific network to which the subscriber is connected. Many countries will have only one network, and therefore really only need to use the Data Country Code (DCC) portion. Others, like the USA, will have a number of networks (more than 10). In this case, a block of country codes will be assigned to take care of that nation's needs.

INTERNATIONAL DATA NUMBER - The total subscriber address is made up of two basic parts, with a maximum total length of 14 digits. The first combination uses the 4-digit DNIC plus a Network Terminal Number (NTN) having up to a maximum of 10 digits. The alternate combination uses the 3-digit DCC plus a National Number having a maximum of 11 digits. These two different combinations lead to another complication for the interworking of networks. There is no means to identify the kind of address being used. Therefore each gateway is going to have to have prior knowledge of the structure of the address information.

X.121 INT'L NUMBERING PLAN

DATA NETWORK IDENTIFICATION CODE–DNIC ← For international Routing!

Z X X	X
DATA COUNTRY CODE DCC	NETWORK DIGIT

Z= 0, 1: RESERVED

2–7: WORLD ZONES

8,9: TELEX/TELEPHONE NETWORK INTERWORKING

X= 0–9

CS007A.016

INTERNATIONAL DATA NUMBER

P	+	DNIC	+	NTN
(PREFIX)		(DATA NETWORK IDENTIFICATION CODE)		(NETWORK TERMINAL NUMBER)
		FIXED–4 DIGITS		MAX–10 DIGITS

OR

P	+	DCC	+	NN
(PREFIX)		(DATA COUNTRY CODE)		(NATIONAL NUMBER)
		FIXED–3 DIGITS		MAX–11 DIGITS

CS007B.016

EXAMPLE NUMBERING PLAN FOR PRIVATE NETWORKS

With the establishment of public data networks, there is still a large requirement for connection of users' private data networks in the same way as PABX's (private automatic branch exchanges) are connected with the public telephone network. In order to interconnect efficiently, compatible numbering schemes should be used by the private networks. If not, additional internetwork address conversions and protocols are needed.

Among the recognized approaches are shared address space and subrouting identification codes. Other schemes under study include a universal addressing scheme, which will accommodate a diversity of schemes, and subaddresses, which can be conveyed separately from the primary routing address.

The shared address space comes from the public data network provider allocating part of his basic numbering resource for use by the subscriber's connected private network. This approach is satisfactory where ample blocks of addresses are available from the provider and where the private network is connected only to one public network.

The alternate scheme of defining subrouting identification codes is specified by an annex to Recommendation X.121. This provides allocation of DNICs by CCITT to the requesting countries for specific use in connecting private networks to public data networks. Then the NTN part of the DNIC + NTN block is divided into two parts - the Private Network Identification Code (PNIC) and End Terminal Number (ETN).

The PNIC is a fixed 6-digit code that is used by the public data network or group of public data networks to route a call to the gateway of the private network. The remaining 4-digit ETN is then used by the private network for assignment to individual subscribers. If four digits are not adequate for larger private networks, multiple PNICs can then be assigned. This would result in the low-order digit of the PNIC being as significant as the high order digit of the ETN. Therefore, any size network can be accommodated in multiples of 4-digit address blocks.

The PNIC scheme has the advantage that when a private network is connected to more than one public data network (such as will be possible in the USA), a common international number will apply.

PRIVATE NETWORK NUMBERING

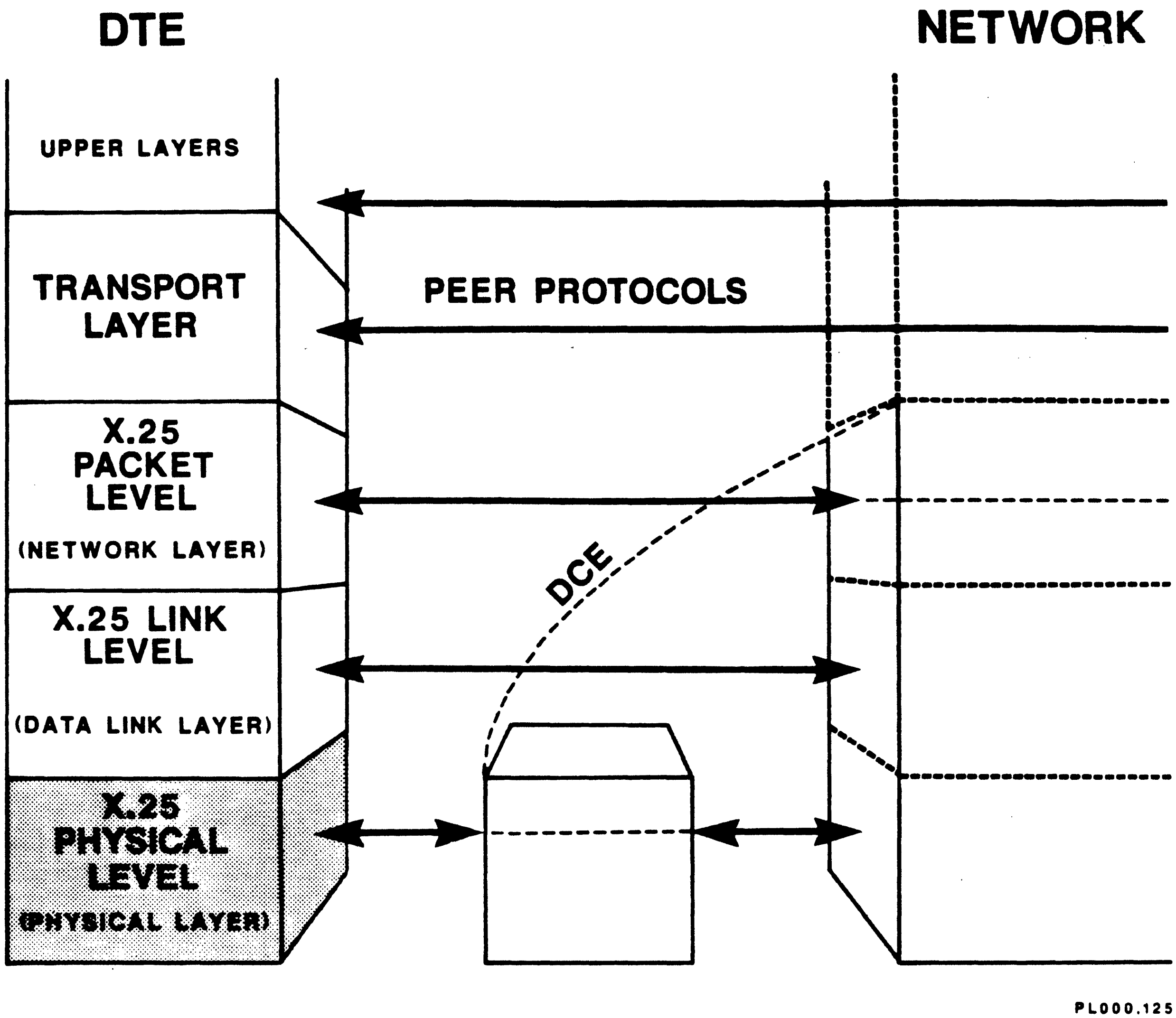
P + DNIC + NTN

P +	PNIC	+	ETN
0, 1	6 DIGITS FIXED		4 DIGITS MAX
	ZXXXXX		XXXX

Z = DIGITS 2 - 9
X = DIGITS 0 - 9

CS008.016

NOTES


DTE
NETWORK
UPPER LAYERS
TRANSPORT LAYER
PEER PROTOCOLS
X.25 PACKET LEVEL
(NETWORK LAYER)
X.25 LINK LEVEL
(DATA LINK LAYER)
X.25 PHYSICAL LEVEL
(PHYSICAL LAYER)
DCE
PL000.125

PL001.074

PHYSICAL LEVEL OF X.25

CCITT Recommendation X.25 references other Recommendations for the Physical Level characteristics. The first is Recommendation X.21, which specifies the general-purpose interface for synchronous operation. In addition to X.21, X.21 bis is specified to allow connection of existing equipment designs to the new public data network services.

While X.21 is a newly designed physical interface specification for which there is no present USA equivalent, X.21 bis specifies the equivalent provisions of the USA RS-232-C as well as RS 449 and CCITT Recommendation V.35 for the 48 kbit/s service. There is no official USA equivalent, but V.35 is commonly used.

The physical access to the X.25 network is specified for a dedicated access circuit. Alternatively, connection through a circuit-switched public data network or Public Switched Telephone Network is specified by X.32.

PHYSICAL LEVEL

X.21 BIS-

RESOLVES "CHICKEN AND EGG" DILEMMA

NETWORK ADAPTATION TO

EIA RS-232-C
CCITT V.35
EIA RS-449

X.21 PHYSICAL ELEMENTS

SPECIFICALLY DESIGNED FOR PUBLIC DATA NETWORK TECHNOLOGY

these are equal alternatives.

PL001.055

Germany + Sweden use X.21

PL002.095

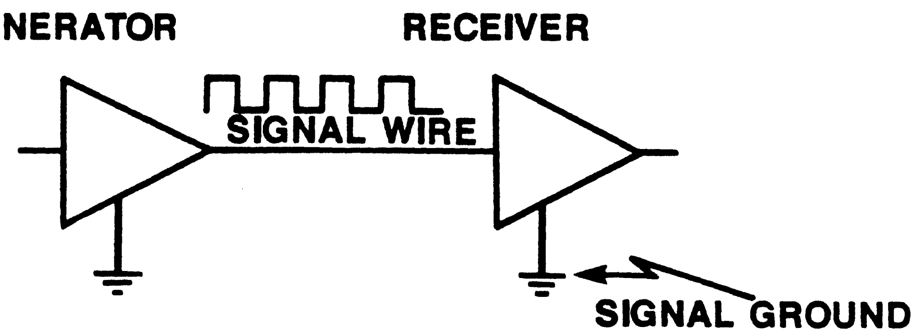
EIA RS-232-C/CCITT V.24, V.28, ISO 2110

RS-232-C and its international equivalent, CCITT V.24/V.28/ISO 2110, has been the pervasive physical interface for data communications applications for over 20 years. While it has served well, it has had a great number of problems associated with it.

Basically RS-232-C is an unbalanced electrical configuration for transmission of simple baseband digital signals. The signals are passed over a signal wire and returned through a common signal ground. As a result, the wire acts as an antenna, which not only nicely radiates signals into nearby circuits but is susceptible to receiving undesired signals from external sources. This noise causes the basic operating limitations of RS-232-C. It is limited to data signalling rates of 20 kbit/s and a cable distance of 50 feet (15 meters) between the DTE and the DCE. While greater performance can be realized from current implementations, additional engineering and optimization of the operating environment is needed. Nevertheless, the majority of existing equipments and designs implement this long-standing interface.

RS-232-C uses separate interchange circuits (wires) in the interface to perform individual functions. There is a circuit in each direction to transmit and receive data. There are also timing circuits to provide the timing signals for synchronous operation and numerous control circuits to perform the function of operation with data modems on the analog access circuits. The familiar 25-pin connector provides the mechanical connection between the DTE and the DCE.

EIA RS-232-C (CCITT V.28/V.24/ISO 2110)



CHARACTERISTICS-

- **UNBALANCED ELECTRICAL-V.28**
- **25-PIN CONNECTOR-ISO 2110**
- **DATA, TIMING, CONTROL-V.24**

LIMITATIONS-

- **MAX DATA RATE-20 kbit\s**
- **MAX CABLE DISTANCE-50 FEET (15 METRES)**
- **NOISE**

PL002.125

PHYSICAL INTERFACE CONFIGURATION

Several circuits are used to interconnect the DTE and DCE. In RS-232-C (CCITT V.24/V.28), each circuit is a single wire that supports a specifically defined function. Some circuits convey information from the DTE to the DCE while others convey information from the DCE to the DTE. Each circuit has an electrical generator, or driver, as the signal source and a receiver to detect the signals. The electrical representation of the logical signals are:

- voltage = BINARY 1, CONTROL OFF, MARK

+ voltage = BINARY 0, CONTROL ON, SPACE

The **Send Data** and **Receive Data** circuits convey information in the form of a serial binary data stream.

The control circuits convey logical control states, and when they are in the logical ON state, their functional indication is:

* **Data Set Ready** - The modem is powered-on and ready for operation

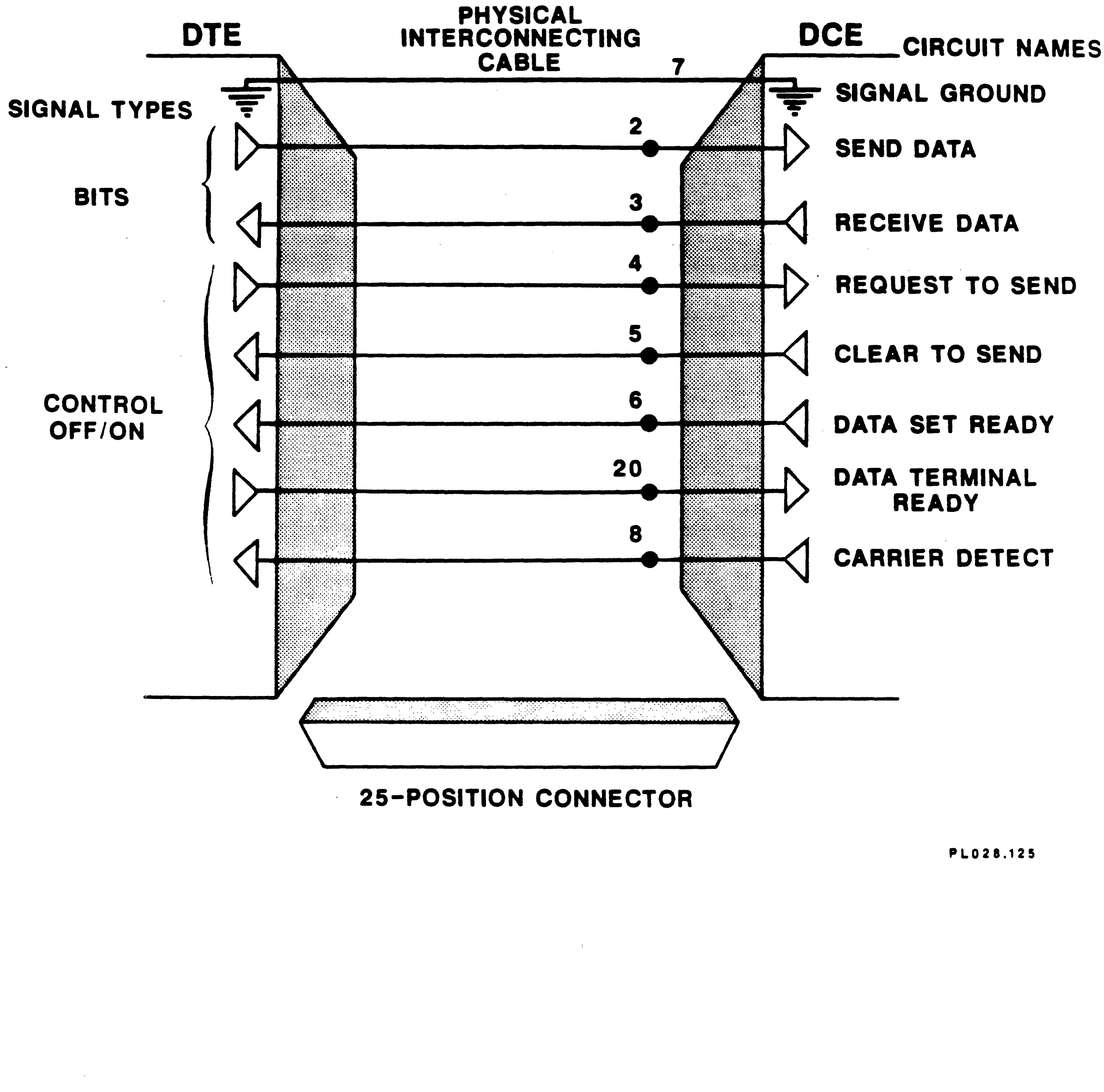
* **Data Terminal Ready** - The terminal is powered-on and ready for operation

* **Request to Send** - The terminal wishes to initiate a transmission

* **Clear to Send** - The modem responds positively to the "Request to Send".

* **Carrier Detect** - The modem is synchronized to the incoming signal.

Certain time delay conditions on control circuits should be observed to ensure proper operation. There should be a delay of more than 1 ms and less than 1 s between request-to-send turning ON and clear-to-send turning ON. In addition, clear-to-send and carrier-detect circuits may go to the OFF condition momentarily during transmission. Higher levels should delay any action for several seconds to avoid false "out-of-order" conditions.


DTE
PHYSICAL
INTERCONNECTING
CABLE
DCE
CIRCUIT NAMES
7
SIGNAL TYPES
SIGNAL GROUND
2
SEND DATA
BITS
3
RECEIVE DATA
4
REQUEST TO SEND
5
CLEAR TO SEND
CONTROL
OFF/ON
6
DATA SET READY
20
DATA TERMINAL
READY
8
CARRIER DETECT
25-POSITION CONNECTOR
PL028.125

PL003.095

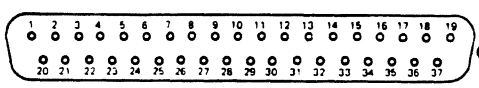
EIA RS-449/CCITT V.24, V.10, V.11, ISO 4902

RS-449 was developed by Electronics Industries Association (EIA) to replace RS-232-C and provide operating characteristics appropriate to meet the advancing demands of higher data signalling rates and longer interface cable distances. The new EIA electrical characteristics, RS-422-A and RS-423-A, were designed to be compatible with integrated circuit technology, and are used in the RS-449 interface together with a 37-pin connector from the same family of connectors as the 25-pin used for RS-232-C. The equivalent specification internationally is covered by CCITT V.10(X.26)/V.11(X.27) electrical characteristics, CCITT V.24 functional characteristics, and ISO 4902 connector standard.

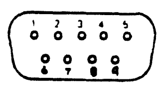
RS-449 follows the same circuit configuration as RS-232-C with a separate circuit for each function, but additional functions have been added. Its operating performance is also superior, with an upper data signalling limit of 2 Mbit/s and cable distances of 200 feet. At the lower data rates, much longer distances are also possible, with some engineering attention to the specific application. Using RS-422-A at the lower data signalling rates, distances of several miles are possible. A key feature of RS-449 is that it is backward compatible with RS-232-C. This facilitates an economical and orderly evolution from the vast existing inventories of equipment. RS-449 has not been extensively implemented and is not being carried to future implementation.

EIA RS-449 never very popular

- IMPROVED ELECTRICAL CHARACTERISTICS
- 10 ADDITIONAL INTERCHANGE CIRCUITS
- NEW CIRCUIT NAMES AND MNEMONICS
- DATA RATES UP TO 2 MBIT/S
- 200 CABLE FEET (AND MORE)



- 37-POSITION CONNECTOR



- 9 POSITION CONNECTOR

PL003.016

PL004.124

EIA RS-423-A/CCITT V.10 (X.26)

The RS-423-A electrical characteristics were designed by the EIA to provide superior performance and to facilitate a transition from the existing RS-232-C to the high-performance RS-422-A. It is fully compatible with CCITT Recommendation V.10(X.26).

As shown in the figure, RS-423-A is an unbalanced circuit, but with a balanced receiver. This overcomes much of the effect of external noise interfering with the data signal. The generator has a controlled output waveshape to limit the amount of noise that can be generated and coupled into adjacent circuits. There are also separate common returns, one for each direction of transmission. They are grounded only at the generator end. This helps overcome the effects of ground potential difference between the ends of the interface connection. RS-423-A can operate over distances of 4000 feet at data signalling rates up to 3 kbit/s. The distance is decreased progressively to 40 feet as the signalling rate increases to a maximum of 300 kbit/s. Finally, these new electrical characteristics are compatible for economic integrated circuit implementation, and most importantly, are inter-operable with both the old RS-232-C and the new RS-422-A.

LEGEND FOR FIGURE -

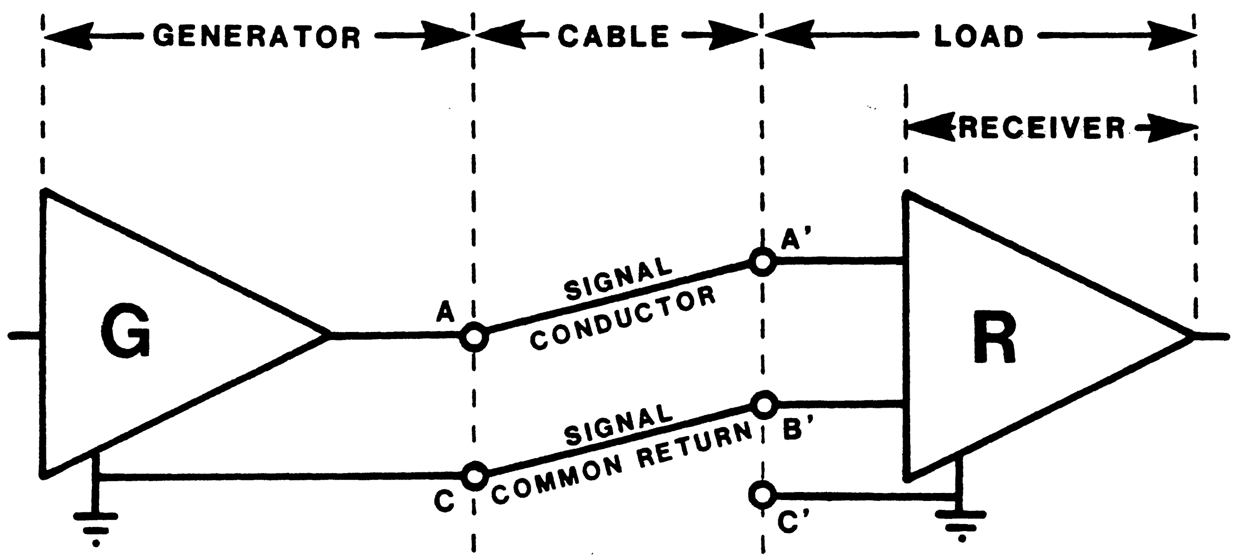
A, C - Generator Interface

A', B' - Load Interface

C' - Load Circuit Ground

C - Generator Circuit Ground

RS-423-A CIRCUIT



PLOO4.055

PL005.124

EIA RS-422-A/CCITT V.11 (X.27)

The RS-422-A electrical characteristics were also designed by the EIA to meet the rapidly advancing technology demands for higher data signalling rates and longer cable distances. This provides the next step in the evolution from RS-232-C through the transition of RS-423-A. RS-422-A is fully compatible with the CCITT equivalent of V.11(X.27).

As shown in the figure, RS-422-A is a fully balanced circuit that provides outstanding noise performance. The balanced generator connected to a balanced pair of wires will emit a minimum amount of noise to adjacent circuits, and the balanced cable and receiver will be nearly immune to any external noise interference. There is an optional cable termination resistance to minimize the effects of signal reflection at the higher data rates over longer cable distances. A maximum data signalling rate of 10 Mbit/s is possible. For rates up to 100 kbit/s, cable distances of 4000 feet can be used. As the signalling rate increases to 10 Mbit/s, the cable distance progressively decreases to 40 feet. These limits are very conservative, and much longer distances are possible with a little engineering attention. As with RS-423-A, RS-422-A is compatible for economical implementation in integrated circuit technology. Because the balanced receiver is identical to that specified for RS-423-A, the two are fully interoperable to facilitate an orderly transition to future technology.

In 1983, EIA published a companion standard, RS-485, which specifies the characteristics of a multipoint bus arrangement using the basic RS-422-A electrical specification.

LEGEND FOR FIGURE

A, B - Generator Interface Points

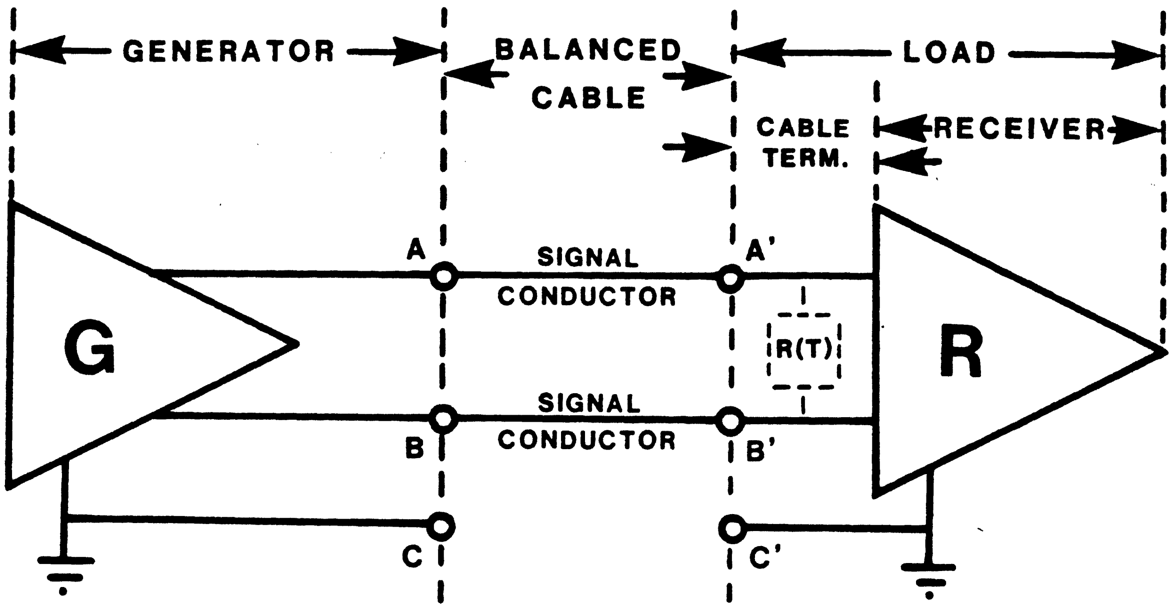
A', B' - Load Interface Points

C - Generator Circuit Ground

C' - Load Circuit Ground

R(T) - Optional Cable Termination Resistance

RS-422-A CIRCUIT



PL005.055

PL007.114

COMPARISON OF ELECTRICAL CHARACTERISTICS

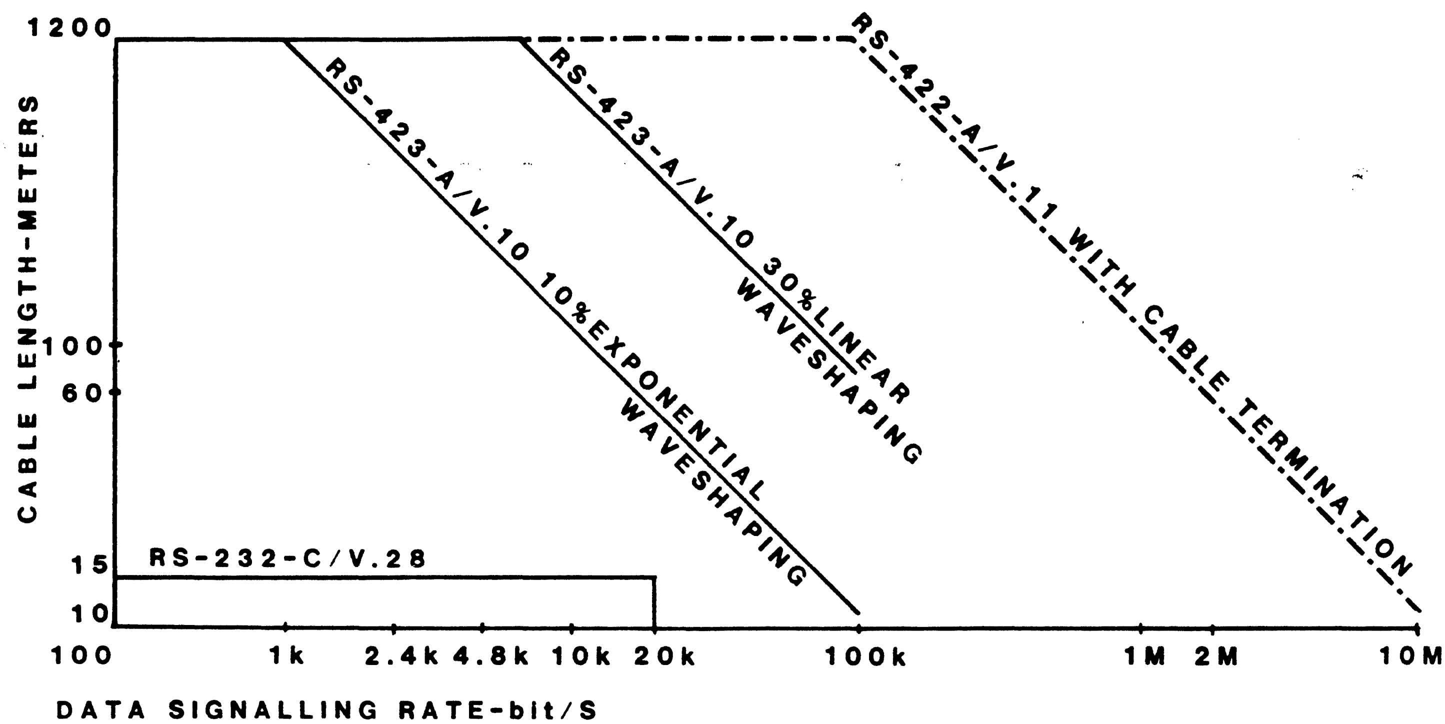
The new electrical characteristics offer significant improvement over the traditional RS-232-C and CCITT V.28 as shown on the chart. The RS-423-A and V.10(X.26), although unbalanced, perform at significantly higher data rates over much greater distances. The major limitation is the maximum amount of coupled near-end crosstalk (or noise) that is allowed to be coupled to adjacent circuits. This value is 1 volt peak. With proper attention to the kind and amount of waveshaping employed, the performance can be further maximized for particular applications.

The balanced electrical characteristics of RS-422-A and V.11(X.27) offer even greater performance improvement because of the superior noise characteristics. The limitation of signalling rate versus distance is the maximum distortion that can be tolerated. These curves are based upon 5% distortion of the bit interval. Most applications can take considerably more (up to 49%), thus giving much greater performance.

At data signalling rates below 100 kbit/s, the cable termination generally is not needed, and distances up to 1 km are practical. Above 100 kbit/s the cable termination should be used to help preserve the risetime characteristics.

No performance data is specified for V.35. Therefore, no comparison can be made on the chart.

PERFORMANCE COMPARISON



PL007.055

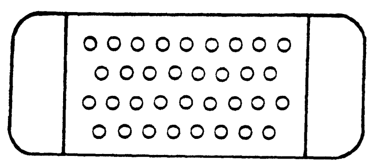
PL006.095

CCITT RECOMMENDATION V.35

CCITT Recommendation V.35 is a standard for a wideband 48 kbit/s modem for use on 60 - 108 kHz group channels. Included in the Recommendation is a specification for balanced electrical characteristics using a current source for the data interchange circuits across the interface. The interchange circuits are as defined by V.24 (RS-232-C). The control circuits use the CCITT V.28 (RS-232-C) unbalanced electrical characteristics. The connector used is specified in ISO 2593 and has 34 pins. There is no equivalent USA standard, but the V.35 electrical characteristics have been implemented in 56 kbit/s wideband modems.

CCITT V.35

- BALANCED FOR DATA AND TIMING
- V.28 (RS-232-C) FOR CONTROL
- DATA RATE - 48 (56) KBIT/S
- 34 POSITION CONNECTOR



PL005.074

PL008.095

X.21 bis PHYSICAL INTERFACE SIGNALS

For the link and packet levels to become operational, the physical interface must be in an active condition. On either dedicated access circuits or a circuit-switched connection, the interface circuits must be in the following states:

V.28/V.24
V.35/V.24 Circuits 107, and circuits 105, 106, 108, and 109, if provided, must be in the ON control condition. Signals on circuits 103 and 104 convey data between the data link peer entities.

RS-232-C Circuits CC, and circuits CA, CB, CD, and CF, if provided, must be in the ON control condition. Signals on circuits BA and BB convey data between the data link peer entities.

RS-449 Circuits DM, RS, CS, and circuits TR, and RR, if provided, must be in the ON control condition. Signals on circuits SD and RD convey data between the data link peer entities.

When any of the control circuits are in the OFF-condition, the INACTIVE state is assumed. This may be considered by higher levels to be an "out-of-order" state.

Note -- clear-to-send and carrier-detect may momentarily change to OFF during transmissions. When this happens, upper layers should delay any action for several seconds in order to avoid false disconnects.

PHYSICAL OPERATIONAL PHASE

CONTROL CIRCUITS

	V.24	RS-232-C	RS-449
REQUEST TO SEND	105	CA	RS
CLEAR TO SEND	106	CB	CS
DATA SET READY (DATA MODE)	107	CC	DM
DATA TERMINAL READY	108	CD	TR
CARRIER DETECT (RECEIVER READY)	109	CF	RR

UPPER LEVEL SIGNALS

SEND DATA	103	BA	SD
RECEIVE DATA	104	BB	RD

INACTIVE STATE
ANY CONTROL CIRCUITS = OFF

ACTIVE STATE
ALL CONTROL CIRCUITS = ON

PL008.064

PL009.095

CCITT RECOMMENDATION X.21

X.21 - Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for Synchronous operation on Public Data Networks - is actually a two-part standard. First, it specifies the basic physical elements of the DTE/DCE interface. These are the "general purpose" provisions applicable to all public data network interfaces. The second part specifies the procedures for establishing connections through circuit-switched networks. Typically, just the physical elements will apply to applications like X.25, but it is also recognized that access to an X.25 DSE is possible using a circuit-switched connection. The architectural and interworking implications of this type of access, however, are left for further study by CCITT.

The physical elements of X.21 consist of the electrical characteristics of X.26 (RS-423-A) and X.27 (RS-422-A), the functional characteristics of X.24, and the mechanical characteristics of ISO 4903, which specifies a 15-pin connector from the same family as the 25- and 37-pin connectors used for the other interfaces. There is presently no USA equivalent of X.21, X.24, and ISO 4903.

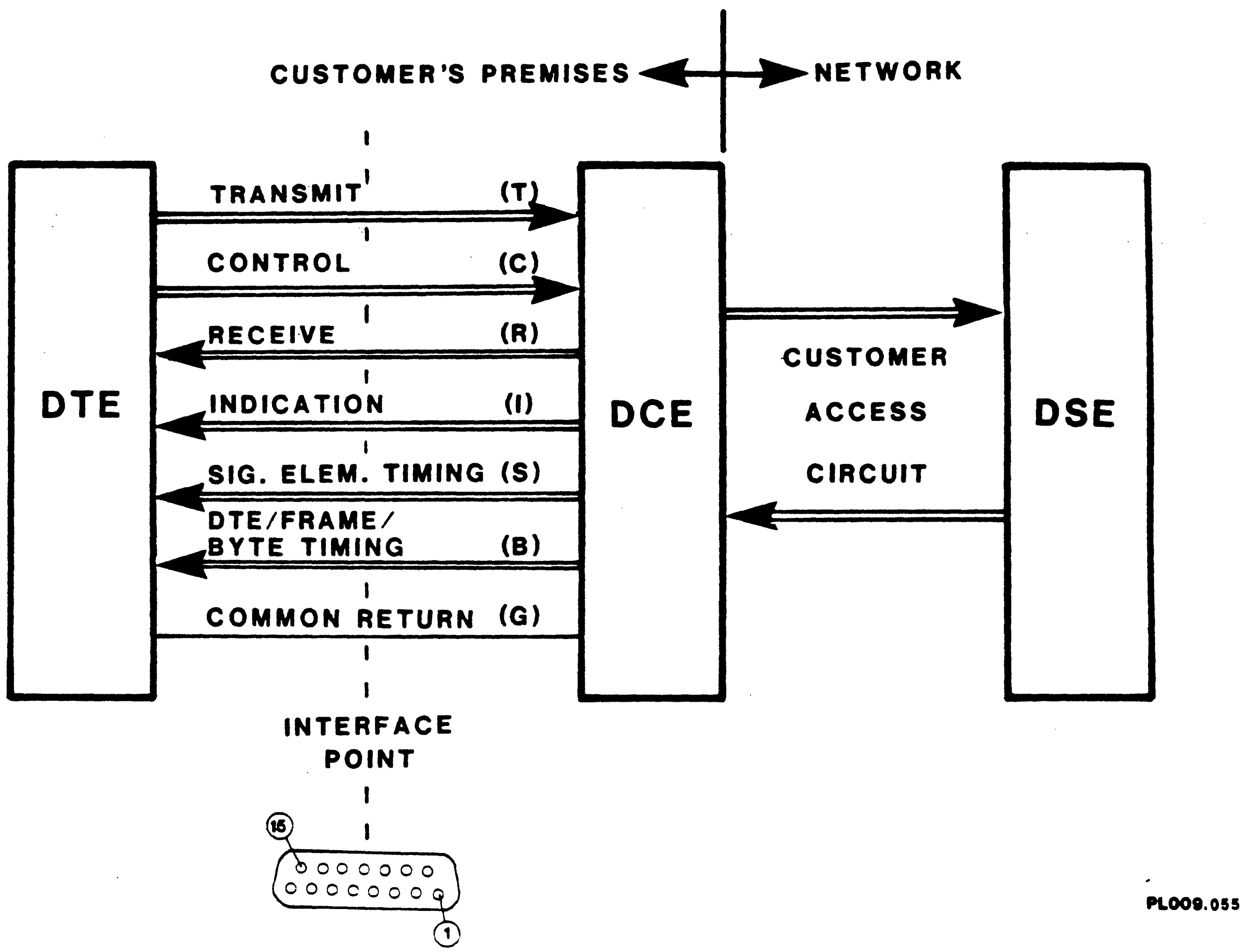
X.21 provides for two circuits to transmit encoded data and control information. These are designated T for transmit and R for receive. The Control (C) circuit and the Indication (I) circuit provide ON/OFF control conditions. The S circuit provides bit timing from the network to furnish both receive and send timing, and the B circuit provides a pulse every 8 bits to enable octet or character synchronization with a network. This latter feature does not apply to X.25 applications and is only used in the Nordic countries.

For operation at 9.6 kbit/s and below, the DTE can use either RS-423-A or RS-422-A electrical characteristics. The DCE must use the balanced RS-422-A. There is direct compatibility between the two. The RS-423-A DTE can connect directly to an RS-422-A DCE. Above 9.6 kbit/s, both the DTE and the DCE must use the balanced RS-422-A electrical characteristics, and can also use the optional cable termination.

So far there has not been wide implementation of the X.21 physical interface except in the X.21 circuit-switched applications. There has been little implementation of X.21 for X.25 networks. The majority of the physical level interfaces will be the X.21 bis, using RS-232-C. RS-449 has not gained in popularity and is dying away.

The new physical interface specified by CCITT Recommendations I.430 and I.431 for the Integrated Services Digital Networks (ISDN) were agreed upon in 1984 and will become the base for a future universal interface that will replace all the existing standards.

X.21 PHYSICAL INTERFACE



PL010.095

X.21 PHYSICAL INTERFACE SIGNALS

There are two basic phases of interface signals at the physical level of X.21.

The first is the Inactive, or Quiescent Phase, which is analogous to ON-HOOK in telephony. The Ready state indicates that all is well and either the DTE or the DCE is capable of entering the operational phase. The Not Ready state indicates that the DTE or the DCE is out of service and unable to operate properly. The physical interface has a fail-safe feature: if the interconnecting cable is disconnected or power is turned off, the Not Ready state will be signalled. The "not ready" signal may be considered by upper layers as "out-of-order".

The other phase is the Operational Phase which is analogous to OFF-HOOK in telephony. In OSI applications, for the Data Link and the Network Layers to become active, the physical interface must to be in the operational phase. For dedicated access, the physical interface should endeavor to be in the operational condition whenever possible. When C=ON and I=ON, signals on the T and R circuits are according to procedures of the higher levels.

PHYSICAL INTERFACE SIGNALS

INACTIVE PHASE

READY

DTE T=1, C=OFF

DCE R=1, I=OFF

NOT READY

DTE T=0, C=OFF

DCE R=0, I=OFF

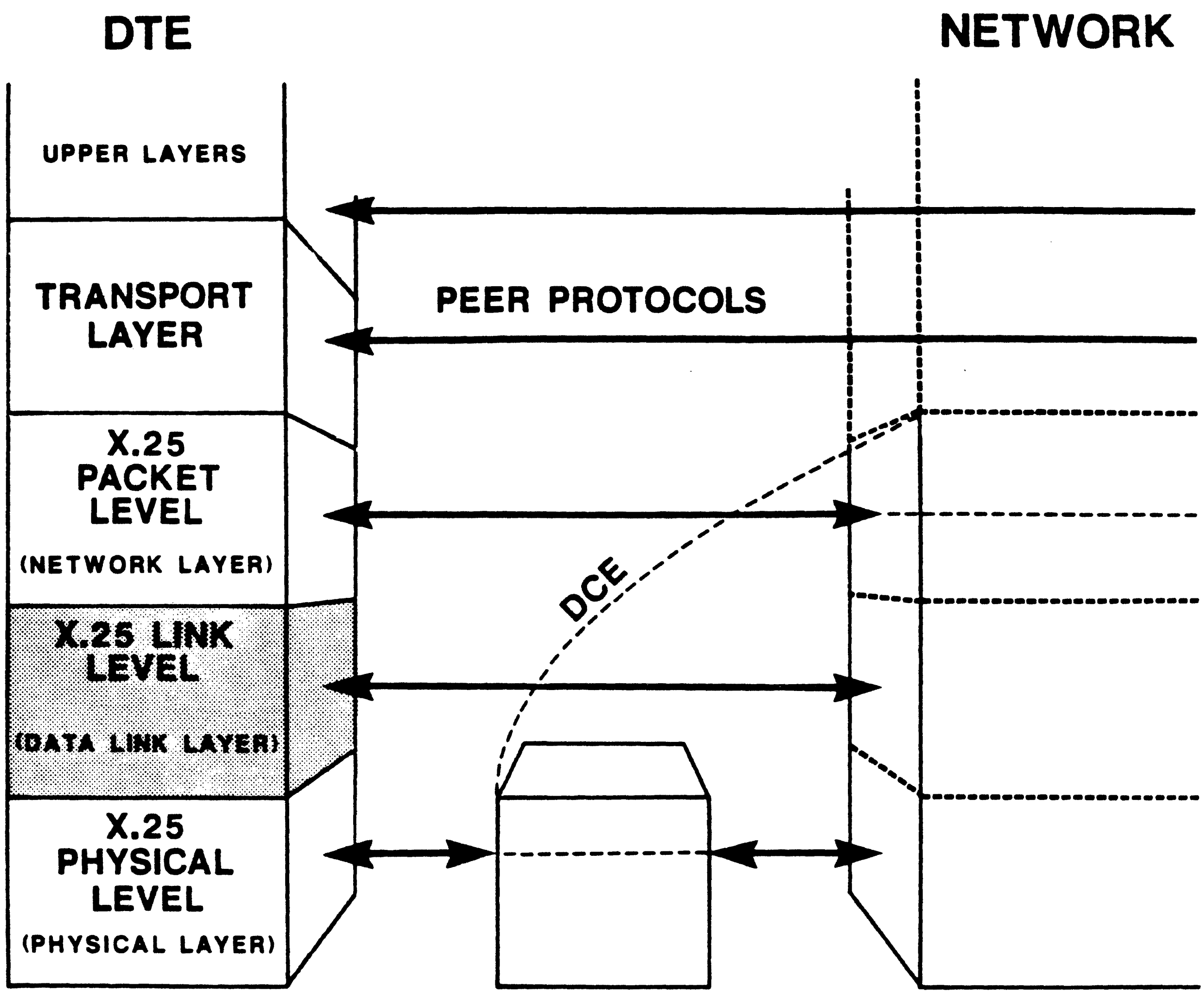
ACTIVE PHASE

DTE T=ANY BITS, C=ON

DCE R=ANY BITS, I=ON

PL010.055

NOTES


DTE
NETWORK
UPPER LAYERS
TRANSPORT LAYER
PEER PROTOCOLS
X.25 PACKET LEVEL
(NETWORK LAYER)
X.25 LINK LEVEL
(DATA LINK LAYER)
DCE
X.25 PHYSICAL LEVEL
(PHYSICAL LAYER)

DL000.016

DL001.095

PURPOSE OF A DATA LINK LAYER

The Data Link Layer is responsible for transmission and error-free delivery of information over a physical medium. The content of the information is not relevant; the layer's only concern is that it be delivered with no detected errors. To do this, the following functions are defined:

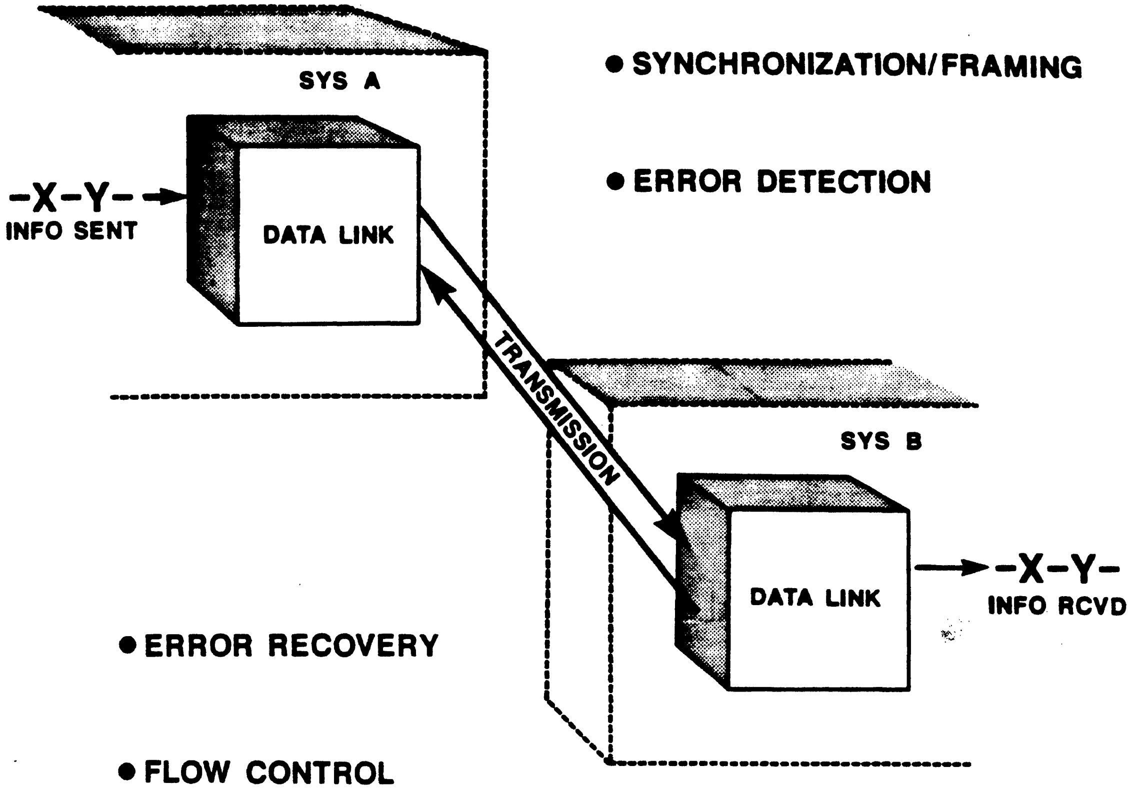
* Logical establishment of a link between communicating stations so that orderly flow of information can occur.

* Detection of transmission errors. This can be done with a simple character parity mechanism, a block check sum, or a more powerful cyclic redundancy check (CRC).

* Procedures to recover from error conditions without involving upper layers.

* Flow control of the information over the link so that buffer capacity is not exceeded.

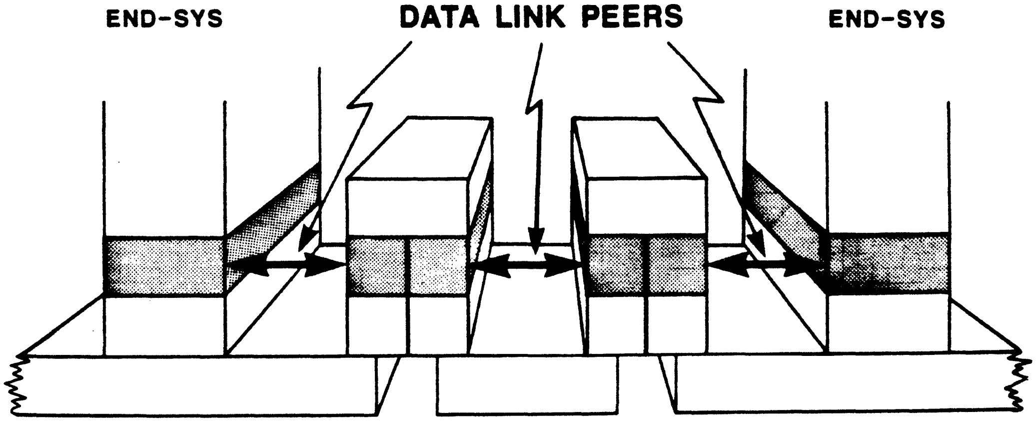
In a switched telecommunications environment, a Network connection consists of two or more physical and data links in tandem. They are bridged together via the Network relays.



DL001A.125

TANDEM DATA LINKS

- ERROR CONTROL
- FRAMING
- FLOW CONTROL



DL001B.036

DL052.095

DATA LINK PROTOCOL EVOLUTION

The beginning of the data communications efforts in the early 1960's, saw work on the development of protocols for transfer of data over point-to-point and multipoint circuit configurations interconnecting distributed terminals and hosts.

As character-oriented work matured, technology advanced into the bit-oriented world to provide greatly enhanced functionality, flexibility, and efficiency. This led to the general purpose supersets of ISO's High Level Data Link Control (HDLC) and the American National Standard Advanced Data Communication Control Procedures (ADCCP). Subsequently, subsets started to emerge for specific applications. These started with the CCITT Link Access Procedure (LAP), which was accepted as a best quest of what ISO would ultimately standardize. ISO, however, decided to make major changes before they finalized HDLC; this led to LAP being non-compatible. Following ISO's recommendation, CCITT developed LAP B as a consistent subset to HDLC two years later. This subset is also used for the X.75 internetworking protocol for public packet networks.

Since then, multilink procedures have been developed and agreed upon. And now the next step into the ISDN era brings LAP D, which provides a multiplexing capability to the Data Link Layer.

The IEEE 802 work also established the Logical Link Control (LLC) procedures in 802.2, which is an extension of the basic HDLC provisions. The provisions of 802.2 are expected to be incorporated into the HDLC specification as a compatible subset.

DATA LINK PROTOCOL EVOLUTION

For D channel on ISDN

1984	**ISDN LAP D, LLC**
1980	**MULTILINK** *mostly between networks*
1978	**CCITT LAP B/X.75**
1977	**ADCCP, HDLC**
1976	**CCITT LAP**
1974	**FIRST DRAFTS - ADCCP, HDLC**
1971	**BASIC MODE - ANSI X3.28, ISO 1745**
1969	**WORK BEGAN ON BIT-ORIENTED PROTOCOL**
1962	**CHARACTER-ORIENTED DEVELOPMENT BEGAN**

DL052.124

DL065.026

BIT-ORIENTED PROTOCOLS

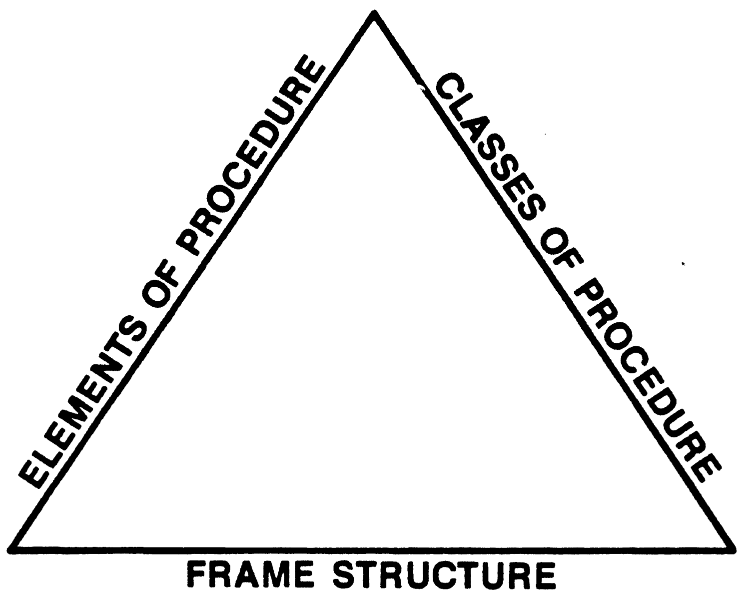
High Level Data Link Control (HDLC) is the name used by ISO and CCITT for a family of data link protocols that use fixed positions and bit fields in the protocol data units for the protocol control information. Many national and international organizations have standards that are equivalent to HDLC but use different names (e.g., Advanced Data Communication Control Procedures - ADCCP from ANSI). Also, many manufacturers have developed products that implement part or all of the HDLC family of protocols (e.g., Synchronous Data Link Control-SDLC).

There are three parts of HDLC from which a protocol is constructed:

1. Frame Structure
2. Elements of procedure
3. Classes of procedure

All of the bit-oriented protocol standards and products have the same parts as HDLC.

PARTS OF HDLC



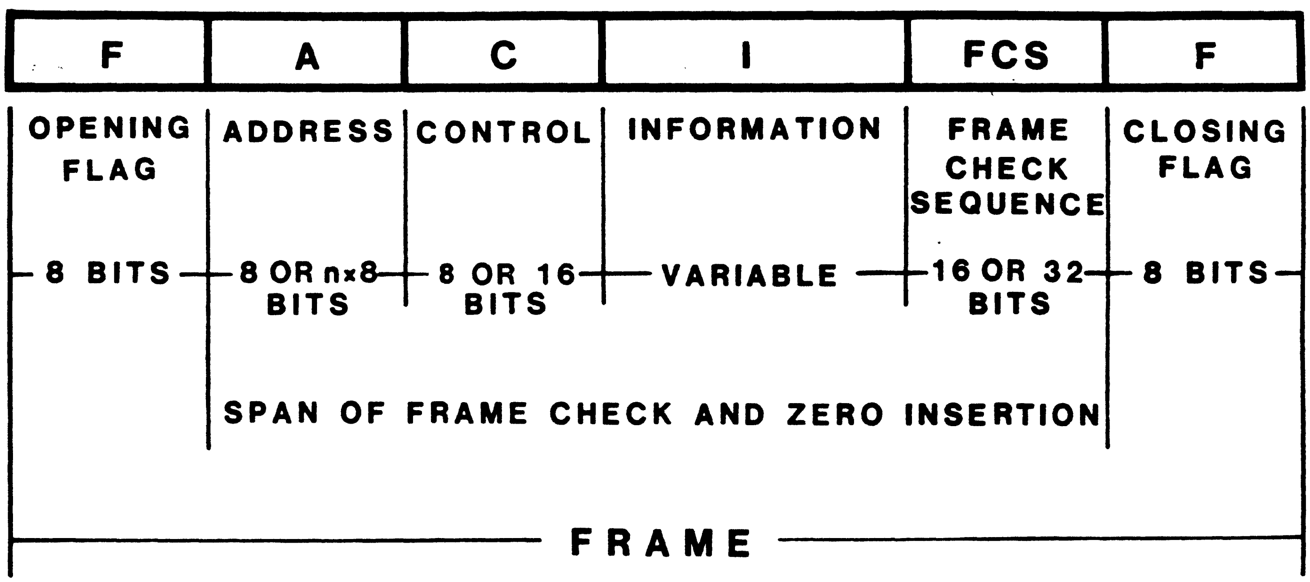
DL065.026

DL014.124

FRAME STRUCTURE IN THE BIT-ORIENTED PROTOCOLS

The bit-oriented protocols define positions within the frame as having certain meanings. The start of a frame is always indicated by a FLAG sequence of 8 bits. The field that follows the opening FLAG of the X.25 frame is for data link address information. It may be 8 or nx8 bits long. The next field is for control information. It may be 8 bits or 16 bits long depending on the options employed. Next is the information field, which can be any size within the maximum that is agreed upon between the communicating ends. After the information field of the frame is the FCS (Frame Check Sequence), which is used to check for transmission errors. The frame is then closed with another 8-bit FLAG sequence. All the bits enclosed by FLAGS are checked for transmission errors and are subject to zero bit insertion, which is used to provide full transparency of the transmitted information.

BIT ORIENTED FRAME STRUCTURE



DL014.125

DL015.095

TRANSPARENCY IN BIT-ORIENTED PROTOCOLS

The 8-bit FLAG sequence is a delimiter used to indicate the start and end of a frame. As shown, it starts with a 0 followed by 6 contiguous 1-bits and ends with a 0. Only one FLAG is needed to achieve synchronization of the frame. Between frames, it is possible for the concluding FLAG of the previous frame to be the starting FLAG of the next frame. Interframe time fill between frames during the active link state is accomplished by continuous FLAGS, which must be full 8-bit FLAG sequences (i.e., the 8th bit of one FLAG cannot be used as the 1st bit of the next FLAG).

As bit-oriented protocols do not intermix data with control information, there is no requirement for an escape mechanism to distinguish between control and text. However, there is a need for unambiguous detection of the start and end of a frame. Therefore protection is needed to avoid bit patterns that look like FLAGS within the boundaries of the true FLAGS. This protection is achieved through 0-bit insertion. The FLAGS that bound the frame are exempt from 0-bit insertion and thus have six contiguous 1-bits. The frame itself, on transmission, undergoes the insertion of a 0 bit when a sequence of 5 1-bits is encountered. This ensures that within the frame six contiguous 1-bits will not occur.

The receiver, upon detecting a frame, counts the number of contiguous 1-bits. If it counts 5 bits and the following bit is a zero, then this 0-bit is removed from the data stream. If the following two bits are one and zero, respectively, end of frame is indicated - a FLAG has been detected.

If 7 1-bits in a row are encountered before the closing FLAG, an abort condition has occured and the whole frame is discarded. When 15 or more contiguous 1-bits are present, an idle link state is established. The treatment of the idle condition varies among implementations, but the 1984 version specifies that after time T3, the DCE will consider the link in a non-operational state and advise the packet level accordingly. The link may then be reactivated by a new set-mode command.

The DCE will indicate that it is unable to set up the link by transmitting continuous FLAGS. This is called the active channel state.

FLAG = 0 1 1 1 1 1 1 0

ABORT = 0 1 1 1 1 1 1 1

SEND DATA	0 0 1 0 1 1 1 1 1 0 1 0	0 1 1 0 1 1 1 1 1 1 0 1 0
ADD 0s	↓	↓
TRANSMITTED DATA	0 0 1 0 1 1 1 1 1 0 0 1 0	0 1 1 0 1 1 1 1 1 0 1 0 1 0
DELETE 0s		
RECEIVED DATA	0 0 1 0 1 1 1 1 1 0 1 0	0 1 1 0 1 1 1 1 1 1 0 1 0

DL015.115

DL059.095

DATA LINK FRAME PROCESS

A particular sequence of events must be followed by the peer Data Link entities at each end of a link to process outgoing and incoming frames. The protocol control information (PCI) for the address (A) and control (C) fields is processed and added to the Data Link Service Data Unit (DLSDU), if present, which becomes the information (I) field of the outgoing frame.

The bits of these three fields are then processed through a frame checking sequence, which a 16-bit, or optionally a 32-bit sequence that has been processed through a generator polynomial. The remainder of this process becomes the value of the Frame Check Sequence (FCS) field of the frame.

Next, the bits of the four fields are processed through the 0-insertion (bit-stuffing) mechanism to protect the transparency of the information. Finally, the frame with the beginning and closing flags (F) is passed to the Physical Layer for transmission on the physical medium.

Upon receipt by the peer Data Link entity, the opening flag is detected to synchronize the frame; and the address, control, information (if present), and FCS fields are processed through the bit-destuffer to remove the inserted 0-bits. The bits of these four fields are then processed through the generator polynomial, and upon detection of the closing flag, the value of the remainder is checked. If it is binary 0001110100001111 (hex 1D0F), the frame is considered to have no transmission errors. Any other remainder value will cause the frame to be discarded and no further processing will occur.

The remaining error free (within a finite probability) fields will then be processed further. The address and control fields will be acted upon and the remaining I field, if present, will be the DLSDU that is passed to the Network Layer.

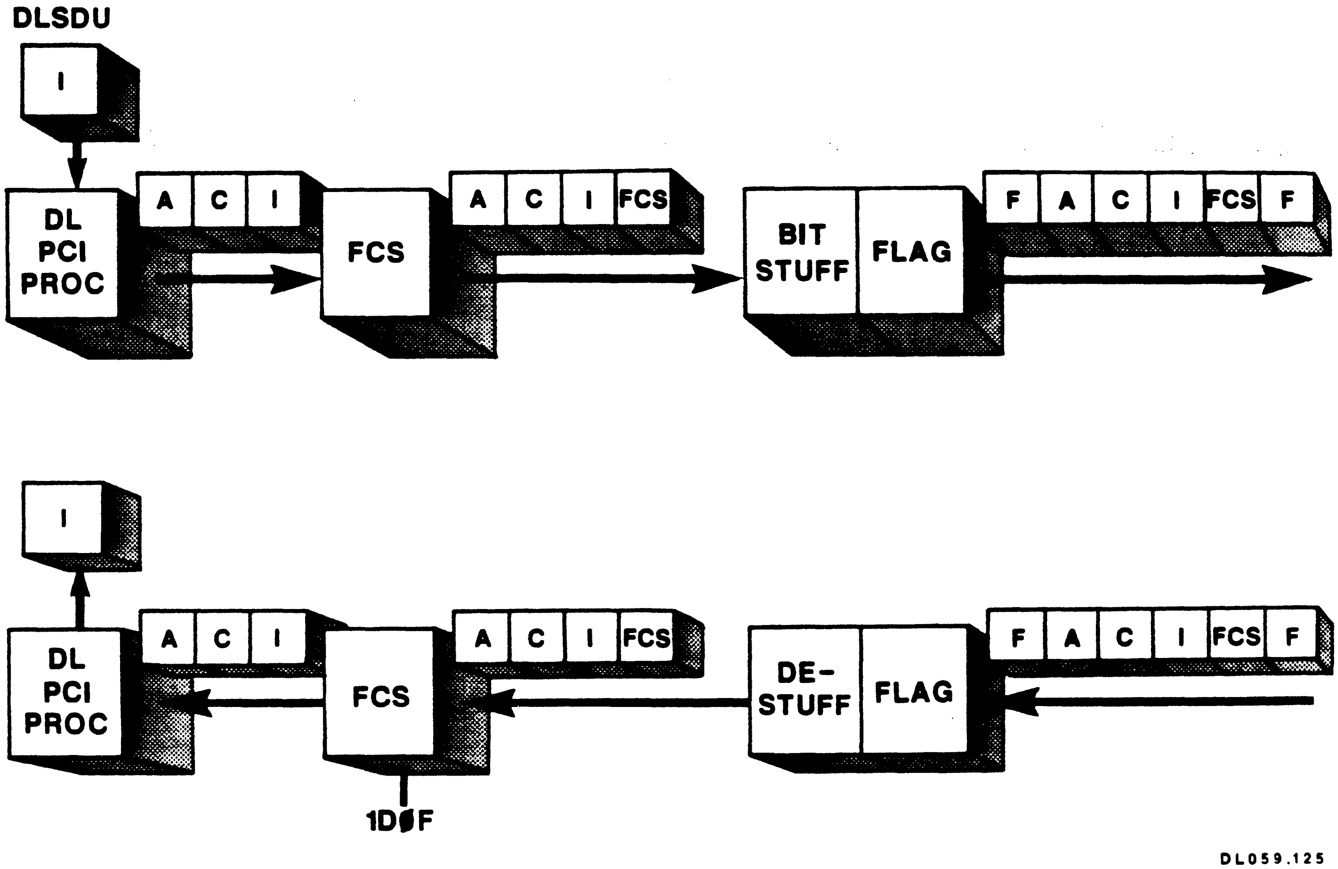
The optional 32-bit algorithm is not employed in X.25 or ISDN, but has been applied by the US Department of Defense in a number of implementations.

Standard ICs are available for processing the FCS and 0-insertion mechanisms so normally a software implementation is not necessary.

Legend:

A = Address
C = Control
I = Information
F = Flag
DLSDU= Data Link Service Data Unit
DL = Data Link
PCI = Protocol Control Information
PROC = Procedure
FCS = Frame Check Sequence

DATA LINK FRAME PROCESS



DL026.095

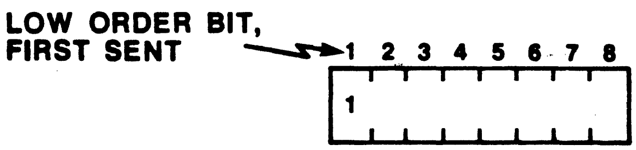
ADDRESS FIELD

The basic address field is 8 bits long. As shown in the figure, bit 1 is on the left side and is the least significant bit, and is transmitted first. Bit 1 is always set to a value of 1 in X.25, or any other data link protocol that uses single octet addressing, e.g., US Federal Standard 1003 and FIPS 71, which only use a one-octet address field.

An extended format is also provided for in ISO HDLC. This enables an indefinite address length, although there was no requirement or application identified initially for the extension. When another octet of address is to follow, bit 1 is set to a value of 0. The last octet of the series has bit 1 set to 1, which is the case with the normal single octet address field. Extended addressing is one of the functional options of HDLC and is used in the LAP D subset for ISDN.

ADDRESS FIELD FORMAT

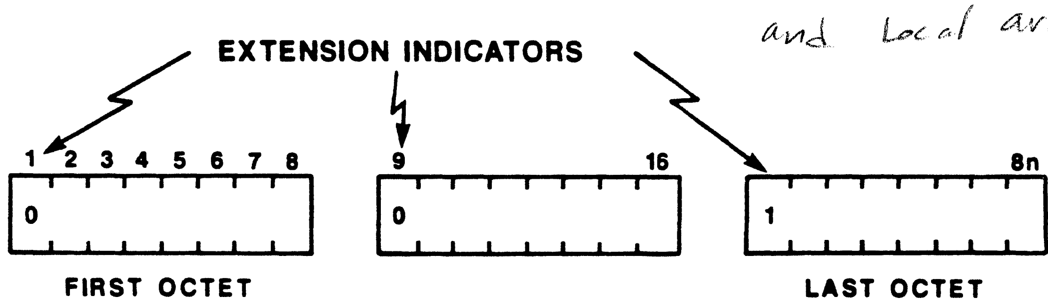
BASIC ADDRESS FIELD



X.25 always uses an 8 bit field.

EXTENDED ADDRESS FIELD

USED IN ISDN and Local area Network



DL026.016

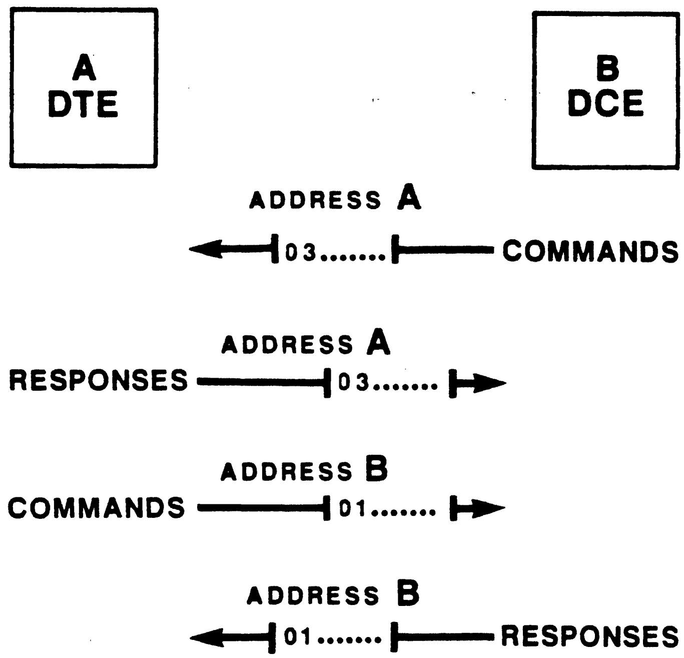
DL027.112

ADDRESSING CONVENTION FOR X.25

X.25 specifies two addresses - one for the DTE, and another for the DCE. The DTE is address A (Hex 03) and the DCE is B (hex 01). Commands from the DCE and Responses to the DCE carry address A (H'03), while Commands from the DTE and Responses to the DTE carry address B (H'01). This signifies the difference between a Command and a Response frame.

A simple validity check can be made at the receive end to verify the frame type. This is shown in the figure. Invalid frames are discarded as being invalid.

FRAME ADDRESSING



in X.25

DL027A.125

Addresses only used to differentiate commands and responses.

DL028.095

CONTROL FIELD FORMATS

There are three basic formats for the control field. Each basic format is 8 bits long. There are also two additional control field formats that are 16 bits long for extended numbering. Bit 1 is the low-order bit and is always transmitted first. In these figures bit 1 is shown on the left-hand side, as it is presented in the X.25 and HDLC specifications.

I-frames are used to transport the information from the originating Network Layer entity to the destination Network entity at the other end of the link. In the case of X.25 the I-field carries the packet. The Information frame is identified by the 0 value of bit 1. Bits 2-4 represent the send sequence count, N(S), for modulo 8. The N(S) is the number assigned to the frame being sent. It starts at 0 and steps to seven before starting at 0 again. The fifth bit is the Poll bit of command information frames and a Final bit of response information frames. The last three bits represent the receive sequence count, N(R). The value of N(R) represents the number of the frame that is expected to be received next. It also implicitly acknowledges all preceding frames.

The S-frames are used for flow control, recovery, and acknowledgment of I-frames. The supervisory frame uses the encoding of bits 1 and 2 to identify its format. Bits 3 and 4 are used to identify the specific type of S-frame, as shown on the command/response repertoire. Bit 5 is used as the Poll bit in command frames, while it is the Final bit in response frames. Finally, the last three bits are the N(R) count, which is used for acknowledgment of I-frames and the indication of the next I-frame to be received.

The U-frames are primarily used for link establishment and control. The Unnumbered frame also uses bits 1 and 2 to identify its format. Bits 3, 4, 6, 7, and 8 are all used to identify the specific U-frame command or response. Bit 5 is the P/F bit for checkpointing.

When the optional modulo 128 sequence count is selected, an additional octet is needed for the control field in I and S frames. This is to accommodate the expansion of the sequence count (N[S]) acknowledgment (N[R]) fields from 3 to 7 bits as shown in the figure. The format for U frames stays the same (1 octet) because there are no sequence or acknowledgment fields.

LEGEND-- N(S) = send sequence count

N(R) = receive acknowledgment count

P/F = poll bit in command and final bit in response

S = code for supervisory frames

M = code for unnumbered frames

BASIC CONTROL FIELD FORMATS

MOD 8

LOW ORDER BIT, SENT FIRST

INFORMATION

1	2	3	4	5	6	7	8
0	N(S)			P/F	N(R)		

SUPERVISORY

1	2	3	4	5	6	7	8
1	0	S	S	P/F	N(R)		

UNNUMBERED

1	2	3	4	5	6	7	8
1	1	M	M	P/F	M	M	M

this applies in both Mod 8 and Mod 128 operation

MOD 128

LOW ORDER BIT, SENT FIRST

INFORMATION

1	2	3	4	5	6	7	8
0	N(S)						
P/F	N(R)						

SUPERVISORY

1	2	3	4	5	6	7	8
1	0	S	S	0	0	0	0
P/F	N(R)						

DL028.016

DL022.095

COMMAND/RESPONSE REPERTOIRE

The data link frame repertoire is divided into three categories - Information frames, Supervisory frames, and Unnumbered frames.

The primary function of the Information frame is to carry sequenced data over a link. Its secondary functions are to acknowledge received information and solicit status (using the poll bit).

The Supervisory frames are responsible for acknowledging correctly received information, requesting retransmission (SREJ and REJ), and transmitting inability to receive further information (RNR). They are also used to solicit the status of a station (the command supervisories with the poll bit set).

The Unnumbered frames are responsible for establishing the mode of operation between communicating stations: for example, Set Asynchronous Balanced Mode (SABM), Exchanging station identifiers (XID), and communicating problem conditions with a Frame Reject (FRMR). There is also a facility enabling out-of-band data communication using the Unnumbered information frame (UI).

**** The encoding shown is as specified by the HDLC and X.25 specifications. Bit 1 of the control field is the low-order bit and is transmitted first.**

* Bit 5 represents the poll/final bit which is used for status inquiry, recovery, and other functions.

HDLC COMMAND/RESPONSE REPERTOIRE

FORMAT	CONTROL FIELD BIT ENCODING 1 2 3 4 5 6 7 8	COMMANDS	RESPONSES
INFORMATION	0 -N(S)- * -N(R)-	I-INFORMATION	I-INFORMATION
SUPERVISORY	1 0 0 0 * -N(R)-	RR-RECEIVE READY	RR-RECEIVE READY
	1 0 0 1 * -N(R)-	REJ-REJECT	REJ-REJECT
	1 0 1 0 * -N(R)-	RNR-RECEIVE NOT READY	RNR-RECEIVE NOT READY
	1 0 1 1 * -N(R)-	SREJ-SELECTIVE REJECT	SREJ-SELECTIVE REJECT
UNNUMBERED	1 1 0 0 * 0 0 0	UI-UNNUMBERED INFORMATION	UI-UNNUMBERED INFORMATION
	1 1 0 0 * 0 0 1	SNRM-SET NORMAL RESPONSE MODE	
	1 1 0 0 * 0 1 0	DISC-DISCONNECT	RD-REQUEST DISCONNECT
	1 1 0 0 * 1 1 0		UA-UNNUMBERED ACKNOWLEDGE
	1 1 1 0 * 0 0 1		FRMR-FRAME REJECT
	1 1 1 1 * 0 0 0	SARM-SET ASYNC RESPONSE MODE	DM-DISC. MODE
	1 1 1 1 * 1 0 0	SABM-SET ASYNC BALANCED MODE	
	1 1 1 1 * 1 0 1	XID-EXCHANGE IDENTIFICATION	XID-EXCHANGE IDENTIFICATION

DL022A.095

HDLC COMMAND/RESPONSE REPERTOIRE

FORMAT	CONTROL FIELD BIT ENCODING 1 2 3 4 5 6 7 8	COMMANDS	RESPONSES
UNNUMBERED	1 1 0 0 * 1 0 0	UP-UNNUMBERED POLL	
	1 1 0 0 * 1 1 1	TEST-DATA LINK TEST	TEST-DATA LINK TEST
	1 1 0 1 * 0 0 0	NON RESERVED 0	NON RESERVED 0
	1 1 0 1 * 0 0 1	NON RESERVED 1	NON RESERVED 1
	1 1 0 1 * 0 1 0	NON RESERVED 2	NON RESERVED 2
	1 1 0 1 * 0 1 1	NON RESERVED 3	NON RESERVED 3
	1 1 1 0 * 0 0 0	SIM-SET INITIAL-IZATION MODE	RIM-REQUEST INITIAL-IZATION MODE
	1 1 1 1 * 0 0 1	RSET-RESET	
	1 1 1 1 * 0 1 0	SARME-SET ARM EXTENDED MODE	
	1 1 1 1 * 0 1 1	SNRME-SET NRM EXTENDED MODE	
	1 1 1 1 * 1 1 0	SABME-SET ABM EXTENDED MODE	

DL022B.016

DL003.124

SEQUENCING CONCEPTS

The purpose of sequence numbers is to detect out-of-sequence frames or the loss of an information frame.

An information frame has sequence numbering in the control field. The size of the sequence number is either 3 or 7 bits, giving a maximum sequence count of 8 and 128, respectively. Sequence numbering starts from zero and increments by one to the maximum number that can be stored in this field, then continues with zero again. This is referred to as MODULO numbering. Modulo 8 uses the numbers 0 through 7, whereas Modulo 128 uses the numbers 0 through 127. X.25 presently recognizes MODULO 8 as default, and uses MODULO 128 as an option. The modulo used is established by subscription.

This numbering system enables the transmitter to have multiple frames outstanding, because each frame can be identified by a unique sequence number.

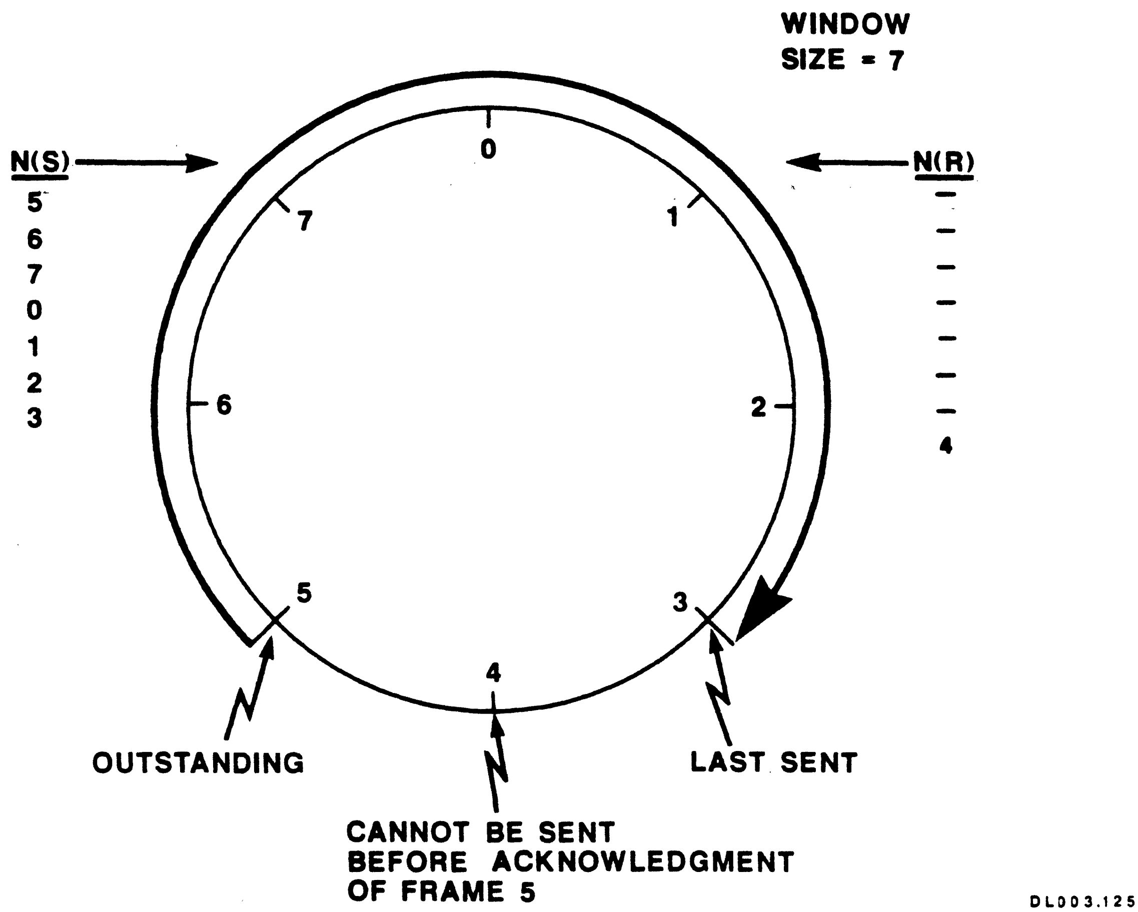
The receiver, for its part, can acknowledge groups of received information frames by transmitting the next expected sequence number, thereby implicitly acknowledging all frames of preceding sequence numbers.

Since no two information frames can be transmitted with the same sequence number, the transmitter must halt the transmission of frames when the next sequence number to be transmitted is equal to the sequence number of the oldest unacknowledged frame.

The number of frames that can be outstanding before the transmitter must cease transmission of information frames is referred to as the WINDOW SIZE. For X.25 the window size is not specified, but 7 is generally accepted as the window for MODULO 8. The window size must be no larger than the modulo count minus 1 in order to avoid ambiguity in acknowledgment.

The figure shows an instance of rotating sequence of N(S) counts. With a maximum window size of 7 (8-1), this example shows the sending of frames 5 through 3. A single value of N(R)=4 acknowledges all seven frames.

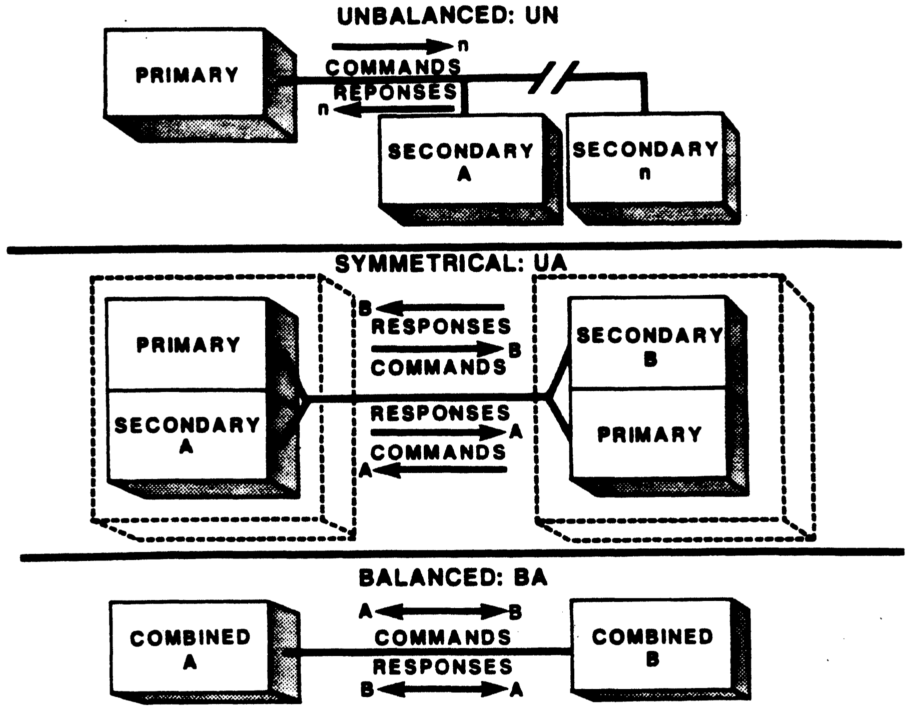
WINDOW CONTROL



DL023.015

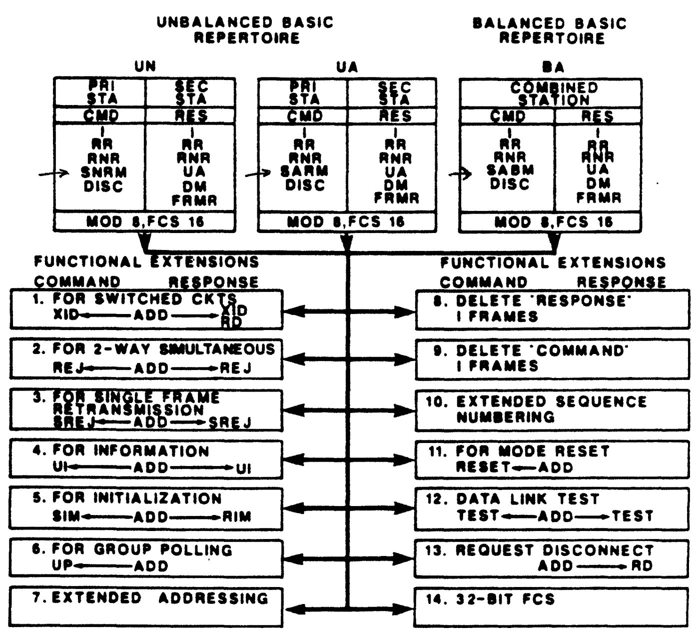
HDLC CLASSES OF PROCEDURE

There are three classes of procedures defined in the basic HDLC standard. They are the Normal Response Mode (UN), Asynchronous Response Mode (UA), and Asynchronous Balanced Mode (BA). Each class has a basic repertoire of commands and responses plus a number of functional extensions that can be selected. Some of the options add commands and responses, while others delete them from the basic repertoire.



DL023A.125

HDLC COMMANDS/RESPONSES BY CLASS



DL023B.016

LAPB SUBSET OF HDLC

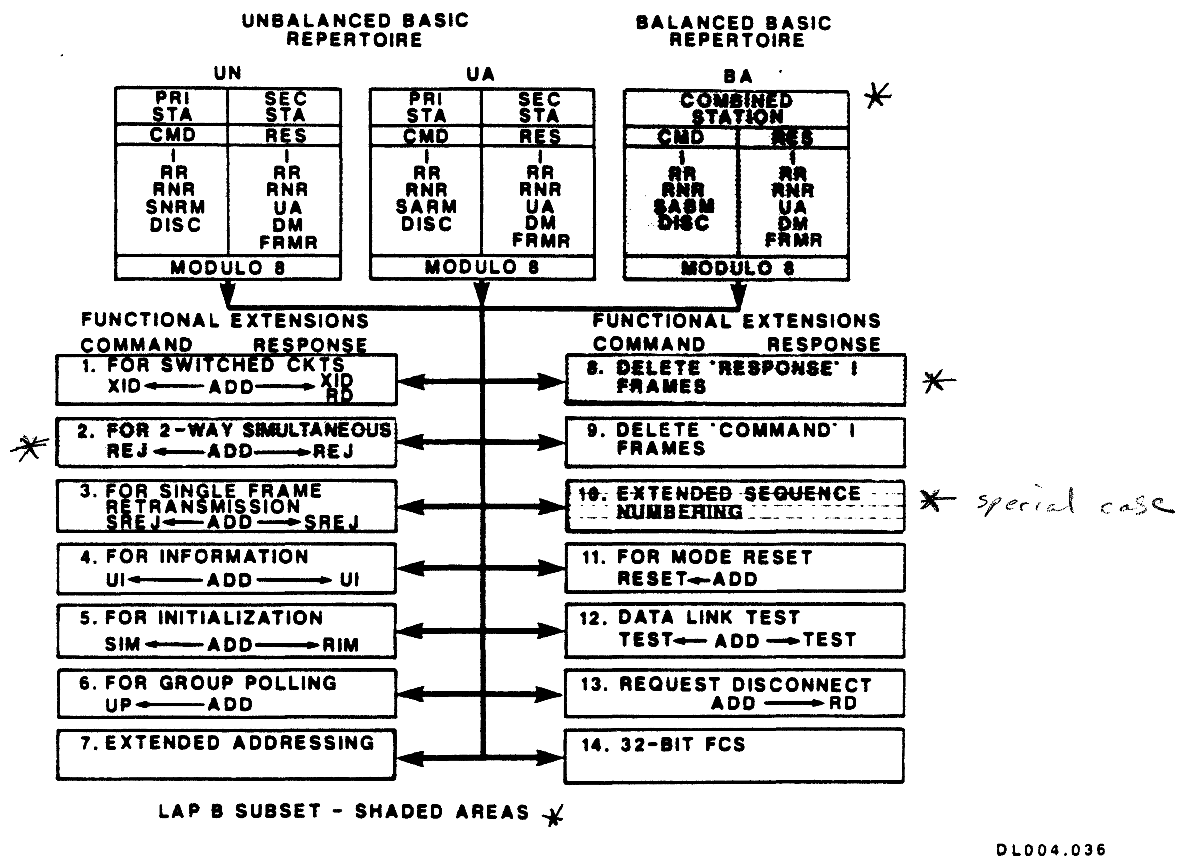
LAPB is a subset of the ISO HDLC class BA procedures. It is defined to have option 2, add REJECT, and option 8, delete response Information frames.

The following frames are defined for use in LAPB:

I	Information	Command
RR	Receive Ready	Command/Response
RNR	Receive Not Ready	Command/Response
REJ	Reject	Command/Response
SABM	Set Asynchronous Balanced Mode	Command
UA	Unnumbered Acknowledgment	Response
DISC	Disconnect	Command
DM	Disconnect Mode	Response
FRMR	Frame Reject	Response

Option 10, extended sequence numbering, is now recognized in the 1984 version of X.25. Its use is by subscription agreement only.

HDLC COMMANDS/RESPONSES BY CLASS



DL029.026

ENCODING OF FRAME HEADERS

FOR THE REMAINDER OF THIS SECTION, THE PRESENTATION OF THE FORMATS IS REVERSED TO FACILITATE AN UNDERSTANDING OF THE ENCODING IN HEX AS APPLIED BY PROGRAMMERS IMPLEMENTING THE PROTOCOL.

* * * * * * * * * * *

Bit 1 is still the low-order bit that is transmitted first, but now it is shown on the right-hand side of the figures. The first 8-bit field is the address field; the second field is the control field. Below is a representation of the hex encoding of these two header fields for each type of frame. The format of the hex encoding for the DTE- or the DCE-originated frame is as follows:

H'aacc

aa = hex for address field - 03 = command to DTE or response to DCE

01 = command to DCE or response to DTE

cc = hex for the control field - ? = variable depending on N(S), N(R) values or P/F bit setting.

The subsequent figures show the encoding of the various frames using the modified format.

NOTES

I-FRAME

LAPB defines only one information frame. This is the command information frame. Option 8 of ISO HDLC is used to delete the response information frame.

Information frames carry packets over the link in the I field. Each frame contains a header consisting of two octets. The first is the address and is always a command address. The second octet is the control field.

The control field provides the following indications:

Bit 1	Always zero.
Bit 2,3,4	Sequence number for this I-Frame N(s).
Bit 5	Poll - set to one to demand status.
Bit 6,7,8	Acknowledgement - next expected sequence number N(r).

INFORMATION FRAME

OCTET \ BIT	8	7	6	5	4	3	2	1
1	COMMAND ADDRESS							
2	N(R)			P	N(S)			0
3	I FIELD							

DCE: H'03??...

DTE: H'01??...

DL005.125

Poll BIT is used as a check pointing function.
Request status.

DL006.026

S-FRAMES

Supervisory frames are used to control the flow of information over the link, send the status of the receiving station, demand status from the receiving station, request retransmission, and rotate the window.

Option 2 of the ISO HDLC BA class of procedures is used in LAP B as "reject".

Supervisory frames can be either responses or commands; therefore, the address field can be set to either the command address or the response address, depending on the intended function.

The control field can be broken down into three parts. The first part is the frame type identifier (bits 1,2,3,4) and indicates the frame type. The next bit is the P/F bit. The high-order bits (6,7,8) are used to convey the next expected sequence number -- N(r).

The Frames Are:

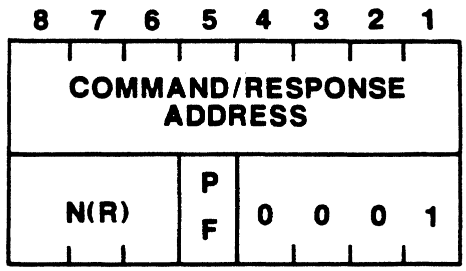
RR Receive Ready - Acknowledge and/or demand status.

RNR Receive Not Ready - Indicate busy condition and acknowledge and/or demand status

REJ Reject - Request retransmission and acknowledge and/or demand status

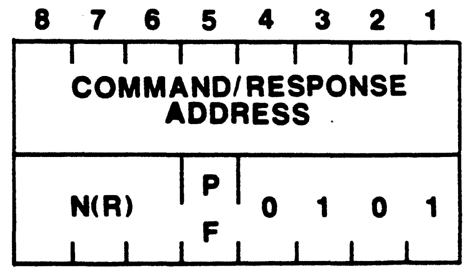
SUPERVISORY FRAMES

RR



RSP-DCE:H'01?1 DTE:H'03?1
CMD-DCE:H'03?1 DTE:H'01?1

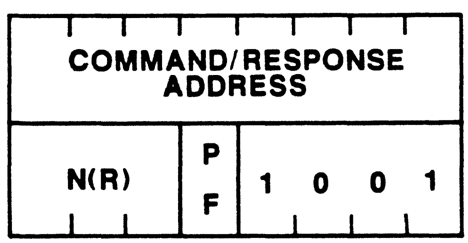
RNR



RSP-DCE:H'01?5 DTE:H'03?5
CMD-DCE:H'03?5 DTE:H'01?5

Not Ready to Receive
Strictly I Frames

REJ



RSP-DCE:H'01?9 DTE:H'03?9
CMD-DCE:H'03?9 DTE:H'01?9

DL006.125

DL007.026

U-FRAMES

The functions of the unnumbered frames are to control overall link operation and selection of modes. This includes:

* Establishing link set-up conditions to commence information transfer
* Acknowledging entry into a new operational state
* Conveying error information about an error not recoverable by retransmission
* Resetting of the link state after an unrecoverable error
* Indicating discontinuation of information transfer.

All unnumbered frames, except for the FRMR, are two octets long and consist of an Address field and a Control field. The FRMR (LAPB) is five octets long. The first two are address and response, the last three consist of error and diagnostic information.

The LAPB frames are:

SABM	Set asynchronous balanced mode
UA	Unnumbered acknowledgment
DISC	Disconnect
DM	Disconnect mode
FRMR	Frame reject

UNNUMBERED FRAMES

SET ASYNC BALANCED MODE (LAP B)

SABM

8	7	6	5	4	3	2	1
COMMAND ADDRESS							
0	0	1	P	1	1	1	1

DCE:H'03?F DTE:H'01?F

DISC

8	7	6	5	4	3	2	1
COMMAND ADDRESS							
0	1	0	P	0	0	1	1

DCE:H'03?3 DTE:H'01?3

UA

8	7	6	5	4	3	2	1
RESPONSE ADDRESS							
0	1	1	F	0	0	1	1

DCE:H'01?3 DTE:H'03?3

DM

8	7	6	5	4	3	2	1
RESPONSE ADDRESS							
0	0	0	F	1	1	1	1

DCE:H'01?F DTE:H'03?F

DL007.026

UNNUMBERED REJECT FRAMES

The Frame Reject (FRMR) for LAP B is used as a Response by the DTE or DCE to report an error condition that cannot be recovered by the retransmission procedure. Such conditions are as follows:

* The receipt of a command or response which is not valid or used
* The receipt of an I-frame which has too long an I-field
* The receipt of an invalid N(R)
* The receipt of an S or U frame with an I-field or that is of incorrect length.

REJECT frames have a diagnostic field providing information to assist in determining the source of the problem. This field consists of three octets. The first octet provides the control field of the rejected packet. The last two octets provide an indication of additional conditions. They contain a number of variables which are identified in the figure and are defined as follows:

V(S) is the current send state variable value at the DTE or DCE reporting the rejection.

V(R) is the current receive state variable value at the DTE or DCE reporting the rejection.

W set to 1 indicates that the control field received and returned above is invalid or not implemented.

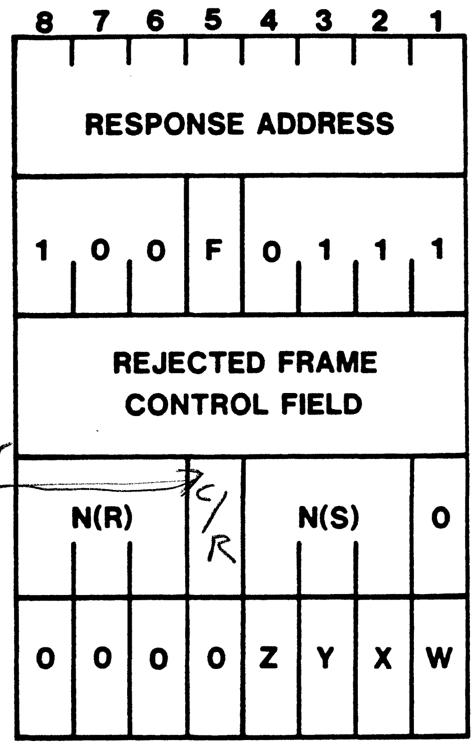
X set to 1 indicates that the control field received and returned above is invalid because the frame contained an I-field which is not permitted or is a U or S frame of incorrect length.

Y set to 1 indicates that the I-field received exceeded the maximum established capacity.

Z set to 1 indicates that the control field received and returned contained an invalid N(R).

UNNUMBERED FRAME

FRMR



Thought Frame in error was Command or Response

DCE:H'01?7????0? 1 FOR RESPONSE
DTE:H'03?7????0? 0 FOR COMMAND

DL034.026

This FRAME should not be received in normal operation. IT is for severe error conditions,

DL035.112

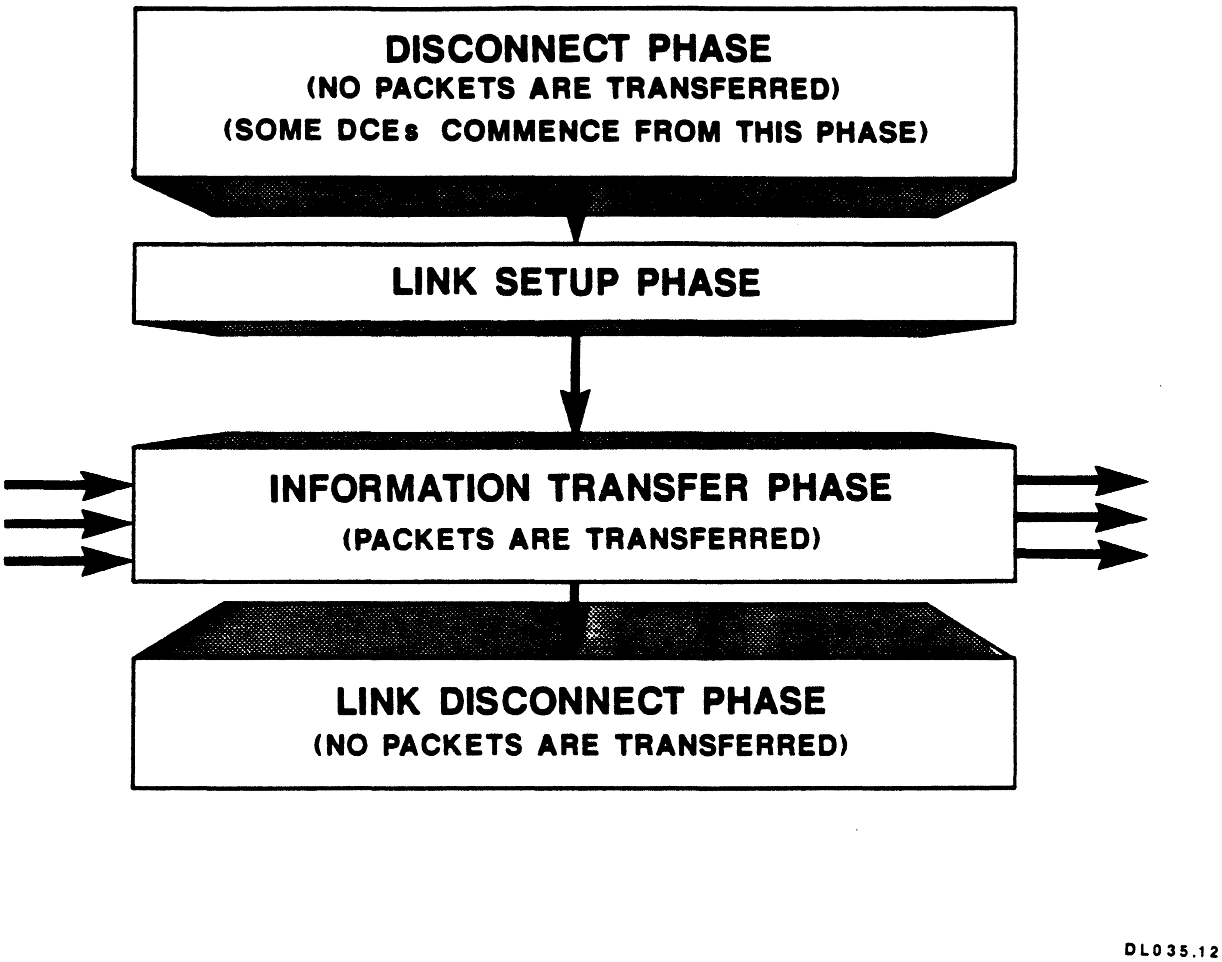
LINK LEVEL PROCEDURE PHASES

The link level procedures consist of three primary phases:

* The Link Set-up Phase. In this phase, the stations, referred to in LAP B as combined stations, synchronize their station variables and prepare to enter the Information Transfer Phase.

* The Information Transfer Phase. In this phase the stations transfer information in such a manner that errors can be detected and action taken to recover from these discovered errors.

* The Disconnect Phase. In this phase the stations move out of the Information Transfer Phase and enter an idle Disconnect State. No data are transferred in this state. Some networks use the Disconnect procedure to initialize before establishing the link using the Set Mode procedures. This will be discussed later.


DISCONNECT PHASE
(NO PACKETS ARE TRANSFERRED)
(SOME DCEs COMMENCE FROM THIS PHASE)
LINK SETUP PHASE
INFORMATION TRANSFER PHASE
(PACKETS ARE TRANSFERRED)
LINK DISCONNECT PHASE
(NO PACKETS ARE TRANSFERRED)
DL035.125

DL017.094

STATION VARIABLES

The following variables must be supported by an X.25 station:

V(S) - The send station variable. This is set to zero when receiving or transmitting an acknowledgment to a "set mode" command. This value is lifted and inserted into the I-frame just prior to transmission. Its value is then incremented using Modulo arithmetic. In the I-frame it is known as the send sequence number -- N(S).

V(R) - The receive station variable. This value is set to zero when receiving or transmitting an acknowledgment to a set mode command. Upon receiving an I-frame, the N(S) is extracted and compared against the V(R). If the V(R) and the N(S) are equal, then the received I-frame is in the correct sequence and the V(R) is incremented by one using modulo arithmetic. If a mismatch occurs, then the station enters the frame reject state.

K - The number of outstanding I-frames. This station variable is incremented each time an Information frame is transmitted, and decremented each time a previously sent I-frame is acknowledged. The value of K is not standardized but is normally set to 7.

N1 - N1 represents the maximum number of bits that can be inserted into the information field of an I-frame. This value is set when the X.25 service is first initiated. For X.25, assuming 128 octet data packets, the N1 value would have to be 1056 bits or, when fast select is used, 1688 bits.

N2 - N2 represents the number of retries of an operation that must be performed before recovery action takes place. This value is set when the X.25 service is first initiated. This value is not standardized, but is left for specific implementations.

T1 - T1 is the time value that must elapse before recovery actions take place. For proper operation, T1 should be greater than the maximum time between transmission of a command frame and the reception of the response. This value is not standardized, but is left for specific implementations.

T2 - T2 indicates the amount of time available before an acknowledging frame must be issued so the other station will receive the acknowledgment before its T1 timer expires.

T3 - Upon detection of the idle channel condition (15 contiguous 1-bits), the DCE shall wait for period T3 before a specific action is taken to advise the packet level. The link may be reactivated by a set-mode command (SABM).

STATION VARIABLES

V(S)	**SEND VARIABLE**
V(R)	**RECEIVE VARIABLE**
K	**NUMBER OF I-FRAMES OUTSTANDING**
N1	**MAXIMUM NUMBER OF BITS IN AN I-FRAME**
N2	**MAXIMUM RETRANSMISSION COUNT**
T1	**RETRANSMISSION TIMER**
T2	**MAX TIME FOR ACK ACTION**
T3	**DCE IDLE CHANNEL TIMER**

implementation specific. could be bytes, etc

new in 1984
Typical values: a few seconds

DL017.115

DL057.114

BALANCED ASYNCHRONOUS MODE - EXAMPLE OPERATION

The Balanced Asynchronous Mode (BA) merges the primary and secondary functions together in a combined station. This configuration provides a single link on a single physical circuit with fully symmetrical capabilities for each station.

The BA mode of operation is the basis for X.25 LAP B. The link is set up with the SABM command and acknowledged with a UA response. The addresses identify the nature of the frame as a command or response - a command carries the address of the destination station and a response carries the address of the source station.

Data transfer can be initiated from either station and, in the LAP B configuration, I-frames are always commands; but they can also acknowledge I-frames received from the other station using the N(R) parameter. Each I-frame has its send sequence number N(S) as an identification and an N(R) value that acknowledges to the destination station I-frames successfully received.

After data transfer is completed, a good procedure to follow is to complete the acknowledgment by using an RR command frame with the P-bit set to 1 as a check-pointing procedure to make sure that all the data has been successfully transferred. The appropriate response from the receiving station if all data has been accepted is to send an RR response with the F-bit set to 1. Then the link can be disconnected with the DISC command followed by an UA response.

LEGEND:

A or B = station address

Frame Type:

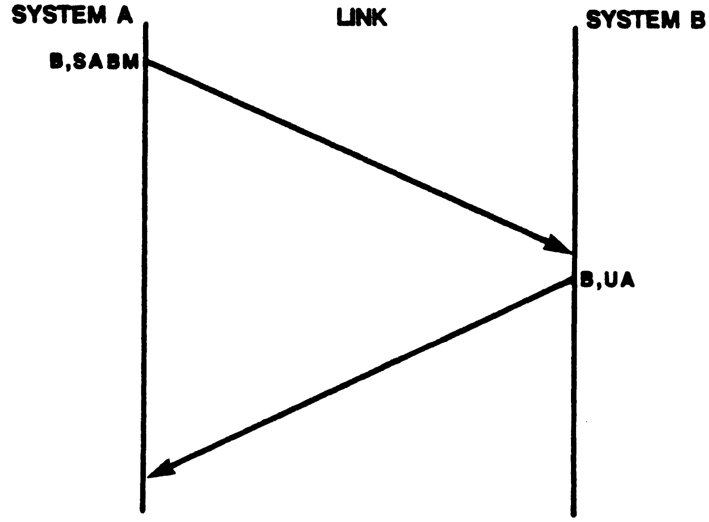
SABM = Set Asynchronous Balanced Mode
UA = Unnumbered Acknowledge
I = Information
RR = Receive Ready
DISC = Disconnect

Sequence Count: S=N(S) R=N(R) values. Note - number after RR is N(R) value.

P = poll-bit set to 1   F = final-bit set to 1

BALANCED ASYNCHRONOUS MODE

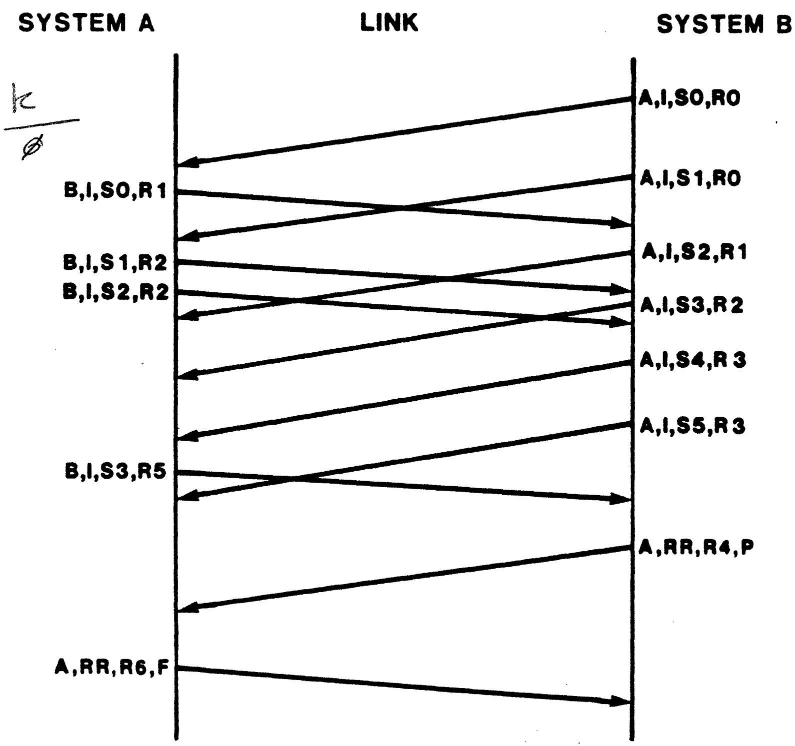
SETUP LINK



DL057A.016

BALANCED ASYNCHRONOUS MODE

DATA TRANSFER



DL057B.016

DL038.094

RECOVERY VIA REJECT

A receiving station can detect an I-frame lost during transmission because of the reception of an out of sequence N(S). When this occurs, the receiving station should discard any further I-frames received and transmit a REJECT frame.

The REJECT frame should be assembled using the last correctly received I-frame sequence number plus one. This lets the transmitter know which I-frame to use to begin the retransmission.

A station receiving the REJECT frame should halt transmission of any I-frames and commence retransmission of the I-frame with an N(S) equal to the REJECT frame's N(R). All I-frames with a sequence number equal to N(R)-1 and below are acknowledged.

NOTE: To ensure that the link does not enter an unrecoverable retransmission condition, a REJECT frame can only be transmitted once during a reject cycle. Should the REJECT frame be lost during transmission, the timer recovery system will ensure that the I-frames lost will be retransmitted.

LEGEND:

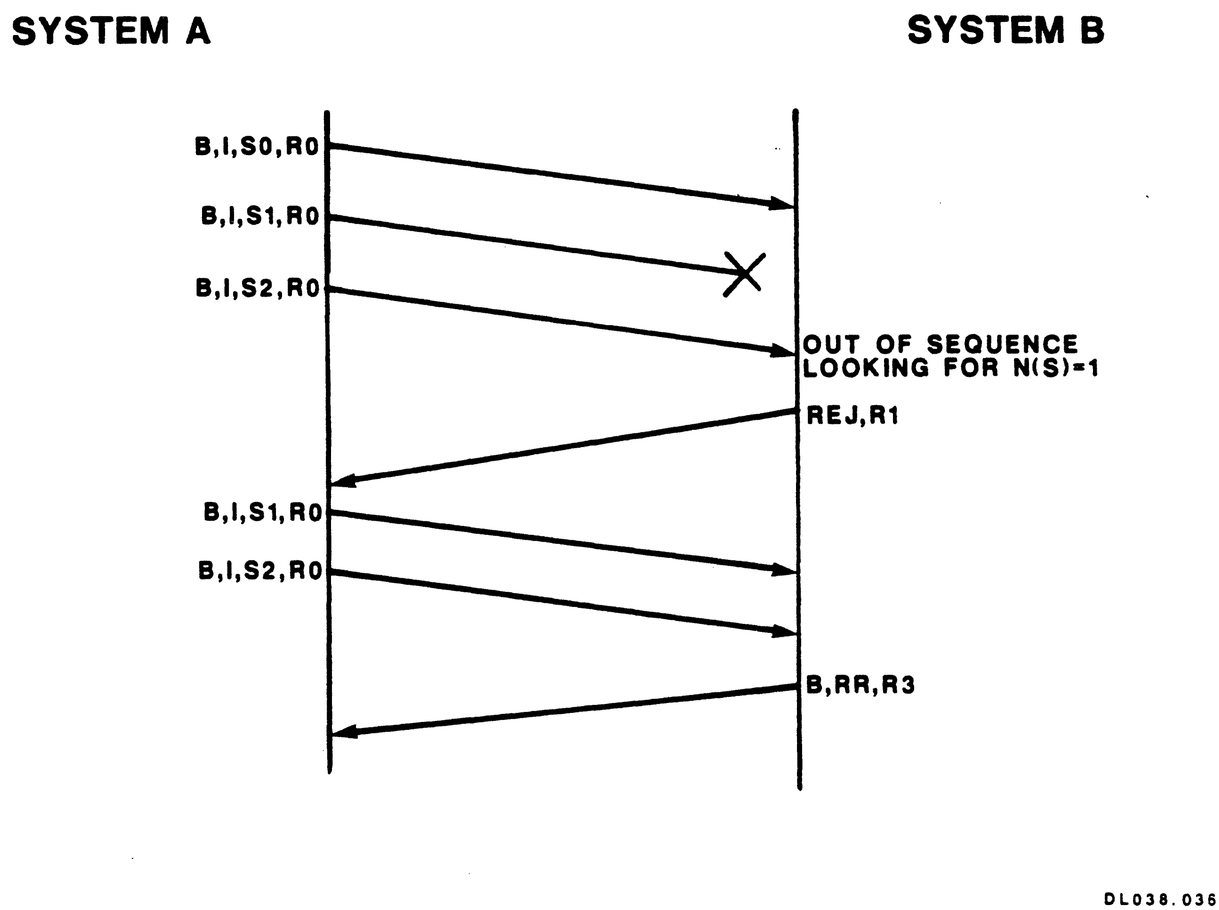
A or B = Station address

Frame Type:

I = Information
REJ = Reject
RR = Receive Ready

Sequence Count: S = N(S), R = N(R) values. Note: number after RR and REJ is N(R) value.

RECOVERY VIA REJECT



DL039.094

TIMER RECOVERY

The T1 timer is used to guard against the loss of command frames or their acknowledgments. After transmitting a command, the T1 timer must be started. This timer should be stopped when an acknowledgment is received. However, the timer **must be restarted** in the case of other outstanding I-frames.

Upon expiration of the T1 timer, the station should enter the timer recovery state and transmit a command with the POLL bit set to 1. The expected response must have the FINAL bit set to 1.

When the T1 timer expires on an outstanding I-frame, the transmitter should send a supervisory command with the POLL bit set. In response to this frame, the receiving station will transmit a supervisory response with the FINAL bit set and with the latest acknowledgment. This is a procedure known as "check pointing". The recovering station should, upon receiving the "F" response, commence retransmission of all I-frames that remain unacknowledged.

LEGEND:

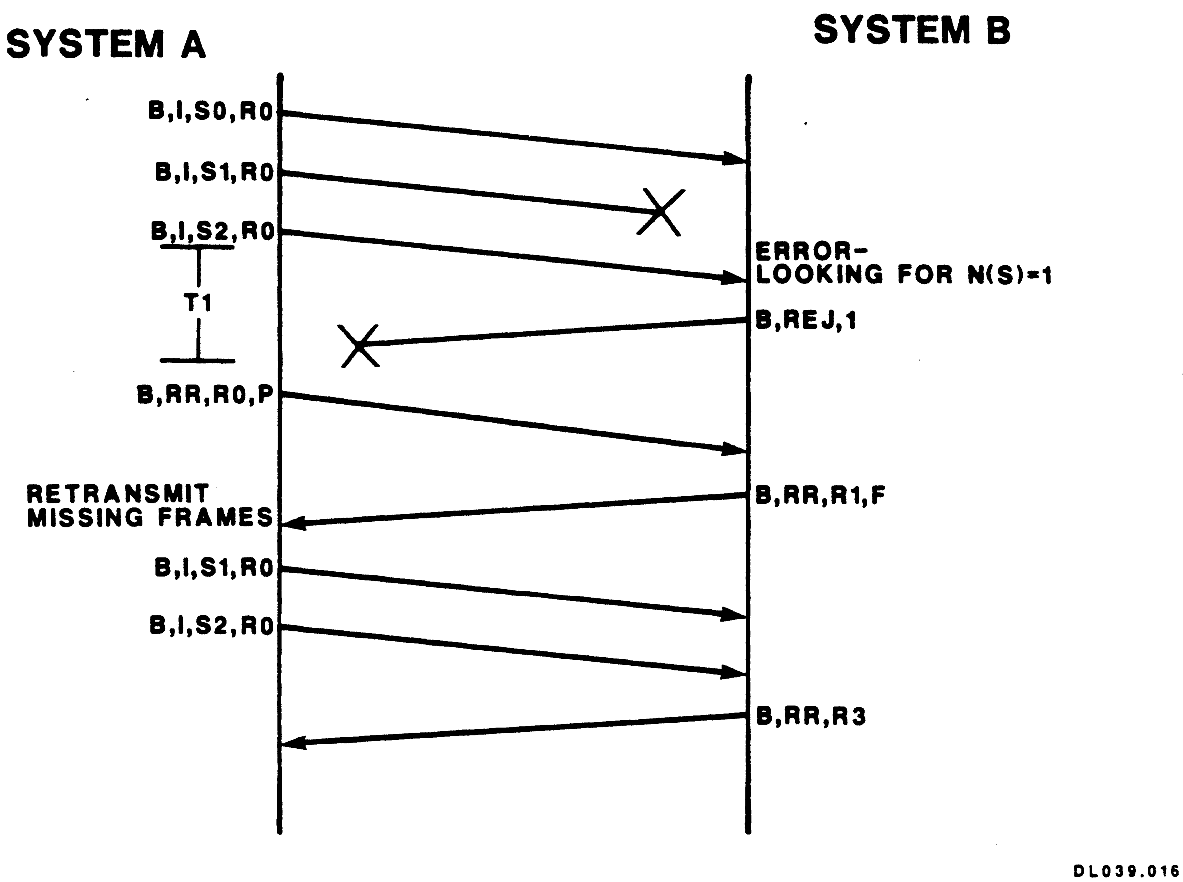
A or B = Station address

Frame Type:

I = Information
RR = Receive Ready
P = Poll bit = 1
F = Final bit = 1

Sequence Count: S = N(S), R = N(R) values. Note: number after RR and REJ is N(R) value.

TIMER RECOVERY



DL041.094

BUSY CONDITION

If a station cannot receive additional I-frames, it may send an RNR frame to the transmitter indicating a temporary inability to accept any further I-frames. All frames received after the RNR is transmitted may be discarded, but need not be if they are still within the originally authorized window.

When the station leaves the busy condition it transmits an RR frame. There are other conditions, such as reject, that also clear the busy condition.

It is possible for this RR frame to be lost. To ensure that this does not lead to lockup during busy condition, the transmitter should start the T1 timer and poll the busy station. The station, in turn, will respond with an RNR with the FINAL bit set to 1, indicating that it is still busy, or an RR with the FINAL bit set to 1, indicating that the data transfer state has again been entered.

LEGEND:

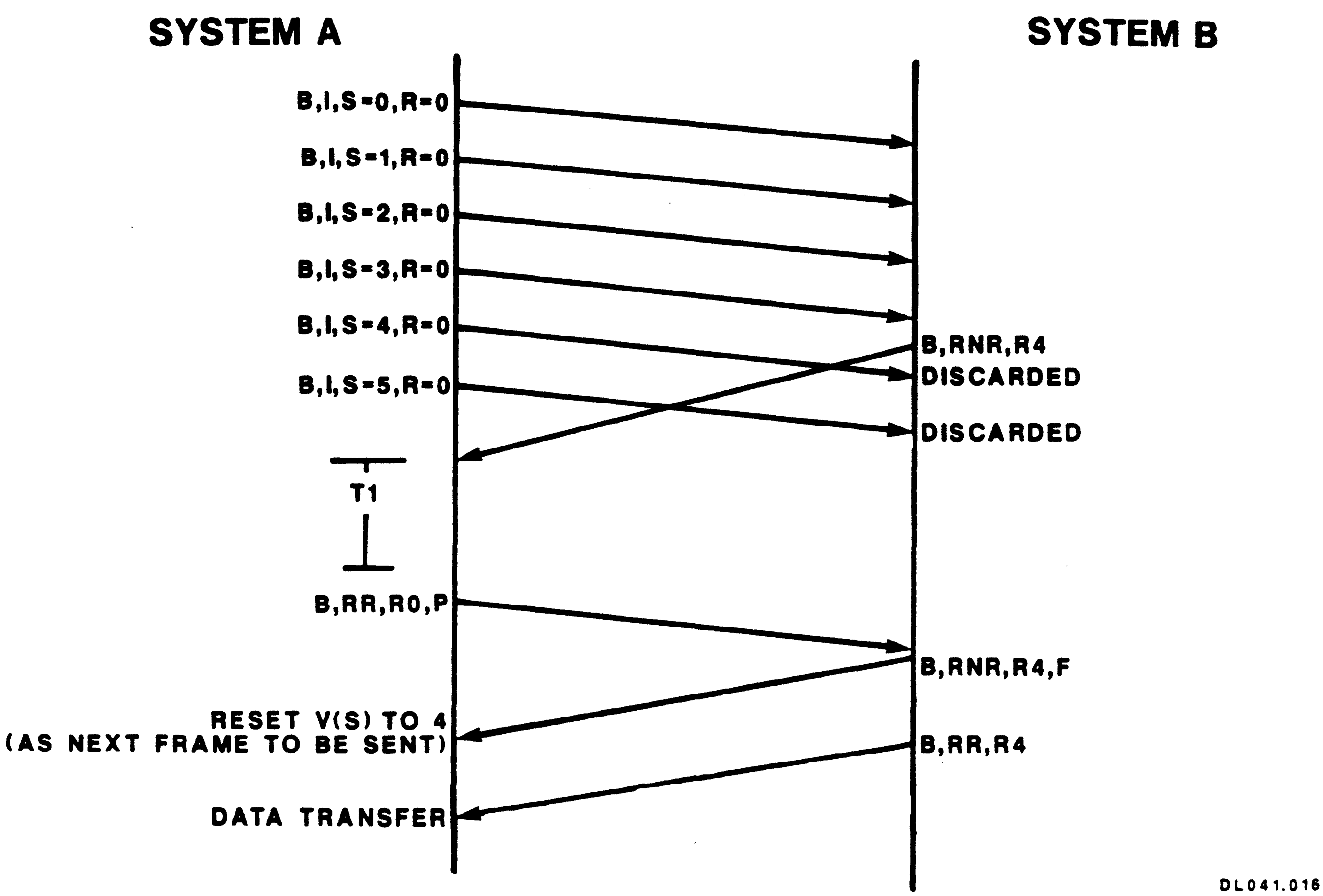
A or B = Station address

Frame Types:

I = Information
RNR = Receive Not Ready
RR = Receive Ready
P = Poll bit = 1
F = Final bit = 1

Sequence Count: S = N(S), R = N(R) values. Note - number after RR and RNR is the N(R) value.

BUSY CONDITION



DL036.094

FRAME REJECTION

Frame Reject (FRMR) is used in LAB B as a response by the DTE or the DCE to report an error condition that cannot be recovered from by the retransmission procedure. The conditions where FRMR is applied are as follows:

* The receipt of a command or response that is not valid or used

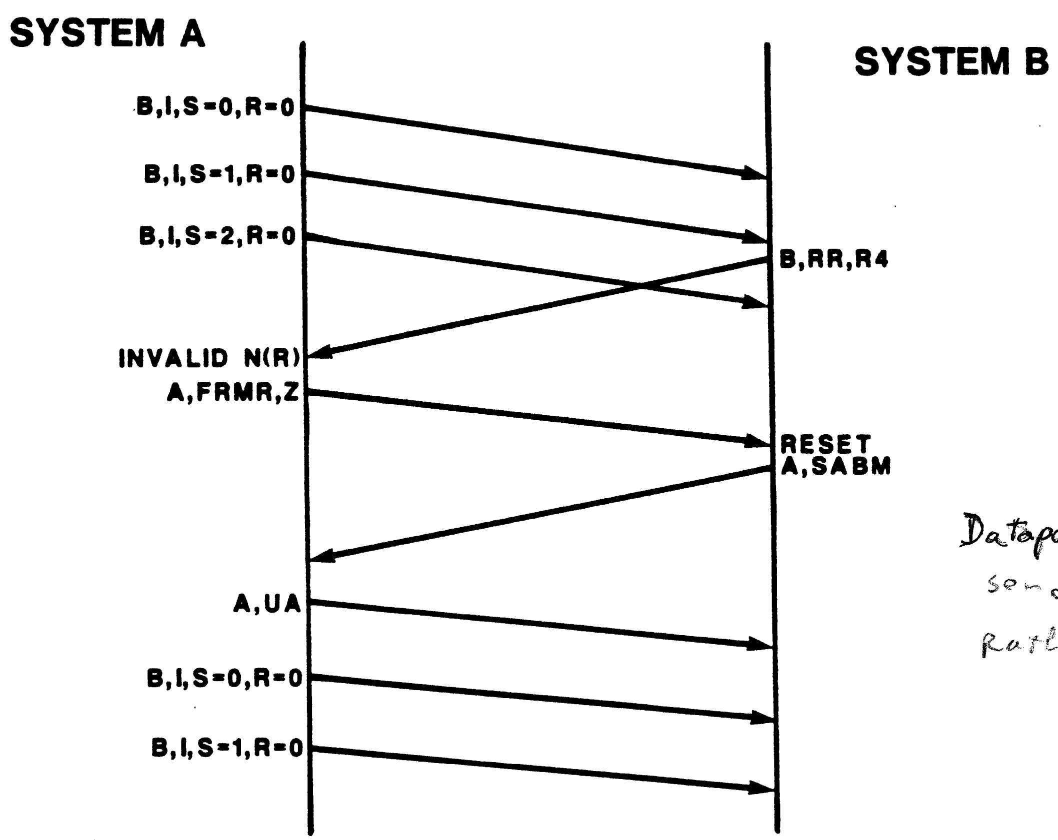
* The receipt of an I-frame that has too long an I-field

* The receipt of an invalid N(R)

* The receipt of an S or U frame with an I-field or that is of incorrect length.

In this example, an RNR response was returned to the DTE with a P(R) of 4. But the DTE had only sent frames up to a P(S) value of 2 and would expect a P(R) of 3 in response for acknowledgment. As a result the DTE recognized the RNR as being in error. The error could have been a fault in the DCE or an undetected transmission error. To recover from this situation the DTE invokes the FRMR command with the appropriate diagnostic information (see the earlier explanation under the FRMR format presentation). The DCE responds appropriately with a new set-mode command SABM to reset the link.

FRAME REJECTION



DL036.016

Datapac will send DM Rather than RESET

DL042.094

LINK DISCONNECT

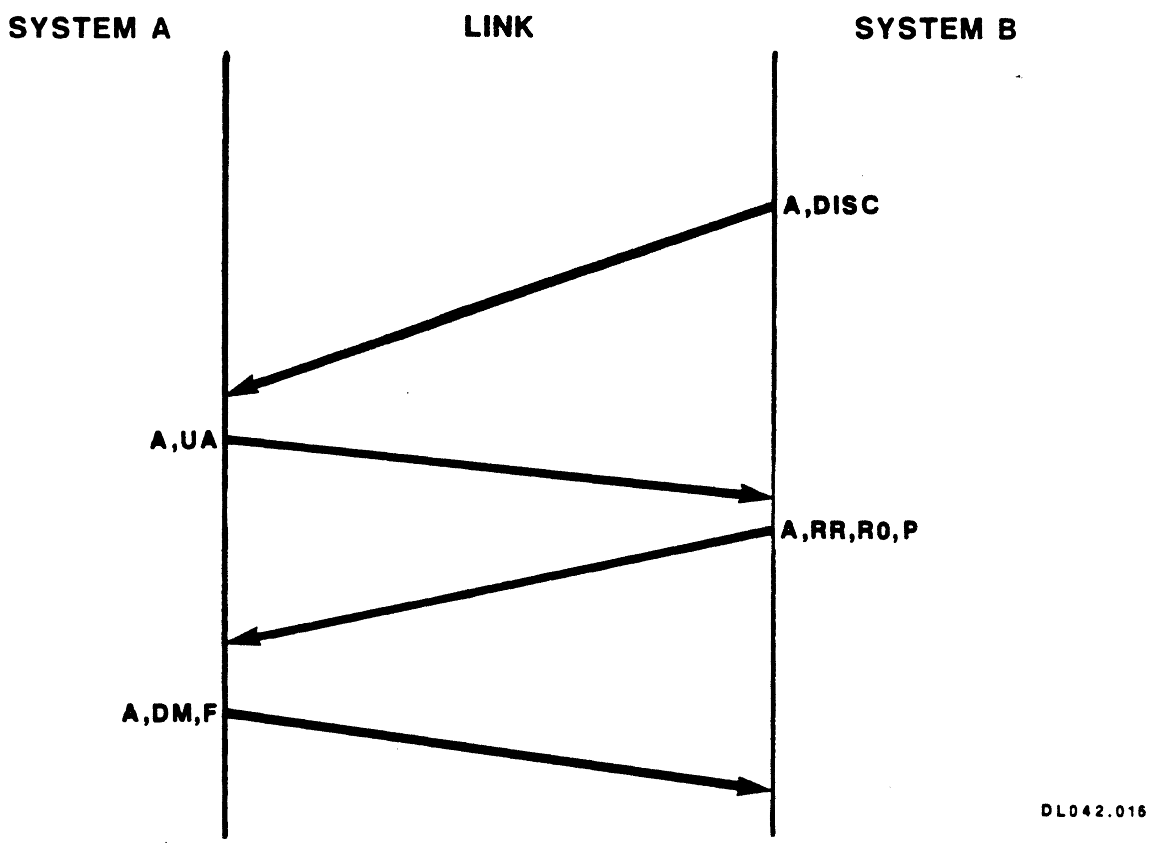
With a balanced protocol a DISCONNECT frame transmitted from either station will cause the link to be disconnected. The station receiving the DISC frame should acknowledge receipt by returning a UA response.

In the disconnect phase, a station may initiate link set-up. A station may not transmit an I-frame during the disconnect phase.

The DCE in the disconnect phase will transmit a DM command to a received DISC frame. Should a command with a POLL bit set to 1 be received by the DCE during the disconnect phase, which is not an SABM and where the DCE does not wish to enter the link set-up phase, it will respond with a DM with the FINAL bit set to 1. All other frames will be discarded.

BALANCED ASYNCHRONOUS MODE

LINK DISCONNECT



DL045.122

MULTILINK CONFIGURATION

Trunks interconnecting public data networks generally carry a high volume of traffic and must provide a dependable, high quality of service that is transparent to the communicating end-users. Depending on only single interconnecting links can be risky and makes it difficult to maintain the level of performance necessary.

The multilink configuration was developed to solve this problem. By grouping a number of independent physical links, each operating with its own single link level protocol, a greatly improved performance can be realized.

Under variable traffic loads, circuits can be added or deleted from the group to provide the necessary bandwidth without employing excessive resources. Multiple circuits also provide a much higher reliability because if a circuit fails, the other circuits still remain active to carry the traffic, although with a reduction in total bandwidth. Under more hostile conditions, as circuits fail only the bandwidth is reduced, thereby providing a graceful degradation of service rather than an abrupt outage.

While the multilink configuration was originally specified for use on X.75 internetwork connections, the 1984 version of X.25 now includes the same optional procedures for user access to packet networks.

MULTILINK

MULTIPLE PARALLEL CIRCUITS

- EXPAND BANDWIDTH
- INCREASE RELIABILITY
- GRACEFUL DEGRADATION

DL045.115

DL044.095

MULTILINK PROTOCOL

Trunks interconnecting public data networks on large host computer systems generally carry a high volume of traffic and must provide a dependable, high quality of service that is transparent to the communicating end-users. Dependence on only single interconnecting links can be risky, and makes it difficult to maintain the necessary level of performance.

The multilink configuration was developed to solve this problem. By grouping a number of independent physical links, each operating with it own single link level protocol, greatly improved performance can be realized.

The multilink procedures are defined by CCITT in Recommendations X.25 (1984) and X.75 as well as by ISO 7478. The Multilink capability is achieved by having an independent Single Link Procedure (SLP) for each physical connection and by having an intelligent "arbitrator" or Multilink Procedure (MLP) acting as an interface between the link and the packet layers.

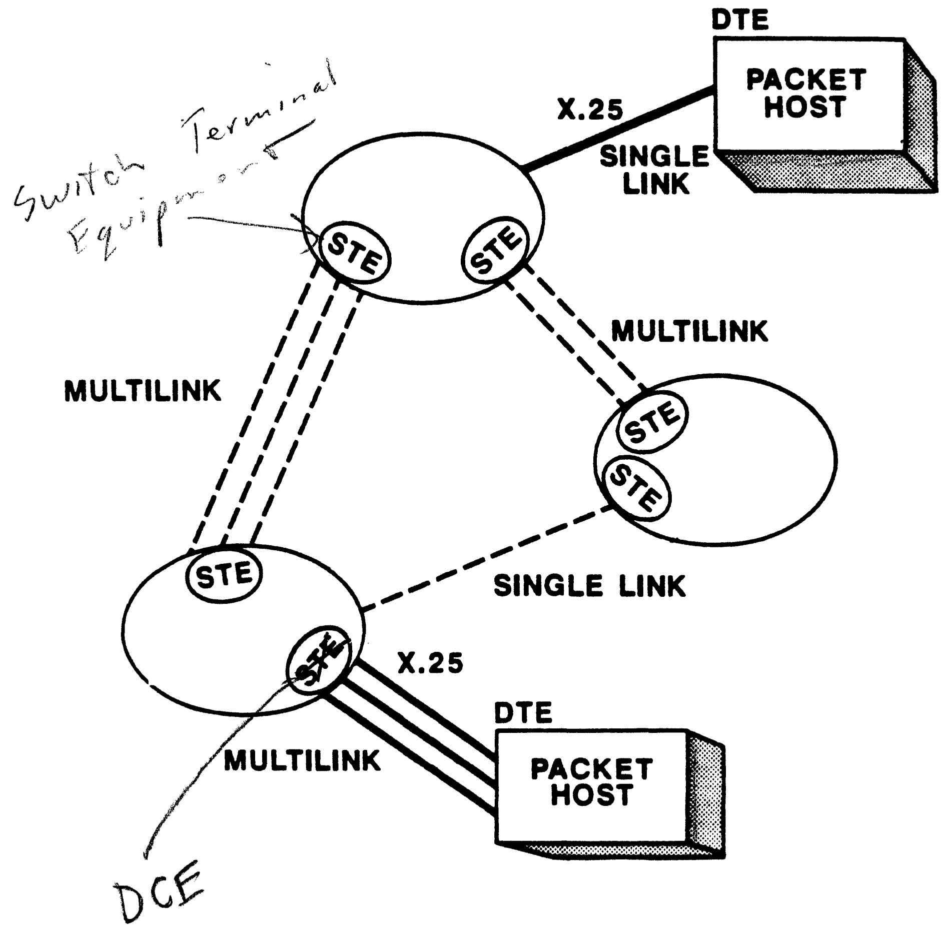
The procedure referred to as the MLP takes packets from the Packet Level and allocates them to an operating SLP for transmission. Frames arriving at the other SLP peer are passed to the peer MLP for resequencing and passage to the peer Packet Level.

An SLP operating with an MLP above will use addresses C (Hex 0F) and D (Hex 0E), instead of the normal addresses A and B, respectively, when operating on their own. By monitoring the individual lines, identification can be made as to whether a link is part of a multilink group or not. The same rules apply to addressing of commands and responses using C and D as with A and B.

SUMMARY OF ADVANTAGES:

* Expand bandwidth
* Increase reliability
* Graceful degradation.

MULTILINK

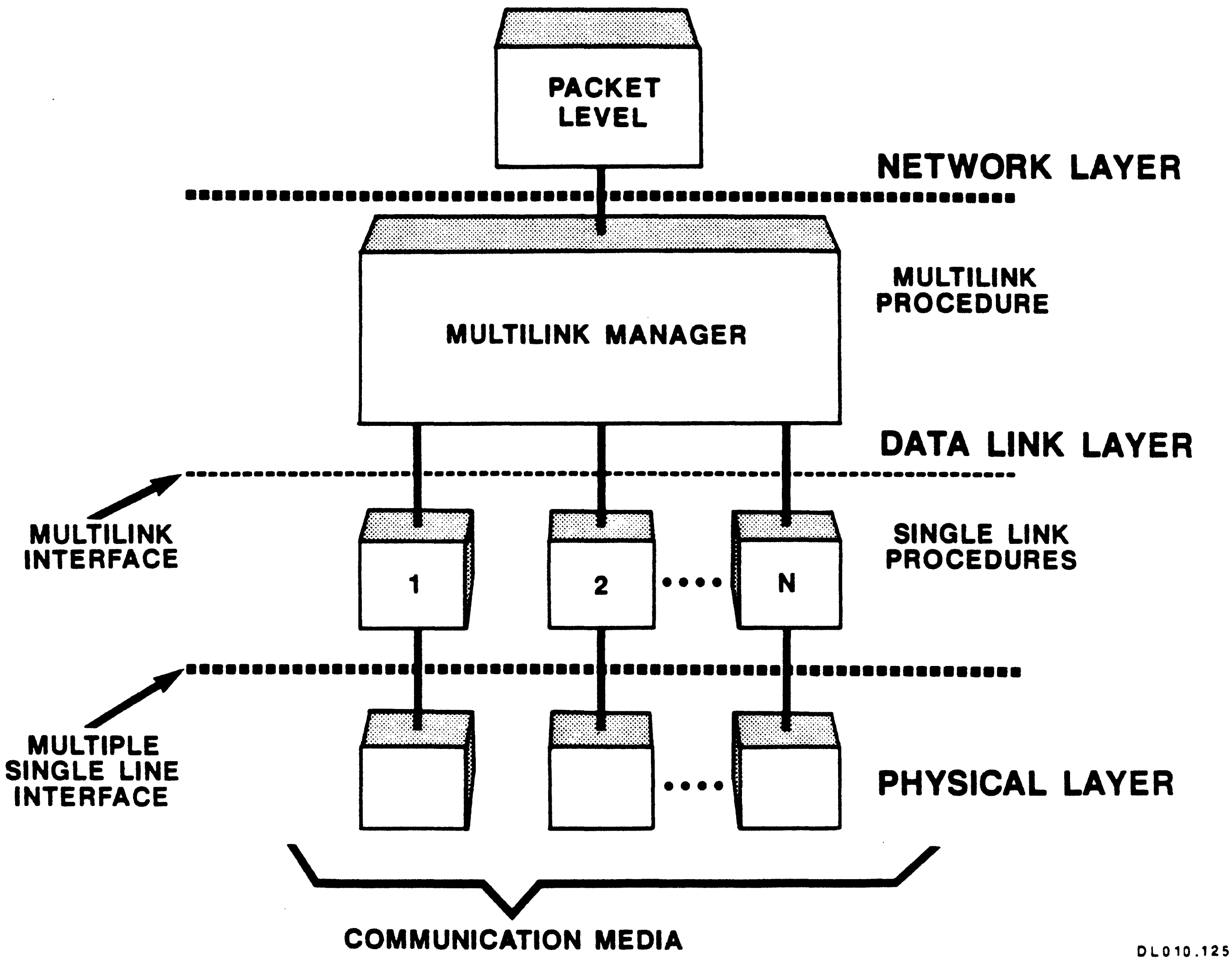


DL044.016

DL010.095

MULTILINK ORGANIZATION

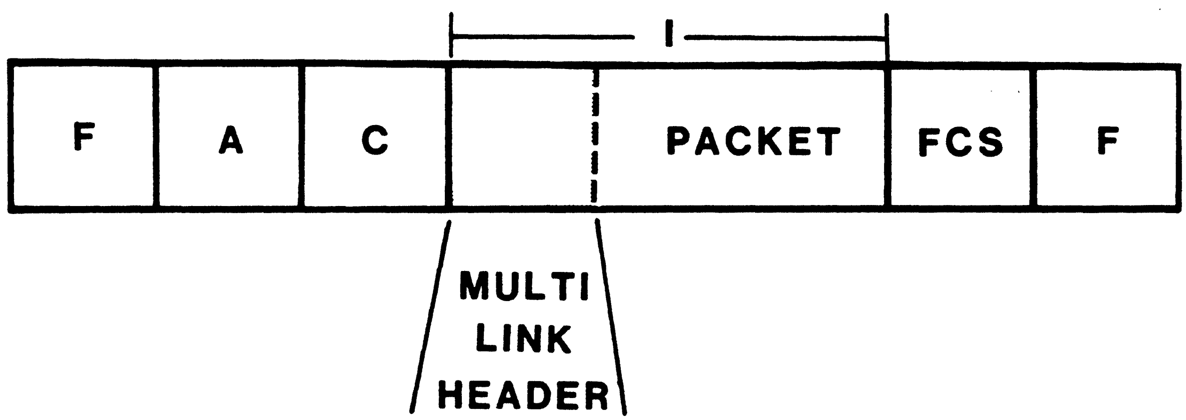
The multilink procedure, or MLP, forms a new interface to the Network Layer from the Data Link Layer. Below the multilink level there are multiple data link procedures, called single link procedures, or SLPs. The MLP controls and distributes multilink frames to these single link procedures. It takes multilink frames from the single link procedures and, after processing, passes them up to the packet level once they are in sequence. Acknowledgments are conveyed via the normal SLP.


PACKET
LEVEL
NETWORK LAYER
MULTILINK MANAGER
MULTILINK
PROCEDURE
DATA LINK LAYER
MULTILINK
INTERFACE
1
2
N
SINGLE LINK
PROCEDURES
MULTIPLE
SINGLE LINE
INTERFACE
PHYSICAL LAYER
COMMUNICATION MEDIA
DL010.125

DL011.095

MULTILINK FRAME ORGANIZATION

To control the MLP procedures, a new MLP header is required. This header is positioned in the first two octets of the information field of the SLP's Information frame. The MLP frame consists of a header and an Information field. The Information field contains the packet in the case of X.25, or the DLSDV.



DL011.000

DL046.035

MULTILINK HEADER

The multilink header consists of a 12-bit sequence number MN(S) and four control bits. These control bits are:

8 (C) is the reset confirmation bit in response to a reset request

7 (R) is the reset request bit for initializing the link

6 (S) is the sequence number check option (pertinent only if V=1)

0 = MN(S) number assigned - discard duplicate MLP frames

1 = no MN(S) assigned

5 (V) void sequencing bit

0 = sequencing required (normal setting for virtual circuits)

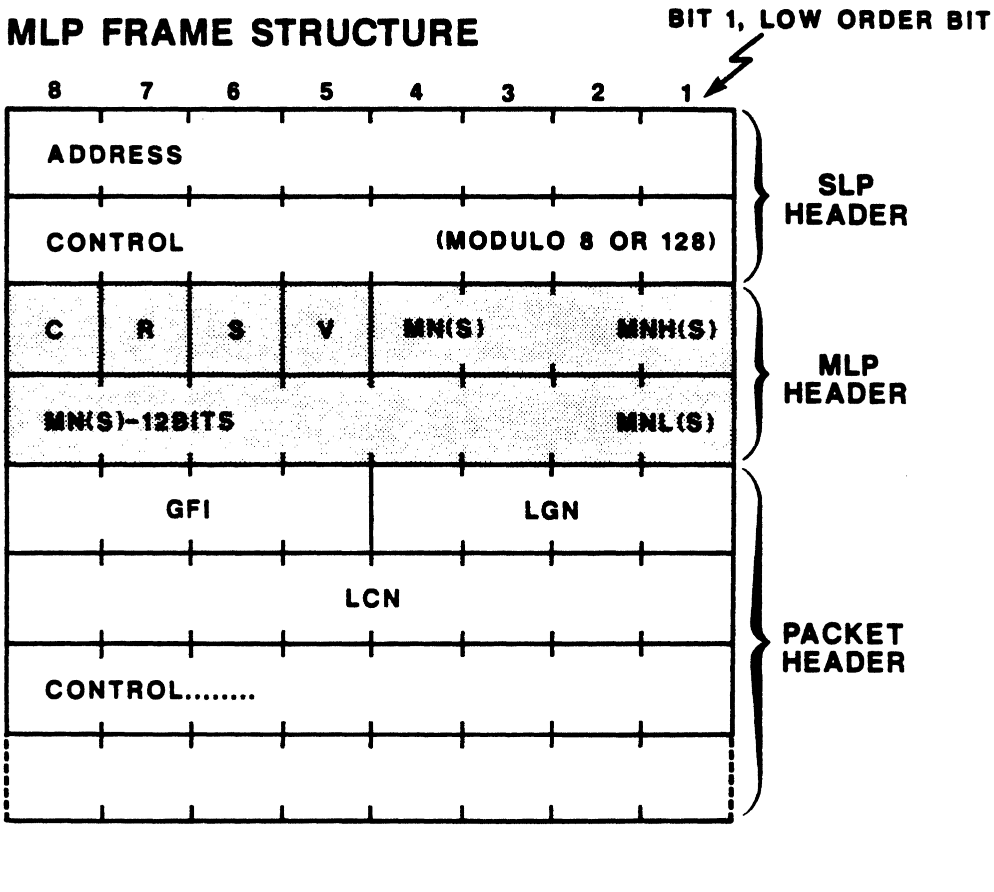
1 = sequencing not required (considered for Datagram service).

The weight of the bits in the MN(S) sequence number fields are specified so that bit 4 of the MNH(S) portion is the high order bit of the 12-bit sequence number and bit 1 of the MNL(S) is the low order bit. This gives a total sequence count of 0 to 4095 or modulo 4096.

The MLP header is placed before the packet in the data stream. The SLP adds its own protocol control information as previously defined. In effect the MLP header is contained in the I-field immediately before the data unit (packet) from the packet level.

The receiving station SLP removes the SLP control information prior to passing the contents of the I-field to the MLP entity. The MLP entity removes its header, performs the necessary operations, and passes the remaining data to the packet level.

MULTILINK HEADER



DL033.095

PROCEDURE: RECEIVING MLP FRAME

The receiving STE accepts MLP frames from the SLPs. If an MLP frame is passed with less than two octets, the frame is discarded. The MN(S) of this frame will be compared to the MV(R) state variable. Action occurs as follows:

* If equal, then the MLP header is stripped from the frame and the packet is passed to the packet level
* If greater, but less than MV(R) plus MW, the MLP will hold the frame until the above condition is met (resequencing has taken place); if it is a duplicate, it is discarded
* Otherwise, the MLP frame is discarded.

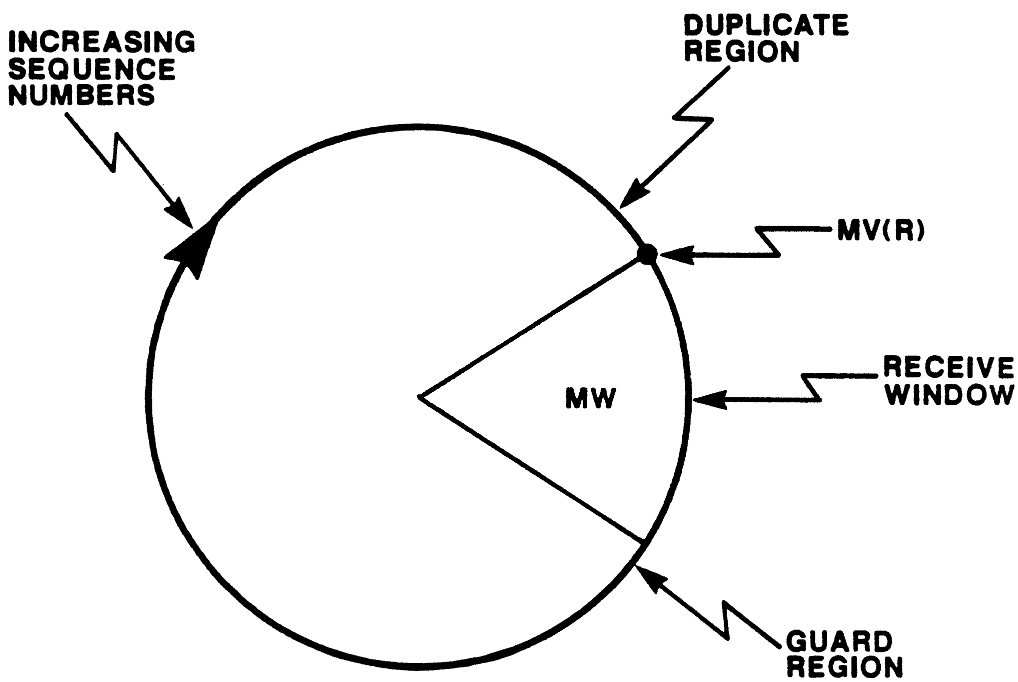
MV(R) is incremented whenever an MLP header is stripped and the DL5DU is passed to the Network Layer; or if timer T3 expires, then MV(R) is updated to the next MLP frame awaiting delivery to the Network Layer.

NOTE - If DLPDUs are lost, the Network Layer should be informed for reasons of recovery.

LEGEND:

MV(R) = lowest sequence number yet to be received

MULTILINK - RECEIVING



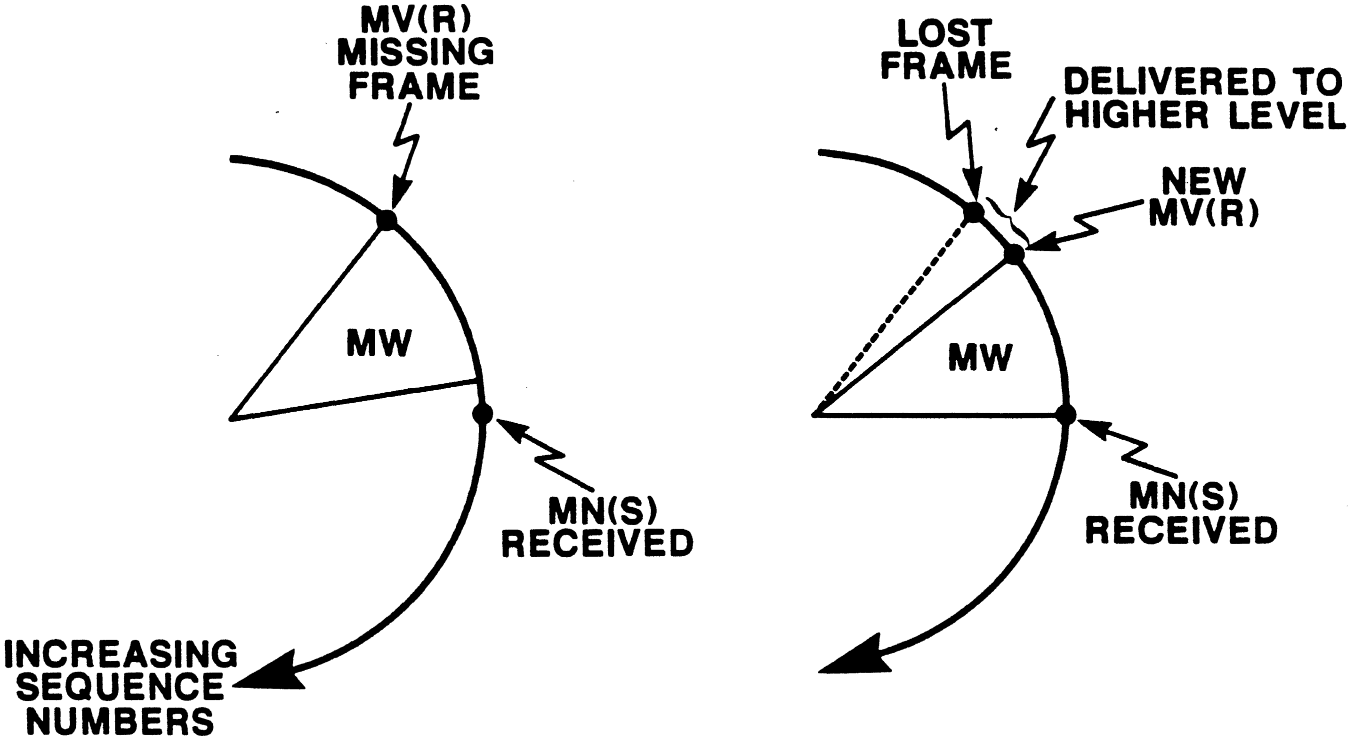
MV(R) = LOWEST SEQUENCE NUMBER
YET TO BE RECEIVED

DL033.015

DL019.044

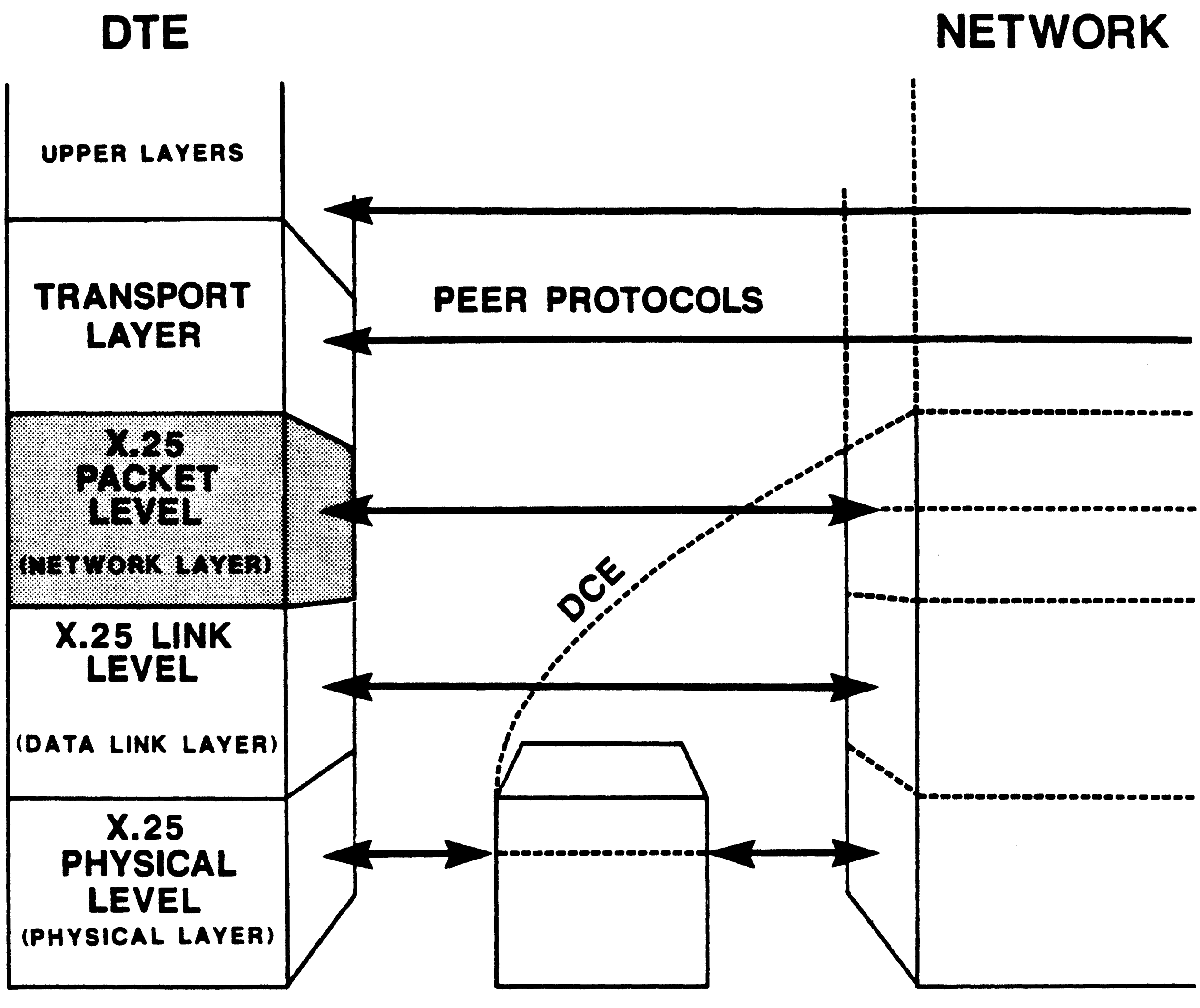
MULTILINK WINDOW ROTATION

The MN(S) received indicates a lost multilink frame, since it represents a position beyond the window's edge. The frame with sequence number MV(R) is declared lost. All frames queued between MV(R), the missing frame, and MN(S) minus MW plus one, are delivered to the higher level. The window's edge is moved forward so that MV(R) is at least MN(S) minus MW plus 1.


MV(R)
MISSING
FRAME
MW
MN(S)
RECEIVED
INCREASING
SEQUENCE
NUMBERS
LOST
FRAME
DELIVERED TO
HIGHER LEVEL
NEW
MV(R)
MW
MN(S)
RECEIVED

DL019.016

NOTES


DTE
NETWORK
UPPER LAYERS
TRANSPORT LAYER
PEER PROTOCOLS
X.25 PACKET LEVEL
(NETWORK LAYER)
X.25 LINK LEVEL
(DATA LINK LAYER)
DCE
X.25 PHYSICAL LEVEL
(PHYSICAL LAYER)
PK000.016

PK001.095

PACKET LEVEL OF X.25

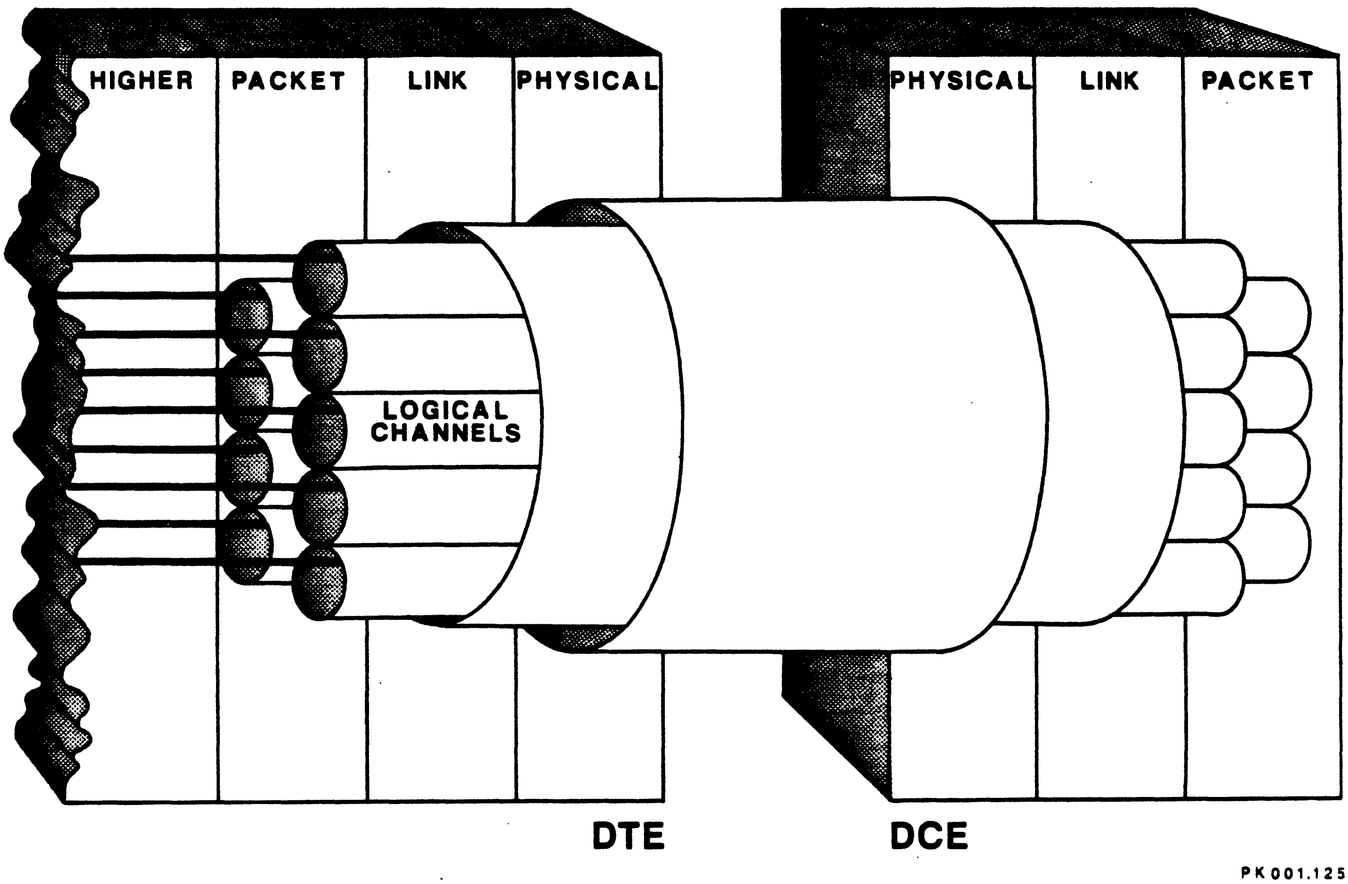
The basic structure of X.25 is illustrated in the figure. The details of the Physical Level and the Link Level have already been presented. The Packet Level closely maps into the Network Layer of the OSI Reference Model. The figure shows the DTE/DCE relationship as specified in X.25, but the use of the term DCE should be taken figuratively and not literally. The DCE actually represents intelligence within the connected DSE.

The Packet Level provides the Virtual Circuit Service. Two kinds of virtual circuits are available: Permanent Virtual Circuits (PVC), like dedicated leased circuits, or Virtual Calls (VC), analogous to dial-up circuits.

Logical Channels are used to differentiate among the virtual circuits supported by the Packet Level. Multiple communications are provided simultaneously by multiplexing virtual circuits over the access line. There is one PVC or VC established at a time on each logical channel.

In the figure, the Packet Level represents the entity that provides the functionality for the services within the Network Layer. This is then connected to entities at the upper layers, where additional functionality is provided.

MULTIPLEXING OF LOGICAL CHANNELS



PK002.095

PACKET/FRAME RELATIONSHIP

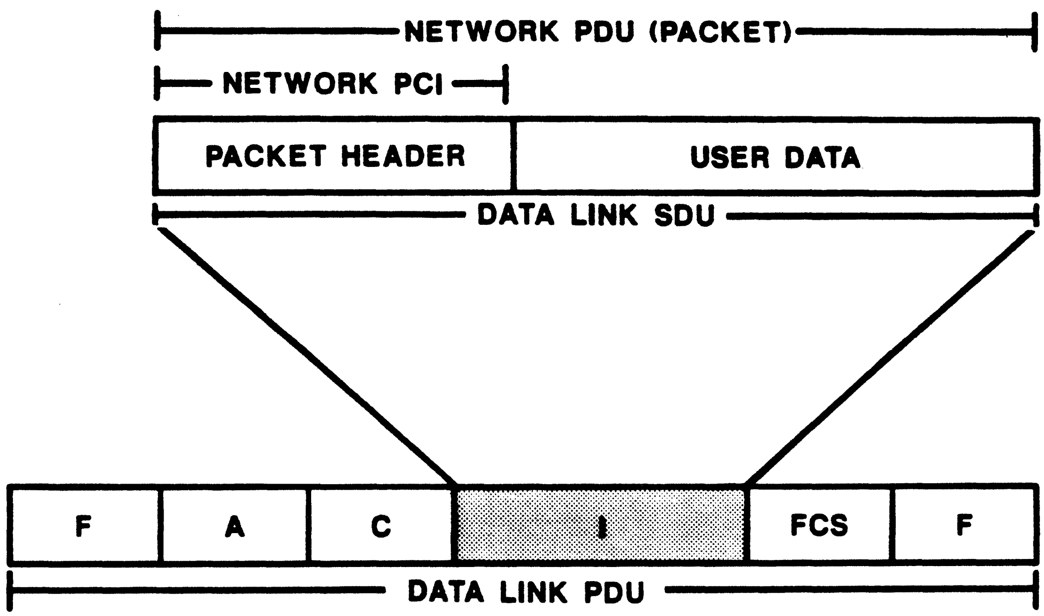
As presented in the previous section, the Data Link Layer provides for the synchronization - framing - and error control of the information transferred over the physical link. The I-field carries the data unit that is provided by the next upper layer. This is the information that is associated with the functioning of the Packet Level of X.25. The I-field thus contains the packet in transit between the Packet Level entities. There is only one packet transmitted in a single frame at the Link Level.

The Packet contains two basic parts, the packet header, to convey peer-to-peer protocol information, and the user data from the higher layers. Some packets may convey only peer control information. In this case, there may be no user data.

LEGEND:

F - Flag
A - Address
C - Control
I - Information
FCS - Frame Check Sequence
SDU - Service Data Unit
PCI - Protocol Control Information
PDU - Protocol Data Unit

PACKET/FRAME RELATIONSHIP



PK002.095

One Packet per FRAME.

PK003.095

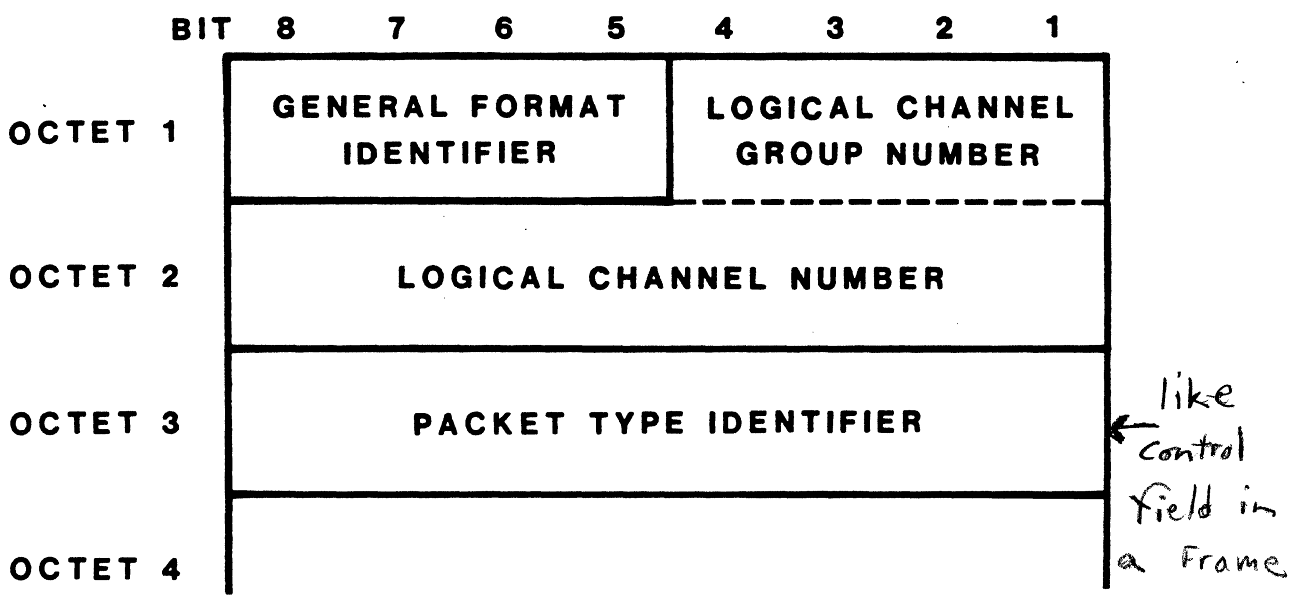
BASIC PACKET HEADER FORMAT

All of the packets in X.25 follow a basic header format for the first three octets. One half of the first octet is the General Format Identifier which is somewhat a misnomer. The various bits are used for a number of purposes. In the other half of the first octet, the Logical Channel Group Number is given. This, combined with the Logical Channel Number of octet 2, provides the complete logical channel identification of 12 bits to give a total possiblity of 4096 channels. The various networks treat these two numbers in different ways. In some networks the two fields are treated as one 12-bit number. Other networks treat them as separate fields. In any case, the potential capacity for logical channels is not affected. Finally, the Packet Type Identifier indicates the specific purpose of the packet. This includes a number of control packets as well as the data packets, which will be described in detail later.

Following these first three basic octets in the header, there may be either user data or additional control fields to support the communication.

Bit 1 is the low-order bit and the first bit transmitted. The next octet is progressively lower in order of the previous octet. For example, bit 8 of octet 2 is the next lower bit to bit 1 of octet 1. This makes the "logical channel group number" and the "logical channel number" a contiguous logical value.

BASIC PACKET HEADER FORMAT



PK003.012

PK004.044

GENERAL FORMAT IDENTIFIER

The table indicates the various types of packets that are defined for X.25 operation and the respective sequence number moduloand encoding.

The call set-up packets include Call Request, Incoming Call, Call Accepted, and Call Connected. Bit 7 is known as the D bit and is used to facilitate confirmation for delivery of the packet to the destination. Bits 5 and 6 are used to indicate the sequence count that will be used. Modulo 8 is the most widely used, but 128 can be found in Japan.

In the next grouping of packet types, the encoding is about the same, except for bit 7, which does not apply. Although the modulo is also indicated, it cannot be changed from packet to packet nor can it be changed from communication to communication. It is fixed by subscription for all logical channels in the interface.

The data packets utilize all four bits. Bits 5, 6, and 7 are as described for call set-up packets. Bit 8, called the Q bit, is used to qualify two levels of user data in the packet. An example of using the Q bit is found in the procedures defined in Recommendation X.29 for communicating with an asynchronous terminal through an X.3 PAD.

In the 1980 version, the General Format Identifier Extension was added to provide an escape to additional formats and codings in the future. With the introduction of the D bit, this compromise was made to ensure that an expanded capability would be possible in the future. Further allocation of the additional codings has been made in the 1984 version to allow the X.25 packet level to be distinguished from other Network Layer protocols by the value of the General Format Identifier.

GENERAL FORMAT IDENTIFIER

PACKET TYPE	SEQUENCE NUMBERING MODULO	OCTET 1 BITS 8 7 6 5
CALL SET-UP	8	0 X 0 1
	128	0 X 1 0
CLEARING, FLOW CONTROL, INTERRUPT, RESET, REGISTRATION, RESTART, AND DIAG.	8	0 0 0 1
	128	0 0 1 0
DATA	8	X X 0 1
	128	X X 1 0
GENERAL FORMAT IDENTIFIER EXTENSION		0 0 1 1
RESERVED FOR OTHER APPLICATIONS		* * 0 0

* UNDEFINED

PK004.016

PK005.044

LOGICAL CHANNEL ASSIGNMENT

A scheme is specified to assign the logical channel in an interface. Any number of logical channels may be assigned up to a maximum of 4095. Logical channel 0 is always reserved for Restart, Diagnostic and Registration packets, which have a common association with all channels.

The scheme does not restrict the number of channels in each category, but specifies only the order in which they will be allocated. The numbers do not have to be consecutive nor do the groups have to be immediately following each other. Gaps in the numbers are allowed. The first group in the allocation is for PVC channels. The actual numbers assignment to this first set of channels is made by agreement with the carrier.

The next category is One-way Incoming VC. This means that only incoming calls from the network can be made on these channels. This is often confused with the direction of data flow, but that is not the case. Calls that are destined for the DTE are assigned by the DCE to the next available, lowest numbered logical channel within this group.

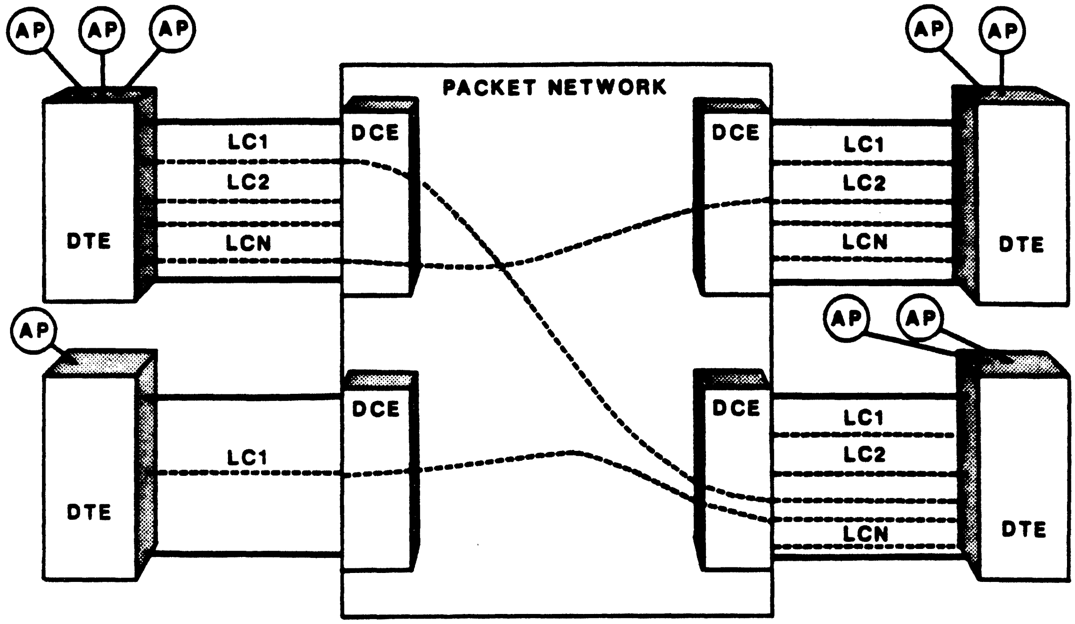
The One-way Outgoing VC group is selected by the DTE when a call is being originated. The highest numbered, first available logical channel is chosen. By having separate groups of logical channels for incoming and outgoing calls, the probability of collision on a particular channel is greatly reduced. If channels were selected by the DTE and DCE at random, or from the same starting point in the same direction, the probability for simultaneous selection of a particular logical channel for an incoming and an outgoing call would be greatly increased.

The middle group for Two-way VC provides an overflow that is shared for allocation by the DTE and DCE. This allows for peak differences in the traffic flow. Each particular user's operating patterns are taken into consideration in grading and configuring the dynamic allocation of the logical channels for virtual calls.

For example, if a DTE subscribed to 512 logical channels but did not subscribe to any PVCs or to making outgoing calls, the logical channel assignment variables might have these values (hexadecimal):

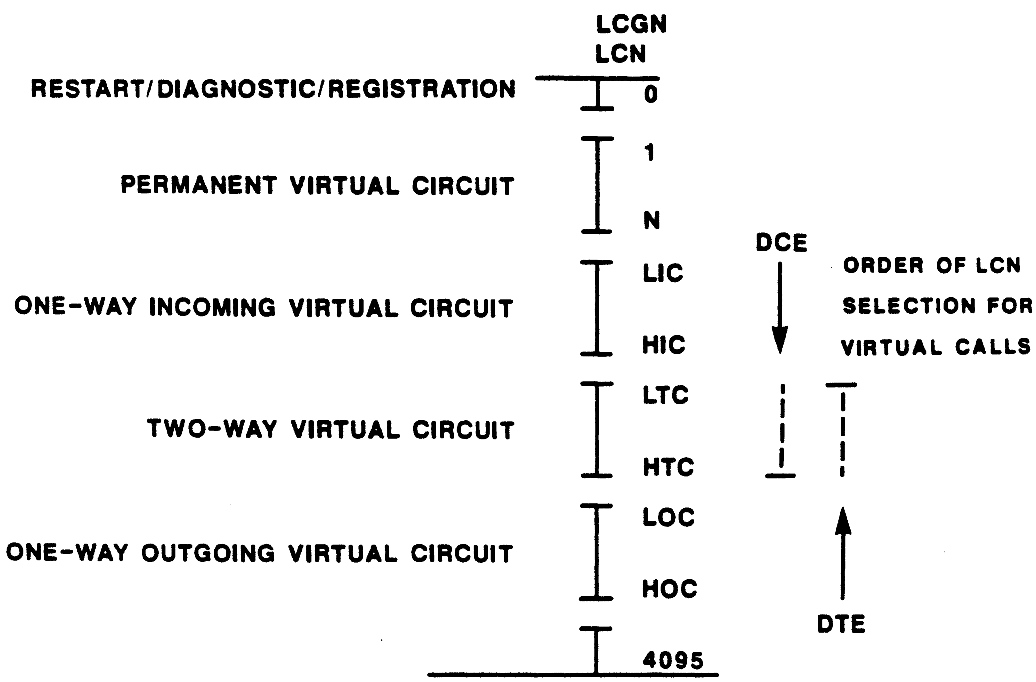
LIC = 005
HIC = 204
LTC = 204
HTC = 204
LOC = 204
HOC = 204

VIRTUAL CIRCUIT SERVICE



PK005A.125

LOGICAL CHANNEL ASSIGNMENT



PK005B.016

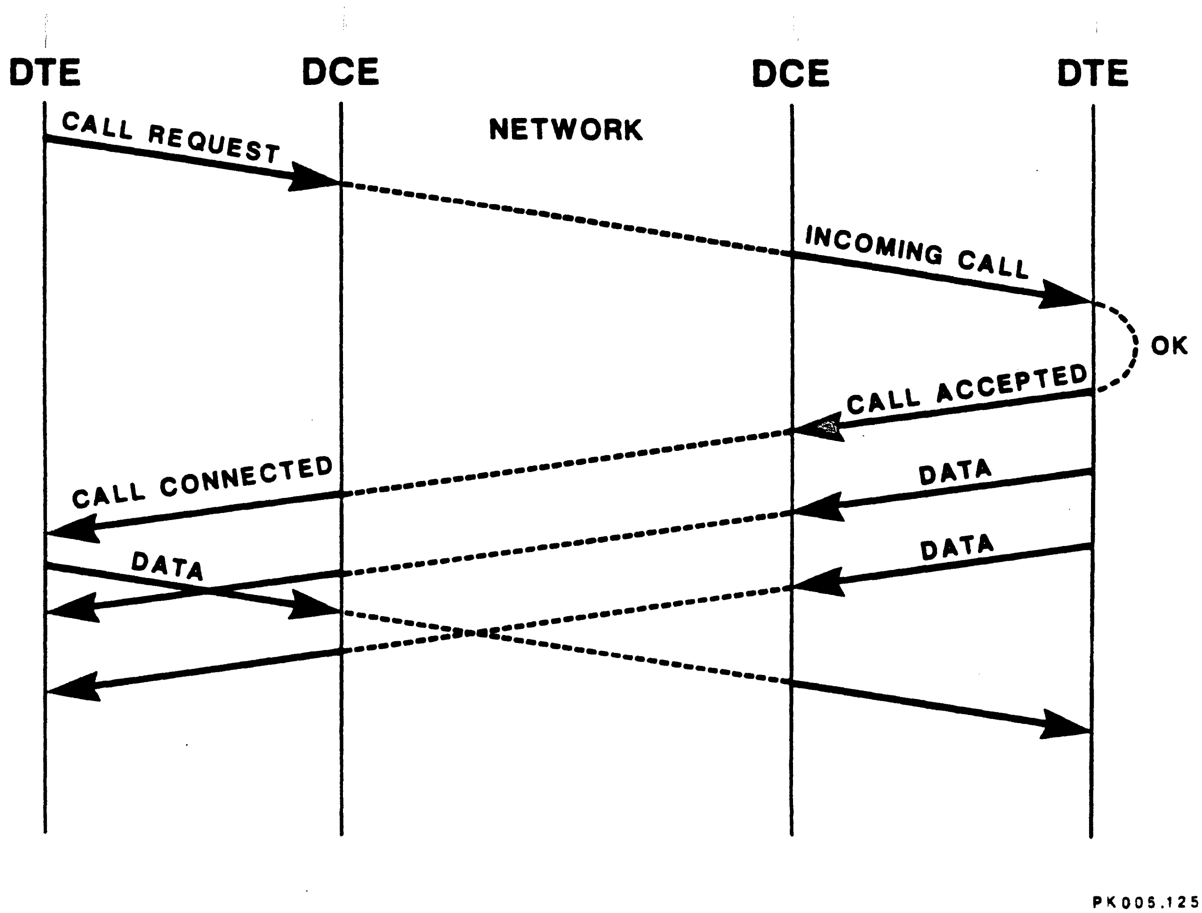
PK006.095

CALL ESTABLISHMENT

The establishment of a virtual circuit follows the classic procedures that have long been associated with circuit switching. The originating end issues a Call Request, which is processed by the network to establish the communication path with the desired destination. The receiving end is then sent an Incoming Call indication. If it is accepted, a Call Accepted packet is issued. In turn, the network notifies the originating end of the acceptance with a Call Connected packet.

Once the called DTE accepts the call, data can be sent. At the calling end, data can be sent after Call Connected is received. X.25 provides for duplex operation so that data can be transferred in both directions at the same time.

CALL ESTABLISHMENT



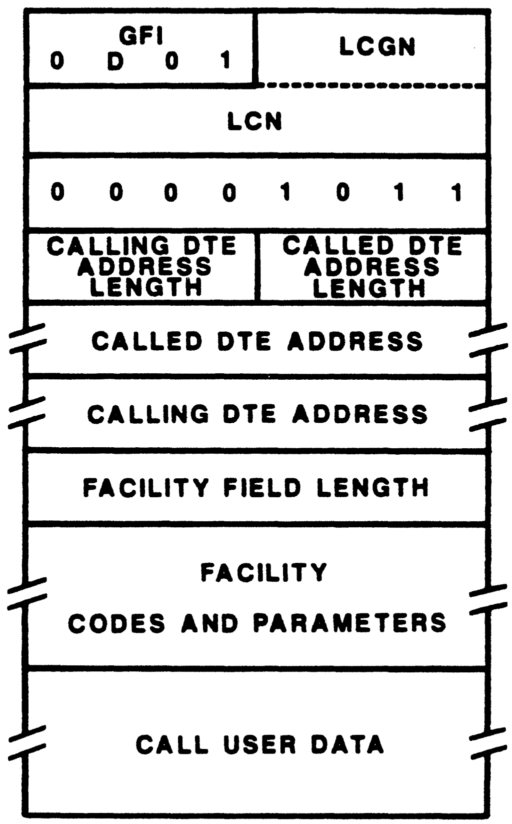
Does not apply to PVCs

PK024.124

CALL REQUEST/INCOMING CALL PACKET

The first three fields of these packets are described earlier. The additional fields contain the address and facility information associated with the establishment of the virtual calls. The address length fields define the boundaries of the addresses and locate the facility length field. The facility length field has a value range of 0 to 109 (expanded in 1984 from the 63 octets specified in the 1980 version). Its coding is binary. The address length fields and the facility length field are always present. There is also a 16 octet field that can contain user data which is conveyed transparently to the called destination. Optionally, the call user data field may be extended to 128 octets when using the Fast Select facility.

CALL REQUEST/INCOMING CALL



PK024.016

PK009.094

ADDRESS FIELDS

There are ten address fields that may be used. These appear immediately after the first three octets of the basic header in the Call Request and the Incoming Call packets. They are optional in the Call Accepted, Call Connected, Clear Request, Clear Indication, DTE Clear Confirmation, DCE Clear Confirmation, Registration Request and Registration Confirmation packets.

The length fields indicate the number of digits in each address and are binary encoded. Generally there is no calling address in a Call Request and no called address in an Incoming Call packet. The network takes care of appropriately mapping the corresponding addresses. When there is no address present, the associated length field is '0'.

The addresses are structured according to Recommendation X.121. They are encoded in binary coded decimal (BCD) in quartets of the address fields. Bits 8, 7, 6, and 5 of the first octet represent the highest-order digit of the number. Then the following digits are entered left to right in the next octets. If the address is an odd number of digits, then bits 4, 3, 2, and 1 of the last octet of the field are set to 0. The maximum length of each address field is fifteen digits, or BCD quartets. Since X.121 has a maximum length of 14 digits, this leaves a spare to use as an extension or access code.

For example, the TELENET network assigns addresses of 12 digits. Optionally, a one or two digit subaddress may be added to the end of the address by the user. The subaddress is passed transparently by TELENET to the remote DTE. On Call Request packets, TELENET requires the presence of the Called DTE Address and does not require the Calling DTE Address, but does not prohibit its inclusion by the DTE. On Incoming Call packets, TELENET includes the Called DTE Address as well as the Calling DTE Address.

The TRANSPAC network is somewhat different. The network assigns addresses of 8 digits. On Call Request packets, TRANSPAC requires the presence of the Called DTE Address and allows it to have an optional one or two digit subaddress on the end. The presence of the Calling DTE Address in Call Request packets is prohibited except for the optional subaddress. On Incoming Call packets, TRANSPAC includes the Calling DTE Address but does not include the Called DTE Address except for a subaddress.

LEGEND FOR FIGURE:

X.121 DNIC = ZXXX
Subscriber number (NTN) digits = N
Called number = ZXXXNNNNNNNNNN
Calling number = 2814102

ADDRESS FIELD EXAMPLES

CALL REQUEST

0 0 0 0	1 1 0 1	LENGTH
Z	X	
X	X	
N	N	CALLED ADDRESS
N	N	
N	N	
N	N	
N	0	

INCOMING CALL

0 1 1 1	0 0 0 0	LENGTH
2	8	CALLING ADDRESS
1	4	
1	0	
2	0	

BOTH ADDRESSES

0 1 1 1	1 1 0 1	LENGTH
Z	X	
X	X	
N	N	CALLED ADDRESS
N	N	
N	N	
N	N	
N	2	CALLING ADDRESS
8	1	
4	1	
0	2	

PK009.016

PK008.044

FACILITY MARKER

There are two basic types of facilities that are recognized. The first are the facilities that are standardized internationally in X.2. Then there are the facilities that are standardized nationally or within a specific network and the facilities which are described by the CCITT for use by DTEs in implementing the OSI Network Service. To keep the codings of the two types of facilities independent, a facility marker is provided.

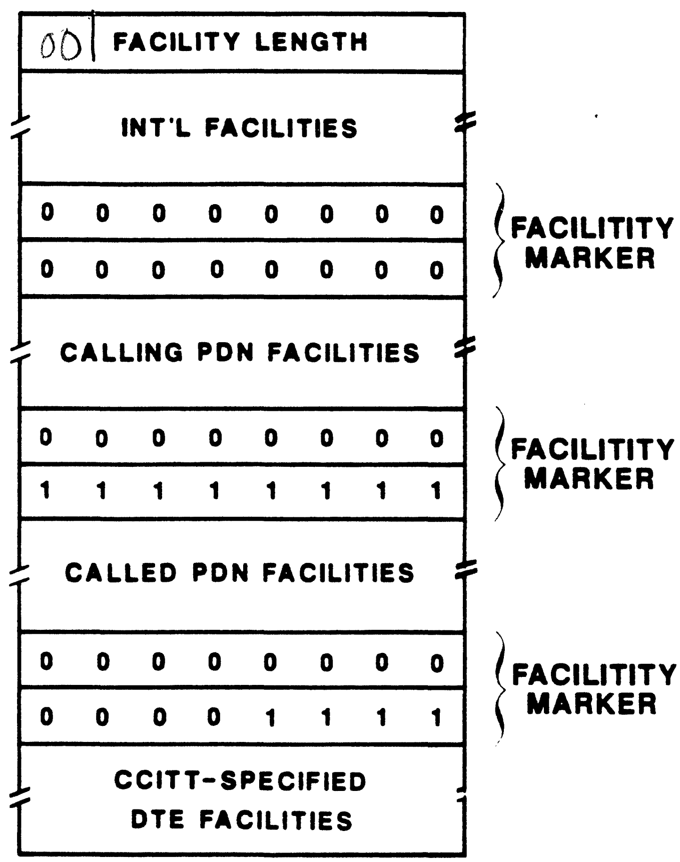
All internationally standardized facilities have a one-octet identifying code. The facility marker has a facility code of 0s and follows all international facility requests, thus marking the beginning of the national facilities. The facility marker code is followed by a parameter field of one octet.

One value of the facility marker parameter indicates that the following facilities are provided in the network where the communication is originating, while another indicates facilities for the network where the communication is destined. Facilities do not apply to any transit network. If there is a need for requests for national facilities in both the originating and the destination networks, both markers will appear with their basic facility code and the appropriate parameter value - each at the beginning of the respective codings for the specifically requested network-defined facilities. A third value of the facility marker parameter indicates that the following facilities are not facilities provided by the network but are facilities which convey Network Layer information required by the DTEs. Although these facilities are not network-provided, networks may check the values presented behind this marker.

The various facilities that can be requested on a per-call basis will be discussed later.

FACILITY MARKER

80 = 63
84 = 109



PK008A.016

PK010.114

FACILITIES FIELD

The facilities field is used to request special service features to be associated with the communication. They are provided optionally on a per-call basis. The details of the user facilities will be presented later. This section will deal only with the formats.

A facility request consists of a basic facility code followed by any associated qualifying parameters. As shown in the figure, there are four possible formats. The first octet in each case is used for the binary encoded facility code. Bits 8 and 7 of that octet are used to indicate the format that is to be used for associated parameters. These two bits are encoded as follows:

* 00 = one octet for the parameter
* 01 = two octets for the parameters
* 10 = three octets for the parameters
* 11 = a variable format.

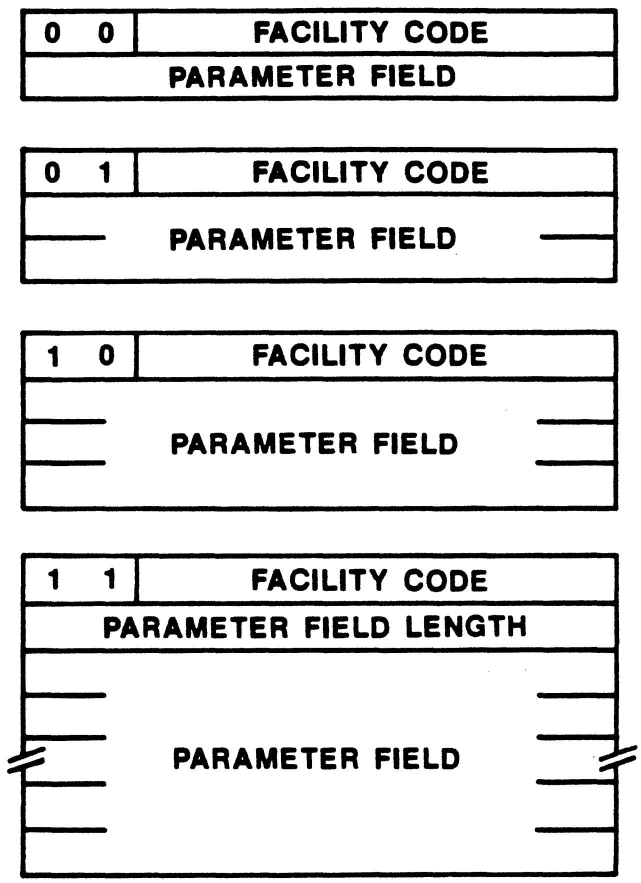
For the variable format, the second octet indicates the total number of octets allocated for specifying the parameters associated with the facility code.

The maximum length of the total facilities field is 109 (increased from 63 in the 1980 version) octets.

The list of facilities that are selectable on a per-call basis is given in Recommendation X.2. An extract of the list is given toward the end of this section. Some typical examples are:

* Closed user group selection
* Fast select call
* Request reverse charge
* RPOA selection
* Select optional data packet size.

FACILITY FIELD FORMATS



PK010.015

PK011.044

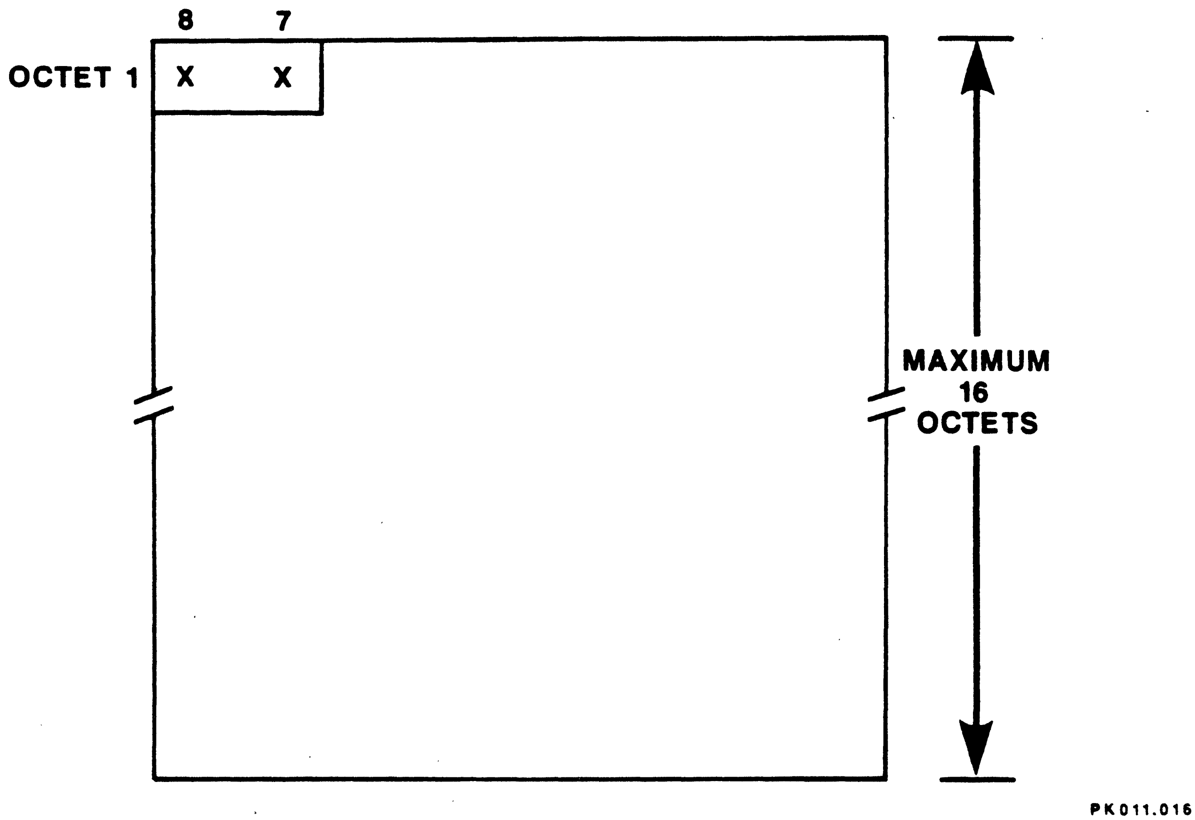
CALL USER DATA FIELD FORMAT

The Call User Data Field allows a maximum of 16 octets of information unless the Fast Select Facility is being used. In that case, the maximum is 128 octets. The structure of the field, however, has certain restrictions placed upon it. Bits 8 and 7 of the first octet have particular significance for protocol identification. These bits are encoded, as specified in Recommendation X.244, as follows:

* 00 = CCITT defined protocol, see X.29
* 01 = ISO defined protocol, none at this time
* 10 = Nationally defined protocol, up to particular network
* 11 = Open for DTE-DTE user definition.

It should be noted that if the user wants to ensure transparent transfer of the Call User Data, bits 8 and 7 of the first octet should be encoded "11." This applies to Call Request, Incoming Call, Call Accepted and Call Connected packets only.

CALL USER DATA FIELD



PK025.095

CALL CONNECTED/CALL ACCEPTED PACKET

In response to an Incoming Call, the called terminal will accept the call with the Call Accepted packet, which is conveyed to the calling end as a Call Connected packet. The address, facility, and called user data fields are optional. The address field is used only in conjunction with the Called Line Address Modified Notification facility. The facility field is used for negotiation during call set-up. The address length fields are all 0s when the address field is not used and there is a facility or called user data to be indicated. The facility field length is all 0s when the facilities field is not used and there is a called user data field.

Parameters, such as throughput class and packet size, are examples of facilities involving negotiation. For instance, the facility fields of the call set-up packets would contain the following hex codes if throughput classes were negotiated for a call:

	Call Request	Incoming Call	Call Accepted	Call Connected
a)	02	02	02	02
b)	A7	A7	97	97

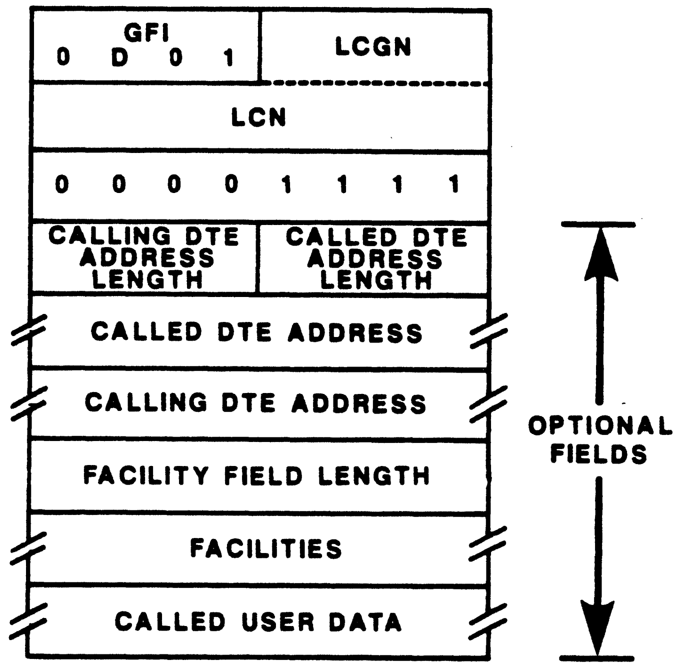
a) Throughput class negotiation facility code
b) Throughput class from called DTE/from calling DTE

The values of the throughput classes are:

Semi-octet (hex)	Throughput class (bits/s)
0	Reserved
1	Reserved
2	Reserved
3	75
4	150
6	600
7	1200
8	2400
9	4800
A	9600
B	19200
C	48000
D	Reserved
E	Reserved
F	Reserved

The value of the bits 8 and 7 in the first octet of the called user data field is subject to the same rules as in the call request and incoming call packets.

CALL ACCEPTED/CALL CONNECTED



PK025.016

PK012.114

DATA PACKET FORMATS

The data packets are made up of the first three basic octets plus a user data field. While the logical channel identification is the same as previously described, the GFI provides some additional functionality. As described earlier, bits 5 and 6 are used to indicate the applicable modulo for the sequence numbering. The two recognized number sequences are 8 and 128, for which there are two different data packet formats, as shown.

Bit 7 (the D-bit) is used to indicate the significance of the acknowledgement of the data packet transmitted. It may be acknowledged locally (D=0) by the network DSE or may be acknowledged after being received at the destination DTE (D=1). The D-bit value may be selected dynamically on a data packet-by-packet basis.

Bit 8 (the Q-bit) is used to indicate two levels of data. It can indicate a different destination application process or can differentiate between data and control information in the user data field. The Q-bit is carried transparently on an end-to-end basis. The only defined application of the Q-bit is in X.29 for the packet assembly/disassembly function.

The third octet is identified as the packet-type field, which up to now has only contained a fixed value. In the data packet, only bit 1 is significant as a fixed bit to indicate the type. In this case, it is always equal to 0. The P(R) and P(S) parts are used to indicate the sequence numbers. For modulo 8, the numbers rotate between 0 and 7, and for 128, between 0 and 127. The first packet in a sequence is always 0. The numbers are only significant between the DTE and the DCE (or DSE), but they may rotate due to the action of either the local DSE or the destination DTE, depending upon the status of the D-bit. The M-bit is used to identify sequences of related packets that make up a complete NSDU being passed between Transport users.

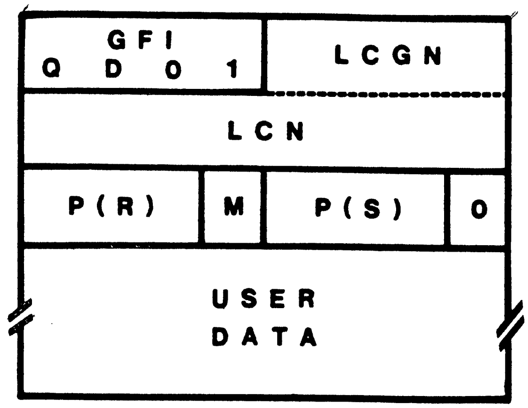
The standard maximum length for the user data field is 128 octets. All X.25 networks must support this value. X.25 also specifies that the user data field can be any number of bits in length up to the maximum. There are a number of networks, however, that will only recognize an integral number of octets up to the maximum allowed. Therefore, the 1980 and 1984 versions of X.25 have a cautionary note that, if full compatibility is to be assured with all networks, the data field in transmitted packets should end on an octet boundary. In other words, the DTE is responsible for padding the odd number of bits to make an even octet. This also applies to any packet, in addition to the data packet, that contains a data field. In the 1984 version, a network, which requires octet alignment, can recover from octet alignment errors using procedures in either the link level or the packet level. Optionally, networks may also provide additional maximum lengths for the data fields of data packets on either a subscription basis or dynamically on a per call basis. The recognized options are: 16, 32, 64, 256, 512, 1024, 2048 and 4096 octets. When different sizes are used by the DTEs or internally in transited networks, there is the requirement for segmenting and blocking of packets to different or more optimum sizes.

DATA PACKET

MODULO 8

Q = user defined

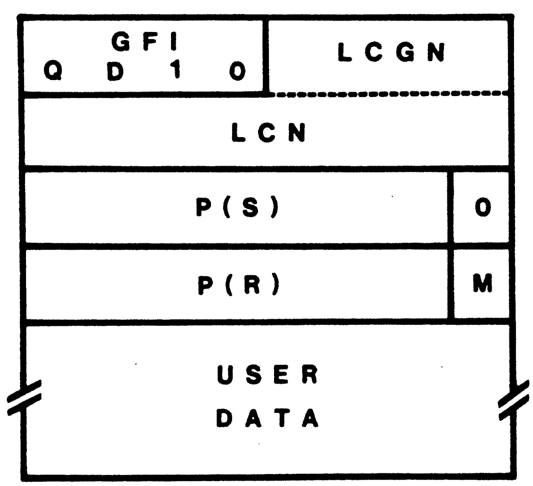
D = Delivery



PK012A.073

DATA PACKET

MODULO 128



PK012B.073

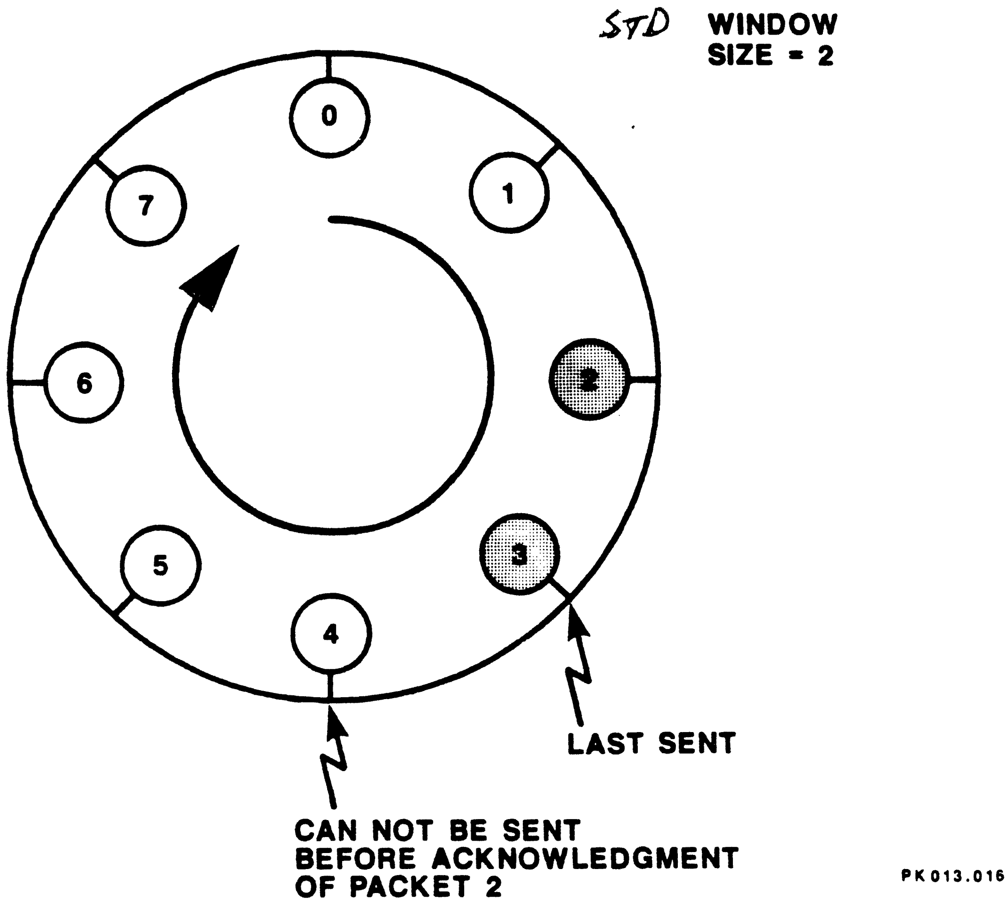
PK013.122

WINDOW DESCRIPTION

The sequence numbers are used for each logical channel and for each direction of transmission. The P(S) is used to identify the sequence number of the data packet sent, while the P(R) is used to identify the sequence number of the next data packet that is expected to be received. The P(R), therefore, implicitly acknowledges receipt of any preceding data packets. These would be packets with sequence numbers of P(R)-1 and less.

In addition, for each logical channel and for each direction of data transmission, a window W defines the maximum set of consecutive data packets authorized to cross the interface before an acknowledgement is received via the P(R). The first packet to be sent when the data phase is initially entered has a P(S)=0. The numbers sequentially rotate from 0 to 7 for modulo 8 as packets are being sent. When the window W value is established as being the standard value of 2, no more than two data packets can be sent before a P(R) is received to acknowledge the first or both of the packets. This serves to limit the flow of packets to a value that can be accommodated by the network or receiving DTE. Other values of W are also possible as options or on a dynamically negotiated basis per virtual call. The maximum possible value of W for modulo 8 is 7.

WINDOW CONTROL



PK014.095

FLOW CONTROL PACKETS

While the window provides one means by which the flow of the data packets can be controlled, there are two control packets that can be used to specify the start and stop of transmissions. These are the Receive Ready (RR) and Receive Not Ready (RNR) packets. Both types include a P(R) value in the packet type field to indicate the next packet sequence number that is expected to be received.

The RNR packet is used to request the other end to stop sending data packets and uses the P(R) to acknowledge the data packets that have been received.

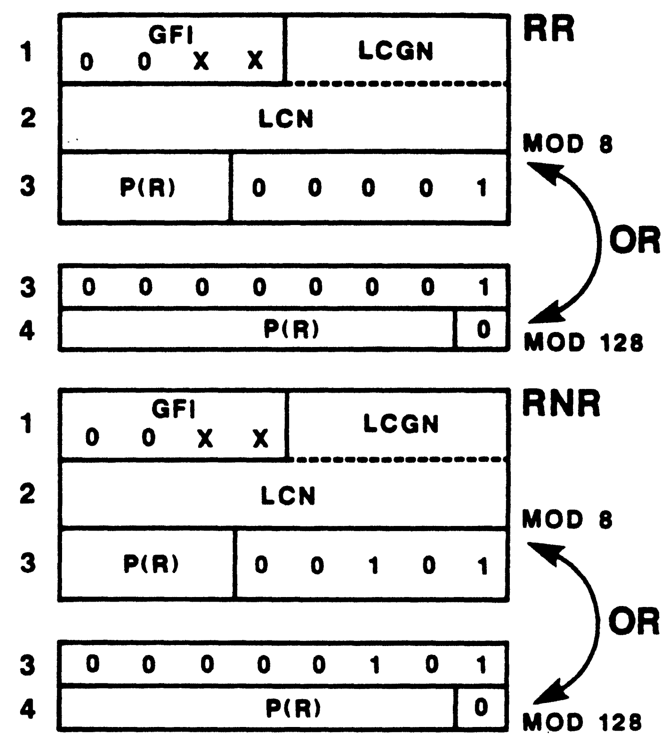
The RR packet is used to tell the other end to start sending data packets and uses the P(R) to acknowledge the data packets that have been received. The RR packet is also used to acknowledge packets received when there are no data packets to convey the P(R) value back to the sending end.

Data packets that are received should be acknowledged promptly if good throughput is desired. The receiving end can effectively hold up the flow of data packets from the sending end by not acknowledging those packets that have been received within the window value.

LEGEND:

X X - Either 0 1 for modulo 8 or 1 0 for modulo 128

FLOW CONTROL



PK014.016

PK015.122

PACKET RETRANSMISSION

Packet retransmission is an optional capability that can be provided by some networks on a subscription basis. It enables the DTE to request retransmission of one or more consecutive data packets that have not been previously acknowledged.

The value of the P(R) in the DTE Reject packet indicates the sequence number from which the network should start to retransmit. The value of this P(R) should be within the range from the last P(R) received by the network up to, but not including, the next P(S) to be sent by the network. The transmission of a DTE Reject packet also clears an RNR condition that may have previously existed in the DTE.

DTE REJECT

MODULO 8

GFI 0	0	0	1	LCGN			
LCN							
P(R)			0	1	0	0	1

MODULO 128

GFI 0	0	1	0	LCGN			
LCN							
0	0	0	0	1	0	0	1
P(R)							0

Some networks may supply this.

DTE packet only!

PK015.016

PK016.114

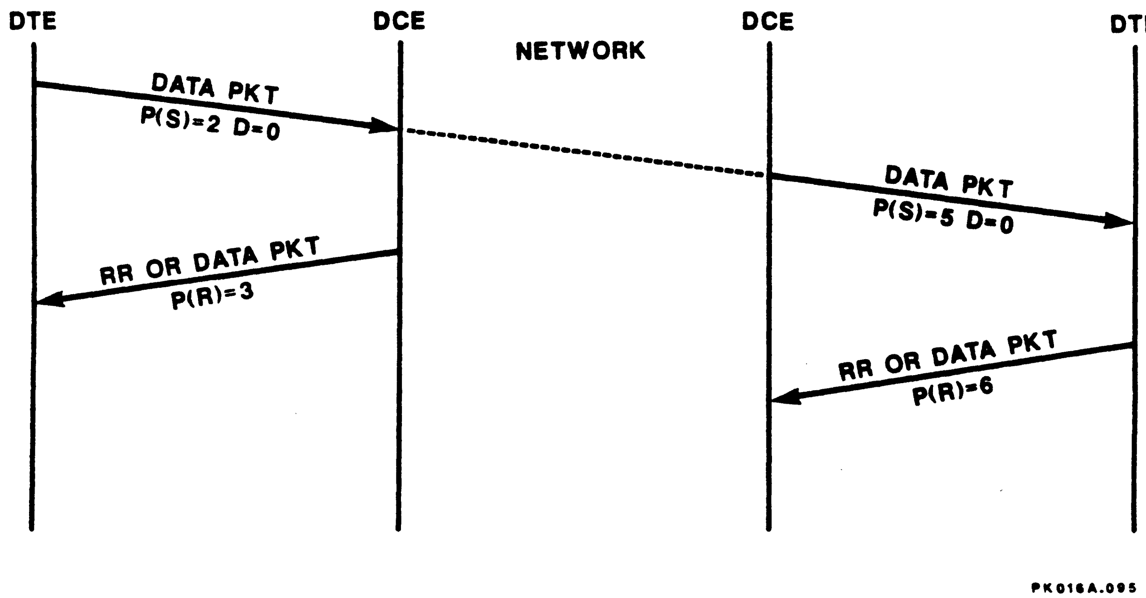
SIGNIFICANCE OF ACKNOWLEDGEMENT

Probably the most controversial addition to X.25 is the provision for using the D-bit to dynamically select the significance of the P(R) acknowledgement. Originally, the standard specified that the P(R) acknowledgement indicated only that the data packet was received by the DSE in the network. It was recognized, however, that in some networks acknowledgement indicated delivery to the destination DTE. Since this led to a conflict in standard operation, a compromise was reached to provide for both capabilities.

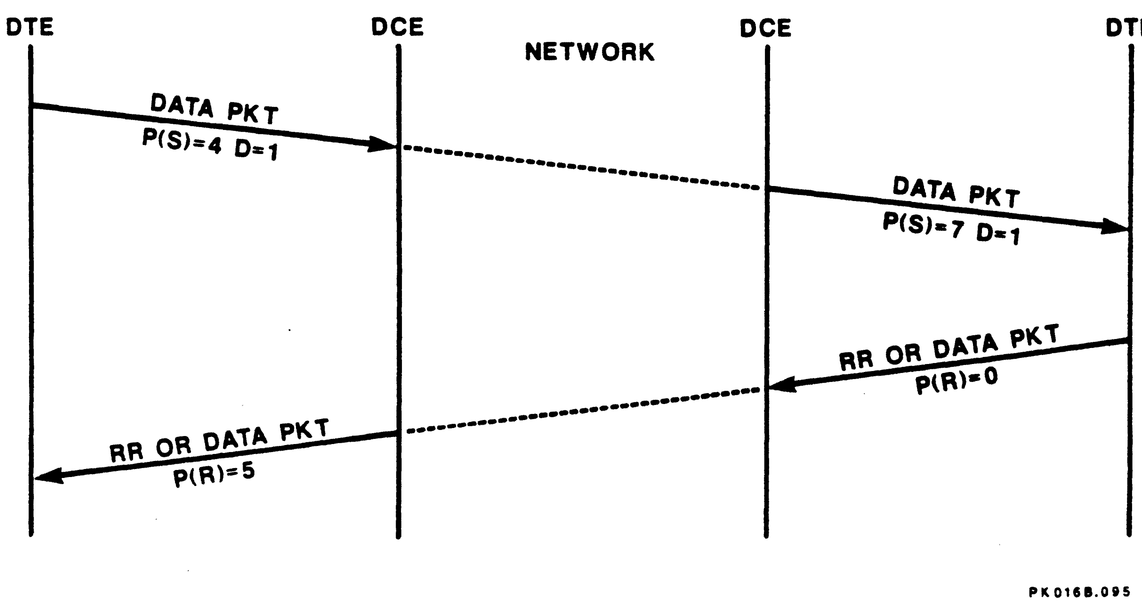
When the D-bit is set to 0, the P(R) value indicates acknowledgement of receipt of the respective data packets by the network. When D=1, P(R) is not given to acknowledge the associated P(S) value until the destination has received and acknowledged that data packet. Therefore, an end-to-end verification is, in effect, provided.

Although the D-bit can be set individually to either value on each data packet, there are additional considerations that need to be taken with respect to the value of the M-bit and a packet sequence. Also, the effect of D-bit usage on throughput must be recognized. The difference between never setting the D-bit and always setting the D-bit is significant. Alternative policies for setting the D-bit between these two extremes can minimize the increase in throughput caused by the end-to-end acknowledgement while maintaining the degree of acknowledgement desired.

P(R) SIGNIFICANCE: LOCAL



P(R) SIGNIFICANCE: END-TO-END



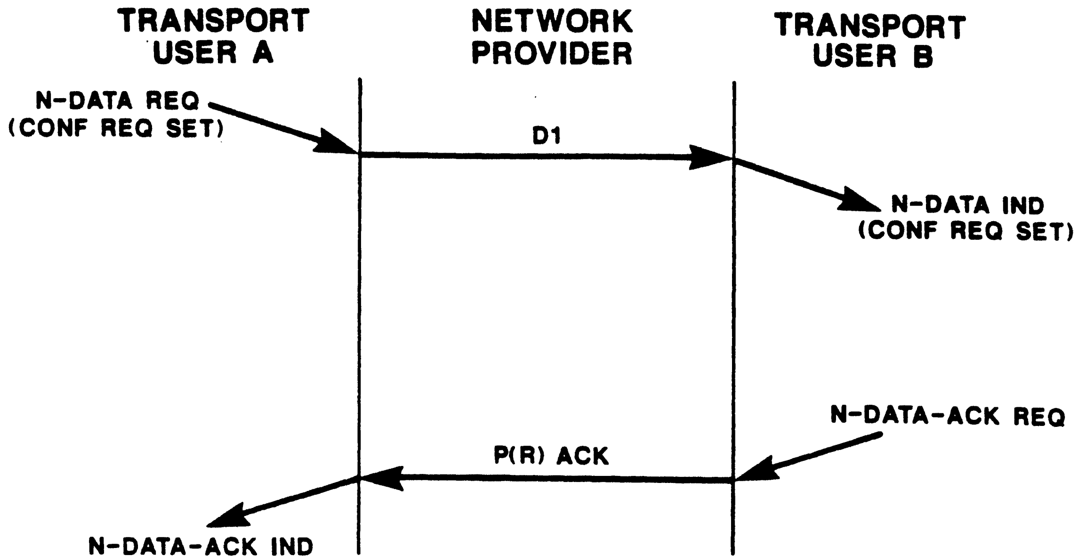
PK031.044

RECEIPT CONFIRMATION

In X.25 there are no rules stating when the packet level in the DTE receiving some data should acknowledge that data in relation to whether or not the next upper layer receives and possibly acknowledges the data. The OSI Network Layer service definition defines such rules as a service, called Receipt Confirmation. This allows the Transport Layer entities to exchange acknowledgements of data within the control information at the Network Layer. The D bit is the mechanism in the X.25 Packet Level used to accomplish this service. The figure shows the packet level using the D bit when the Transport Layer is using the receipt confirmation service and issuing the acknowledgement of data only when notified by the receiving Transport Layer entity. The sending Network Layer entity notifies the Transport Layer when the acknowledgement is received.

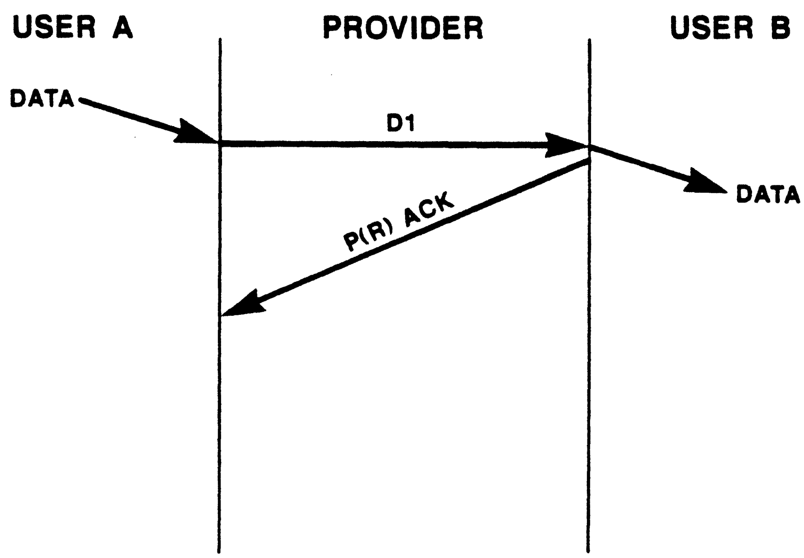
Another kind of confirmation, called Delivery Confirmation, is when the packet level acknowledges data with D=1 upon passing the data to the upper layer, that is, without waiting for a notification of its receipt.

RECEIPT CONFIRMATION



PK031A.125

DELIVERY CONFIRMATION



PK031B.125

PK017.044

COMPLETE PACKET SEQUENCE

X.25 provides the capability to identify a related sequence of packets. This may be used to provide a service to the higher layers in preserving the identification of a block of data or when the network segments or blocks packets. The latter is of particular importance when there is interworking between networks that handle different maximum data field sizes.

A complete packet sequence is defined as being composed of a single category B packet and all contiguous preceding category A packets, if any. Or it can be said that a sequence is a single category B packet or a series of contiguous category A packets followed by one category B packet.

The following are some additional qualifications to be considered:

* A category A packet must contain the maximum amount of data and M=1, D=0.

* A category B packet always ends a sequence.

* Category A packets and the ending category B packet can be combined by the network to make larger packets.

* Only category B packets can have D=1 for end-to-end acknowledgement.

* Any packet that is not as defined as a category A packet is a category B packet.

There are two types of category B packets: those with M=1 and those with M=0. This enables the formation of subsequences as part of a larger super sequence where end-to-end acknowledgements can be done before the end of the larger sequence. In this case category B packets with M=1 are inserted within the larger sequence when an intermediate end-to-end acknowledgement is needed. An illustration is provided later.

* A Data packet which is not full and has M=1 and D=0 is a category B packet but is treated by the network as if it had M=0. The Data packet delivered to the remote DTE would have M=0.

PACKET CATEGORIES

DATA PACKET SENT BY SOURCE DTE			
CATEGORY	M	D	FULL
A	1	0	YES
B	0*	0	NO
B	0	1	NO
B	0	0	YES
B	0	1	YES
B	1	1	NO
B	1	1	YES

PK017.016

PK018.122

PACKET SEQUENCES

When different packet sizes are supported along the route of a virtual connection, it may be necessary for the network to combine or segment packets. By using the M bit, the DTE can identify which packets can be combined by the network. Only A packets and the immediately following B packets can be combined. Two B packets cannot be combined.

For segmenting, any type of packet can be divided into smaller pieces. The M bit can then be used to indicate to the receiving DTE that there is a related sequence.

EXAMPLE PACKET SEQUENCES

ORIGINAL SEQ PKT TYPE	M =	D =		COMBINED SEQ PKT TYPE	M =	D =
A	1	0				
A	1	0	→	A	1	0
A	1	0				
A	1	0	→	A	1	0
A	1	0				
B	0	1	→	B	0	1

ORIGINAL SEQ PKT TYPE	M =	D =		SEGMENTED SEQ PKT TYPE	M =	D =
B	0	0	→	A	1	0
			→	B	0	0

PK018A.016

EXAMPLE PACKET SEQUENCE WITH INTERMEDIATE E-E ACK

PKT TYPE	M =	D =	
A	1	0	*
A	1	0	*
A	1	0	*
B	1	1	*
A	1	0	*
A	1	0	*
B	1	1	*
A	1	0	*
A	1	0	*
A	1	0	*
B	0	1	*

END OF SEQUENCE

* GROUPS OF PACKETS THAT CAN BE COMBINED

PK018B.125

PK019.095

CLEARING

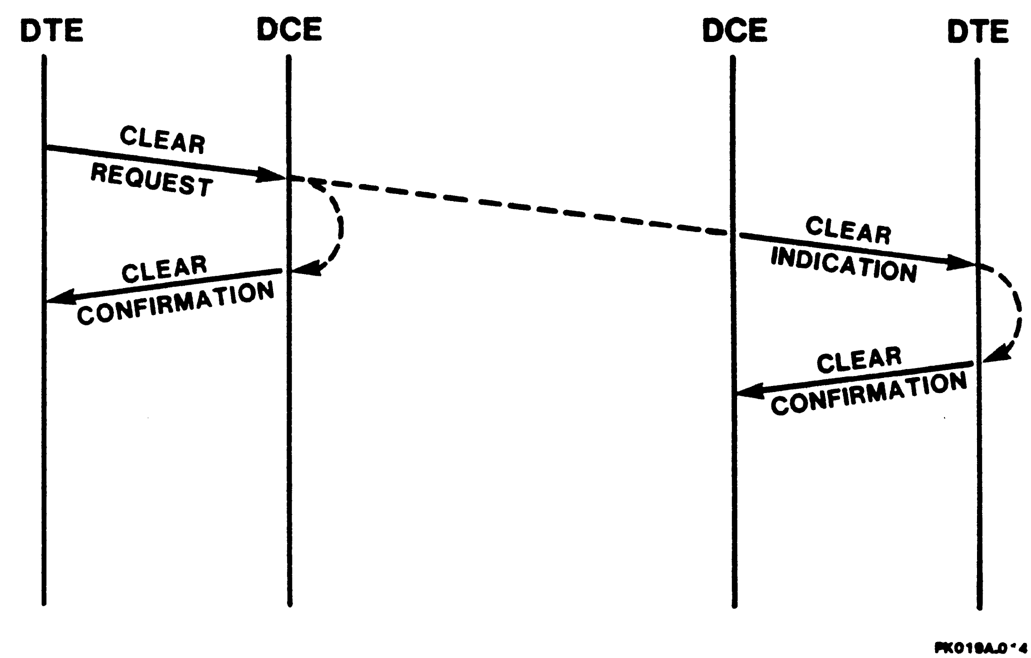
When the communication is completed and the virtual circuit is not needed any longer, it can be released through the clearing procedure. The clearing terminal issues a Clear Request packet to the network. If the network provides end-to-end significance, the call will then be cleared and the other end issued a Clear Indication packet. In response, the cleared DTE sends a Clear Confirmation packet. The network then sends a Clear Confirmation packet to the end that cleared the call. If the network provides only local acknowledgement, then a Clear Confirmation is sent immediately to the clearing DTE while the circuit is being cleared and the other end is notified with a Clear Indication.

If the user or the network initiates the Clear procedure and then receives (for the same logical channel) a Clear Indication or Clear Request packet respectively, the received packet is accepted in place of the Clear Confirmation packet. In this case, a Clear Confirmation packet is not sent.

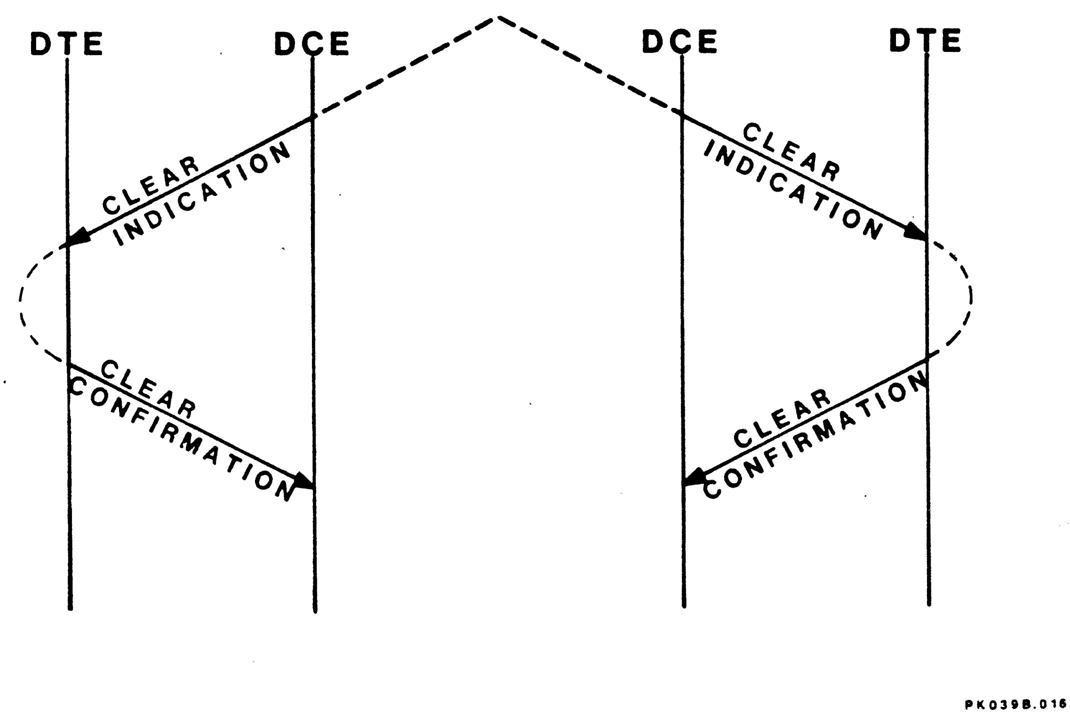
Care must be taken, however, to prevent clearing a call too soon. Since Clearing packets are not flow controlled, they can bypass any flow controlled data packets that may be en route to the destination. If this happens, data will be lost. Therefore, it is recommended that a simple handshake procedure be followed to ensure all data has been received before clearing. Such a procedure - Invitation to Clear - is provided in Recommendation X.29 for the Packet assembly/disassembly operation. The Session protocol also provides for orderly clearing to ensure that data transfer is completed before disconnect.

Since clearing terminates the call, all activities within the data transfer phase of the call are stopped immediately. Therefore, expected data transfer phase acknowledgments like reset confirmation or acknowledgment of data are not necessary for the completion of the clearing procedure.

CLEARING BY DTE



CLEARING BY NETWORK



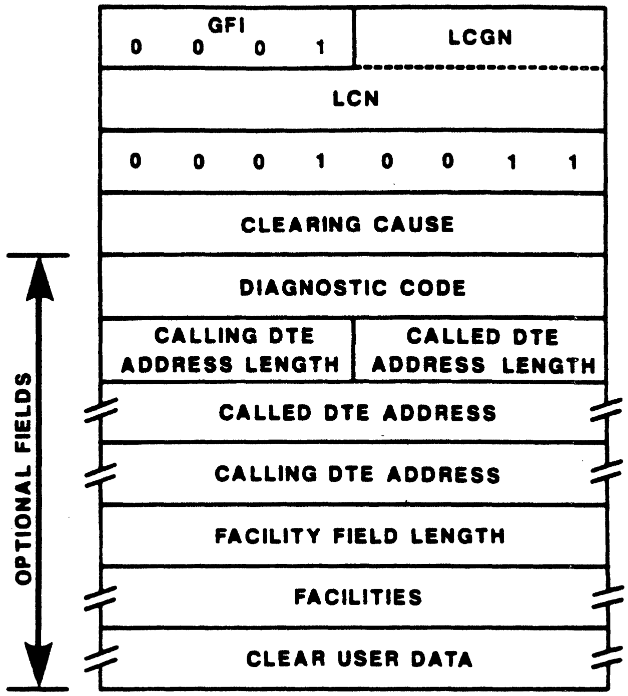
PK038.044

CLEARING PACKETS

The address lengths, address, facilities field length, facilities and clear user data fields on Clear Request and Clear Indication packets are optional. In addition, the diagnostic code field is optional on Clear Request packets. The address field is used in conjunction with the Called Line Modified Notification facility when a call is refused. The facilities field is used for several user facilities including Charging Information. The clear user data field is used as part of the Fast Select facility and has a maximum length of 128 octets (see Recommendation X.244). In the 1980 version, clear user data could only be present on a Fast Select call that was not accepted. The use of this field has been expanded in the 1984 version to allow it in clearing a Fast Select call that has been set-up. The diagnostic code, address lengths and facilities field length fields must be present whenever the packet contains fields which follow them (e.g. the facilities length field must be present whenever there is a clear user data field). When the address field is not present the address lengths field is coded all 0s. When the facilities field is not present the facilities field length is coded all 0s.

The address lengths, address, facilities field length and facilities fields are optional on Clear Confirmation packets. The facilities field is used in conjunction with the Charging Information facility. Currently, the address field is not used, but is defined for consistency with other similar packet formats. Therefore, the address lengths field is coded all 0s. The address lengths field must be present when the facilities field length field is present in the packet.

CLEAR REQUEST/INDICATION

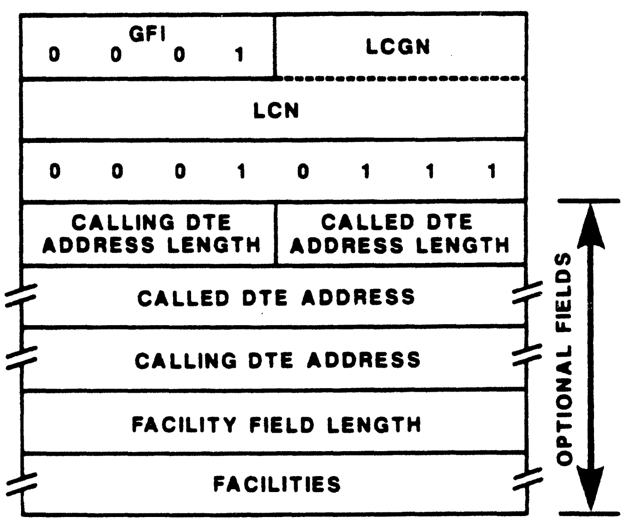


'84 DTE originated non-zero
For private networks high order bit is set to 1.

Only allowed in Fast Select

PK038A.015

CLEAR CONFIRMATION



For charging purposes

PK038B.015

PK036.044

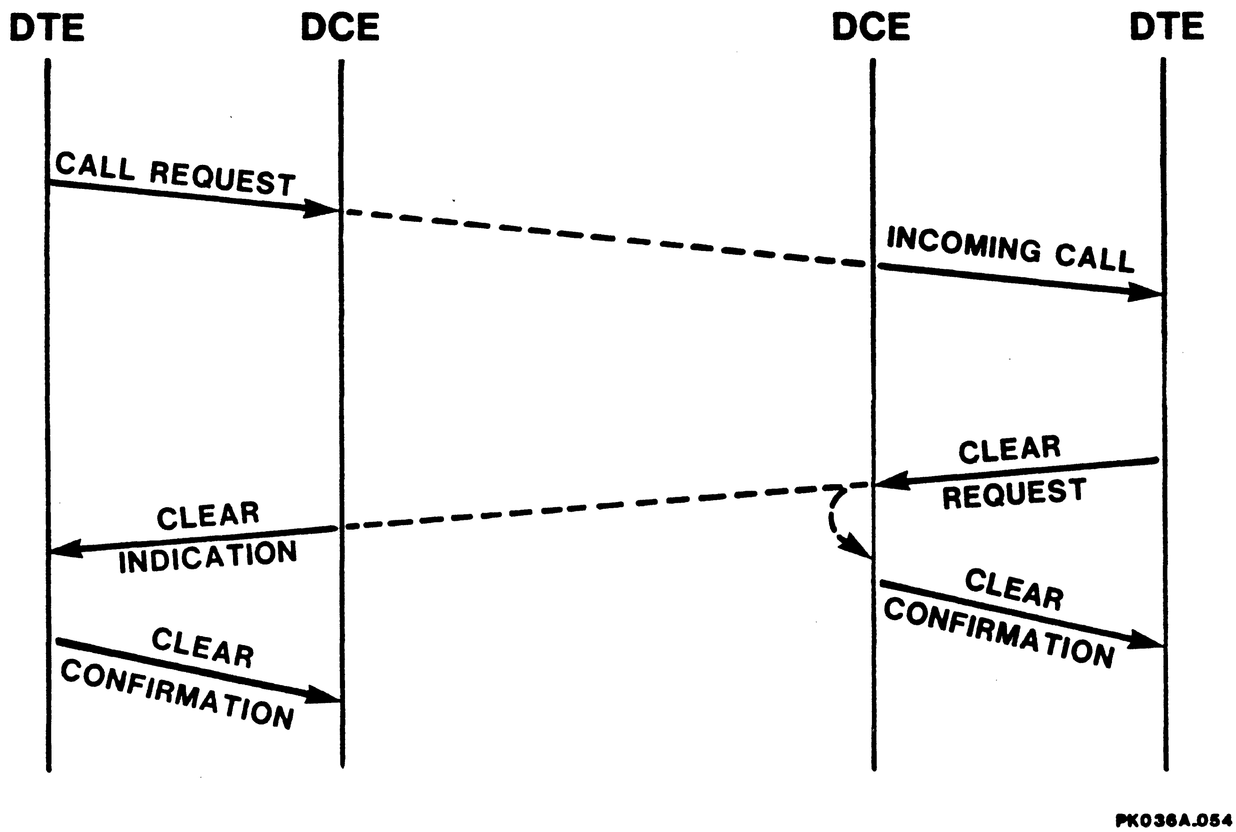
CLEARING CAUSES

Clearing packets can also be issued anytime by a DTE or the network as a result of some operation problem. Such packets issued by the network will indicate the reason in the cause field together with a diagnostic code which can further qualify the reason for the problem.

CLEARING CAUSE CODES

	BITS 8	7	6	5	4	3	2	1
DTE originated	0	0	0	0	0	0	0	0
				or				
	1	X	X	X	X	X	X	X
Number busy	0	0	0	0	0	0	0	1
Out of order	0	0	0	0	1	0	0	1
Remote procedure error	0	0	0	1	0	0	0	1
Reverse charging acceptance not subscribed	0	0	0	1	1	0	0	1
Incompatible destination	0	0	1	0	0	0	0	1
Fast select acceptance not subscribed	0	0	1	0	1	0	0	1
Ship absent	0	0	1	1	1	0	0	1
Invalid facility request	0	0	0	0	0	0	1	1
Access barred	0	0	0	0	1	0	1	1
Local procedure error	0	0	0	1	0	0	1	1
Network congestion	0	0	0	0	0	1	0	1
Not obtainable	0	0	0	0	1	1	0	1
RPOA out of order	0	0	0	1	0	1	0	1

CALL REFUSAL BY DTE

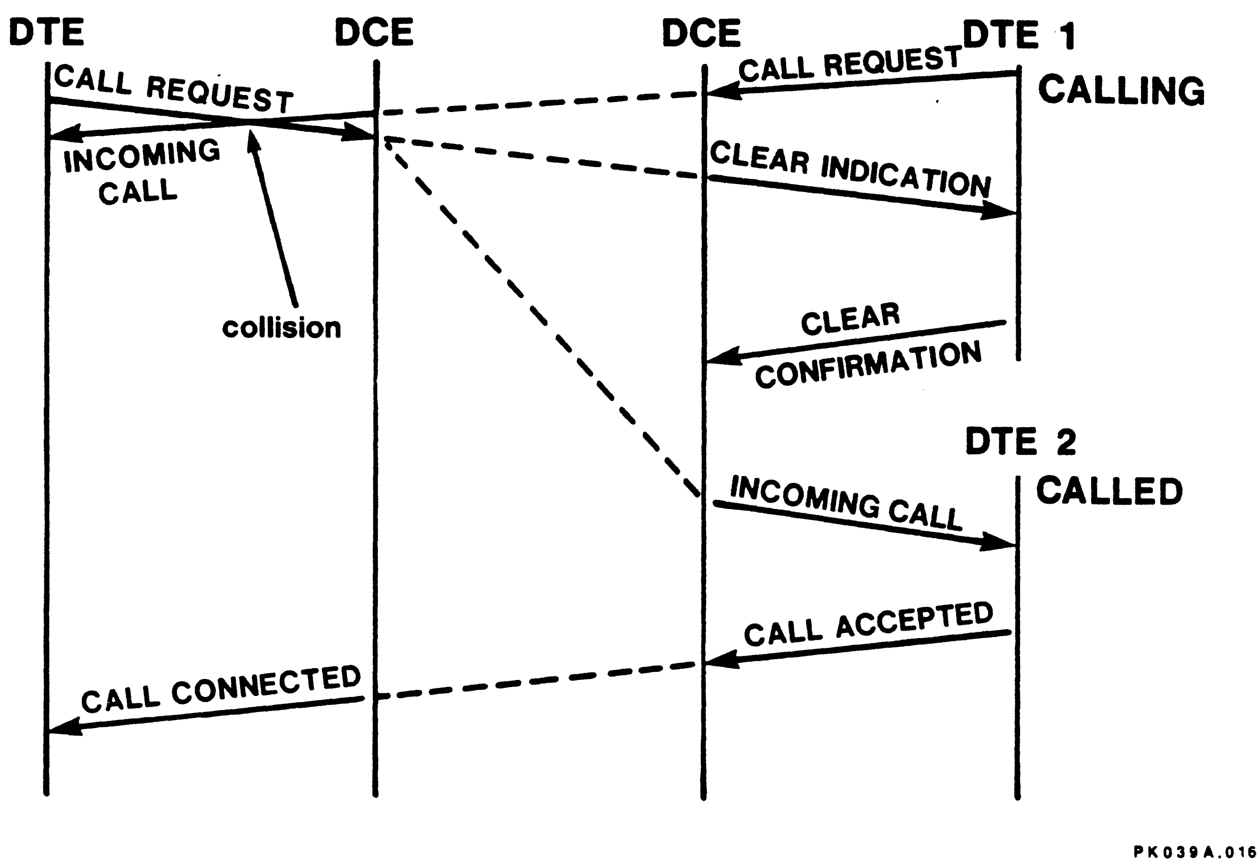


PK039.016

CALL COLLISION

If the user or the network initiates the Call Set-up procedure and then receives, for the same logical channel, an Incoming Call or Call Request packet, respectively, a call collision has occurred. This happens only when all other virtual call logical channels are already in use. The user does not respond to the Incoming Call and waits for its Call Request to be answered. The network responds to the remote DTE, on behalf of which the Incoming Call was sent, with a Clear Indication packet and proceeds with the "collision" Call Request.

CALL COLLISION



PK007.044

INTERRUPT PROCEDURE

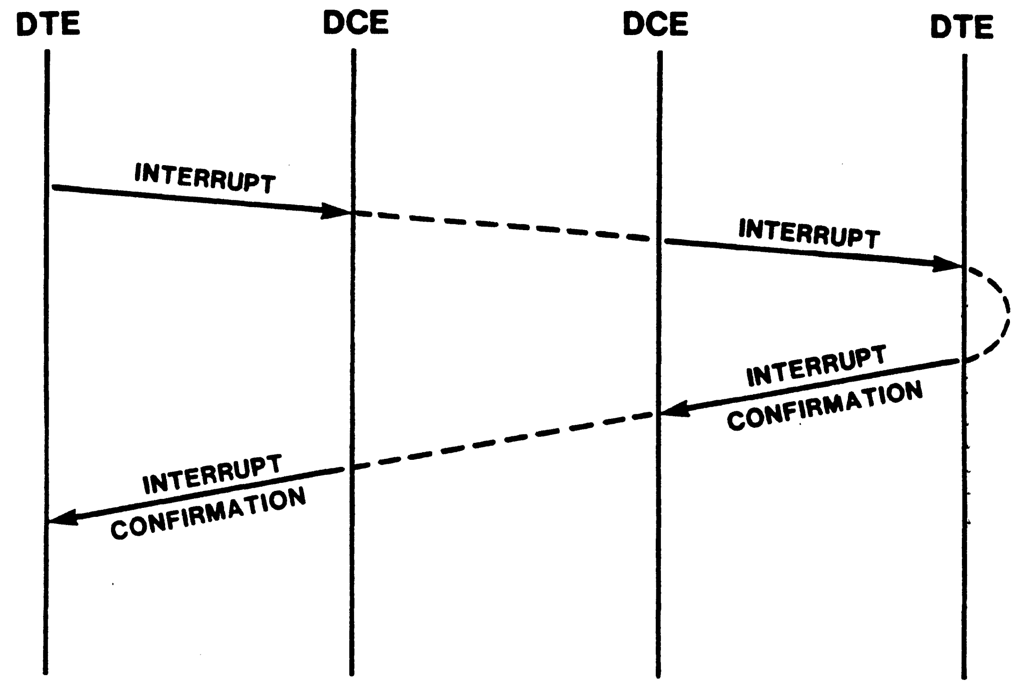
The interrupt procedure enables data to be sent bypassing the normal flow control procedures that normal data packets must follow. This provides a similar capability to OSI Expedited Data. It is intended to pass a limited amount of data infrequently with a notion of priority - it is not to arrive any later than normal data packets sent after the interrupt. These packets should be handled as expeditiously as possible.

The data field size is a minimum of one octet and a maximum of 32 octets. This is an expansion from the one octet defined in previous versions of X.25 and may not be implemented by all networks for some time.

Only one interrupt without a return confirmation can be outstanding at a time. This prevents flooding of the network with non-flow-controlled packets.

The basic use is for recovery, job interruption, and system management functions. It is not intended to provide an alternate path for normal transfer of data that would be sent in proper data packets. Interrupts should be infrequent and contain only a small amount of data.

INTERRUPT



PK007A.014

INTERRUPT

GFI				LCGN			
0	0	0	1				
LCN							
0	0	1	0	0	0	1	1
INTERRUPT USER DATA (MIN. 1 OCTET)							

'84 MAX is 32 octets

INTERRUPT CONFIRMATION

GFI				LCGN			
0	0	0	1				
LCN							
0	0	1	0	0	1	1	1

PK007B.016

PK061.016

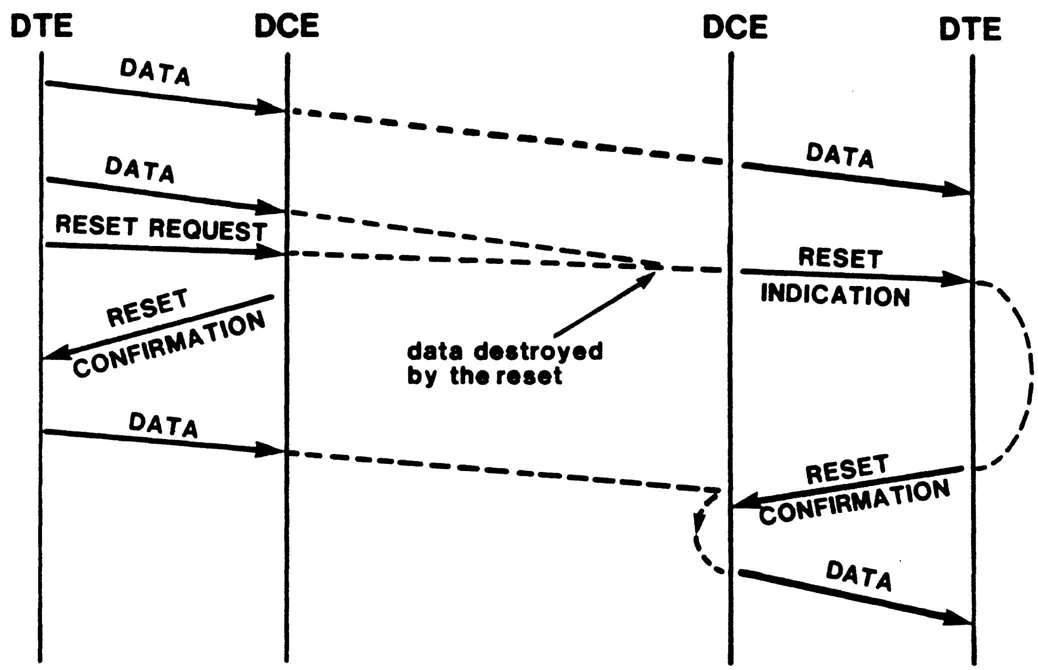
RESETTING

If an error or unrecoverable situation is encountered, the Reset packet can be used to reinitialize the logical channel. The P(R) and P(S) values will be reset to 0 to serve as a new starting point. There is a danger, however, that data packets en route just prior to a Reset may be lost and not delivered to the destination. Procedures at higher layers will have to be invoked to recover from lost data. The flow control and interrupt procedures also start over - there is no RNR condition and no outstanding interrupt packets.

Either the user or the network may initiate the Reset procedure by sending a Reset Request or Reset Indication packet, respectively. Then the network or user responds by sending a Reset Confirmation packet. If the user starts the Resetting procedure, then the network resets the remote user as well. When the user initiates Resetting, if the network provides end-to-end significance for the confirmation, the Reset Confirmation packet is sent to the user after the confirmation has been received from the remote user. Otherwise (if the network provides local significance), the network confirms the Reset Request as soon as it is prepared to handle data again.

If the user or the network initiates the Reset procedure and then receives, for the same logical channel, a Reset Indication or Reset Request packet, respectively, the received packet is accepted in place of the Reset Confirmation packet. In this case, a Reset Confirmation packet is not sent.

RESETTING BY DTE

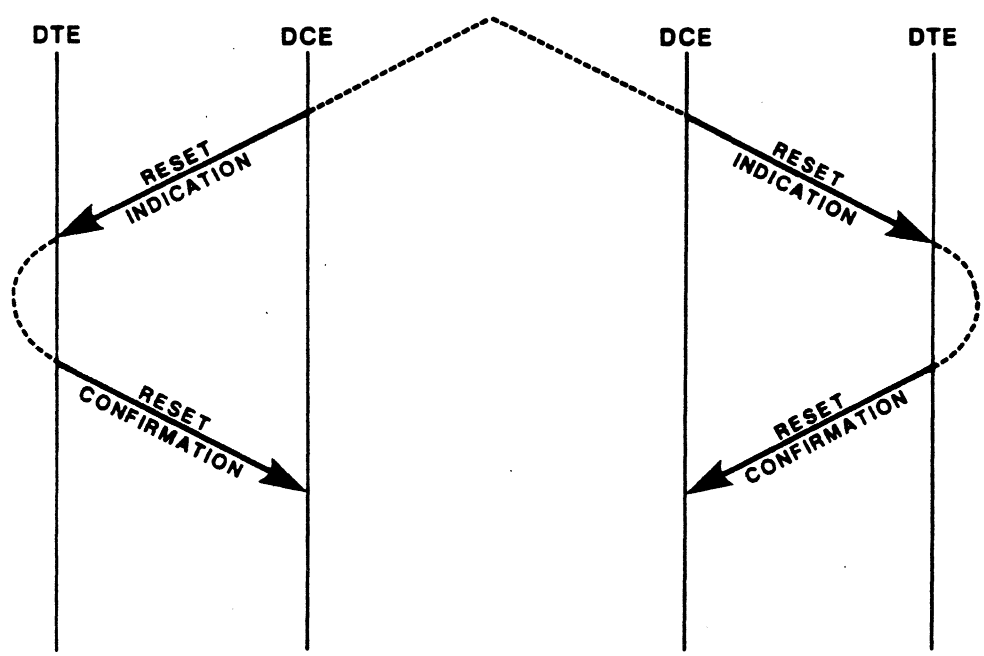


PK020A.014

Keep the connection

RESETTING BY NETWORK

DTE Reject Facility can be subscribed



PK020C.016

PK020.044

RESETTING PACKETS

Reset Request/Indication packets will include a Cause field identifying the reason for the action. Additionally, there is a Diagnostic field with a more detailed explanation of the reason included in Reset Indication packets. This Diagnostic field is optional on Reset Request packets.

RESETTING CAUSE CODES

	8	7	6	5	4	3	2	1
DTE originated	0	0	0	0	0	0	0	0
				or				
	1	X	X	X	X	X	X	X
Out of order*	0	0	0	0	0	0	0	1
Remote procedure error	0	0	0	0	0	0	1	1
Local procedure error	0	0	0	0	0	1	0	1
Network congestion	0	0	0	0	0	1	1	1
Remote DTE operational*	0	0	0	0	1	0	0	1
Network operational*	0	0	0	0	1	1	1	1
Incompatible destination	0	0	0	1	0	0	0	1
Network out of order*	0	0	0	1	1	1	0	1

* Applicable to permanent virtual circuit only

RESET PACKET FORMATS

RESET REQUEST/INDICATION

GFI				LCGN			
0	0	0	1				
LCN							
0	0	0	1	1	0	1	1
RESETTING CAUSE							
DIAGNOSTIC CODE (OPTIONAL) FOR DTEs							

RESET CONFIRMATION

GFI				LCGN			
0	0	0	1				
LCN							
0	0	0	1	1	1	1	1

PK020B.016

PK021.044

RESTARTING

The Restart procedure is only used in a dire emergency when no other recovery procedure is possible. The Restart reinitializes all logical channels in the interface and clears all the virtual calls that are established. Logical channels with Permanent Virtual Circuits are Reset.

Restart packets can only be sent on logical channel 0 which is reserved for control packets affecting all logical channels. There is no quick recovery from a restart because all the calls are cleared. Each call will then have to be reestablished through the normal call establishment procedure. If there is a large number of logical channels active, a considerable amount of time can be taken to getting all communications established. Remember it is possible to have as many as 4095 active channels at the same time. More realistically the figure will not normally exceed a few hundred.

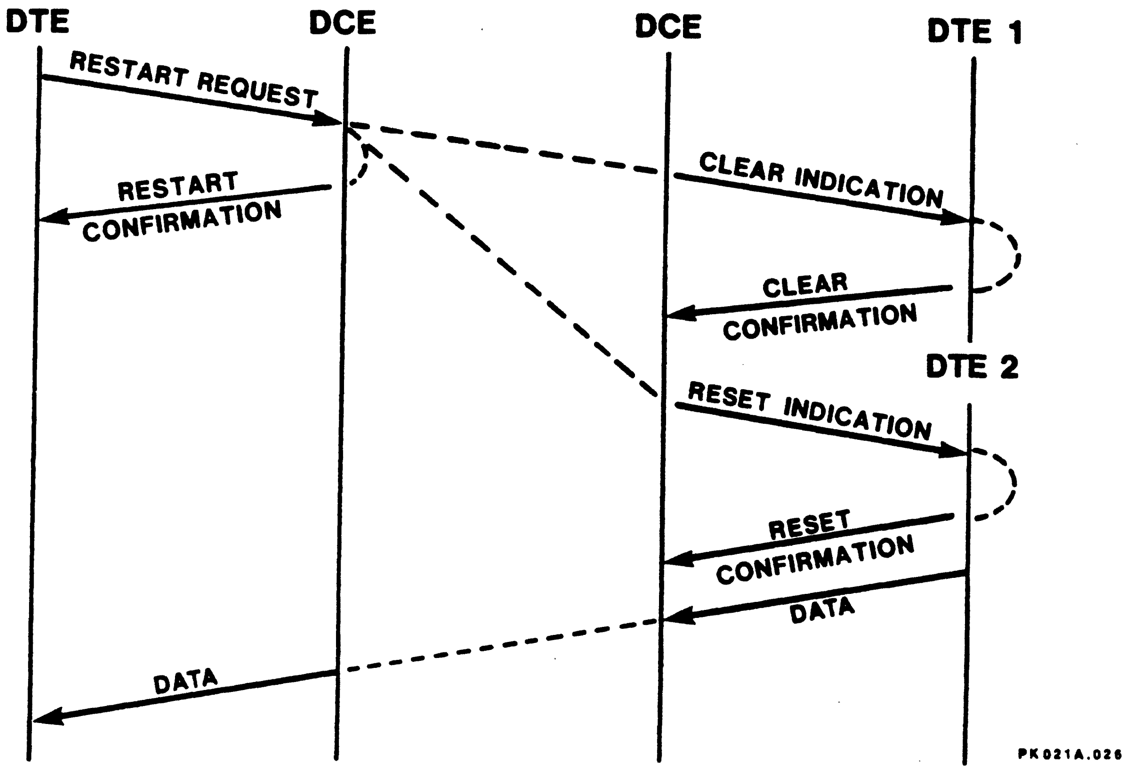
Restart Request/Indication packets will include a Cause field identifying the reason for the action. Additionally, there is a Diagnostic field with a more detailed explanation of the reason included in Restart Indication packets. This Diagnostic field is optional on Restart Request packets.

RESTARTING CAUSE CODES

	8 7 6 5 4 3 2 1
DTE originated*	0 0 0 0 0 0 0 0 or 1 X X X X X X X
Local procedure error	0 0 0 0 0 0 0 1
Network congestion	0 0 0 0 0 0 1 1
Network operation	0 0 0 0 0 1 1 1

* Restart Request packets only

RESTART REQUEST/INDICATION
(DTE HAS 1 PVC AND 1 VC ON ACCESS LINK)



RESTART PACKET FORMATS

RESTART REQUEST/INDICATION

GFI 0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0
1	1	1	1	1	0	1	1
RESTARTING CAUSE							
DIAGNOSTIC CODE							

RESTART CONFIRMATION

GFI 0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1

PK021B.016

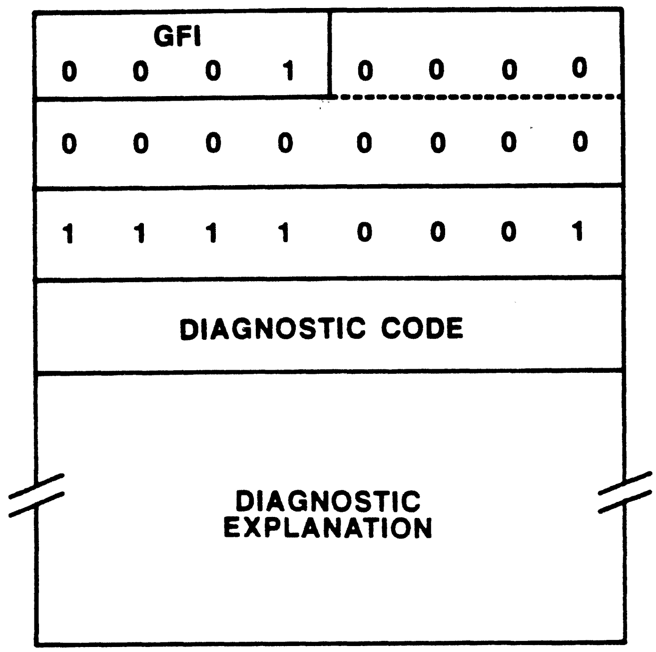
PK022.014

DCE DIAGNOSTIC PACKET

The optional diagnostic packet is sent by the DCE in some networks to indicate error conditions that are considered unrecoverable at the packet level. Such events occur when ambiguous situations arise due to collisions of indication, request, and confirmation packets. After the DCE issues the Diagnostic packet, it maintains the logical channel in the same state as it was before the event unless the problem is the second expiration of a timer in the error recovery procedures. This will be explained in more depth later. The information furnished in the diagnostic fields is intended for analysis of the error and recovery by higher layers of the DTE. Although the diagnostic packet is optional, the development of the error procedures which was done for the 1984 version caused greater recognition of the need for this packet.

When the problem that causes a diagnostic packet to be sent is a DTE packet that has an error or is in error, the diagnostic explanation field contains up to the first three octets of the problem packet. If the problem is the expiration of a DCE time-out period, then the diagnostic explanation field is two octets long and contains the general format identifier value for the interface and the logical channel number of the channel for which the time-out period expired. Also, in this situation, the diagnostic code field indicates which time-out period expired.

DCE DIAGNOSTIC



PK022.016

PK028.095

FAST SELECT FACILITY

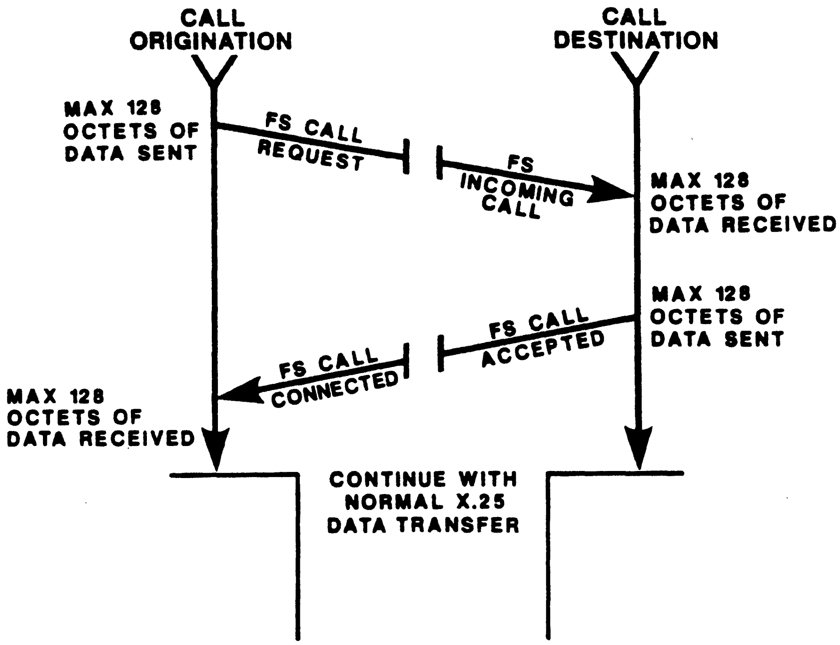
The Fast Select facility was developed for short transaction types of communication using the virtual call service.

A basic X.25 call request packet can have a maximum of only 16 octets of user data, but fast select call request/incoming call packets are expanded to allow a maximum of 128 octets of data. In addition, the call accepted/connected packets and clear request/indication packets can also contain 128 octets of data. In the 1980 version, clear user data could only be included on clear request/indication packets when specifically requested. The 1984 version of X.25 allows up to 128 octets of user data without restriction in all clearing request and indication packets. After call establishment is completed with the initial transfer of 128 octets of data, normal data transfer procedures are followed. This facility could be particularly useful in establishment of the peer relationships of the upper layers during network connection establishment.

A further variation was added to the fast select facility that can be used when there is only a small amount of data to be transferred and the normal data transfer phase is not needed. The fast select call request/incoming call packets can indicate, in the facility parameter field, that the only desired response is a clearing packet and not a call accepted packet. In this case, a clear indication packet is returned by the called DTE with a data field that can contain up to 128 octets of data. The fast select clear request/indication packets then need only the short clear confirmation response at each end.

Although fast select was identified as an optional facility in the 1980 version, it has been designated by the CCITT in 1984 as essential for all networks to provide.

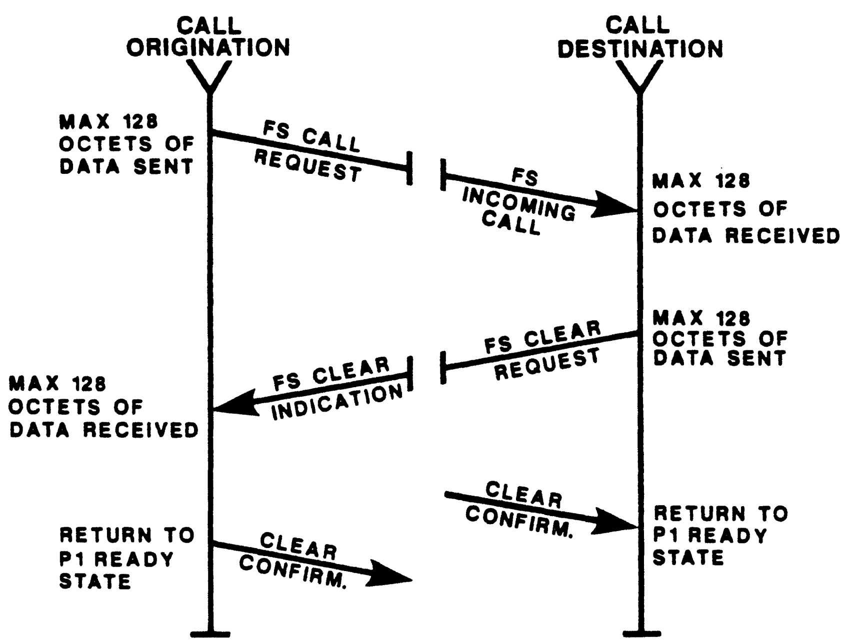
FAST SELECT CALL



PK028A.016

this is an essential facility

FAST SELECT WITH IMMEDIATE CLEAR



PK028B.016

PK029.044

CLOSED USER GROUPS

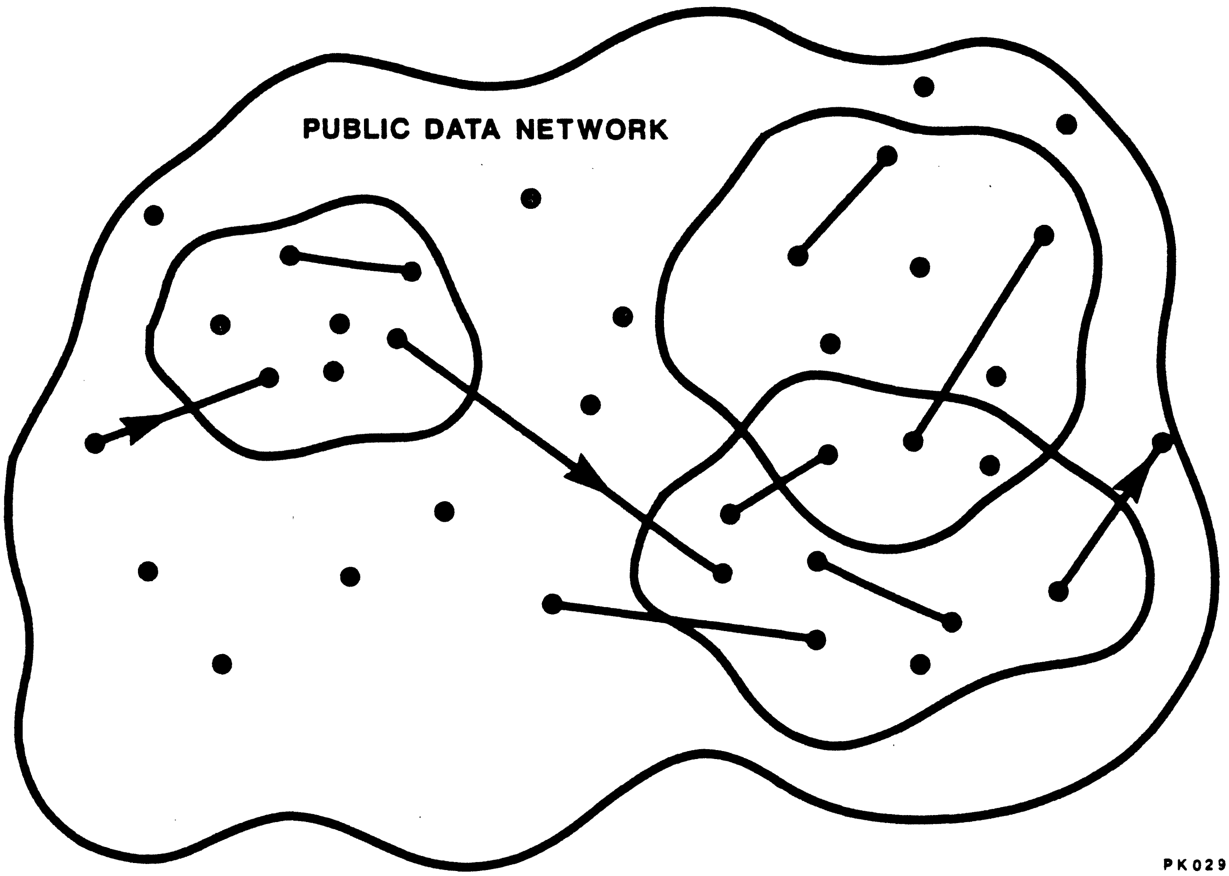
The closed user group facilities are designed to enable a user to establish, in effect, a private network using the public data network resources. Subscribers designated as part of a closed user group can only communicate among themselves. The public data network provides the control and management of the mechanisms that will ensure the security and integrity of the closed user group.

The network controls the operation of closed user groups with interlock codes that are under close control of the administrations and carriers. A call request for a closed user group is checked to ensure it is authorized. If a user is a member of more than one closed user group, the call request facility field must indicate which closed user group applies. This is done by the inclusion of an index number for the closed user group in the facility parameter of the facility request. The network then assigns the appropriate interlock code for call set-up. At the destination the interlock code is verified as appropriate for completing the call to the called subscriber. CCITT Recommendation X.300 (formerly X.87) provides a detailed description of the operation of the closed user group facilities.

There are variations in closed user groups that are also recognized. Some optional provisions allow the user to receive calls from outside the group and make calls outside the group. Other optional provisions limit the placing of calls within a closed user group to only to or only from the user.

The most frequently used or only closed user group is designated as preferred and no facility request is necessary because it will be automatically assumed by the network. Secondary groups would then be designated by a facility request when required. This designation of a preferential closed user group is optional when access outside the group is permitted.

CLOSED USER GROUPS



'84 can belong to 10,000 closed user groups

PK054.044

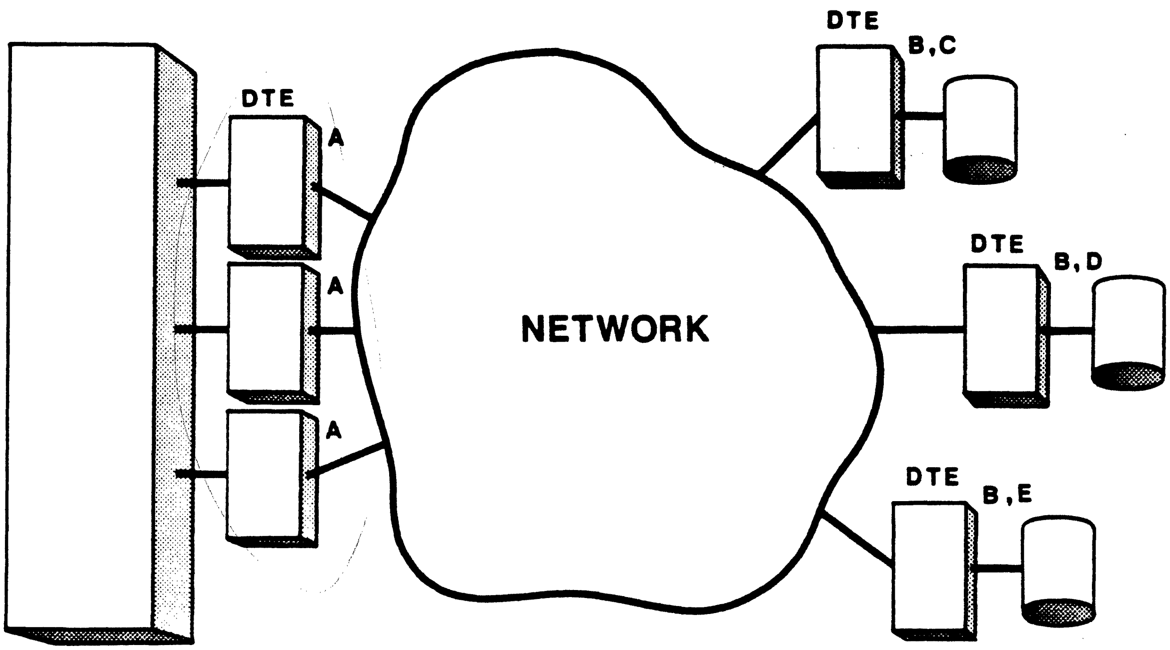
HUNT GROUP FACILITY

The Hunt Group facility was developed for the 1984 version of X.25 to satisfy the need for several users to share a DTE address. Examples of uses of this facility incclude several front-ends for one large system, several systems which offer a common reservation service, or several gateways to a large private network.

In a Hunt Group there are two or more users with the same DTE address but individual access links to which incoming calls are evenly distributed. Each user has an independent subscription in all other respects. Members of a Hunt Group may make outgoing calls. An optional addition to the Hunt Group facility is the capability for each member to be assigned its own individual DTE address in addition to the group DTE address. This allows members to place calls using their independent address and also allows a caller of a hunt group to be told the specific member which accepted the call.

The network will inform the calling DTE of the individual DTE address of the hunt group member by returning the specific DTE address of the member in the Call Connected or Clear Indication packet and by including the Called Line Address Modified Notification facility in the packet.

HUNT GROUP



PK054A.125

Load distribution function by network to DTEs in Hunt group.

Would be limited Geographically

PK042.044

CALL REDIRECTION FACILITY

The Call Redirection facility was developed for the 1984 version of X.25 to allow a user to temporarily block incoming calls and to have those calls delivered to another user. This provides for backing up a system when it is busy, out of order or not available for some user defined reason (known as systematic redirection). The user arranges with the network that when the conditions that are subscribed to occur the incoming calls for this user will be given to another user. Permission to do this must be obtained from the other user.

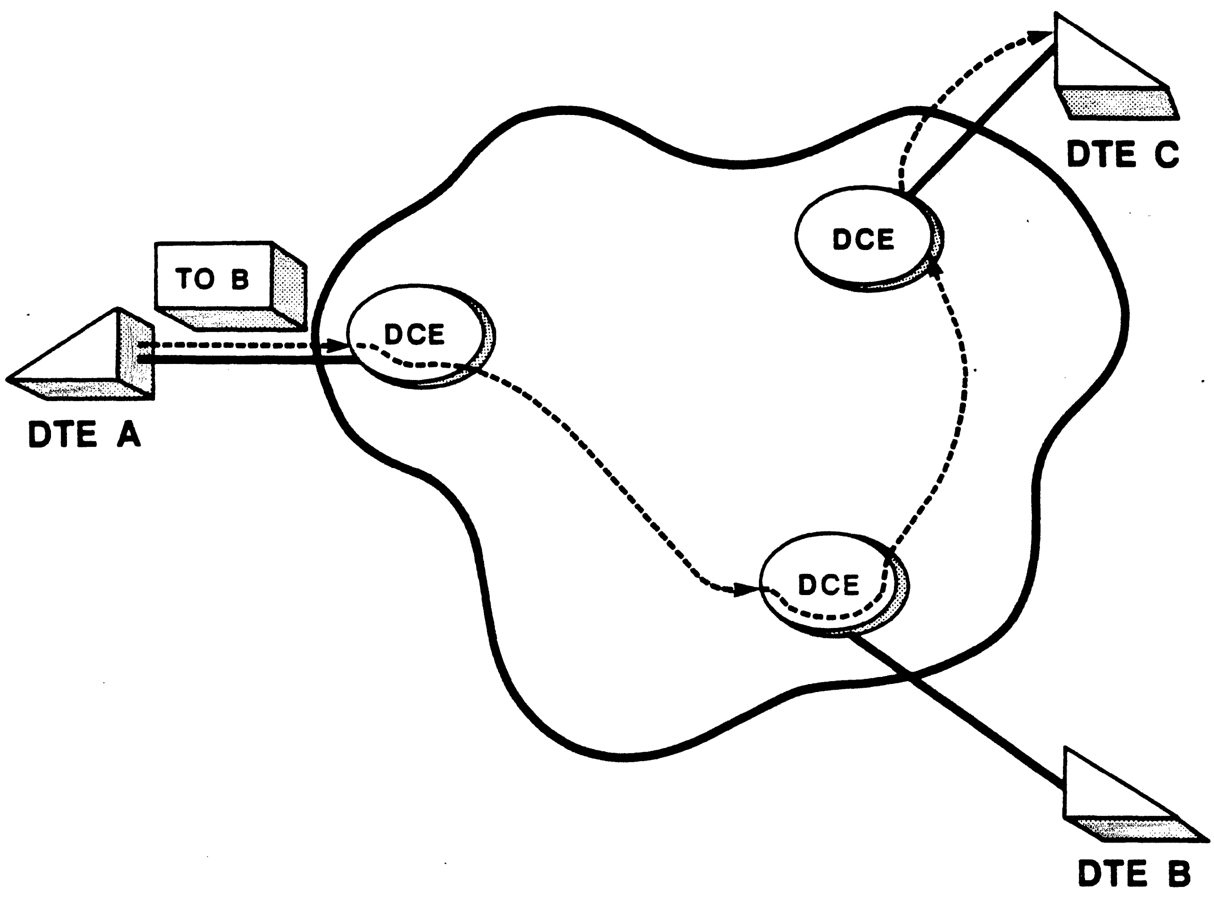
Systematic redirection reasons are not standardized. Networks may offer, for example, to redirect calls between certain times of day or between certain times of the year or until further notice is given via a phone call.

Some networks will offer the capability for calls to be redirected more than once. There are two alternative forms of this capability. In the List alternative, the user lists, in order of use, two or more other users. If the first user on the list has a redirection condition in effect, the call will be redirected to the second user on the list. In the Chain alternative, if the other user has also subscribed to redirection and a redirection condition is in effect the call will be redirected again.

Networks will inform the calling DTE of the call redirection by returning the DTE address of the last user in the Call Connected or Clear Indication packet and by including the Called Line Address Modified Notification facility in the packet. Use of this facility by a DTE has also been specified in order to allow for call redirection within a private network. In fact, a DTE should not return in a Call Accepted or Clear Request packet a called DTE address that is different from the called DTE address in the Call Request packet unless the Called Line Address Modified Notification facility is included as well.

Networks have the option to inform the DTE which is given the call that the call has been redirected by including the Call Redirection Notification facility in the Incoming Call packet.

CALL REDIRECTION



1988 redirection determined by DTE
upon examination of packet.
Can be done on per-call basis

PK051.044

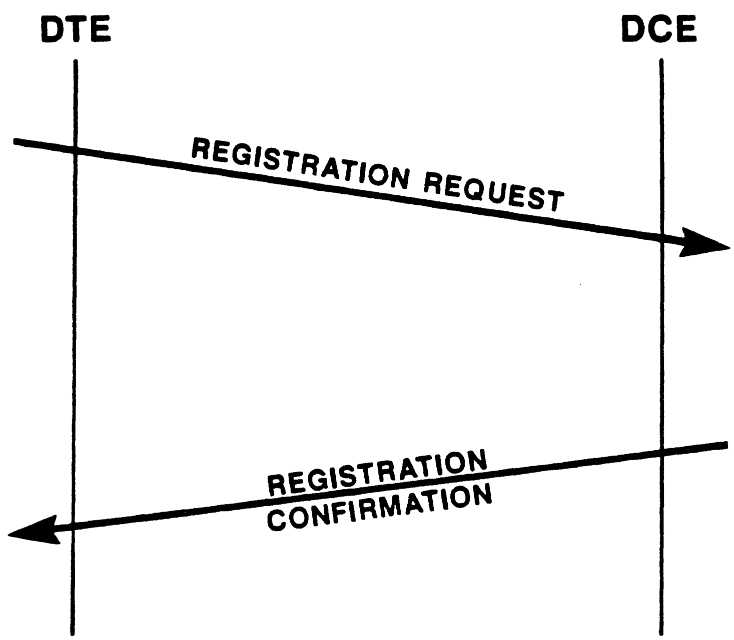
ON-LINE FACILITY REGISTRATION

The On-line Facility Registration facility was first included in the 1984 version of X.25. It was developed to provide a way for a user to alter the configuration that has been subscribed to with the network in real time on a temporary basis. The subscription values that may be changed include the acceptance of reverse charging, the modulo for packet sequence numbering, the acceptance of fast select calls, the barring of incoming and outgoing calls, the ranges of logical channel numbers allocated for the different logical channel types, and the values of the default packet and window sizes.

The uses of this kind of flexibility are numerous; some uses satisfy occasional needs, others satisfy periodic needs. For instance, invoking Incoming Calls Barred could help a user to terminate operation for the day gracefully or could block calls during a test. Invoking Charging Information on an interface basis could be done periodically in order to investigate the charges being accrued in a specific part of the day or week or month. An important feature of the On-line Facility Registration facility is the capability to obtain from the network the configuration that is in effect without requesting a subscription change. This allows a user to initialize a considerable part of the packet level from information provided by the network instead of from locally stored information or to verify the configuration that is in effect.

The On-line Facility Registration procedure requires two types of packets, Registration Request and Registration Confirmation. Since this procedure concerns the DTE/DCE interface as a whole, the Registration Request and Registration Confirmation packets are conveyed only on logical channel 0. The Registration Request packet is sent by the user to obtain the current values of the subscription and/or to change the values of the subscription. The Registration Confirmation packet is sent by the network in response to a Registration Request to report the current values of the subscription and to report the success or failure of any changes that were requested. The new values are in effect for all subsequent calls.

ON-LINE FACILITY REGISTRATION



New in 1984

PK051.125

REGISTRATION PACKETS

The cause field in the Registration Confirmation packet carries the reason a requested change was not made or notes that all changes were made. The diagnostic code field allows the network to amplify the reason that is being reported.

REGISTRATION CAUSE CODES

	Bits 8	7	6	5	4	3	2	1
Registration/cancellation confirmed	0	1	1	1	1	1	1	1
Invalid facility request	0	0	0	0	0	0	1	1
Local procedure error	0	0	0	1	0	0	1	1
Network congestion	0	0	0	0	0	1	0	1

The address field in Registration Request and Registration Confirmation packets is not currently used. The address field and the address lengths field were included for consistency with other similar packet formats with a view to defining the use of addresses in these packets at a later date. The address lengths field is coded all 0s.

The registration length field in Registration Request and Registration Confirmation packets gives the length (in octets) of the registration field up to a maximum of 109 octets.

Registration elements are the mechanism by which the subscription values being changed or reported are conveyed. Similar to the facility elements carried in the facility fields of other packets, Registration packets carry the registration elements in registration fields. The formats of the registration elements are the same as the facility elements.

REGISTRATION REQUEST

GFI							
0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0
1	1	1	1	0	0	1	1
DTE ADDRESS LENGTH				DCE ADDRESS LENGTH			
DTE & DCE ADDRESSES							
REGISTRATION LENGTH							
REGISTRATION							

PK035A.125

REGISTRATION CONFIRMATION

G F I							
0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0
1	1	1	1	0	1	1	1
CAUSE							
DIAGNOSTIC CODE							
DTE ADDRESS LENGTH				DCE ADDRESS LENGTH			
DTE & DCE ADDRESSES							
REGISTRATION LENGTH							
REGISTRATION							

PK035B.125

PK052.044

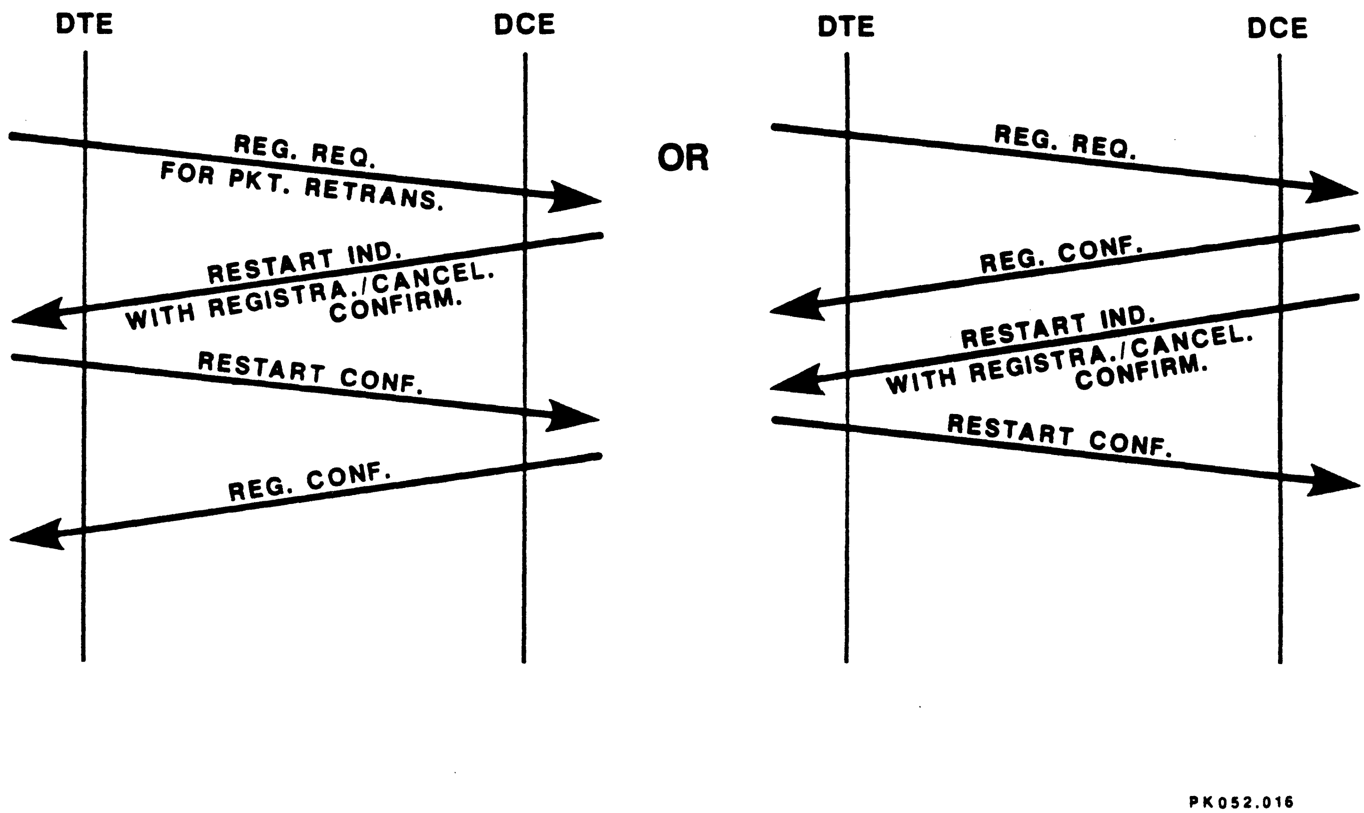
REGISTRATION CONSIDERATIONS

There are some facilities which should not be changed on-line including Local Charging Prevention or Closed User Group. The use of On-line Facility Registration for the Call Redirection facility is still being studied.

The Registration procedure may be used at any time for most subscription changes. However, when the values being altered are for facilities or capabilities where changing the value would affect active logical channels, the Registration procedure is restricted to times when there are no existing Virtual Calls. In addition, in this case, the Restart procedure is used by the network to reinitialize Permanent Virtual Circuits with the new values. The facilities for which the Registration procedure is restricted are Extended Packet Sequence Numbering, D-Bit Modification, and Packet Retransmission. The restriction also applies to the capability to change the ranges of logical channel numbers allocated for different types of logical channels.

Network failures can cause changed subscription values to be lost. Since the Restart procedure is used by networks to signal such failures, the subscription values should be checked by the user whenever the network initiates the Restart procedure with a cause of "Network Congestion" or "Network Operational" (unless the user has not changed the subscription since initiating the access link).

CHANGE AN INTERFACE-WIDE FACILITY WITH PVCs



PK023.014

OPTIONAL USER FACILITIES

INTERNATIONAL FACILITIES

@ * On-line facility registration
* Extended packet sequence numbering
D bit modification
* Packet retransmission
Incoming calls barred
Outgoing calls barred
* One-way logical channel outgoing
* One-way logical channel incoming
* Nonstandard default packet sizes
* Nonstandard default window sizes
* Default throughput class assignment
Flow control parameter negotiation
* Throughput class negotiation
* Closed user group
* Closed user group with outgoing access
* Closed user group with incoming access
* Incoming calls barred within a closed user group
* Outgoing calls barred within a closed user group
@ * Closed user group selection
@ * Closed user group with outgoing access selection
Bilateral closed user group
Bilateral closed user group with outgoing access — Two members. No addresses use!
@ Bilateral closed user group selection
* Fast select
Fast select acceptance
Reverse charging
Reverse charging acceptance
@ Local charging prevention — cannot be changed by registration
@ Network user identification
@ Charging information
RPOA selection
@ * Hunt group
@ * Call redirection
@ * Called line address modified notification
@ * Call redirection notification
@ Transit delay selection and indication

CCITT-SPECIFIED DTE FACILITIES

OSI Related
@ Calling address extention
@ Called address extention
@ Quality of service negotiation
@ Expedited data negotiation

* Indicates facilities already covered in earlier presentation
@ Indicates new facilities in 1984

NOTES

RPOA selection — list of preferred Networks to be used for routing to Destination Network.

↑

"Transit" networks

Does NOT define transit networks in international portion of the call.

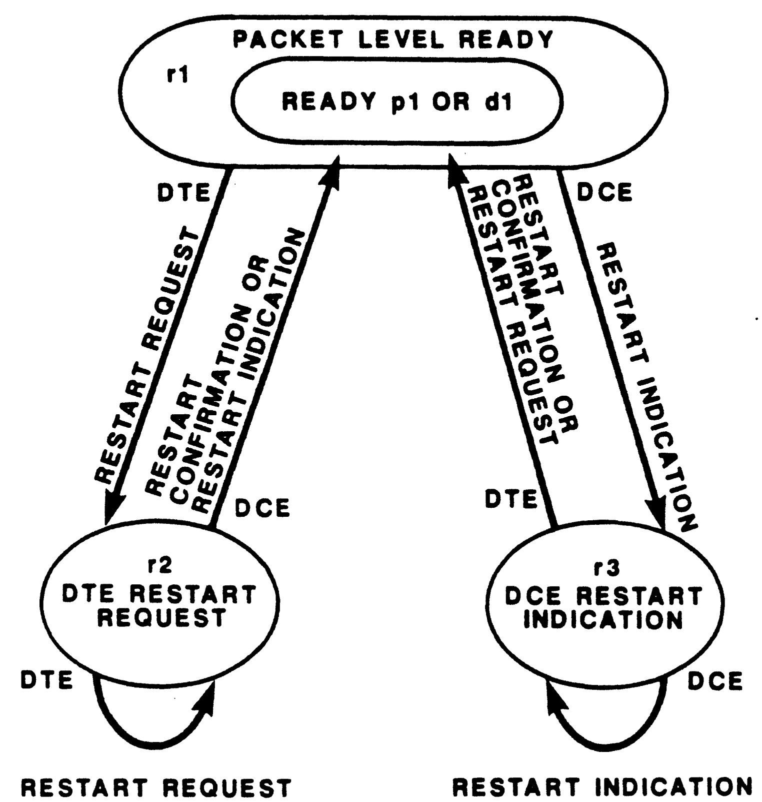
PK026.044

STATE DIAGRAMS

Annex B of X.25 contains a number of simple state diagrams to describe the operation of the packet level procedures. They show the various operational states and the appropriate actions for leaving and entering the states. Formal description techniques are being developed by both the CCITT and ISO. It is expected that packet and frame level procedures will be described using those methods when they are reasonably mature.

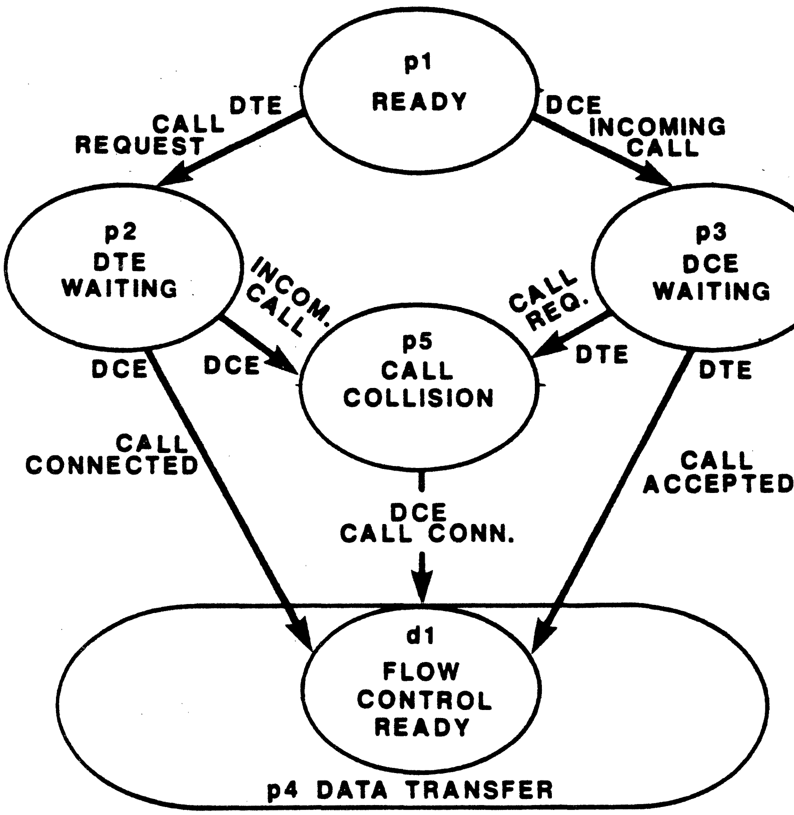
Annex's are important information.

DIAGRAM OF STATES FOR THE TRANSFER OF RESTART PACKETS



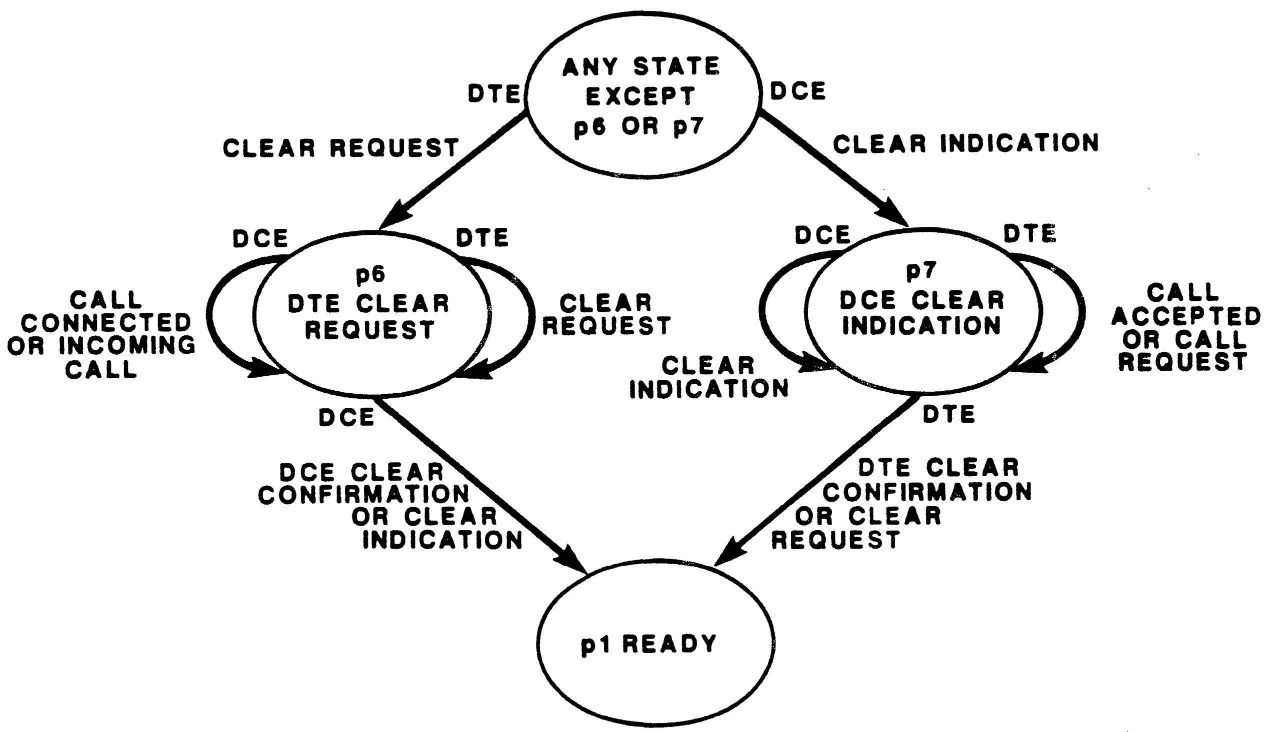
PK026A.016

DIAGRAM OF THE STATES FOR THE TRANSFER OF CALL SET-UP AND CALL CLEARING PACKETS WITHIN THE PACKET LEVEL READY (r1) STATE



a) CALL SET-UP PHASE

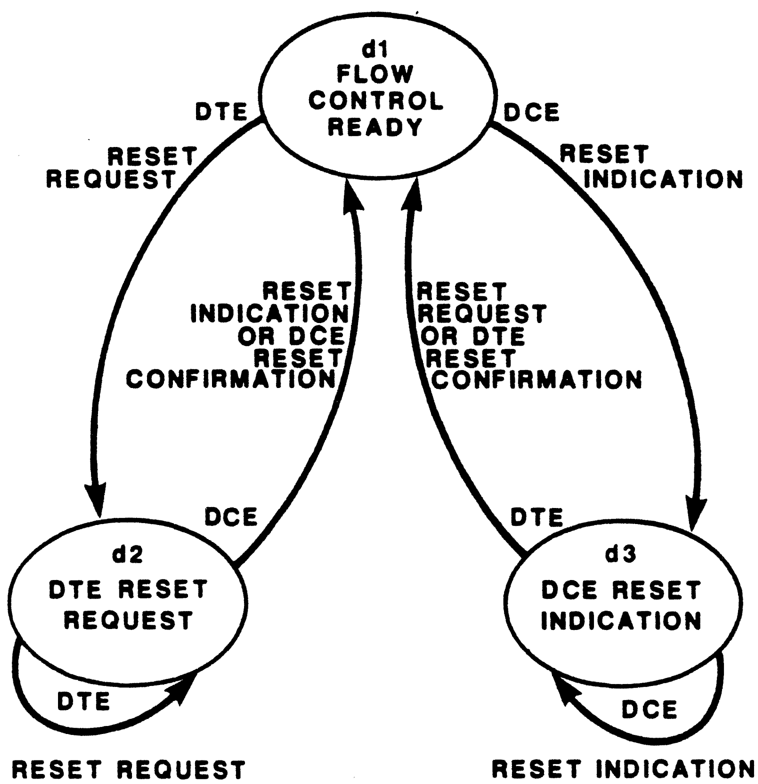
PK026B.016



b) CALL CLEARING PHASE

PK026C.016

DIAGRAM OF STATES FOR THE TRANSFER OF RESET PACKETS WITHIN THE DATA TRANSFER (p4) STATE



PK026D.016

NOTES

PK033.044

DIAGNOSTIC CODES

Annex E of X.25 provides a list of the network generated diagnostic codes. Decimal codes 0 - 127 are internationally standardized, and decimal codes 128 - 256 are reserved for network specific diagnostic information.

ANNEX E

(to Recommendation X.25)

Coding of X.25 network generated diagnostic fields in clear, reset and restart indication, registration confirmation and diagnostic packets

TABLE E-1 X.25

(see Notes 1, 2 and 3)

Diagnostics	Bits								Decimal
	8	7	6	5	4	3	2	1	
No additional information	0	0	0	0	0	0	0	0	0
Invalid P(S)	0	0	0	0	0	0	0	1	1
Invalid (PR)	0	0	0	0	0	0	1	0	2
	0	0	0	0	1	1	1	1	15
Packet type invalid	0	0	0	1	0	0	0	0	16
For state r1	0	0	0	1	0	0	0	1	17
For state r2	0	0	0	1	0	0	1	0	18
For state r3	0	0	0	1	0	0	1	1	19
For state p1	0	0	0	1	0	1	0	0	20
For state p2	0	0	0	1	0	1	0	1	21
For state p3	0	0	0	1	0	1	1	0	22
For state p4	0	0	0	1	0	1	1	1	23
For state p5	0	0	0	1	1	0	0	0	24
For state p6	0	0	0	1	1	0	0	1	25
For state p7	0	0	0	1	1	0	1	0	26
For state d1	0	0	0	1	1	0	1	1	27
For state d2	0	0	0	1	1	1	0	0	28
For state d3	0	0	0	1	1	1	0	1	29
	0	0	0	1	1	1	1	1	31
Packet not allowed	0	0	1	0	0	0	0	0	32
Unidentifiable packet	0	0	1	0	0	0	0	1	33
Call on one-way logical channel	0	0	1	0	0	0	1	0	34
Invalid packet type on a permanent virtual circuit	0	0	1	0	0	0	1	1	35
Packet on unassigned logical channel	0	0	1	0	0	1	0	0	36
Reject not subscribed to	0	0	1	0	0	1	0	1	37
Packet too short	0	0	1	0	0	1	1	0	38
Packet too long	0	0	1	0	0	1	1	1	39
Invalid general format identifier	0	0	1	0	1	0	0	0	40
Restart or registration packet with nonzero in bits 1 to 4 of octet 1, or bits 1 to 8 of octet 2	0	0	1	0	1	0	0	1	41
Packet type not compatible with facility	0	0	1	0	1	0	1	0	42
Unauthorized interrupt confirmation	0	0	1	0	1	0	1	1	43
Unauthorized interrupt	0	0	1	0	1	1	0	0	44
Unauthorized reject	0	0	1	0	1	1	0	1	45
	0	0	1	0	1	1	1	1	47
Time expired	0	0	1	1	0	0	0	0	48
For incoming call	0	0	1	1	0	0	0	1	49
For clear indication	0	0	1	1	0	0	1	0	50
For reset indication	0	0	1	1	0	0	1	1	51
For restart indication	0	0	1	1	0	1	0	0	52
	0	0	1	1	1	1	1	1	63

PK033A.046

TABLE E-1/X.25 *(cont.)*

Diagnostics	Bits 8	7	6	5	4	3	2	1	Decimal
Call set up, call clearing or registration problem	0	1	0	0	0	0	0	0	64
Facility/registration code not allowed	0	1	0	0	0	0	0	1	65
Facility parameter not allowed	0	1	0	0	0	0	1	0	66
Invalid called address	0	1	0	0	0	0	1	1	67
Invalid calling address	0	1	0	0	0	1	0	0	68
Invalid facility/registration length	0	1	0	0	0	1	0	1	69
Incoming call barred	0	1	0	0	0	1	1	0	70
No logical channel available	0	1	0	0	0	1	1	1	71
Call collision	0	1	0	0	1	0	0	0	72
Duplicate facility requested	0	1	0	0	1	0	0	1	73
Non zero address length	0	1	0	0	1	0	1	0	74
Non zero facility length	0	1	0	0	1	0	1	1	75
Facility not provided when expected	0	1	0	0	1	1	0	0	76
Invalid CCITT-specified DTE facility	0	1	0	0	1	1	0	1	77
	0	1	0	0	1	1	1	1	79
Miscellaneous	0	1	0	1	0	0	0	0	80
Improper cause code from DTE	0	1	0	1	0	0	0	1	81
Not aligned octet	0	1	0	1	0	0	1	0	82
Inconsistent Q bit setting	0	1	0	1	0	0	1	1	83
	0	1	0	1	1	1	1	1	95
Not assigned	0	1	1	0	0	0	0	0	96
	0	1	1	0	1	1	1	1	111
International problem	0	1	1	1	0	0	0	0	112
Remote network problem	0	1	1	1	0	0	0	1	113
International protocol problem	0	1	1	1	0	0	1	0	114
International link out of order	0	1	1	1	0	0	1	1	115
International link busy	0	1	1	1	0	1	0	0	116
Transit network facility problem	0	1	1	1	0	1	0	1	117
Remote network facility problem	0	1	1	1	0	1	1	0	118
International routing problem	0	1	1	1	0	1	1	1	119
Temporary routing problem	0	1	1	1	1	0	0	0	120
Unknown called DNIC	0	1	1	1	1	0	0	1	121
Maintenance action (see Note 4)	0	1	1	1	1	0	1	0	122
	0	1	1	1	1	1	1	1	127
Reserved for network specific diagnostic information	1	0	0	0	0	0	0	0	128
	1	1	1	1	1	1	1	1	255

New in 1984

Note 1 – Not all diagnostic codes need apply to a specific network, but those used are as coded in the table.

Note 2 – A given diagnostic need not apply to all packet types (i.e. *reset indication, clear indication, restart indication, registration confirmation* and *diagnostic* packets).

Note 3 – The first diagnostic in each grouping is a generic diagnostic and can be used in place of the more specific diagnostics within the grouping. The decimal 0 diagnostic code can be used in situations where no additional information is available.

Note 4 – This diagnostic may also apply to a maintenance action within a national network.

PK033B.046

NOTES

PK034.014

ERROR TABLES

Annex C of X.25 provides a number of tables to identify error situations and the actions that are to be taken by the DCE. The Restart, Clear and Reset procedures are the basis of the error recovery process. No detail is provided for DTE actions; these are left to the implementer. ISO, however, has developed a companion standard further describing the DTE behavior and actions when operating with a standard X.25 DTE. This standard has been approved and is in the process of being printed.

There are five categories of errors that can occur in the packet level.

1. The format of a packet received from the DTE can be wrong.

2. There can be something wrong with the contents of a DTE packet - either invalid or inconsistent.

3. The DTE does not respond with a correct packet within a time period in some circumstances.

4. The DCE receives a packet which is invalid for the state of a channel or the interface.

5. A network can invoke the error handling procedures for a number of its own reasons.

Some of the things that cause procedural errors include a stopped DTE, loss of a packet by the link level, timing and time-out problems, and configuration mismatches between the DTE and DCE.

The time periods allowed for various responses are defined in Annex D. Also, the action to be taken by the DCE at the expiry of the time period is given. The combination of the actions defined in Annexes C and D specify the error handling procedures for the DCE, including one attempt to retry a procedure if it is unsuccessful the first time.

In order to minimize the problems caused by DTEs which do not function properly, many networks have established conformance validation requirements. This means that the DTE manufacturer must prove an X.25 DTE product to the network before that product is allowed to be connected to the network. In addition, in the United States, the National Bureau of Standards has established a set of test procedures which DTE and DCE products must pass before being eligible to be marketed to the federal government. There is a movement starting to try to standardize some of these requirements so that this considerable duplication can be greatly reduced.

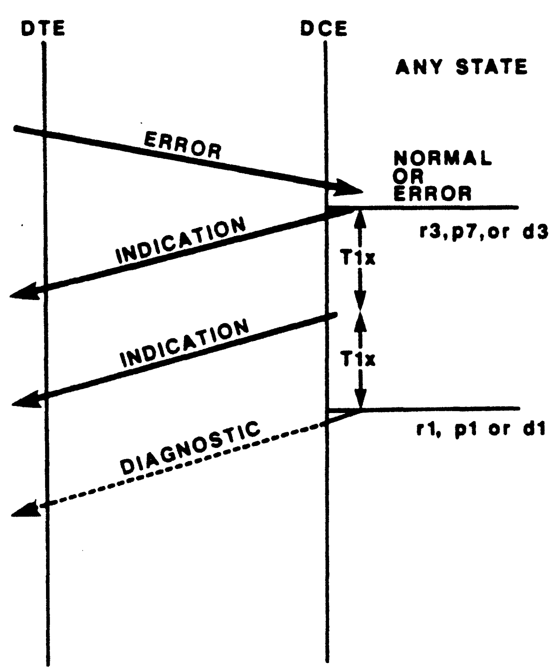
Legend: r1 - Packet level ready   p4 - Data transfer
p1 - Ready   p5 - Call collision
p2 - DTE waiting   p6 - DTE clear request
p3 - DCE waiting   p7 - DCE clear indication
NORMAL, ERROR - processes defined in Annex C
20, 21, 22, 23, 24, 25, 41 - diagnostic code values from Annex E
T1x - T10, T12, or T13 time out from Annex D
Dashed arrow - optional packet transmission

DCE ACTION TABLES - EXTRACT

STATE SEEN BY THE DCE / PACKET FROM THE DTE	r1						
	p1	p2	p3	p4	p5	p6	p7
CALL REQUEST	NORMAL p2	ERROR p7 21	NORMAL p5	ERROR p7 23	ERROR p7 24	ERROR p7 25	DISCARD
DATA	ERROR p7 20	ERROR p7 21	ERROR p7 22	TABLE C-4	ERROR p7 24	ERROR p7 25	DISCARD
RESTART REQUEST WITH LCN≠0	ERROR p7 41	ERROR p7 41	ERROR p7 41	TABLE C-4	ERROR p7 41	ERROR p7 41	DISCARD

PK034N.026

DCE ERROR HANDLING



PK034P.026

PK060.044

SUBSCRIBING TO A NETWORK

As has been seen throughout this chapter, there are many parameters and options the values of which must be agreed upon by the user and the network administration before the user can operate on the network. Most networks provide new users a subscription form which, when completed, establishes the agreement between them. An example of a subscription form which covers all of the parameters and options in the 1984 version of X.25 appears on the following pages. This example is far larger than any subscription form existing today because networks offer only a subset of the features explained here.

PK060a.044

EXAMPLE

SUBSCRIPTION FORM

1. Subscriber Name ________________________________

2. Subscriber Address ________________________________
____
____

3. Subscriber Telephone ________________________________

4. Emergency Contact in Subscriber Organization

   a. Name ________________________________

   b. Address ________________________________
   ____
   ____

   c. Telephone ________________________________

5. Billing Address ________________________________
____
____
____

6. DTE X.121 Address [Network Assigns]

   Shared Address Space?

   _____ Yes: Addresses Range ________________
   ____

   _____ No: Address ________________

7. Hunt Group Member?

   _____ Yes

   Individual Address?

   _____ Yes: Individual DTE X.121 Address [Network Assigns]
   ____

   _____ No

   _____ No

PK060b.044

SUBSCRIPTION FORM cont.

8. Multi-Link Attachment?

_____ Yes

Number of Single Links _______

Lost Frame Timer MT1 _______

Group Busy Timer MT2 _______

MLP Reset Confirmation Timer MT3 _______

9. Single Link Parameters

	Link 1	Link 2	Link 3
a. Speed			
4800 bps	_______	_______	_______
9600 bps	_______	_______	_______
19200 bps	_______	_______	_______
b. Frame Sequencing			
Normal	_______	_______	_______
Extended	_______	_______	_______
c. DTE T1	_______	_______	_______
d. DCE T1	_______	_______	_______
e. DTE T2	_______	_______	_______
f. DCE T2	_______	_______	_______
g. T3	_______	_______	_______
h. DTE N1	_______	_______	_______
i. DCE N1	_______	_______	_______
j. DTE N2	_______	_______	_______
k. DCE N2	_______	_______	_______
l. k	_______	_______	_______

PK060c.044

SUBSCRIPTION FORM cont.

	Link 1	Link 2	Link 3
m. Procedure			
LAPB	______	______	______
LAP	______	______	______

For additional single links, add another page.

10. Extended Packet Sequence Numbering?

_____ Yes

_____ No

11. Logical Channels

a. Number of Logical Channels _____

b. PVCs

1. Number of PVCs _____

2. Range of PVC LCNs: LCGN _____
[Network Assigned] LCN _____
_____

3. PVC Parameters

	Throughput Classes (3-12)		Packet Sizes (16-4096)		Window Sizes (1-7, or 1-127)	
	Send	Receive	Send	Receive	Send	Receive
PVC1	_____	_____	_____	_____	_____	_____
PVC2	_____	_____	_____	_____	_____	_____
PVC3	_____	_____	_____	_____	_____	_____
PVC4	_____	_____	_____	_____	_____	_____
PVC5	_____	_____	_____	_____	_____	_____
PVC6	_____	_____	_____	_____	_____	_____
PVC7	_____	_____	_____	_____	_____	_____
PVC8	_____	_____	_____	_____	_____	_____

PK060d.044

SUBSCRIPTION FORM cont.

Correspondent Subscriber

	Name	DTE X.121 Address
PVC1	____________	____________
PVC2	____________	____________
PVC3	____________	____________
PVC4	____________	____________
PVC5	____________	____________
PVC6	____________	____________
PVC7	____________	____________
PVC8	____________	____________

For additional PVCs, add another page.

c. Virtual Calls

1. Number of Virtual Calls _____
2. Number of One-way Incoming Logical Channels _____
3. One-way Incoming LCNs: [Network Assigns]
   - LCGN _____
   - LIC _____
   - HIC _____
4. Number of Two-way Logical Channels _____
5. Two-way LCNs: [Network Assigns]
   - LCGN _____
   - LTC _____
   - HTC _____
6. Number of One-way Outgoing Logical Channels _____
7. One-way Outgoing LCNs: [Network Assigns]
   - LCGN _____
   - LOC _____
   - HOC _____

PK060e.044

SUBSCRIPTION FORM cont.

12. On-line Facility Registration?

    ______ Yes

    Change Incoming Calls Barred?

    ______ Yes

    ______ No

    Change Reverse Charging Acceptance?

    ______ Yes (may not have Local Charging Prevention)

    ______ No

    Change Charging Information on an Interface Basis?

    ______ Yes

    ______ No

    ______ No

13. D-bit Modification?

    ______ Yes

    ______ No

14. Packet Retransmission?

    ______ Yes

    ______ No

15. Incoming or Outgoing Calls Barred?

    ______ Yes

    ______ Incoming

    ______ Outgoing

    ______ No

PK060f.044

SUBSCRIPTION FORM cont.

16. Non-standard Default Packet Sizes?

_____ Yes: (16-64, 256-4096)

_____ Send

_____ Receive

_____ No

17. Non-standard Default Window Sizes?

_____ Yes: (1, 3-7 or 1, 3-127)

_____ Send

_____ Receive

_____ No

18. Default Throughput Classes Assignment

_____ Yes: (3-12)

_____ Send

_____ Receive

_____ No

19. Flow Control Parameter Negotiation?

_____ Yes

_____ No

20. Throughput Class Negotiation?

_____ Yes

_____ No

PK060g.044

SUBSCRIPTION FORM cont.

21. Closed User Groups?

_____ Yes

a. Incoming or Outgoing Access?

_____ Yes

_____ Incoming

_____ Outgoing

_____ Both

Preferential CUG?

_____ Yes

_____ No

_____ No

b. Number of CUG?

c. Closed User Group

	Index # (00-99 or 0000-9999) [Network Assigned]	Identity	Incoming Calls Barred (Yes or No)	Outgoing Calls Barred (Yes or No)
pref	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____
	_____	_____	_____	_____

For additional CUGs, add another page.

_____ No

PK060h.044

SUBSCRIPTION FORM cont.

22. Bilateral Closed User Groups?

_____ Yes

a. Outgoing Access?

_____ Yes

_____ No

b. Number of BCUGs _____

c. Bilateral Closed User Group

Index # (0000-9999) [Network Assigned]	Identity
0000 (Pref)	____________
____	____________
____	____________
____	____________
____	____________
____	____________

For additional BCUGs, add another page.

_____ No

23. Fast Select Acceptance?

_____ Yes

_____ No

24. Reverse Charging Acceptance? *

_____ Yes

_____ No

PK060i.044

SUBSCRIPTION FORM cont.

25. Local Charging Prevention? *

_____ Yes

_____ No

* These cannot both be Yes

26. Network User Identification?

_____ Yes

a. Number of NUIs _____

b. NUIs

Value	Administrative Information
___________	______________________________
___________	______________________________
___________	______________________________
___________	______________________________

For additional NUIs, add another page.

_____ No

27. Charging Information on an Interface Basis?

_____ Yes

_____ No

PK060j.044

SUBSCRIPTION FORM cont.

28. RPOA Selection?

_____ Yes: Predetermined Selection?

_____ Yes: List of RPOAs in order of use:

DNIC	Name
_____	_____________________
_____	_____________________
_____	_____________________
_____	_____________________

For additional RPOAs, add another page.

_____ No

_____ No

29. Call Redirection?

_____ Yes

a. On Out of Order?

_____ Yes

_____ No

b. On Busy?

_____ Yes

_____ No

c. On Systematic Condition?

_____ Yes: Condition: _____________________

____

_____ No

PK060k.044

SUBSCRIPTION FORM cont.

d. Destination of Redirection
(in order of use)

Subscriber Name	DTE X.121 Address
____________	____________
____________	____________
____________	____________
____________	____________

For additional redirection destinations, add another page.

_____ No

30. Call Redirection Authorization

_____ Yes: subscribers authorized to redirect calls to this subscriber

Name	DTE X.121 Address
____________	____________
____________	____________
____________	____________
____________	____________

For additional redirection authorization, add another page.

_____ No

31. Network-specific Facilities

NOTES

ADDITIONAL TERMINAL CONSIDERATIONS

ISO 7776
ISO 8208

TC000.026

TC001.016

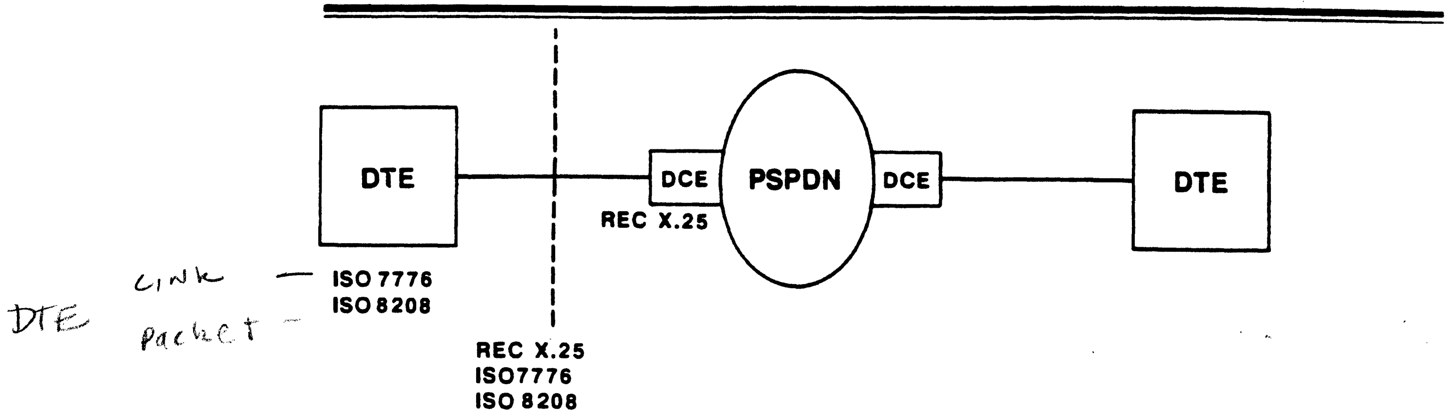
ADDITIONAL TERMINAL CONSIDERATIONS

Recommendation X.25 describes the interface between a packet mode terminal and the Public Packet-Switched Data Network in terms of the formats of the frames and packets used; and it describes the behavior on the DCE side of the interface. The behavior on the DTE side of the interface is for the most part defined only by implication and, in a number of circumstances, is undefined.

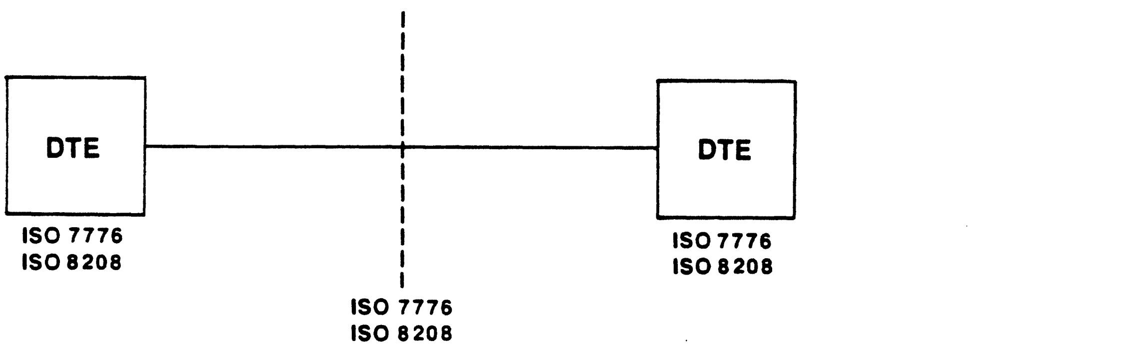
ISO has developed two standards to remedy this situation. The link level standard is ISO 7776, "Description of the 1984 X.25 LAPB-Compatible DTE Link Procedures". The packet level standard is ISO 8208, "X.25 Packet Level Protocol for Data Terminal Equipment". These standards describe the interface between the terminal and the Packet-Switched Public Data Network in terms of the formats of the frames and packets used; and they describe the behavior on the DTE side of the interface. In some places where options and alternatives have been provided in X.25, one course of action has been selected. In other cases, the choice has been described.

In addition to specifying the interface between the terminal and the Public Packet-Switched Data Network, both standards specify the interface between two terminals which both comply with these standards and are connected directly together, i.e., without an intervening packet network. This is known as the DTE/DTE interface. The purpose of defining the DTE/DTE interface is to make possible a general standard terminal which has the advantages of the reliable data link procedures and the flexibility and multiplexing capabilities of the packet level procedures of X.25.

DTE/DCE INTERFACE



DTE/DTE INTERFACE



TC001.036

TC002.016

ISO 7776

Since LAPB is preferred in X.25, ISO 7776 defines the LAPB procedure and does not define the LAP procedure. Like X.25, ISO 7776 includes the Multi-link procedure as an option. One addition to X.25 is that when the DCE or remote DTE is in a Busy Condition and the DTE has I frames waiting to be sent, the DTE will solicit the status of the other device every T1 period. Another addition is a timer for soliciting the status of the other device when there is no other traffic. This timer is named T4.

The adjustment made for the DTE/DTE interface is that everything that was agreed at subscription time for the DTE/DCE interface must be set by bilateral agreement between the two DTEs. In addition, the bilateral agreement must include the link level address assignments.

ISO 7776/X.25 LINK LEVEL

1984

Rec. X.25	ISO 7776	
LAPB	LAPB	
LAP	—	
MULTI-LINK	MULTI-LINK	option
T1	T1	
T2	T2	
T3	T3	
—	T4	— Activity Timer "keep alive"
N2	N2	
N1	N1	
K	K	
MOD 8	MOD 8	
MOD 128	MOD 128	option

TC002.026

Make link level address value settable.

TC003.016

ISO 8208

The packet level standard is much more completely explained than in Recommendation X.25.

In the body of the standard, the DTE definition for working with a network is given, including DTE versions of the state diagrams and action tables comparable to those in X.25. Incorporated into that definition, but carefully highlighted, are the considerations, additions and limitations that are necessary for working with another ISO 8208 terminal directly.

One section describes the capabilities that are not needed for compatibility with a 1980 network.

An annex contains guidelines for private networks to use in attaching to a Packet-Switched Public Data Network.

A very useful term is coined by this standard - the DXE. A DXE is the device the DTE being defined is attached to, whether that device is a DCE or another DTE.

Although ISO is very concerned about how to use X.25 to provide the Connection-oriented Network Layer Service, that information is being put in a different standard, ISO 8878.

ISO 8208

- DTE/DCE SPECIFICATION
- DTE/DTE SPECIFICATION
- PRIVATE NETWORK GUIDELINES
- 1980 COMPATIBILITY

TC003.125

TC005.016

DIFFERENCES FROM X.25

For the most part, the DTE specification is the same as the X.25 DCE specification except that it describes the behavior on the DTE side of the interface. In a few cases however, there are additions; and in some cases, options that were given to the DTEs have been restricted.

ISO 8208 requires that the DTE initiate the Restart procedure when the packet level is started up. As a result, frequently a Restart collision occurs at the beginning of packet level operation.

ISO 8208 requires that the DTE always send octet-aligned packets and, at least in the DTE/DTE environment, treat the receipt of a non-octet aligned packet as an error.

The DTE is required to never send a data packet that has the M-bit equal to 1 and the D-bit equal to 0 and does not have the full maximum size. If such a data packet is received, the DTE is required to treat it as an error.

Likewise, the DTE must always set the Q-bit consistently when transmitting a complete packet sequence and enforce Q-bit value consistency on receiving a complete packet sequence.

In addition to the Reject or Reset procedures, ISO 8208 defines a method of recovering from out-of-order data by retransmitting the data. This procedure is most effective in the DTE/DTE environment because, in most situations, the network will reset whenever data is retransmitted. The DTE detecting the out-of-order situation discards the data packets received until the packet with the correct sequence number arrives. The DTE transmitting the data determines the need to retransmit the unacknowledged data packets by using a timer (T25) whenever waiting for acknowledgment of data.

In addition to T25, ISO 8208 defines three other timers besides those given in X.25. The T24 timer is used to send an RR or RNR packet periodically when there is no data being sent. This presents the status of the receiving window of the DTE on a regular basis. The T26 timer is used to detect that an Interrupt packet has not been confirmed. The T27 timer is used to detect that the Data packet requested via a Reject packet has not been received.

ISO 8208 formalizes the retrying of the Restart, Reset, Clear, Data transmission, Reject and Registration procedures by defining retransmission counts that correspond to the timers. The values shown in the figure are recommended values, not required settings of these parameters.

The fields, that are defined in X.25 as optional for a DTE to transmit but required for the DCE (e.g., Reset Request diagnostic code field), are required for the DTE by ISO 8208.

SYSTEM PARAMETERS

TIMERS

- T20 180s RESTART REQUEST
- T21 200s CALL REQUEST
- T22 180s RESET REQUEST
- T23 180s CLEAR REQUEST
- * T24 60s P(R)
- * T25 150s DATA
- * T26 180s INTERRUPT
- * T27 60s REJECT
- T28 300s REGISTRATION REQUEST

*** RETRANSMISSION COUNTS**

- R20 1 RESTART REQUEST
- R22 1 RESET REQUEST
- R23 1 CLEAR REQUEST
- R25 0 DATA
- R27 0 REJECT
- R28 1 REGISTRATION REQUEST

TC006.016

TC007.036

DTE DIAGNOSTIC CODES AND STATE TABLES

The value of the cause code in a Request packet is limited to either 00000000 or 10000000 in order to reserve the other cause values in which the most bit is set to 1 for the use of private networks.

Diagnostic codes to be used by the DTE are specified in ISO 8208. For those situations that have been defined in X.25 for DCEs, the same diagnostic code values are used. The figure lists the additional codes that are defined for DTE use. In particular, values have been defined for problems that can occur in providing the OSI Connection-Mode Network Service. Although these values are defined in ISO 8208, how to accomplish the OSI Connection-Mode Network Service using the X.25 Packet Level Protocol is being specified in a separate standard, DIS 8878.

An escape mechanism is included in ISO 8208 so that a DTE can use a non-ISO 8208 set of diagnostic code values. This is done by assigning to the cause code value 00000000 the meaning "DTE originated and ISO 8208 diagnostic code" and to the cause code value 10000000 the meaning "DTE originated and non-ISO 8208 diagnostic code". This mechanism allows for the existence of diagnostic code values defined by the DTE manufacturer.

In addition to state diagrams that parallel those given in X.25, ISO 8208 has four state diagrams that describe the Interrupt procedure from the DTE to the DXE (i-states), the Interrupt procedure from the DXE to the DTE (j-states), the use of RNR packet from the DXE to the DTE (f-states), and the use of RNR packet from the DTE to the DXE (g-states). The states defined in the ISO 8208 diagrams are in turn used in DTE action tables comparable to the tables in Annex C of X.25.

TC007C.054

DIAGNOSTIC	8	7	6	5	4	3	2	1	DECIMAL
Reserved for DTE-defined diagnostic information	1	0	0	0	0	0	0	0	128
	...								
	1	0	0	0	1	1	1	1	143
Timer expired or retransmission count surpassed	1	0	0	1	0	0	0	0	144
For INTERRUPT CONFIRMATION	1	0	0	1	0	0	0	1	145
For DATA packet retransmissions	1	0	0	1	0	0	1	0	146
For REJECT packet retransmissions	1	0	0	1	0	0	1	1	147
	...								
	1	0	0	1	1	1	1	1	159
DTE-Specific Signals	1	0	1	0	0	0	0	0	160
DTE operational	1	0	1	0	0	0	0	1	161
DTE not operational	1	0	1	0	0	0	1	0	162
DTE resource constraint	1	0	1	0	0	0	1	1	163
Fast Select not subscribed	1	0	1	0	0	1	0	0	164
Invalid partially full DATA packet	1	0	1	0	0	1	0	1	165
D-bit procedure not supported	1	0	1	0	0	1	1	0	166
Registration/Cancellation confirmed	1	0	1	0	0	1	1	1	167
	...								
	1	0	1	0	1	1	1	1	175
Not assigned	1	0	1	1	0	0	0	0	176
	...								
	1	1	0	1	1	1	1	1	223

TC007D.054

DIAGNOSTIC	8	7	6	5	4	3	2	1	DECIMAL
OSI Network Service problem	1	1	1	0	0	0	0	0	224
Disconnection (transient condition)	1	1	1	0	0	0	0	1	225
Disconnection (permanent condition)	1	1	1	0	0	0	1	0	226
Connection rejection--reason unspecified (transient condition)	1	1	1	0	0	0	1	1	227
Connection rejection--reason unspecified (permanent condition)	1	1	1	0	0	1	0	0	228
Connection rejection--requested quality of service not available (transient condition)	1	1	1	0	0	1	0	1	229
Connection rejection--requested quality of service not available (permanent condition)	1	1	1	0	0	1	1	0	230
Connection rejection--NSAP unreachable (transient condition)	1	1	1	0	0	1	1	1	231
Connection rejection--NSAP unknown (permanent condition)	1	1	1	0	1	0	0	0	232
Reset--reason unspecified	1	1	1	0	1	0	0	1	233
Reset--congestion	1	1	1	0	1	0	1	0	234
	......								
	1	1	1	0	1	1	1	1	239
Higher level initiated	1	1	1	1	0	0	0	0	240
Disconnection--normal	1	1	1	1	0	0	0	1	241
Disconnection--abnormal	1	1	1	1	0	0	1	0	242
Disconnection--incompatible information in user data	1	1	1	1	0	0	1	1	243
Connection rejection--reason unspecified (transient condition)	1	1	1	1	0	1	0	0	244
Connection rejection--reason unspecified (permanent condition)	1	1	1	1	0	1	0	1	245
Connection rejection--requested quality of service not available (transient condition)	1	1	1	1	0	1	1	0	246
Connection rejection--requested quality of service not available (permanent condition)	1	1	1	1	0	1	1	1	247
Connection rejection-incompatible information in user data	1	1	1	1	1	0	0	0	248
Connection rejection--unrecognizable protocol identifier in user data	1	1	1	1	1	0	0	1	249
Reset--resynchronization	1	1	1	1	1	0	1	0	250
	......								
	1	1	1	1	1	1	1	1	255

NOTES

TC008.016

DTE/DTE ADJUSTMENTS

When operating in a DTE/DTE environment, the DTE must do some things differently. Also, some of the optional user facilities make no sense because there is no packet-switched network involved. These facilities do not apply in the DTE/DTE environment:

* D-bit Modification
* Incoming Calls Barred
* Outgoing Calls Barred
* Closed User Group Facilities
* Bilateral Closed User Group Facilities
* Fast Select Acceptance
* Charging Facilities
* Network User Identification
* RPOA Selection
* Hunt Group
* Call Redirection
* Notification Facilities
* Transit Delay Selection and Indication.

In the DTE/DTE environment, the two DTEs bilaterally agree on whether or not to use the Reject packet, the Registration procedure, and the Diagnostic packet in each direction of transmission. The impact on a DTE that agrees to receive the Reject packet is that the DTE must save each Data packet it sends until that packet is acknowledged.

A DTE that agrees to accepting the Registration Request packet must be capable of analyzing that packet and responding with the Registration Confirmation packet containing the appropriate information. Also, if the Registration procedure is used in both directions, the DTEs must be able to resolve collisions of Registration Requests.

A DTE that sends the Diagnostic packet must be able to not do so in the DTE/DCE environment.

The Flow Control Parameter Negotiation and Throughput Class Negotiation facilities behave somewhat differently in the DTE/DTE environment because there is no network to insert the facilities when a DTE omits them from Call Request or Call Accepted packets.

DTE/DTE ADJUSTMENTS

- LOGICAL CHANNEL SELECTION
- CALL COLLISION RESOLUTION
- MEANINGLESS FACILITIES
- REGISTRATION
- REJECT

TC009.036

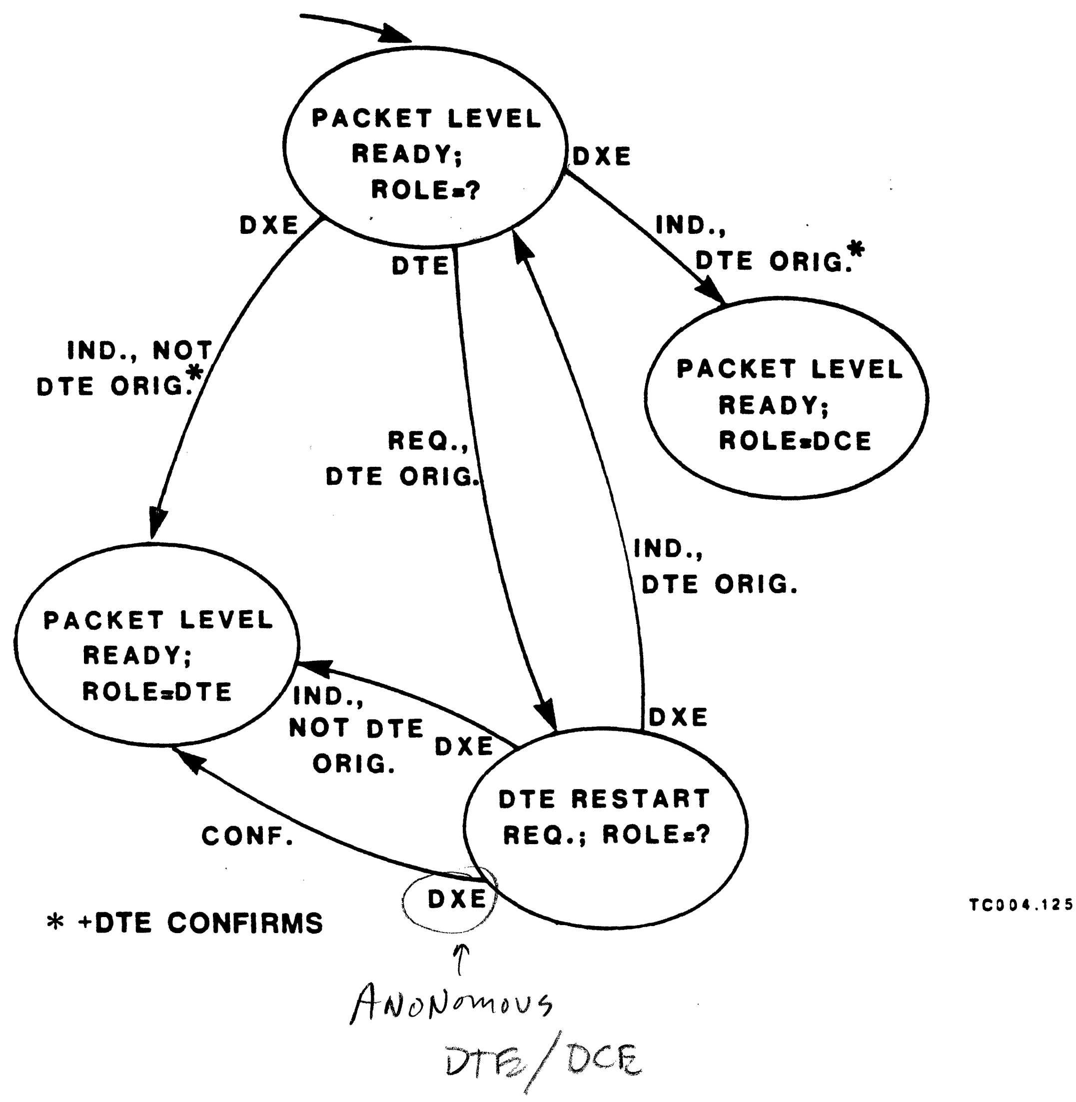
TC004.016

ROLE SELECTION

In the DTE/DTE environment one of the DTEs must behave like a DCE with regard to the order in which logical channels are used and in cases of call collision.

If a terminal is built to work only in a DTE/DCE environment or only in a DTE/DTE environment, then the role of the terminal can be entirely pre-established. However, if a terminal is built to work in both environments, it may need to be able to determine its role dynamically. This can be accomplished quite easily by interpretation of the Restart procedure done at Packet Level initiation time.

DTE ROLE DETERMINATION



TC010.016

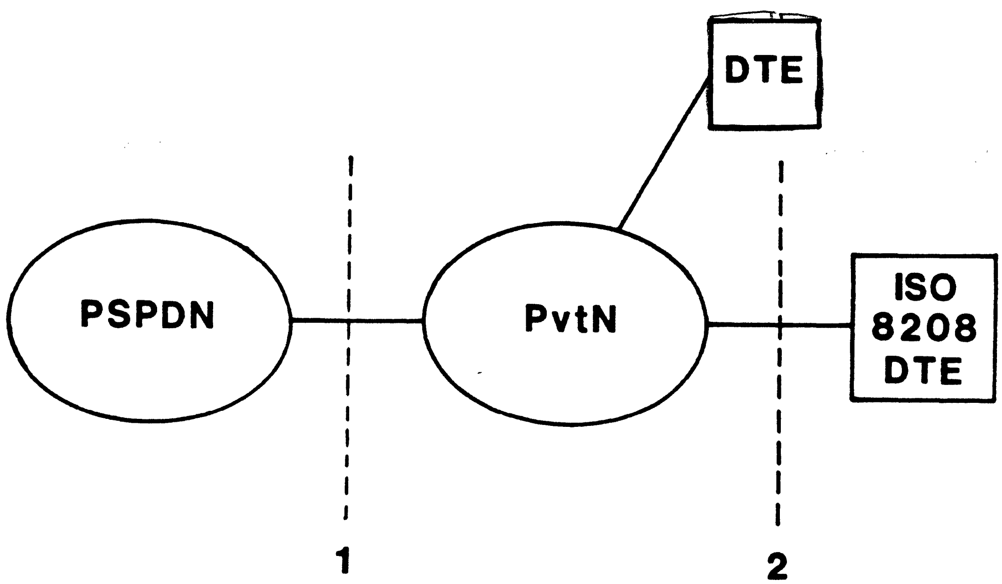
PUBLIC AND PRIVATE NETWORKS

When a private network is attached to a Public Packet-Switched Data Network, the private network appears to the public network as if it is a single-device DTE. This interface is marked in the figure as 1.

However, if the private network has attached to it terminals which comply with this standard, the private network should appear as if it is a network to those DTEs. This is the interface marked 2 in the figure. In Recommendation X.25, several capabilities were allowed for DTEs in order for private networks to perform this function and to help provide information in error situations about the location of the problem. Also, the Closed User Group, Bilateral Closed User Group, and Called Line Address Modified Notification facilities were expanded.

If the private network has terminals attached to it that do not comply with ISO 8208, the private network will need to provide for representing that terminal properly to the public network, if that type of terminal is permitted to communicate through the public network. This may involve, for example, procedural translation, format translation, encapsulation of "foreign" messages in packets, or invocation of optional user facilities.

PUBLIC AND PRIVATE NETWORKS



TC010.125

TC011.016

PRIVATE NETWORK CAUSES

This standard specifies that the cause fields are always coded by DTEs as 00000000 or 10000000 so that the other DTE-originated values with bit 8 = 1 (that X.25 permits) can be used by private networks without confusion. In addition, the following codes have been defined for the packets indicated:

Restart Request Causes

	BITS 8	7	6	5	4	3	2	1
Gateway-detected procedure error	1	1	0	0	0	0	0	1
Gateway congestion	1	1	0	0	0	0	1	1
Gateway operational	1	1	0	0	0	1	1	1

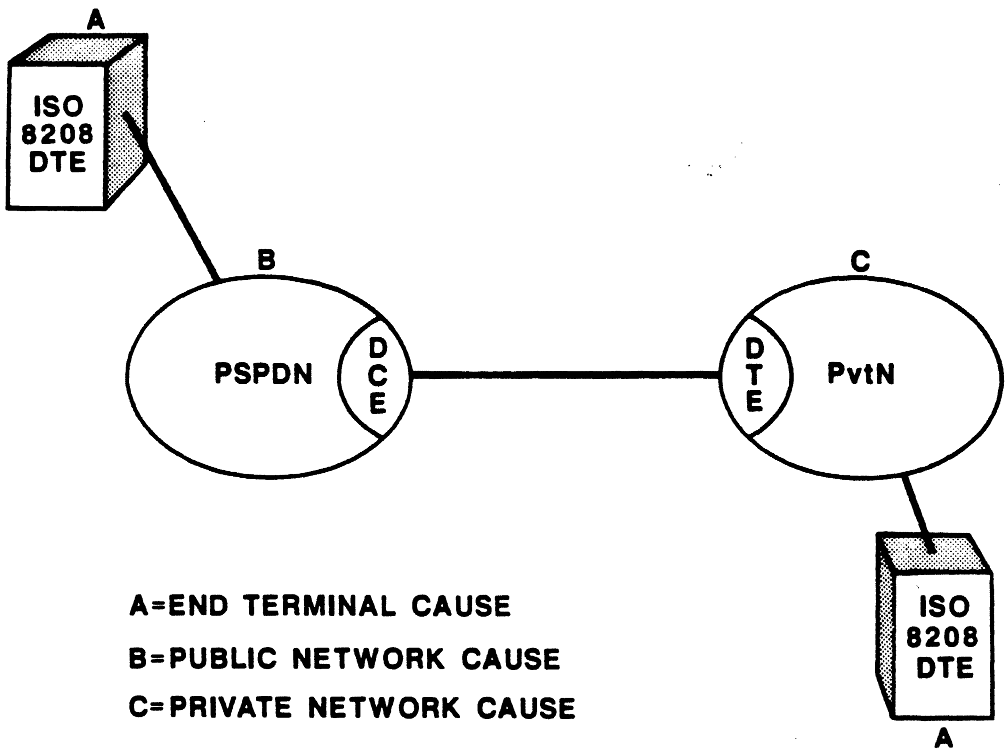
Clear Indication Causes

	BITS 8	7	6	5	4	3	2	1
Gateway-detected procedure error	1	1	0	0	0	0	0	1
Gateway congestion	1	1	0	0	0	0	1	1

Reset Indication Causes

	BITS 8	7	6	5	4	3	2	1
Gateway-detected procedure error	1	1	0	0	0	0	0	1
Gateway congestion	1	1	0	0	0	0	1	1
Gateway operational	1	1	0	0	0	1	1	1

PRIVATE NETWORK CAUSES



TC011.016

TC012.036

ADDITIONAL PRIVATE NETWORK CONCERNS

The private network must subscribe to facilities in the public network properly in order to offer the correct facilities to each terminal on the private network. This is particularly tricky for the closed user group facilities. The charging information, call redirection, hunt group, fast select and other facilities may also require participation of the private network.

Another area of concern for the private network is the question of addressing the individual terminals on the private network. Among the possibilties are subaddressing (digits in the address field that are ignored by the public network), shared address space (several addresses are assigned by the public network to one DTE), and the sharing of a DNIC by several private networks (also called PNIC for Private Network Identification Code).

ADDITIONAL PRIVATE NETWORK CONCERNS

- **FACILITIES**
- **ADDRESSING**

Sub addressing.
Shared address space.
get many address assigned by PSDN
Shared DNIC and PNIC.
NOT GOOD for international private networks.

No such thing as private DNIC
~~but~~ Private nets can have their own addressing schemes.

TC012.036

NOTES

SCENARIO

OSI NETWORK SERVICE
USING X.25

NSS000.000

NSS001.026

SCENARIO CONFIGURATION

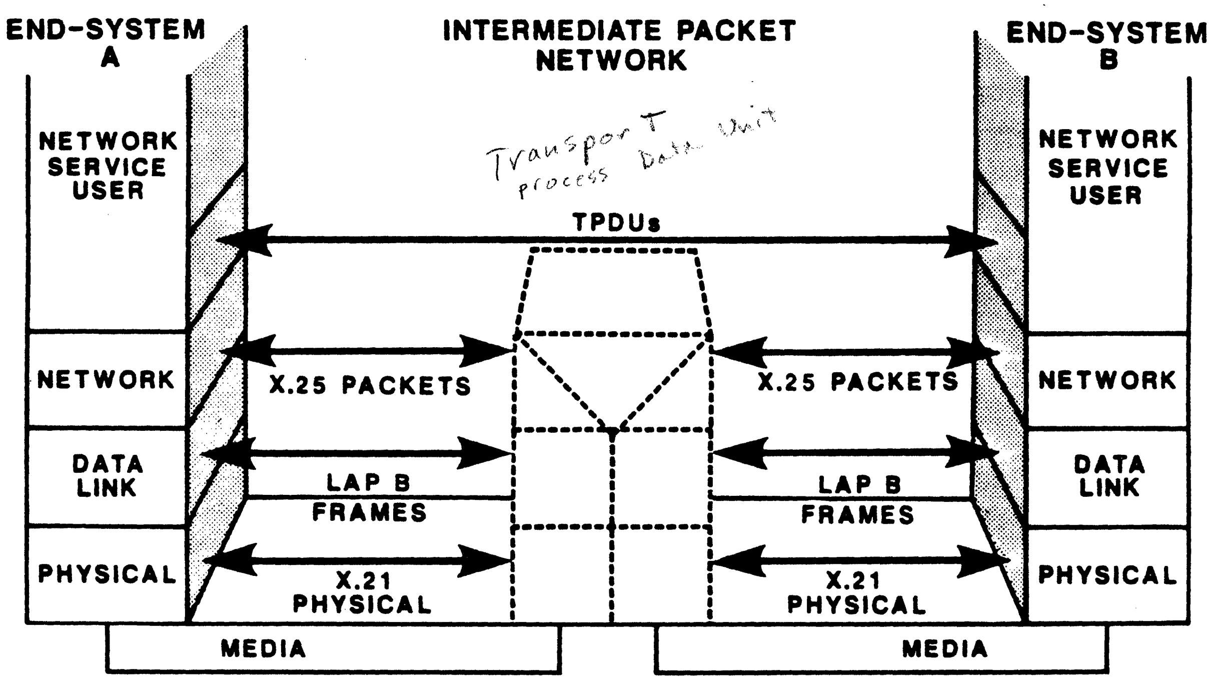
This scenario has been designed to show the dynamics of the lower three layers of the OSI architecture providing the Network Service. Its mission is to provide fully transparent transfer of information with the appropriate quality of service between Transport peer entities. The example is based on using the Network Services provided by X.25 packet-switching.

The Figure shows the configuration that is used for the scenario. The communicating application processes are located in the two end-systems, A and B. The collective functions and actions of the lower three layers in the end-systems and the intermediate packet network are the Network Service Provider to the two Network Service Users. While the intermediate packet network is shown as a single relay-system in dotted lines, it actually represents the collection of relay-systems, or switching nodes, that are involved in the Network connection. The details of operation of the intermediate relay-systems are not covered in order to simplify the scenario. Nevertheless, a clear picture of the total operation of the Network Service can be observed.

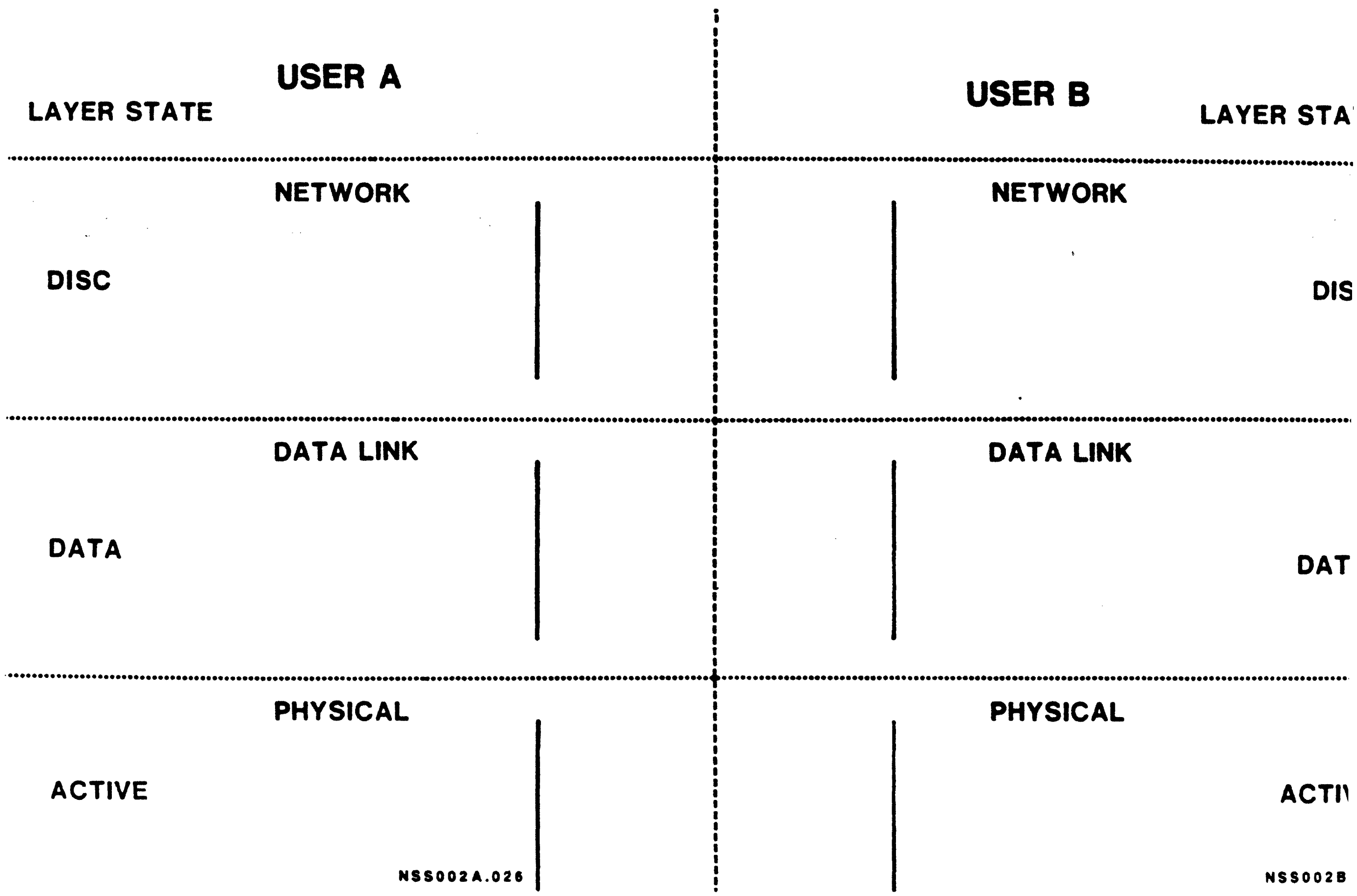
With the two overhead projectors, your left-hand side represents the actions at end-system A and your right-hand side represents the actions at end-system B. The interlayer primitive interactions are shown along with the associated peer protocol actions, sequence numbers and logical channel numbers.

The scenario starts from the inactive, disconnected state for the Transport and Network Services and proceeds through the establishment of activity for each. (The state that each layer is in is shown on the outer edge of each slide.) Data is then transferred using the paclet level protocol on the Network connection between Transport peers. Various error situations are introduced and the appropriate recovery action is taken. The Network connection is then cleared.

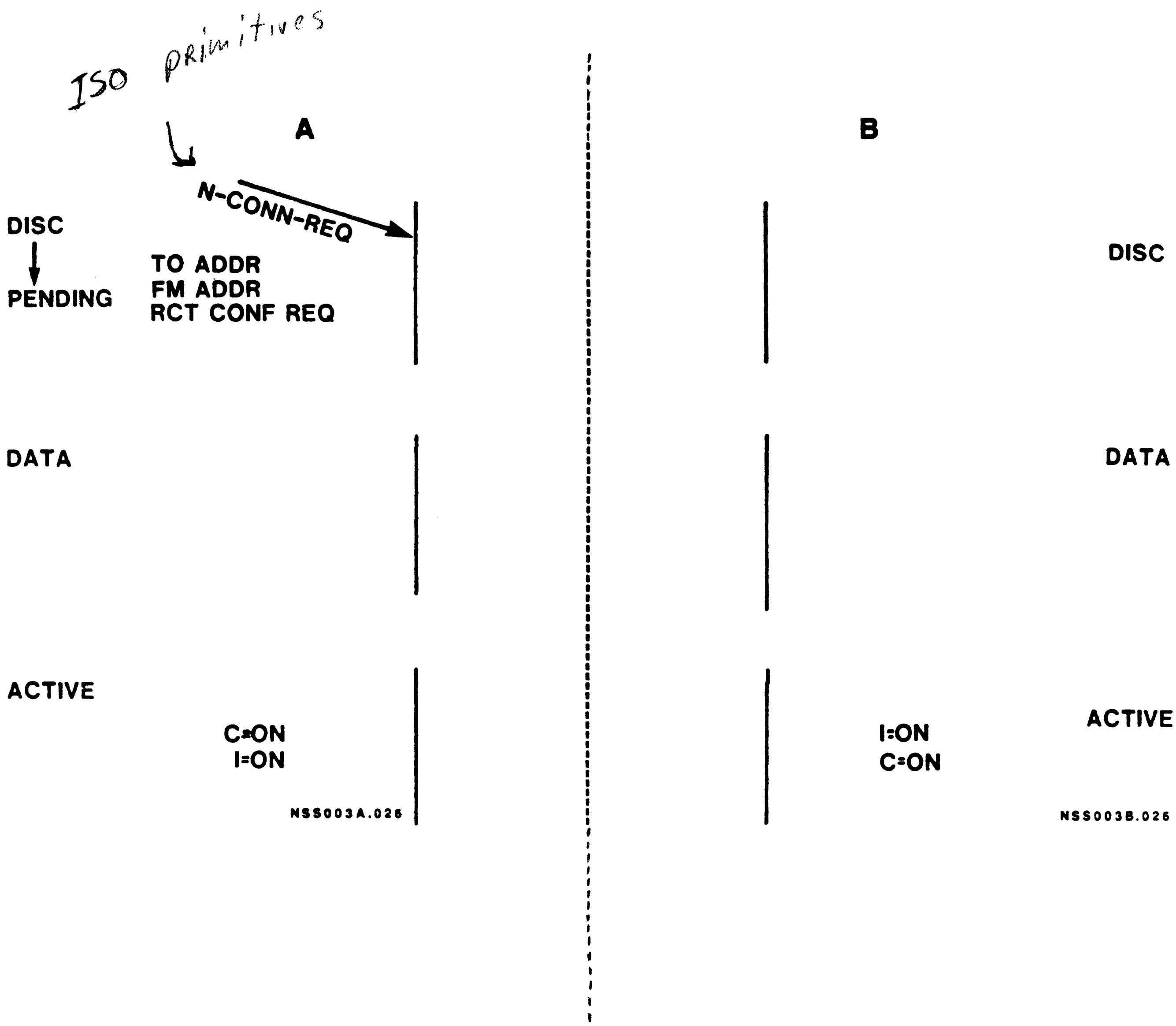
SCENARIO CONFIGURATION

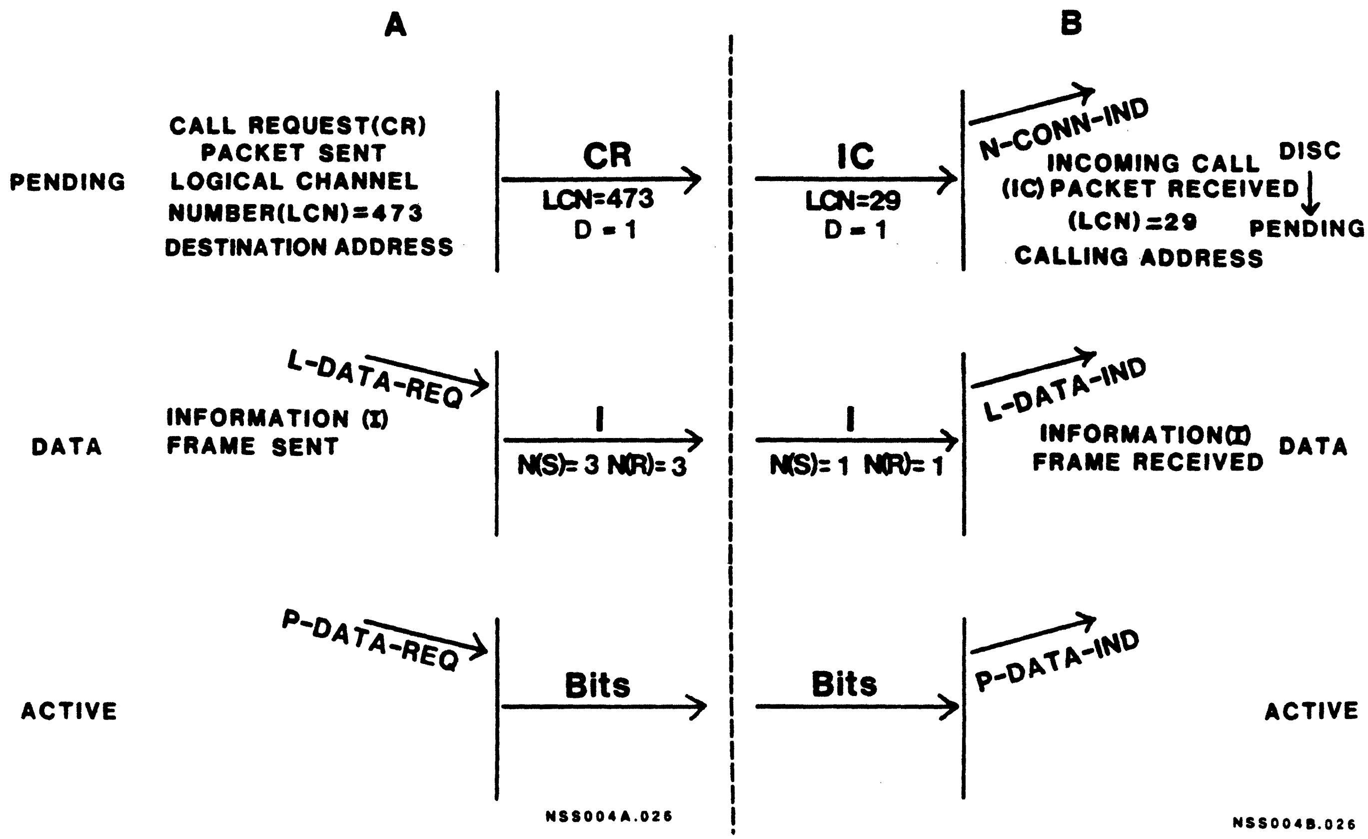


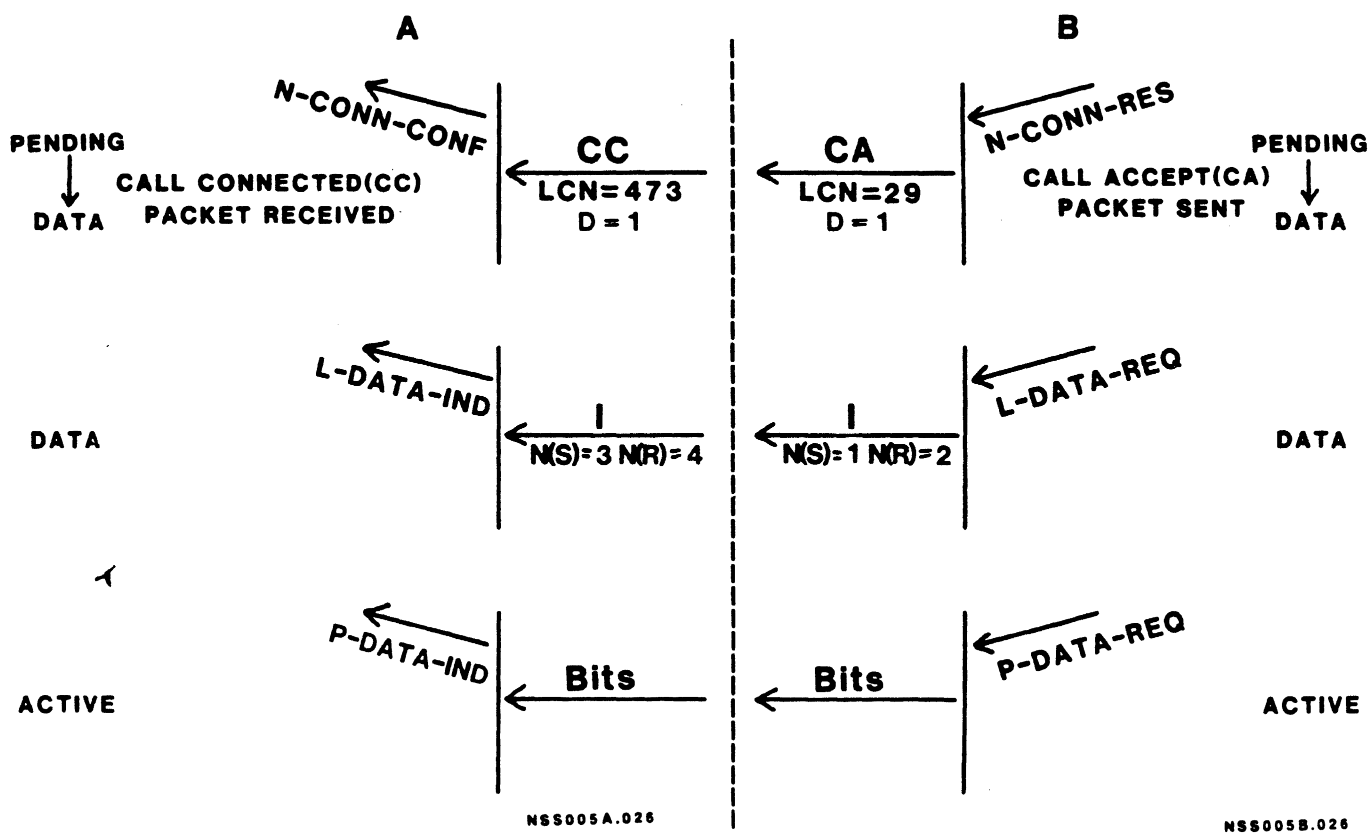
NSS001.026

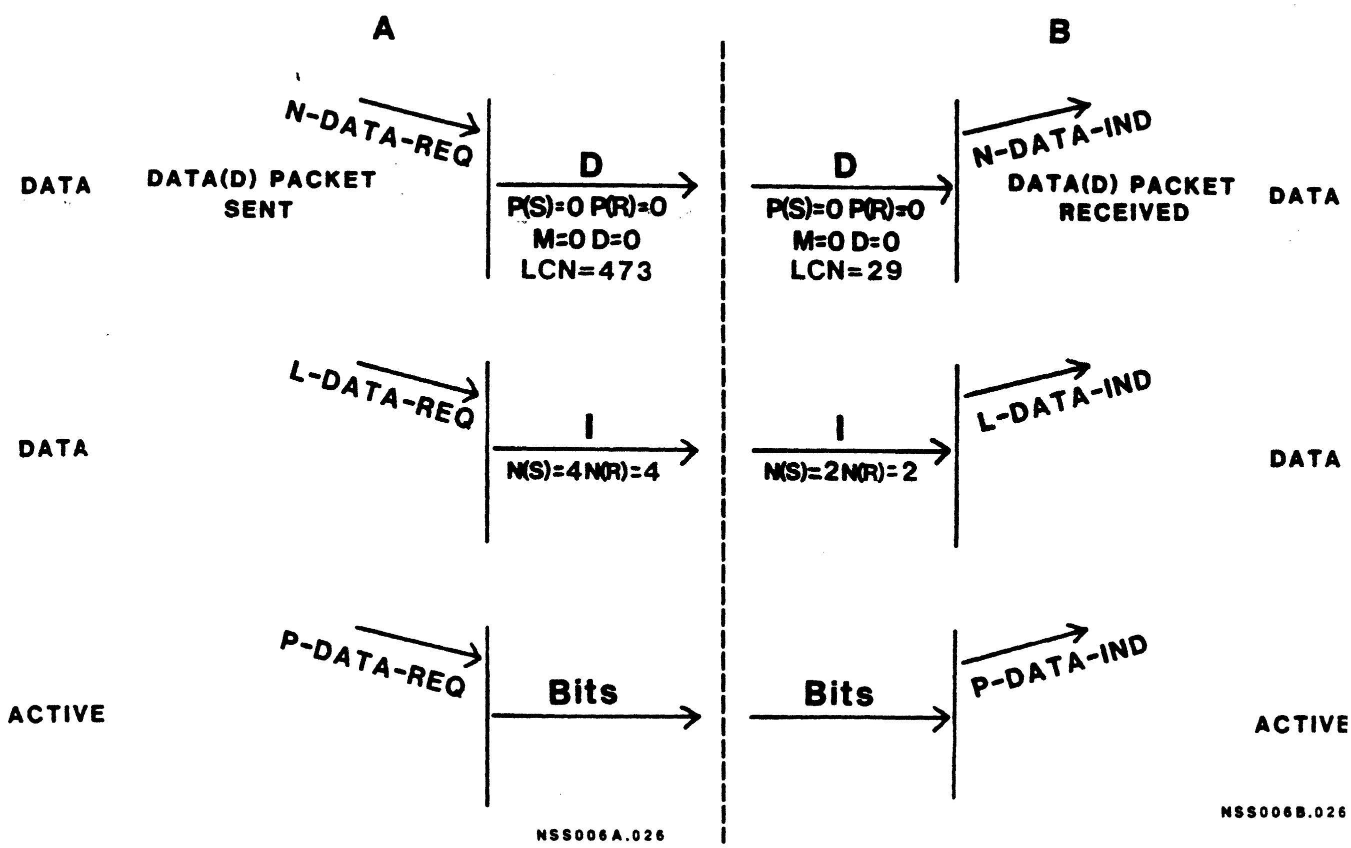


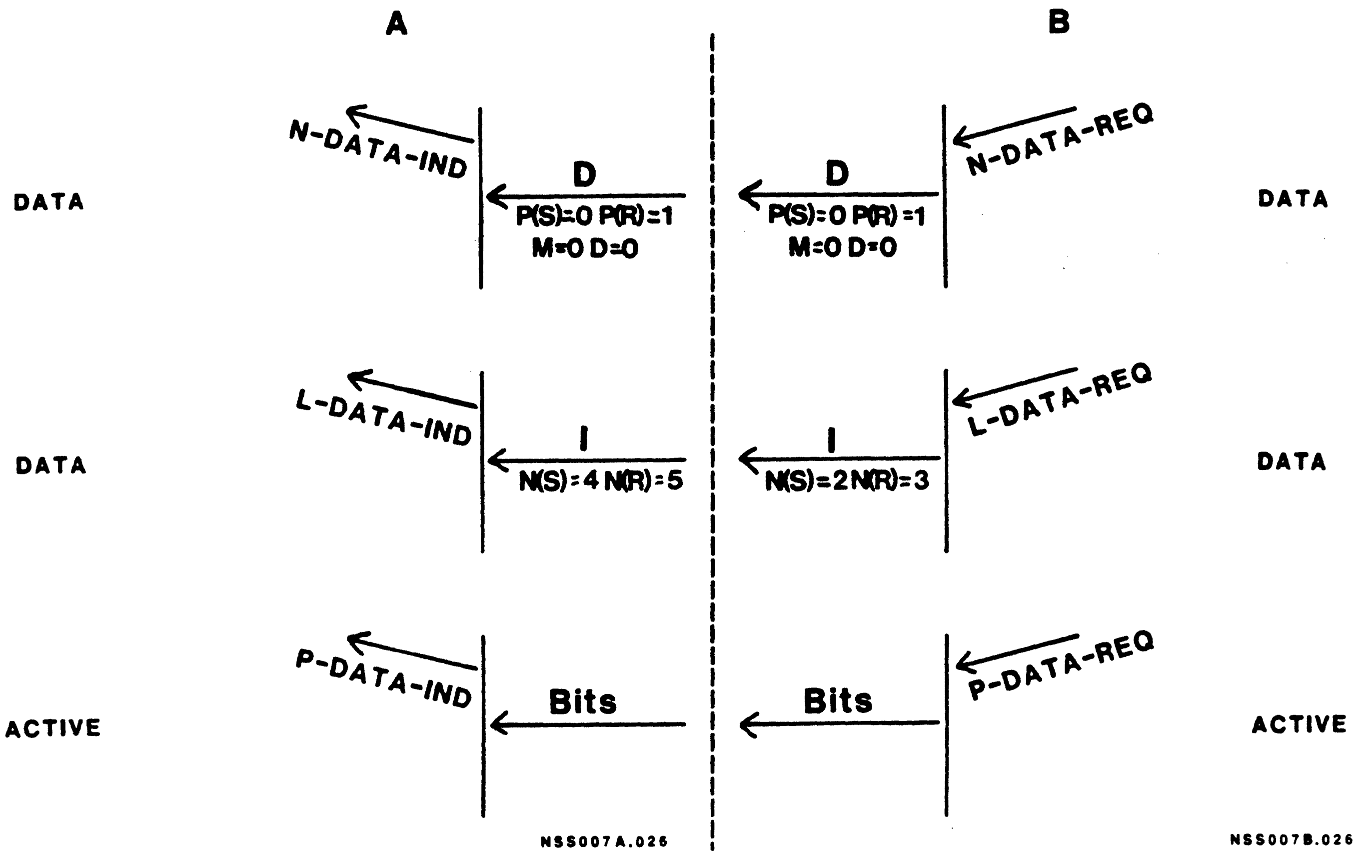
USER A
LAYER STATE
USER B
LAYER STA
NETWORK
NETWORK
DISC
DIS
DATA LINK
DATA LINK
DATA
DAT
PHYSICAL
PHYSICAL
ACTIVE
ACTI\
NSS002A.026
NSS002B

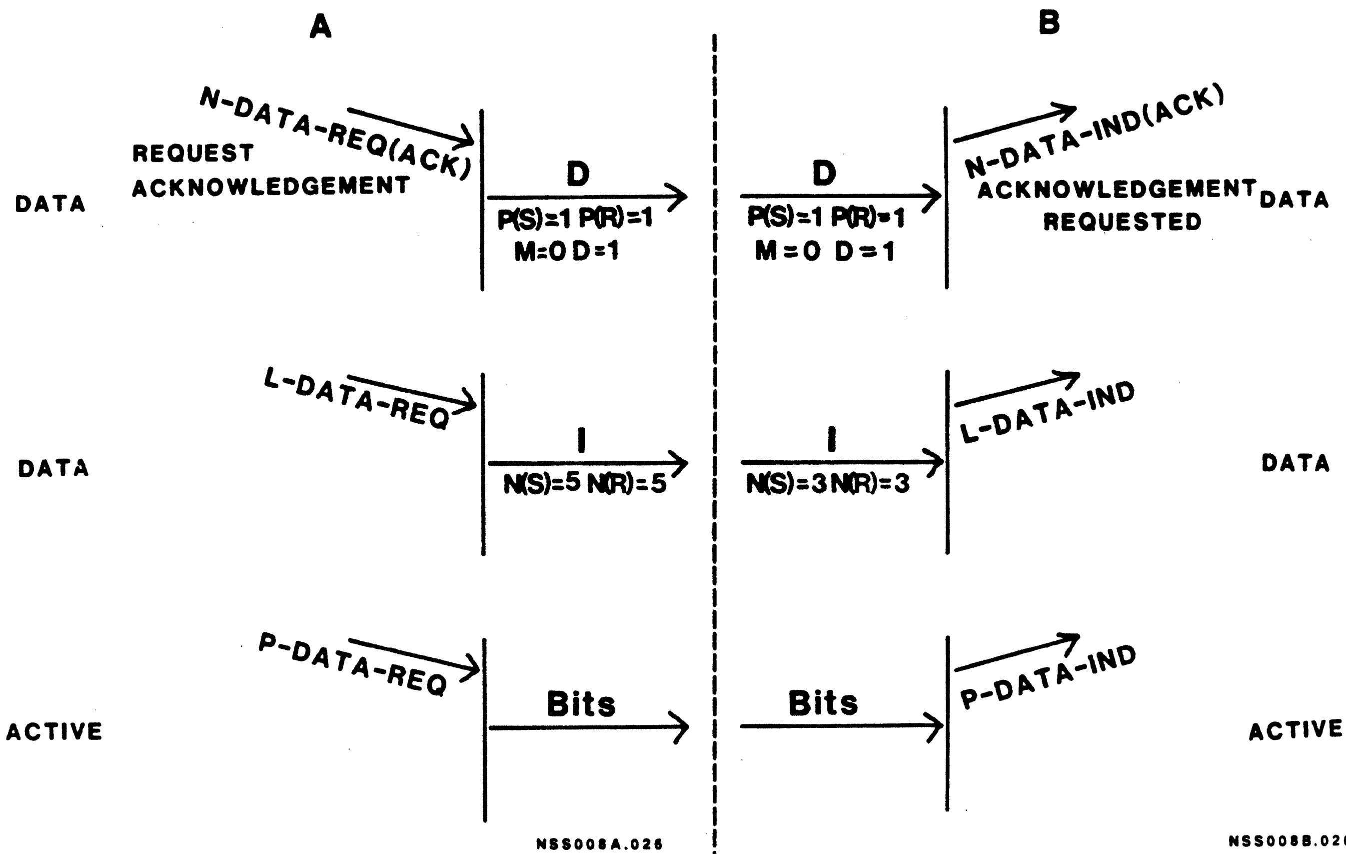

ISO primitives
A
B
N-CONN-REQ
DISC
PENDING
TO ADDR
FM ADDR
RCT CONF REQ
DISC
DATA
DATA
ACTIVE
C=ON
I=ON
NSS003A.026
I=ON
C=ON
ACTIVE
NSS003B.026

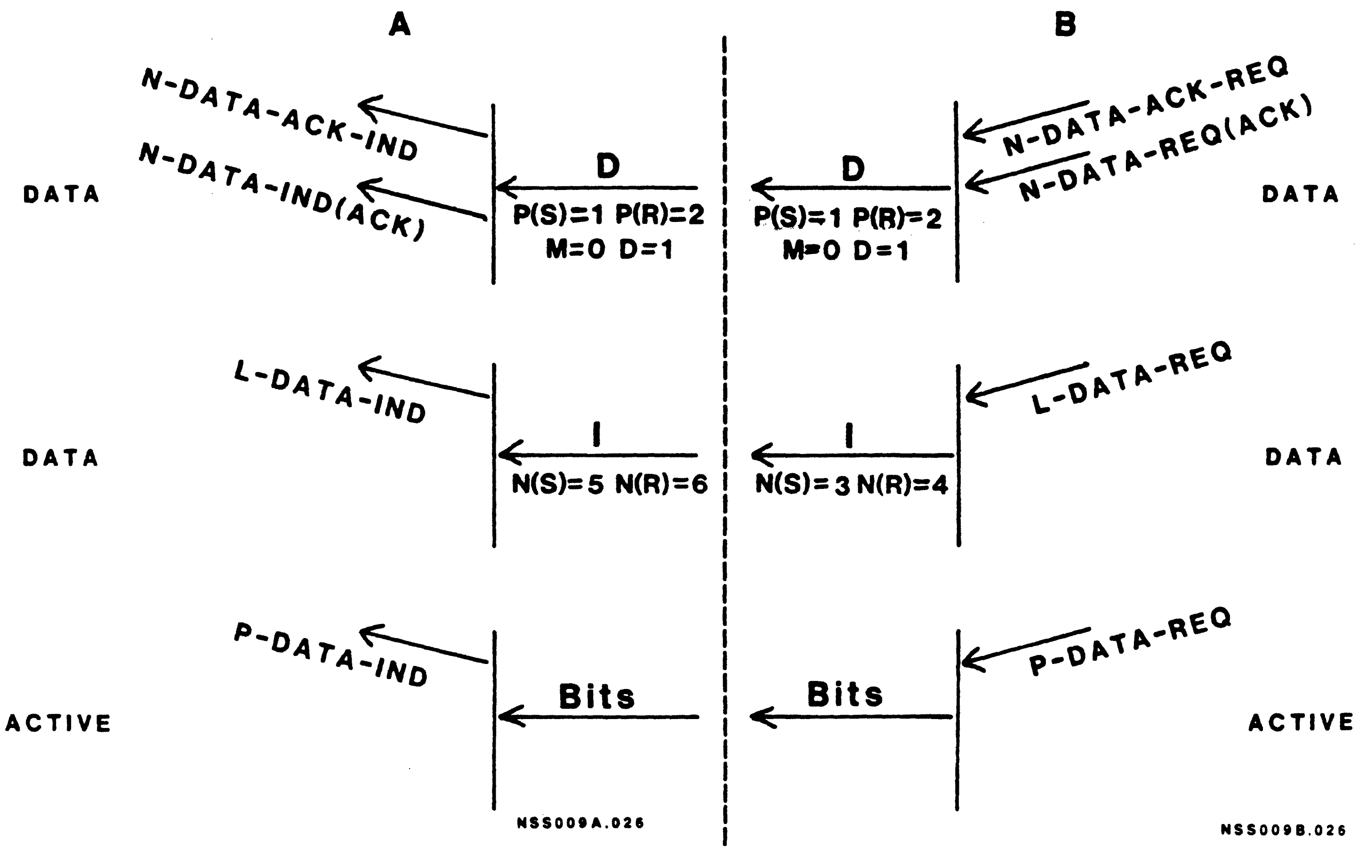

A
B
PENDING
CALL REQUEST(CR)
PACKET SENT
LOGICAL CHANNEL
NUMBER(LCN)=473
DESTINATION ADDRESS
CR
LCN=473
D = 1
IC
LCN=29
D = 1
N-CONN-IND
INCOMING CALL
(IC) PACKET RECEIVED
(LCN)=29
CALLING ADDRESS
DISC
PENDING
L-DATA-REQ
DATA
INFORMATION (I)
FRAME SENT
I
N(S)= 3 N(R)= 3
I
N(S)= 1 N(R)= 1
L-DATA-IND
INFORMATION(I)
FRAME RECEIVED
DATA
P-DATA-REQ
ACTIVE
Bits
Bits
P-DATA-IND
ACTIVE
NSS004A.026
NSS004B.026

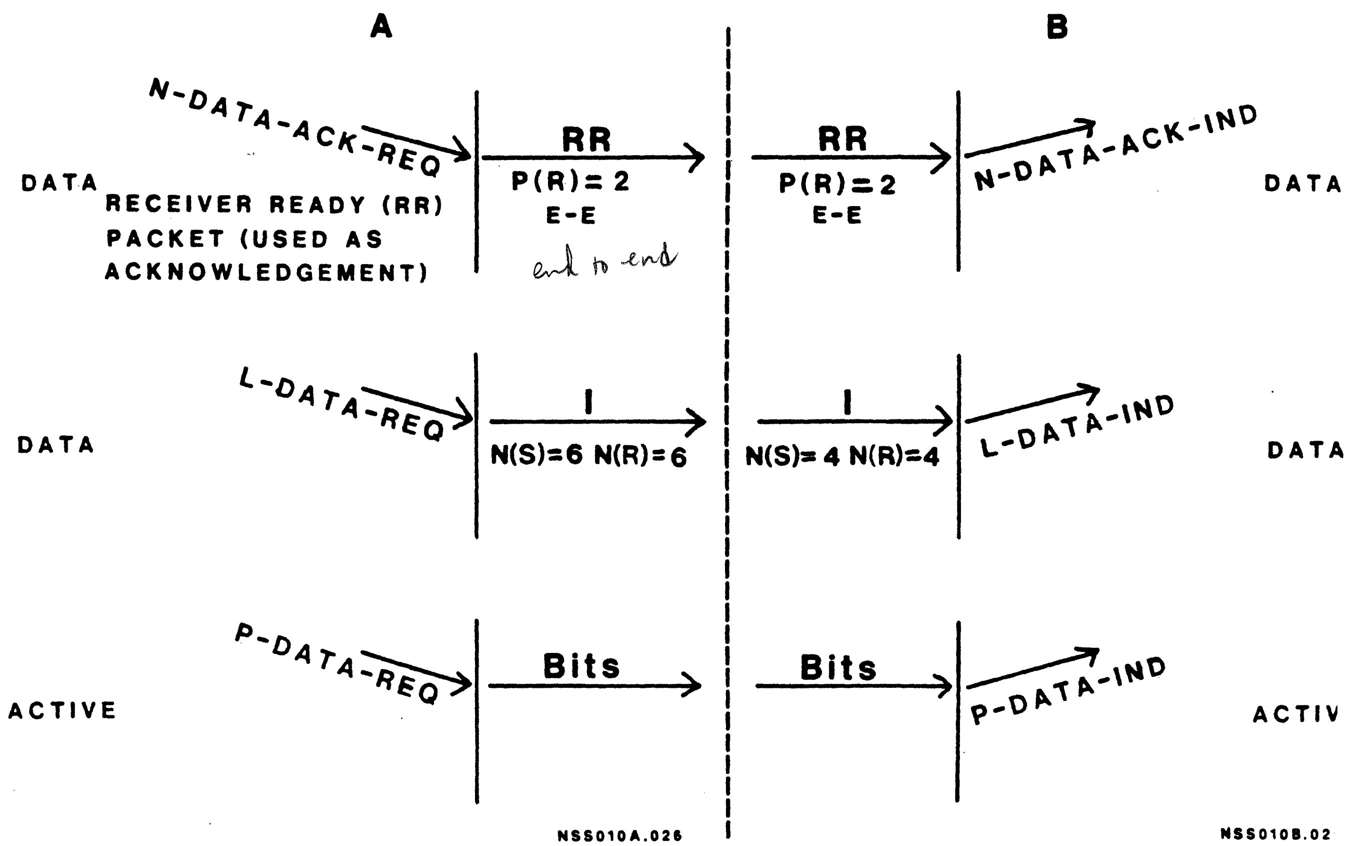

A
B
N-CONN-CONF
PENDING
DATA
CALL CONNECTED(CC)
PACKET RECEIVED
CC
LCN=473
D=1
CA
LCN=29
D=1
N-CONN-RES
PENDING
CALL ACCEPT(CA)
PACKET SENT
DATA
L-DATA-IND
DATA
I
N(S)=3 N(R)=4
I
N(S)=1 N(R)=2
L-DATA-REQ
DATA
P-DATA-IND
ACTIVE
Bits
Bits
P-DATA-REQ
ACTIVE
NSS005A.026
NSS005B.026

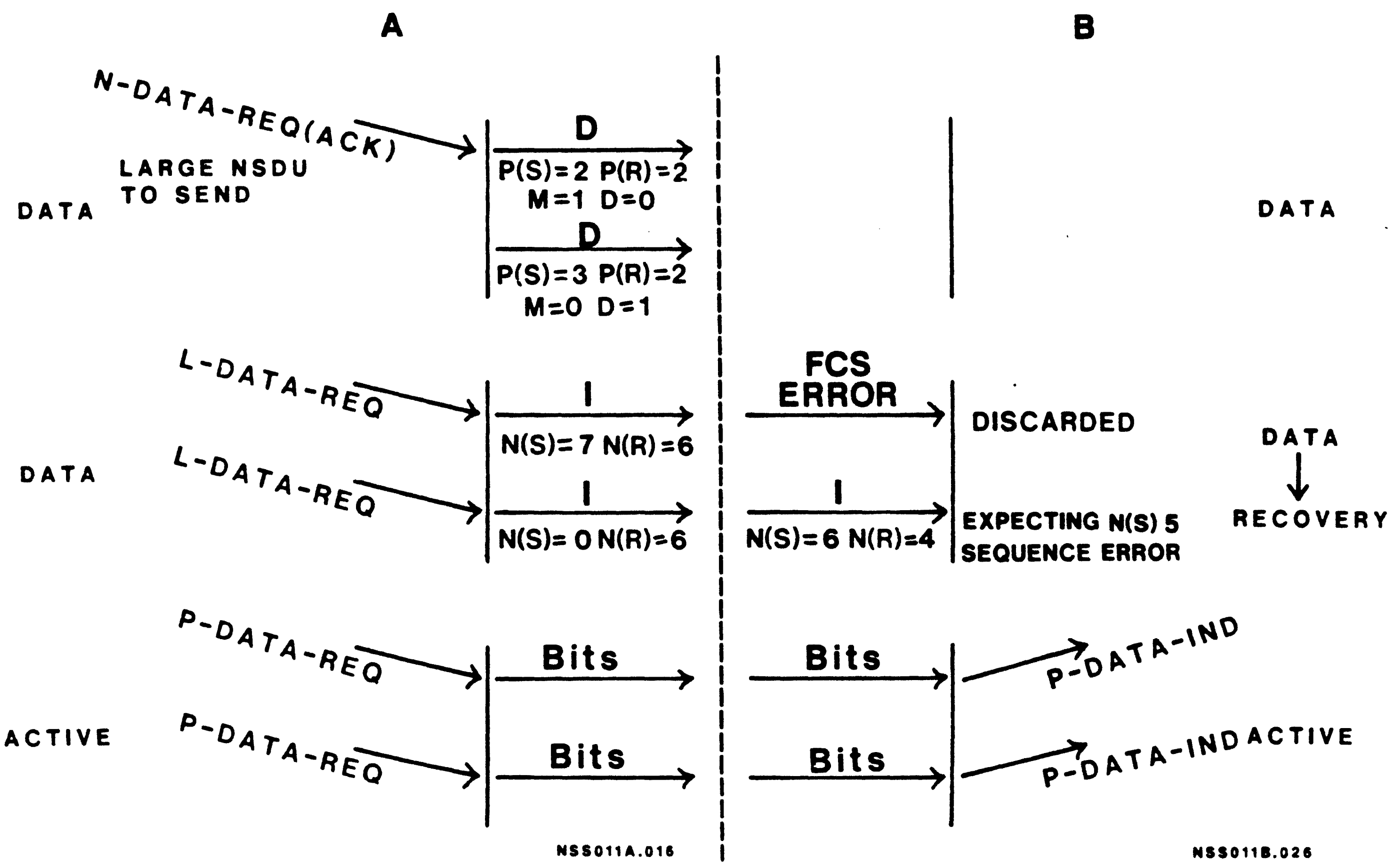

A
B
N-DATA-REQ
N-DATA-IND
DATA
DATA(D) PACKET
SENT
D
P(S)=0 P(R)=0
M=0 D=0
LCN=473
D
P(S)=0 P(R)=0
M=0 D=0
LCN=29
DATA(D) PACKET
RECEIVED
DATA
L-DATA-REQ
L-DATA-IND
DATA
I
N(S)=4 N(R)=4
I
N(S)=2 N(R)=2
DATA
P-DATA-REQ
P-DATA-IND
ACTIVE
Bits
Bits
ACTIVE
NSS006A.026
NSS006B.026

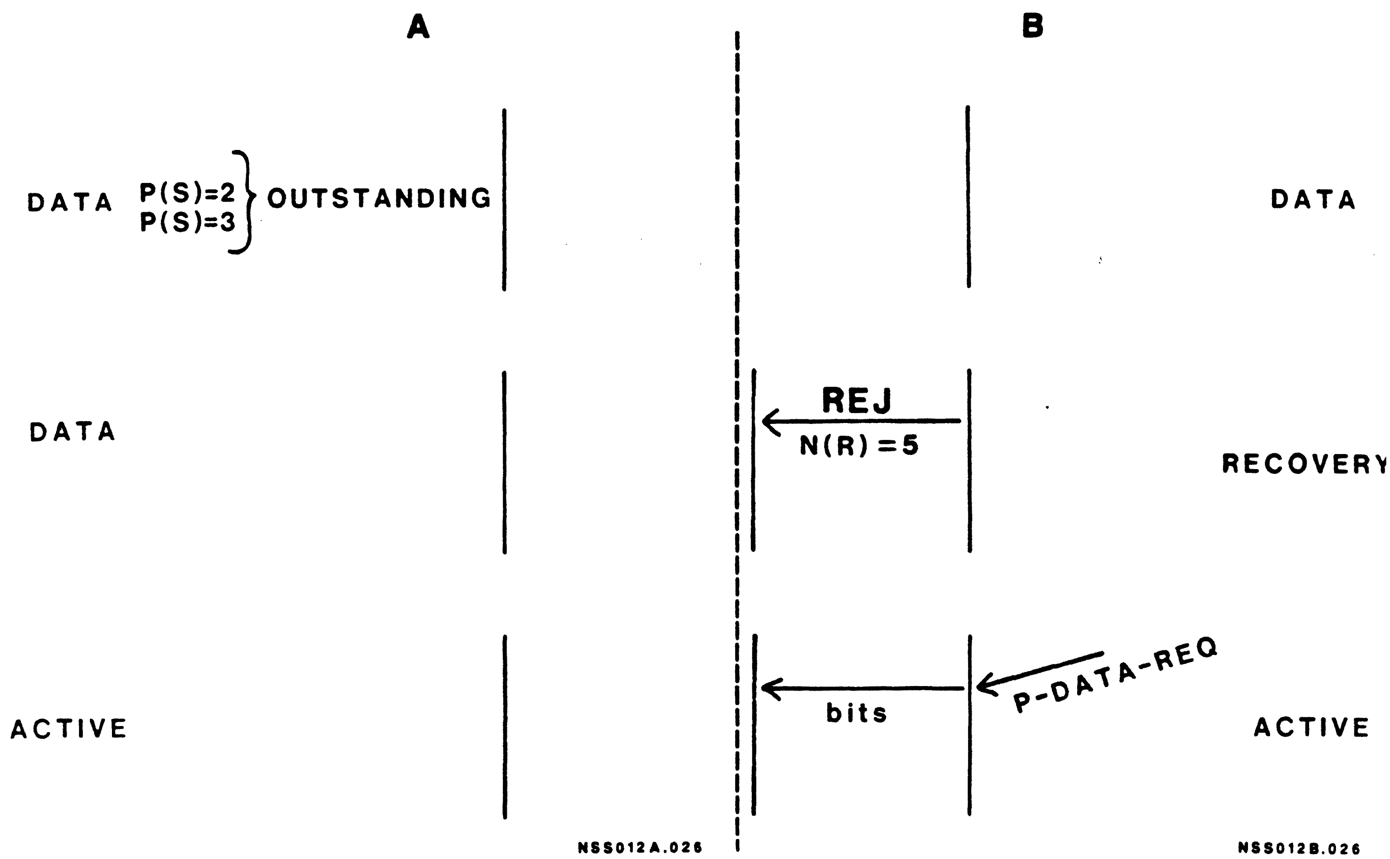

A
B
N-DATA-IND
D
P(S)=0 P(R)=1
M=0 D=0
D
P(S)=0 P(R)=1
M=0 D=0
N-DATA-REQ
DATA
DATA
L-DATA-IND
I
N(S)=4 N(R)=5
I
N(S)=2 N(R)=3
L-DATA-REQ
DATA
DATA
P-DATA-IND
Bits
Bits
P-DATA-REQ
ACTIVE
ACTIVE
NSS007A.026
NSS007B.026

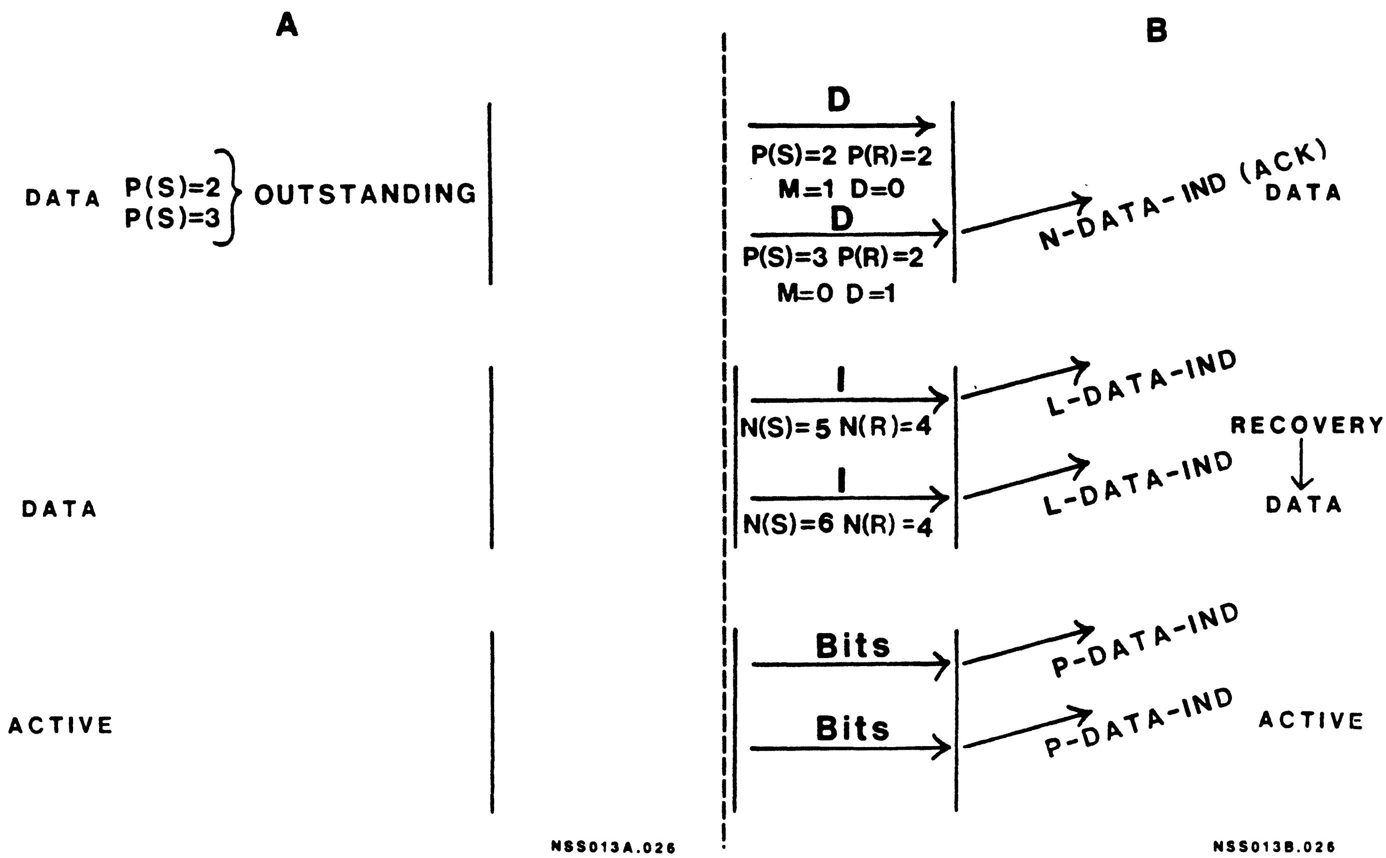

A
B
N-DATA-REQ(ACK)
REQUEST
ACKNOWLEDGEMENT
DATA
D
P(S)=1 P(R)=1
M=0 D=1
D
P(S)=1 P(R)=1
M=0 D=1
N-DATA-IND(ACK)
ACKNOWLEDGEMENT
REQUESTED
DATA
L-DATA-REQ
DATA
I
N(S)=5 N(R)=5
I
N(S)=3 N(R)=3
L-DATA-IND
DATA
P-DATA-REQ
ACTIVE
Bits
Bits
P-DATA-IND
ACTIVE
NSS008A.026
NSS008B.02

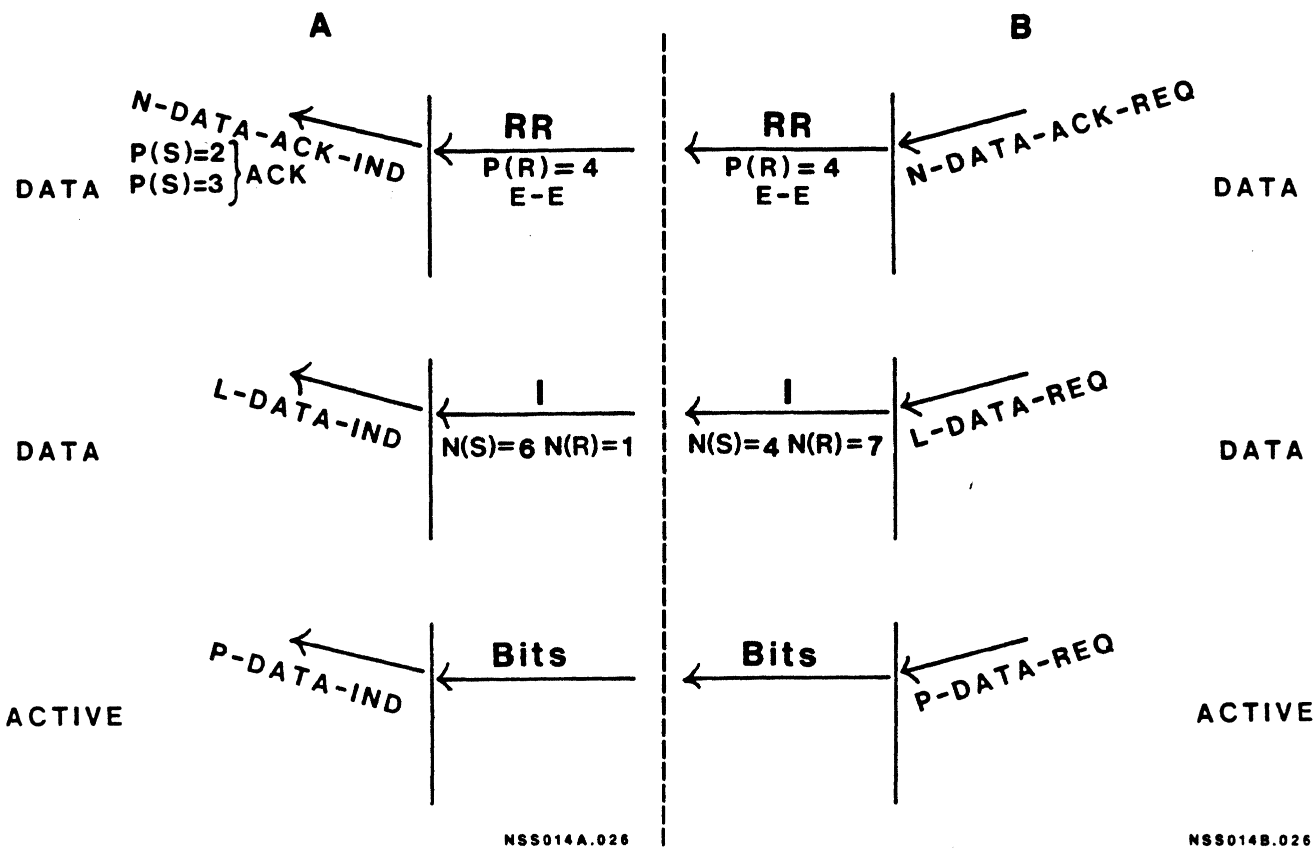

A
B
N-DATA-ACK-IND
N-DATA-IND(ACK)
N-DATA-ACK-REQ
N-DATA-REQ(ACK)
DATA
D
P(S)=1 P(R)=2
M=0 D=1
D
P(S)=1 P(R)=2
M=0 D=1
DATA
L-DATA-IND
L-DATA-REQ
DATA
I
N(S)=5 N(R)=6
I
N(S)=3 N(R)=4
DATA
P-DATA-IND
P-DATA-REQ
ACTIVE
Bits
Bits
ACTIVE
NSS009A.026
NSS009B.026

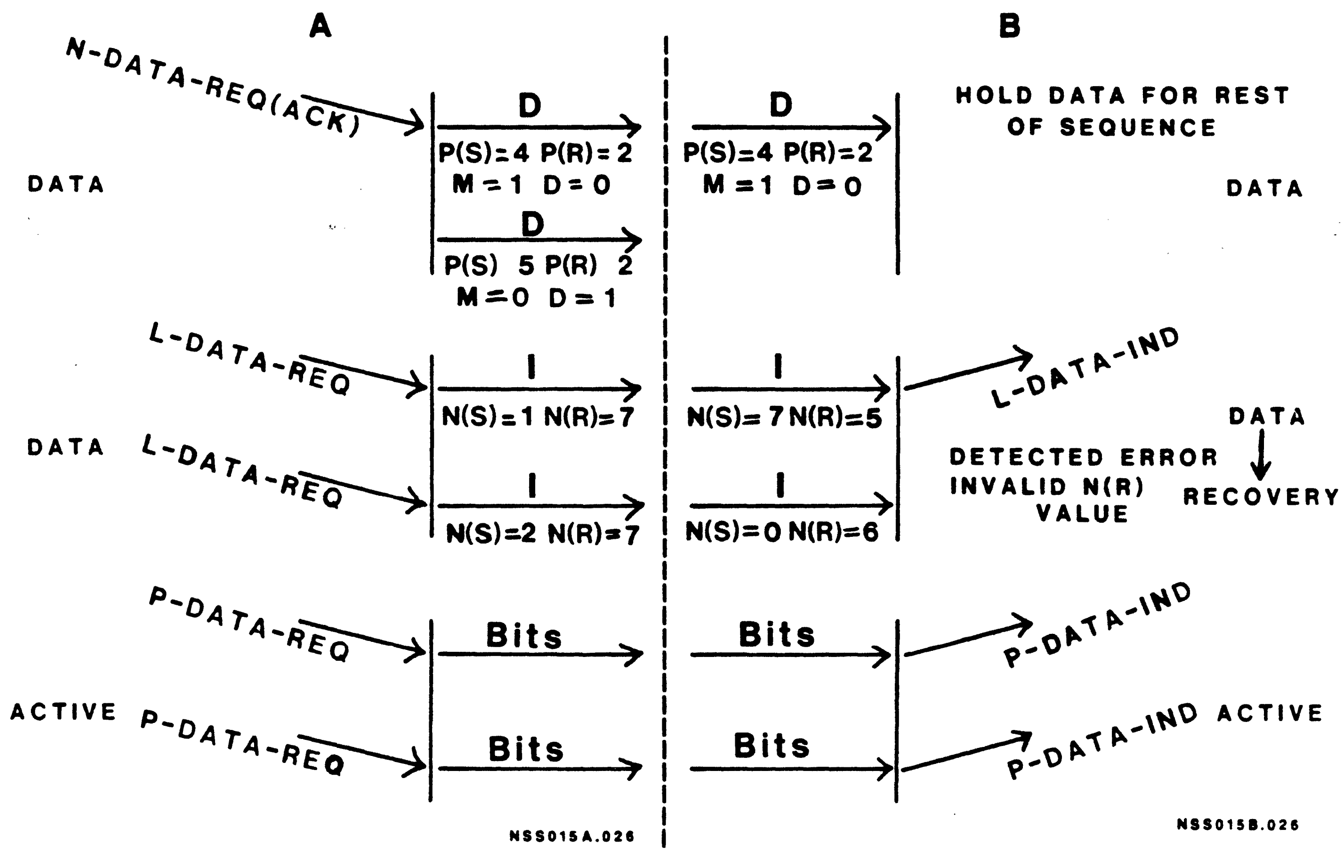

A
B
N-DATA-ACK-REQ
RR
P(R)= 2
E-E
end to end
RR
P(R)=2
E-E
N-DATA-ACK-IND
DATA
RECEIVER READY (RR)
PACKET (USED AS
ACKNOWLEDGEMENT)
DATA
L-DATA-REQ
I
N(S)=6 N(R)=6
I
N(S)= 4 N(R)=4
L-DATA-IND
DATA
DATA
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
ACTIV
NSS010A.026
NSS010B.02

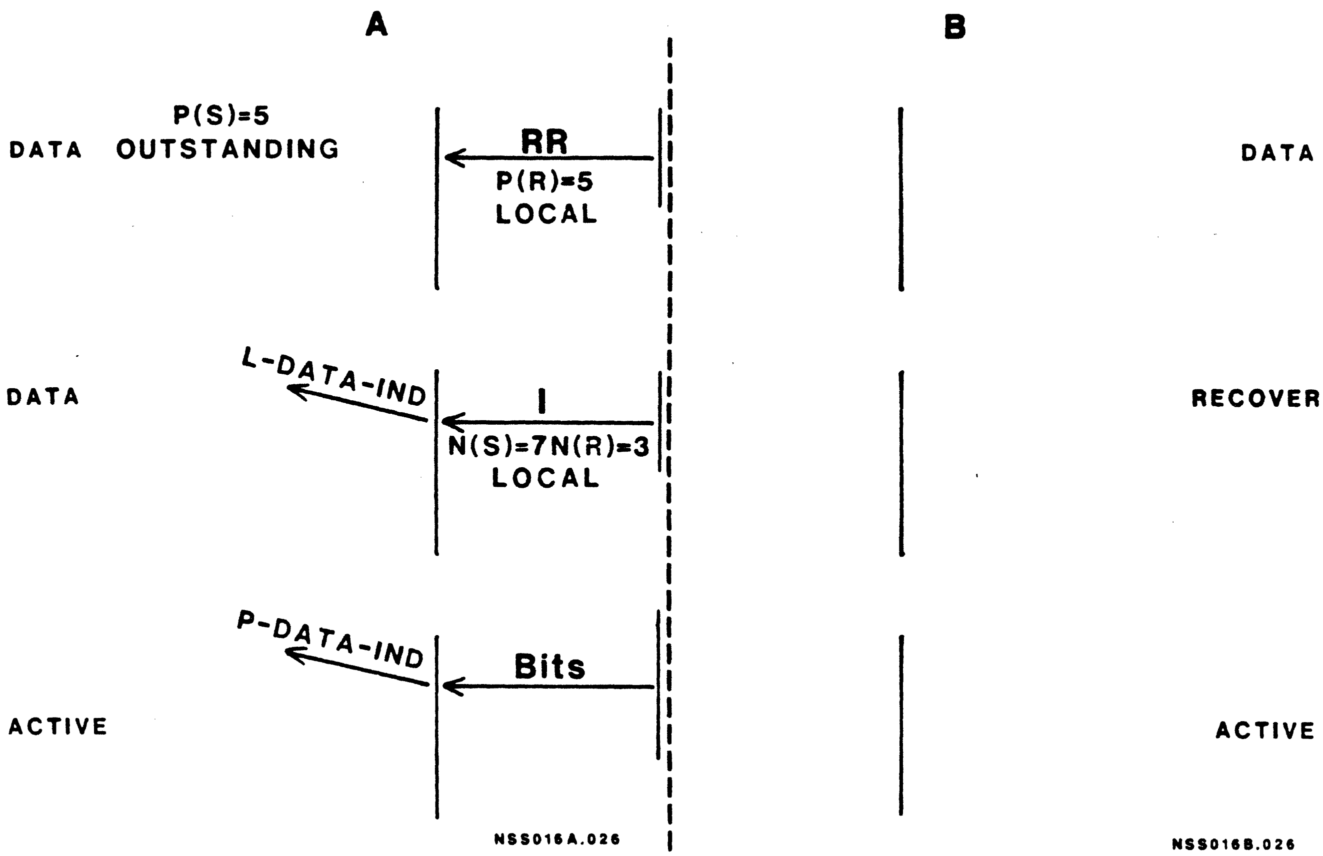

A
B
N-DATA-REQ(ACK)
LARGE NSDU
TO SEND
DATA
D
P(S)=2 P(R)=2
M=1 D=0
D
P(S)=3 P(R)=2
M=0 D=1
DATA
L-DATA-REQ
I
N(S)=7 N(R)=6
FCS
ERROR
DISCARDED
DATA
L-DATA-REQ
I
N(S)= 0 N(R)=6
I
N(S)=6 N(R)=4
EXPECTING N(S) 5
SEQUENCE ERROR
DATA
RECOVERY
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
NSS011A.016
NSS011B.026

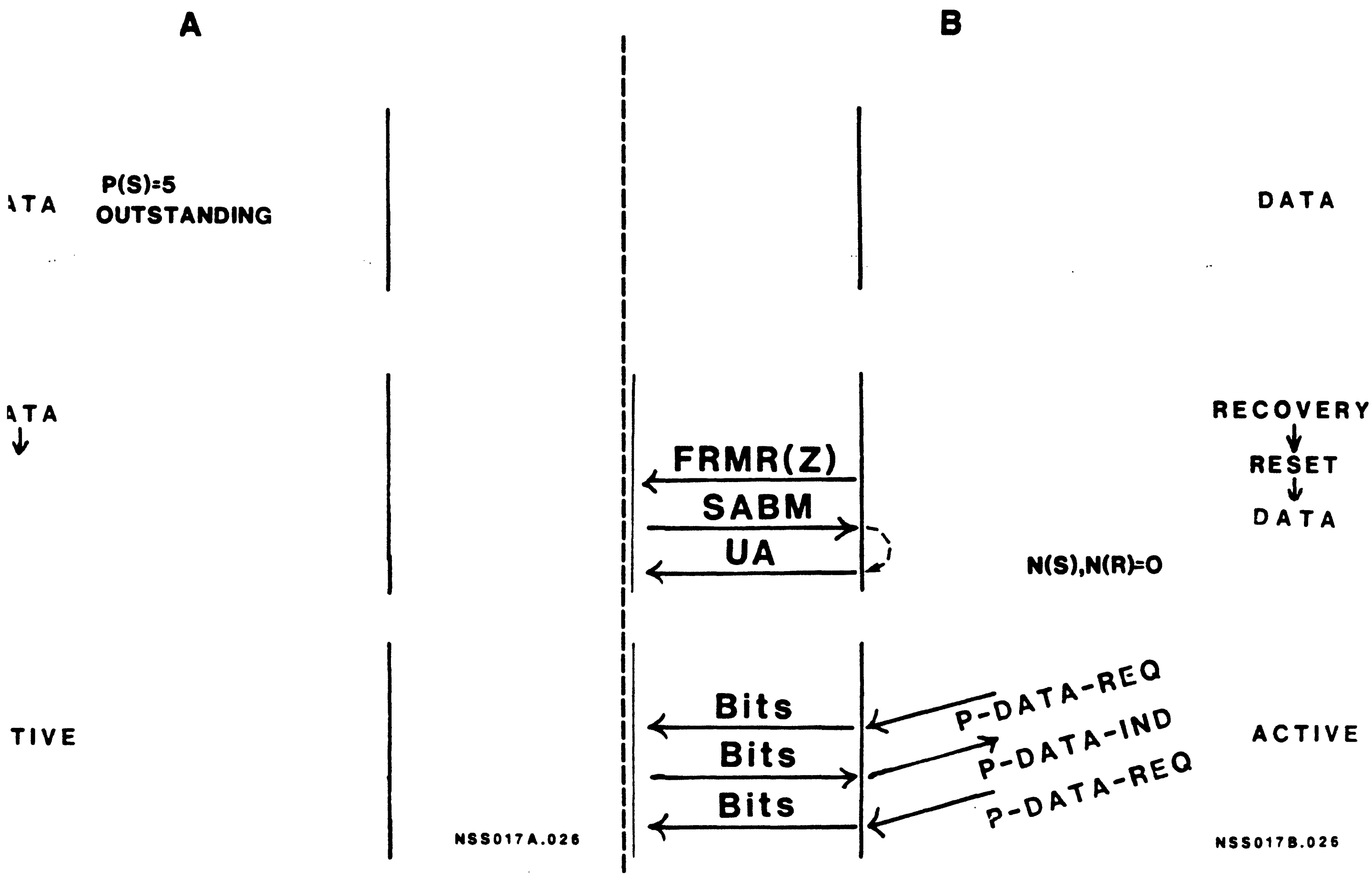

A
B
DATA
P(S)=2
P(S)=3
OUTSTANDING
DATA
DATA
REJ
N(R) =5
RECOVERY
ACTIVE
bits
P-DATA-REQ
ACTIVE
NSS012A.026
NSS012B.026


A
B
D
P(S)=2 P(R)=2
M=1 D=0
D
P(S)=3 P(R)=2
M=0 D=1
DATA
P(S)=2
P(S)=3
OUTSTANDING
N-DATA-IND (ACK)
DATA
I
N(S)=5 N(R)=4
I
N(S)=6 N(R)=4
L-DATA-IND
L-DATA-IND
RECOVERY
DATA
DATA
Bits
Bits
P-DATA-IND
P-DATA-IND
ACTIVE
ACTIVE
NSS013A.026
NSS013B.026

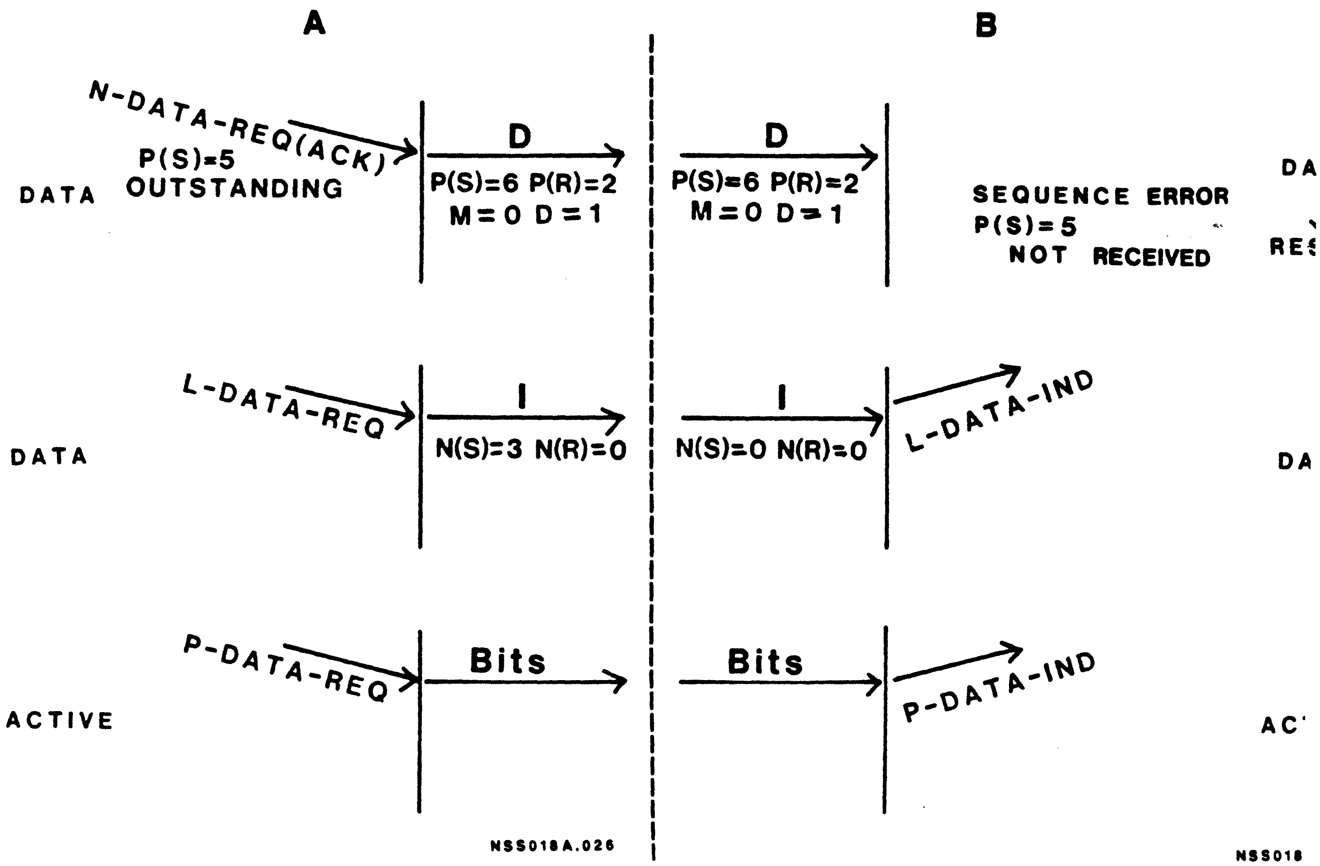

A
B
N-DATA-ACK-IND
P(S)=2
P(S)=3
ACK
DATA
RR
P(R)=4
E-E
RR
P(R)=4
E-E
N-DATA-ACK-REQ
DATA
L-DATA-IND
DATA
I
N(S)=6 N(R)=1
I
N(S)=4 N(R)=7
L-DATA-REQ
DATA
P-DATA-IND
ACTIVE
Bits
Bits
P-DATA-REQ
ACTIVE
NSS014A.026
NSS014B.026

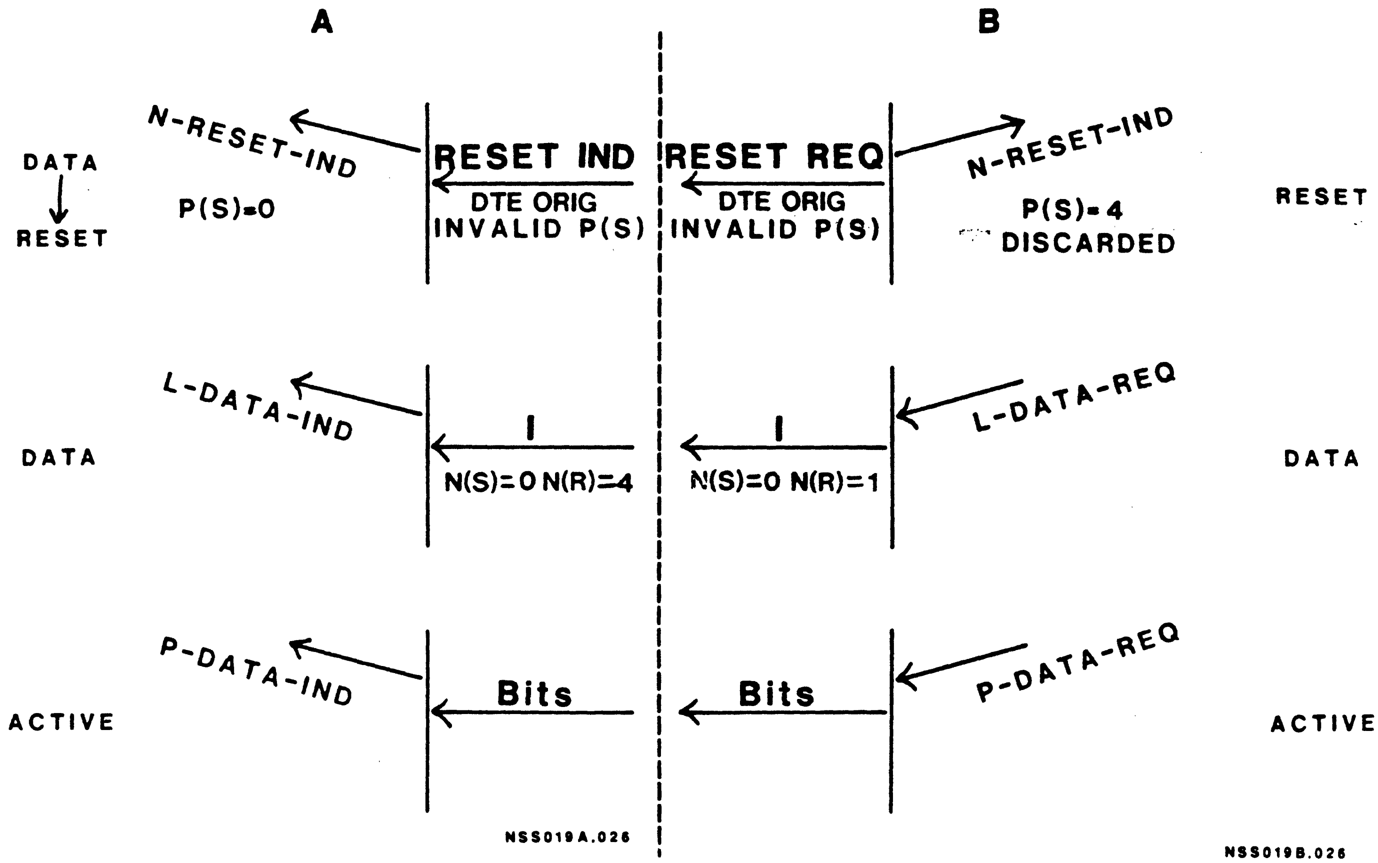

A
B
N-DATA-REQ(ACK)
D
P(S)=4 P(R)=2
M=1 D=0
D
P(S)=4 P(R)=2
M=1 D=0
HOLD DATA FOR REST
OF SEQUENCE
DATA
DATA
D
P(S) 5 P(R) 2
M=0 D=1
L-DATA-REQ
I
N(S)=1 N(R)=7
I
N(S)=7 N(R)=5
L-DATA-IND
DATA
DATA
L-DATA-REQ
DETECTED ERROR
INVALID N(R)
VALUE
RECOVERY
I
N(S)=2 N(R)=7
I
N(S)=0 N(R)=6
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
NSS015A.026
NSS015B.026

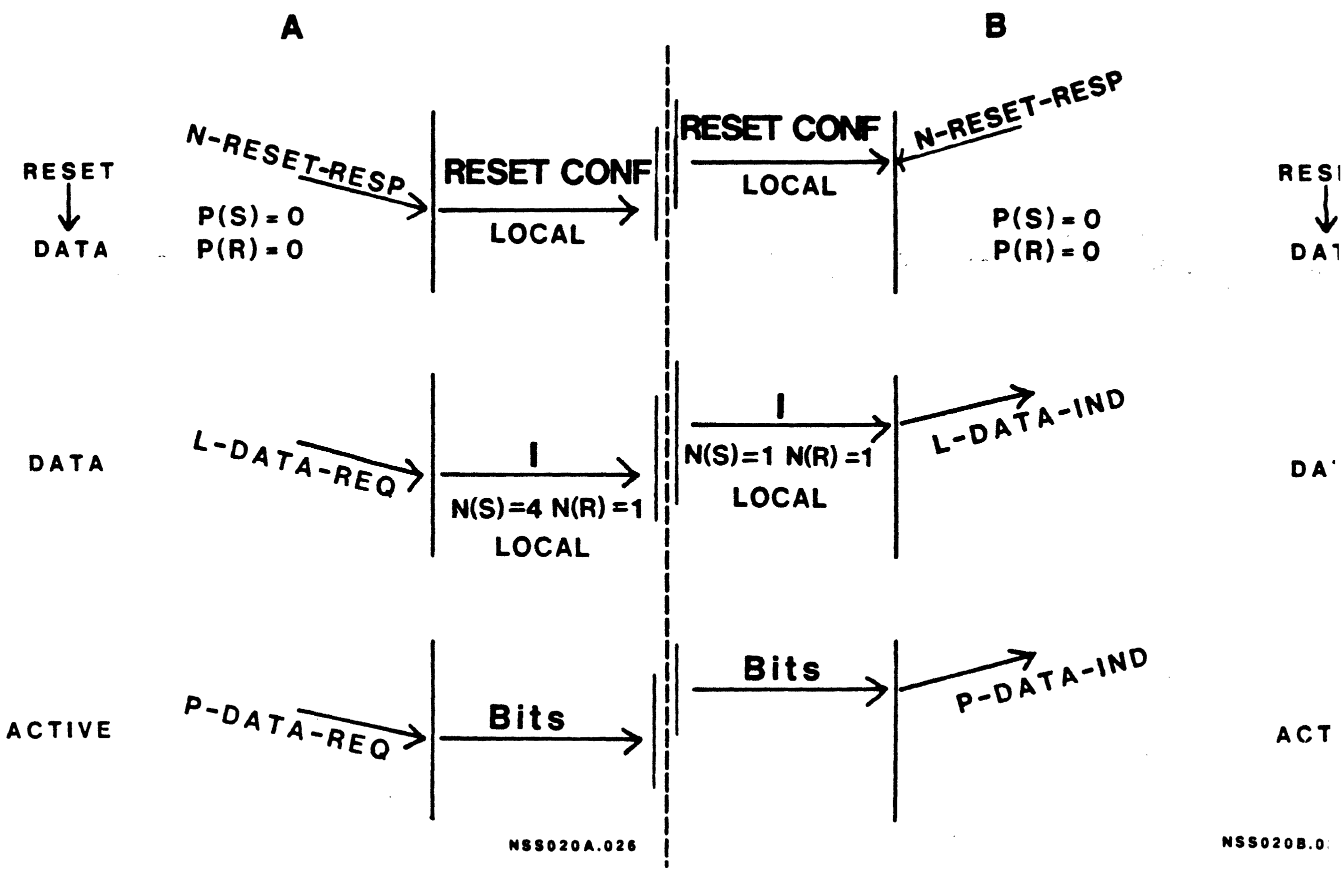

A
B
P(S)=5
DATA OUTSTANDING
RR
P(R)=5
LOCAL
DATA
DATA
L-DATA-IND
I
N(S)=7N(R)=3
LOCAL
RECOVER
P-DATA-IND
Bits
ACTIVE
ACTIVE
NSS016A.026
NSS016B.026

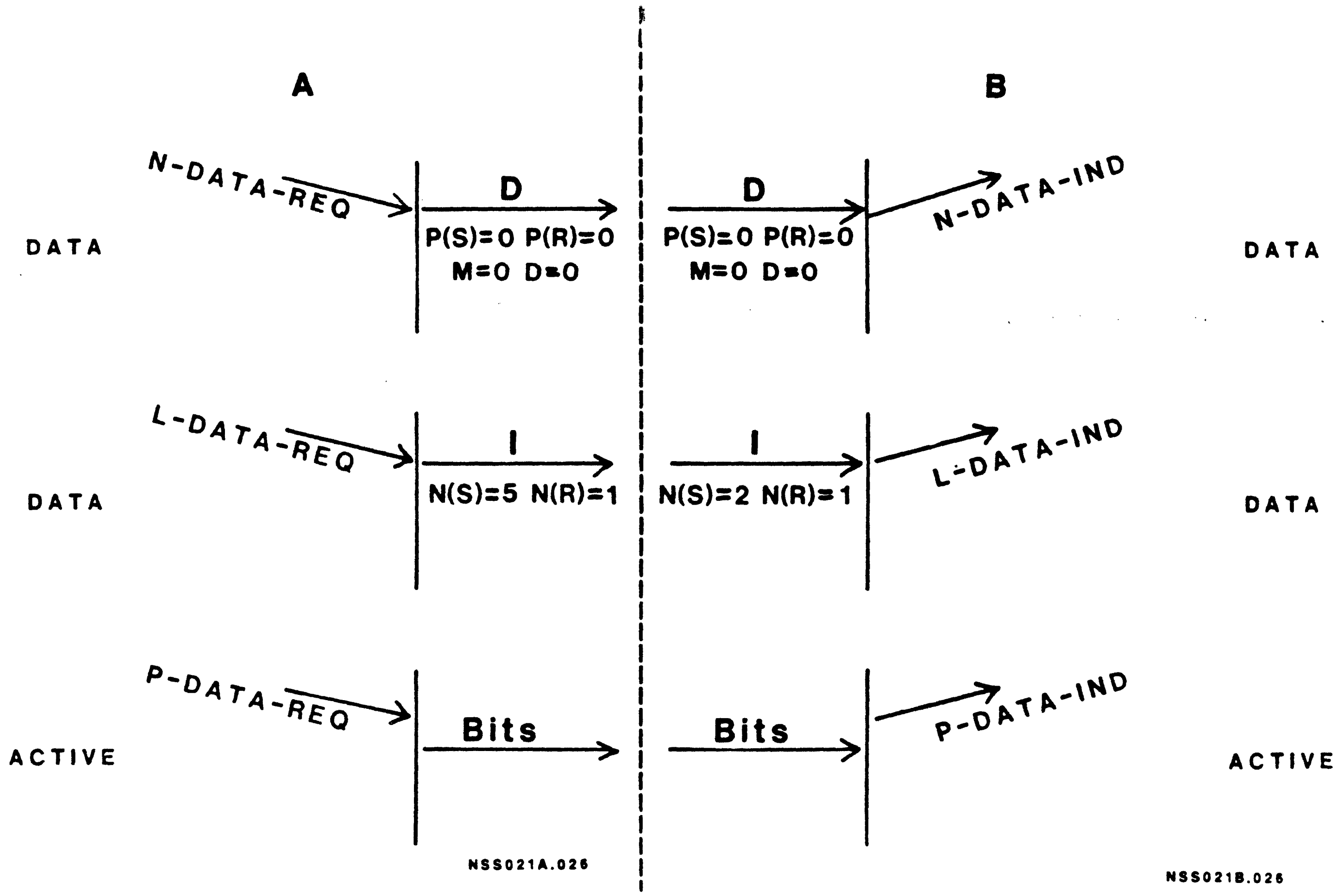


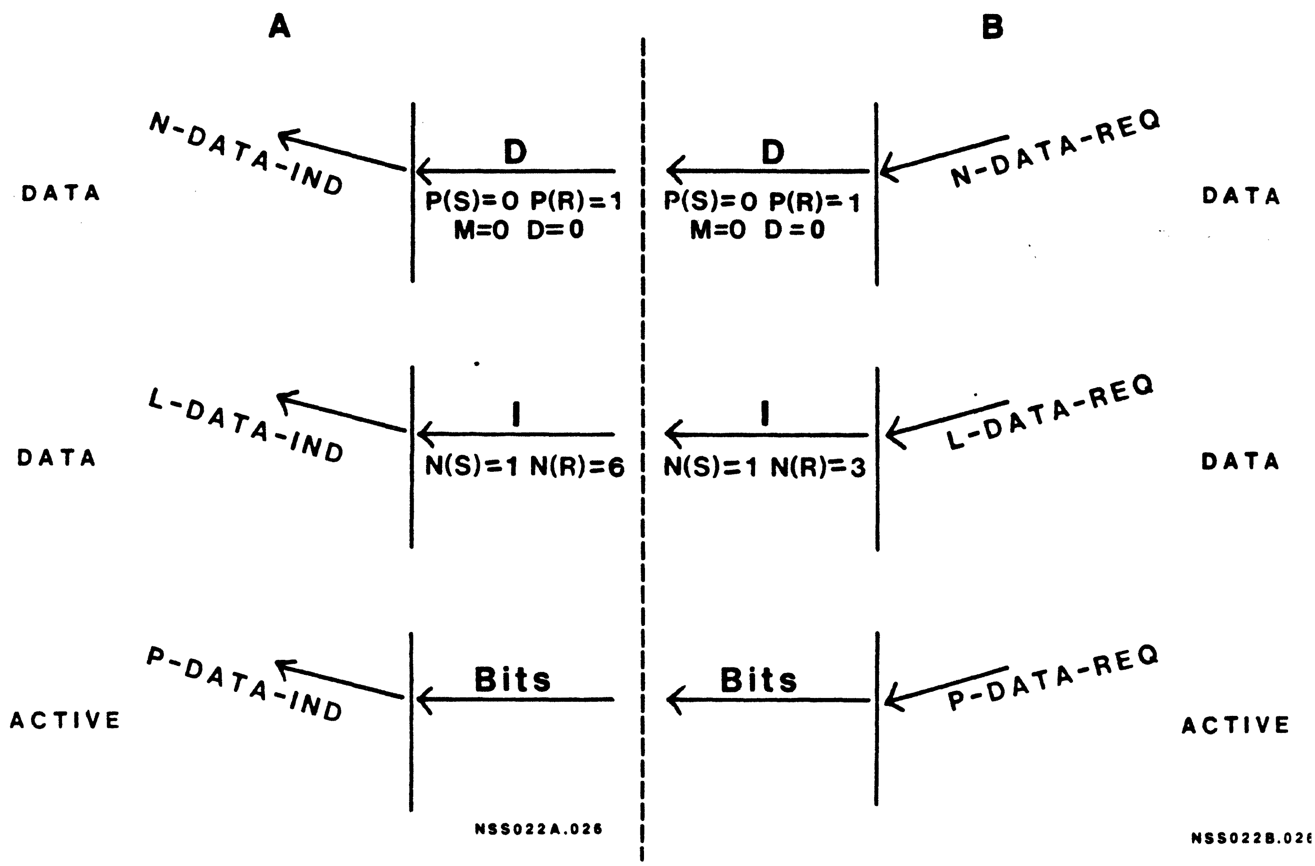
A
B
P(S)=5
OUTSTANDING
DATA
FRMR(Z)
SABM
UA
RECOVERY
RESET
DATA
N(S),N(R)=0
TIVE
Bits
Bits
Bits
P-DATA-REQ
P-DATA-IND
P-DATA-REQ
ACTIVE
NSS017A.026
NSS017B.026

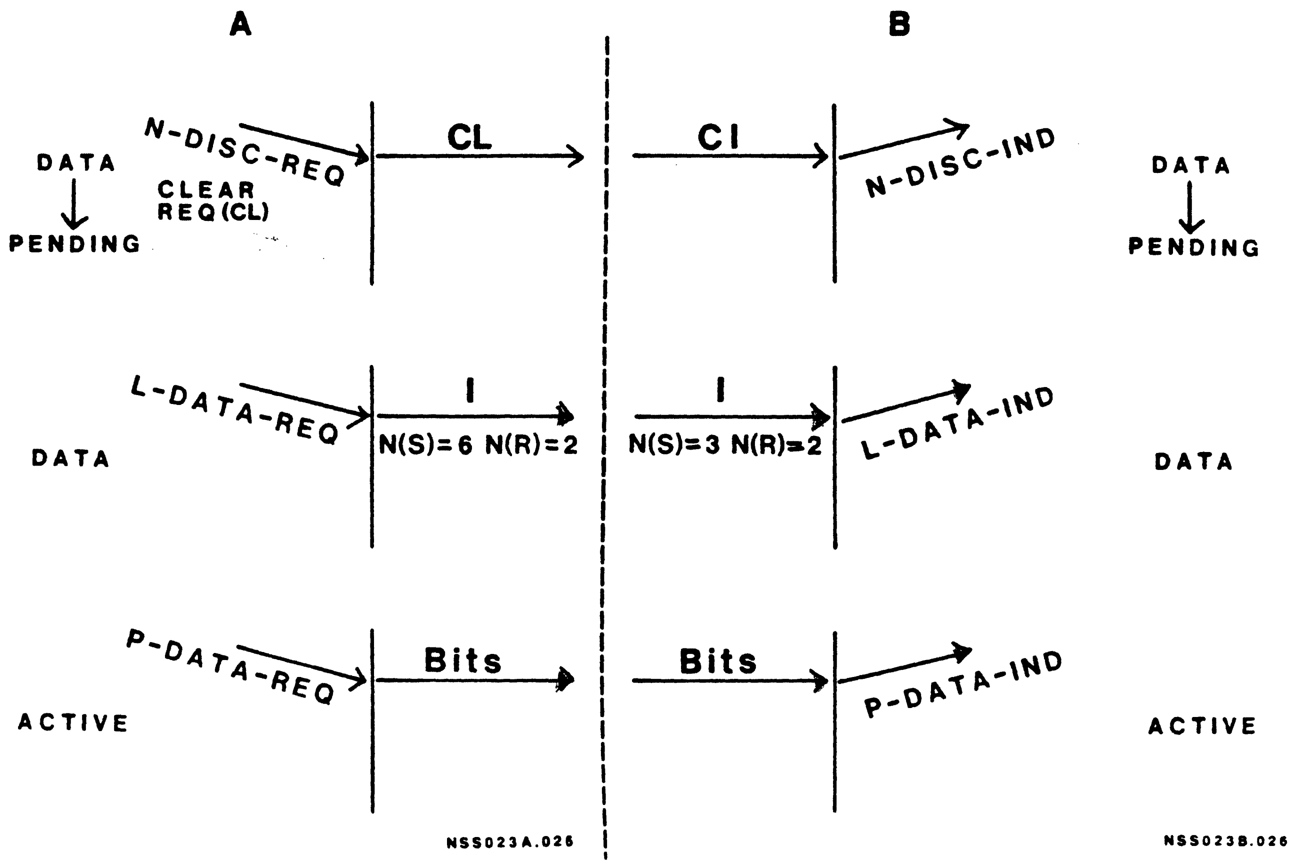

A
B
N-DATA-REQ(ACK)
P(S)=5
OUTSTANDING
DATA
D
P(S)=6 P(R)=2
M=0 D=1
D
P(S)=6 P(R)=2
M=0 D=1
SEQUENCE ERROR
P(S)=5
NOT RECEIVED
DA
RE
L-DATA-REQ
DATA
I
N(S)=3 N(R)=0
I
N(S)=0 N(R)=0
L-DATA-IND
DA
P-DATA-REQ
ACTIVE
Bits
Bits
P-DATA-IND
AC
NSS018A.026
NSS018

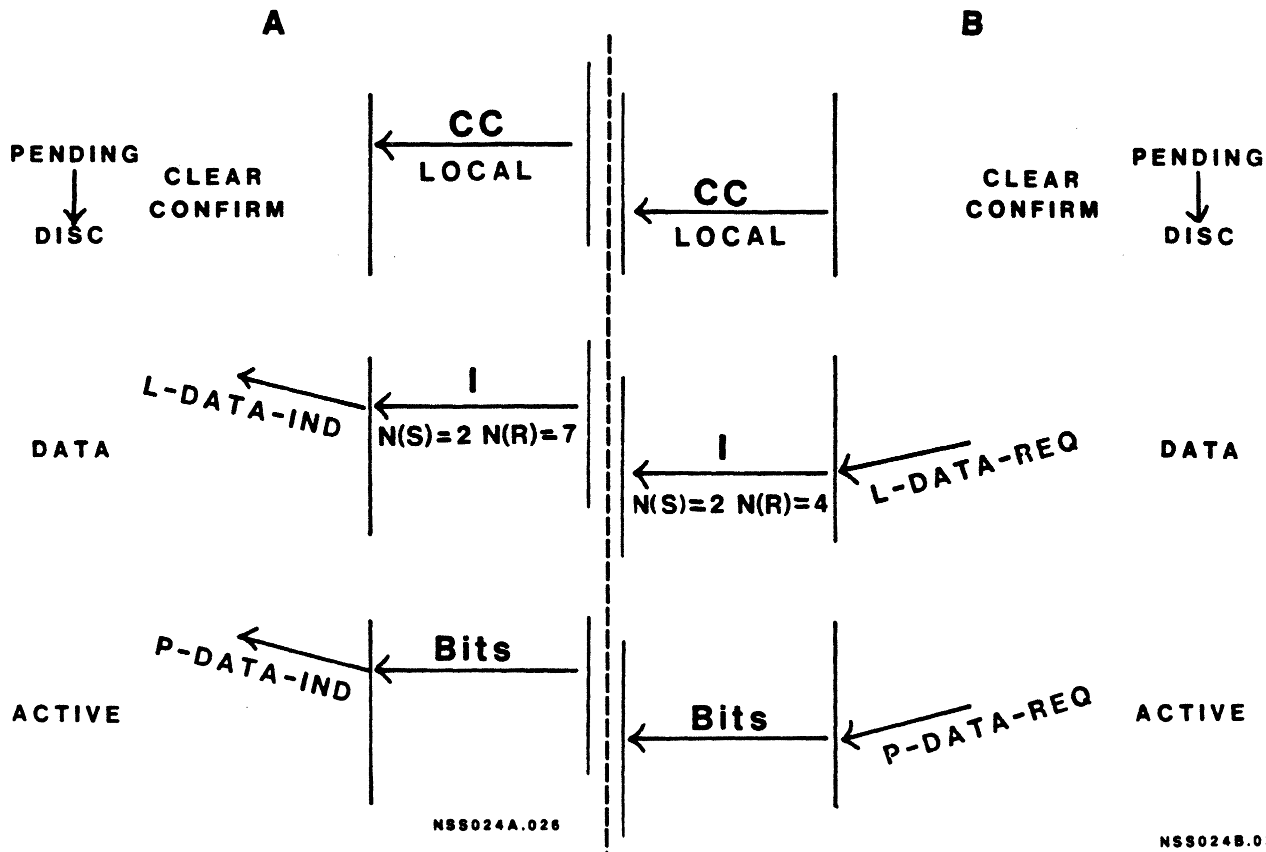

A
B
N-RESET-IND
RESET IND
RESET REQ
N-RESET-IND
DATA
RESET
P(S)=0
DTE ORIG
INVALID P(S)
DTE ORIG
INVALID P(S)
P(S)=4
DISCARDED
RESET
L-DATA-IND
I
I
L-DATA-REQ
DATA
N(S)=0 N(R)=4
N(S)=0 N(R)=1
DATA
P-DATA-IND
Bits
Bits
P-DATA-REQ
ACTIVE
ACTIVE
NSS019A.026
NSS019B.026


A
B
RESET
DATA
N-RESET-RESP
P(S) = 0
P(R) = 0
RESET CONF
LOCAL
RESET CONF
LOCAL
N-RESET-RESP
P(S) = 0
P(R) = 0
RESE
DAT
DATA
L-DATA-REQ
I
N(S)=4 N(R)=1
LOCAL
I
N(S)=1 N(R)=1
LOCAL
L-DATA-IND
DA
ACTIVE
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACT
NSS020A.026
NSS020B.0


A
B
N-DATA-REQ
D
P(S)=0 P(R)=0
M=0 D=0
D
P(S)=0 P(R)=0
M=0 D=0
N-DATA-IND
DATA
DATA
L-DATA-REQ
I
N(S)=5 N(R)=1
I
N(S)=2 N(R)=1
L-DATA-IND
DATA
DATA
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
ACTIVE
NSS021A.026
NSS021B.026


A
B
N-DATA-IND
D
P(S)=0 P(R)=1
M=0 D=0
D
P(S)=0 P(R)=1
M=0 D=0
N-DATA-REQ
DATA
DATA
L-DATA-IND
I
N(S)=1 N(R)=6
I
N(S)=1 N(R)=3
L-DATA-REQ
DATA
DATA
P-DATA-IND
Bits
Bits
P-DATA-REQ
ACTIVE
ACTIVE
NSS022A.026
NSS022B.026


A
B
N-DISC-REQ
CL
CI
N-DISC-IND
DATA
PENDING
CLEAR
REQ (CL)
DATA
PENDING
L-DATA-REQ
I
N(S)=6 N(R)=2
I
N(S)=3 N(R)=2
L-DATA-IND
DATA
DATA
P-DATA-REQ
Bits
Bits
P-DATA-IND
ACTIVE
ACTIVE
NSS023A.026
NSS023B.026


A
B
PENDING
DISC
CLEAR
CONFIRM
CC
LOCAL
CC
LOCAL
CLEAR
CONFIRM
PENDING
DISC
L-DATA-IND
I
N(S)=2 N(R)=7
DATA
I
N(S)=2 N(R)=4
L-DATA-REQ
DATA
P-DATA-IND
Bits
ACTIVE
Bits
P-DATA-REQ
ACTIVE
NSS024A.026
NSS024B.02

X.32 DIAL-UP ACCESS

SA000.026

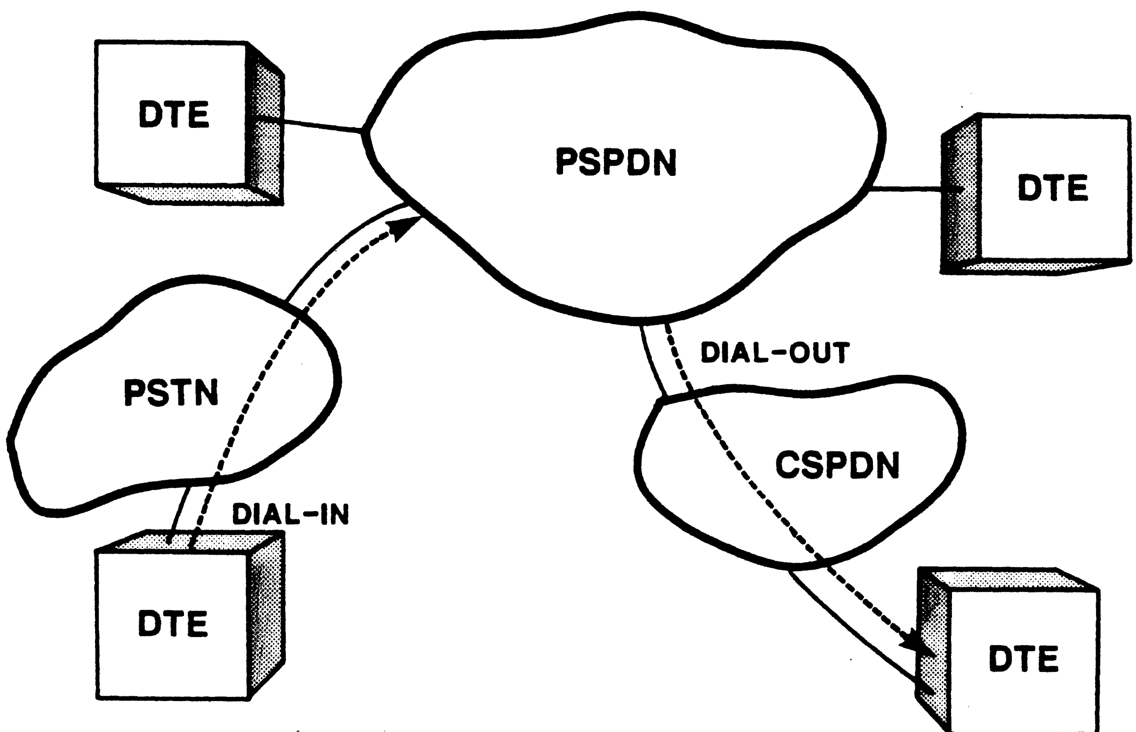
SA001.026

SWITCHED ACCESS OF PACKET-SWITCHED PUBLIC DATA NETWORKS

Recommendation X.32 specifies how an X.25 DTE on a Public Switched Telephone Network or Circuit Switched Public Data Network can be connected to a Packet-Switched Public Data Network. The many purposes for this capability include providing for occasional users who cannot justify a leased connection, for back-up lines or extra lines to expand throughput, for mobile users, and for users who need the flexibility of connecting to a variety of PSPDNs alternately.

The connection through the PSTN or CSPDN can be originated by either the DTE (dial-in) or the PSPDN (dial-out). The direction of set-up of this connection does not necessarily limit the direction of set-up of virtual calls with this DTE.

SWITCHED ACCESS OF PSPDN



SA001.125

Public Switched Telephone Network

Circuit Switched Public Data Network

SA002.026

DTE IDENTIFICATION

The DCE needs to know the identity of the DTE in order to offer many of the capabilities and facilities of the DTE/DCE interface. When the access connection is switched, this means that there must be some on-line procedure for identifying the DTE. This procedure must also provide some knowledge of the authenticity of the identification. However, because not all services require the identity of the DTE, DTE non-identification is an allowed, albeit limited, way of operating.

The DTE identity is a value agreed to explicitly by the DTE user and the PSPDN Administration or is a value which the PSPDN Administration has agreed to accept through an agreement with another authority (e.g., a credit card company).

DTE IDENTIFICATION

- BILLING AND ACCOUNTING
- IDENT. TO CALLED DTE
- OPTIONAL FACILITIES
- PERSONAL DTE/DCE INTERFACE PROFILE

SA002.036

DTE SERVICES

Nonidentified, Identified, and Customized are the three types of switched access service that may be offered to DTEs. In the Nonidentified DTE service, a minimum of capabilities, as defined by the PSPDN, are offered to DTEs that do not use a DTE identification method and, therefore, are not billable. In the Identified DTE service, a set of capabilities defined by the PSPDN is offered to DTEs that use a DTE identification method to become billable, but that do not need any specialized capabilities. In the Customized DTE service, the DTE uses a DTE identification method to become billable and to obtain specialized capabilities or features that the PSPDN offers as additions to the capabilities of the other DTE services.

There are twelve attributes that are used in defining the DTE services. Each attribute describes an aspect of switched access operation. The values of the attributes for a particular DTE identity are known collectively as the DTE profile. The attribute values are:

a) specific to the DTE service,

b) set by the PSPDN for the DTE service, or

c) selected by the user from values offered by the PSPDN.

The attributes are:

* DTE identity
* DTE identification method
* Registered address
* Registered PSN number
* X.25 subscription set
* Logical channels assignment
* Dial-out-by-the-PSPDN availability
* Modem selection
* Temporary location
* Secure dial-back
* DCE identity presentation
* Link level address assignment.

DTE SERVICES

- **NONIDENTIFIED**
- **IDENTIFIED**
- **CUSTOMIZED**

SA018.026

SA003.036

DTE IDENTIFICATION METHODS

There are four methods specified in X.32 for DTE identification.

In the PSTN or CSPDN-provided (also called PSN-provided) method, the telephone or circuit-switched network uses the Calling Line Identification facility to provide the DTE identity to the PSPDN. The DTE does not need to implement any mechanism for giving its identity to the PSPDN.

In the XID method, the DTE uses Exchange Identification (XID) frames to give its identity and, possibly, some authentication information to the PSPDN. This must be done before link set-up is started.

In the Registration method, the DTE uses Registration packets to give its identity and, possibly, some authentication information to the PSPDN. This can be done before, after, or during the Restart operation that occurs at Packet Level start-up but must be done before the set-up of any virtual calls is begun.

These first three methods all establish the characteristics of the DTE/DCE interface (e.g., number of logical channels, optional user facilities in effect) before any virtual calls are made. Therefore, they are called "prior-to-virtual-call" methods.

In the fourth method, the NUI method, the Network User Identification facility that is defined in X.25 is used by the DTE to give its identity in a Call Request packet. This method establishes the characteristics only for the virtual call on which the facility is used and, therefore, is called a "per-virtual-call" method. The NUI method may be used when a prior-to-virtual-call method has been used, with the result of changing the interface for that one virtual call. The NUI method may also be used when no prior-to-virtual-call method is used.

Any of the DTE identification methods may be used to obtain the identified DTE service. Customized DTE service is obtained by using any one of the prior-to-virtual-call methods.

DTE IDENTIFICATION METHODS

PRIOR-TO-VIRTUAL-CALL:

- **PSTN OR CSPDN-PROVIDED** Telephone number
- **XID** ID FRAME
- **REGISTRATION** PACKET

PER-VIRTUAL-CALL:

- **NUI** Network User Identification
  new facility in 1984

SA003.036

SA004.036

DCE IDENTIFICATION

Likewise, the DTE needs to know the identity of the DCE when it wants to verify a dial-in connection or when a PSPDN has dialled out to the DTE, especially if that might be done by more than one PSPDN. Knowing the DCE identity allows the DTE to use the correct password or encryption algorithm, use the correct interface characteristics, and perform the packet level operations correctly, especially address encoding and invocation of network-specific optional facilities. Therefore, on-line identification procedures of the DCE must be defined when the access connection is switched. Again, DCE non-identification is also an allowed way of operating.

DCE IDENTIFICATION

- **SECURITY RELATED INFORMATION**
- **DTE/DCE INTERFACE PROFILE**
- **PROPER OPERATION OF ADDRESSING AND FACILITIES**

SA004.125

SA005.036

DCE IDENTIFICATION METHODS

Recommendation X.32 specifies three methods of DCE identification. They are the same as the prior-to-virtual-call DTE identification methods.

DCE IDENTIFICATION METHODS

- PSTN OR CSPDN-PROVIDED
- XID
- REGISTRATION

SA035.036

SA010.036

REQUIRED CAPABILITY

When connection to a PSPDN via a PSTN or CSPDN is offered, the PSPDN must provide service such that DTEs are not required to implement any optional procedures or use any optional facilities for DTE identification in order to operate. The two methods of operation which satisfy this minimum requirement are the Nonidentified DTE service and PSN-provided DTE identification. The provision of DCE identity is not required in a minimum service.

Also, the PSPDN must offer dial-in operation. Dial-out operation may be offered in addition.

REQUIRED CAPABILITY

NONIDENTIFIED DTE SERVICE

OR

PSTN OR CSPDN-PROVIDED DTE IDENTIFICATION

DIAL-IN OPERATION

SA010.036

SA006.026

PHYSICAL LEVEL

The physical level of X.32 is in accordance with Recommendations V.24 and V.25 for PSTN connections and Recommendations X.21 or X.21bis for CSPDN connections. All networks will support full duplex connections. Half duplex connections are optional. DTEs may use automatic or manual calling and answering procedures. DCEs must use automatic calling and answering procedures.

The speeds offered using the PSTN are 1200 bps, 2400 bps, 4800 bps or 9600 bps. There is no one speed that is required of all networks. For using the CSPDN, the speeds that may be offered are those given in X.1 for CSPDNs.

PHYSICAL LEVEL

- **V.24, V.25**
- **X.21, X.21bis**
- **FULL DUPLEX**
- **HALF DUPLEX**
- **1200bps**
- **2400bps**
- **4800bps**
- **9600 bps**

CALLING PROCEDURES Auto or Manual

ANSWERING PROCEDURES

SA006. 036

LINK LEVEL

The link level of X.32 uses LAPB as the basic procedure. When half-duplex operation is performed, the LAPX procedure is added. LAPX was originally specified for Telematic terminals and is currently Recommendation T.71 (previously S.71). It protects the LAPB function from the half duplex transmission facility by using the Idle Channel Condition to signal when line trunaround should be done.

The inclusion of switched access connections within a multi-link access is for further study. Procedures for using XID frames for identification are defined.

Information for doing DTE/DCE identification or for X.32 facilities is carried in the information field of XID command frames. Each XID command is answered by an XID response frame that does not contain any identification or X.32 facilities information. The first octet of the information field is the XID Format Identifier Subfield and has the value 01000001. The next octet is the first octet of the User Data Subfield which is the User Data Identifier and has the value 11111111. The remainder of the User Data Subfield is the rest of the Information field and contains the identification or X.32 facilities information.

The link level addresses are assigned according to the convention defined in Recommendation T.70 where the initiatior of the switched access has address "A" and the answering equipment has address "B". However, networks are allowed instead to use the X.25 convention where the DTE is "A" and the DCE is "B", thereby reducing the impact of X.32 implementation on existing X.25 equipment. This difference in address assignment is not significant for dial-in operation.

LINK LEVEL

- LAPB
- LAPX ← (T.71 for teletext equipment masks Full duplex from Half duplex facility.
- MULTI-LINK
- XID PROCEDURE XID command → ID INFO
- ADDRESSES

idle channel →
← 4 Flags
← idle channel

SA007.036

SA008.036

PACKET LEVEL AND X.32 FACILITIES

The packet level of X.32 defines use of the Network User Identification facility and the On-line Facility Registration facility procedure for identification. In the Registration packets the Registration field is where the identification and authentication information or X.32 facilities are carried.

A new facility defined in X.32 is the NUI Override Permission facility. This facility prevents the NUI facility from being used to change the interface characteristics for a virtual call unless the definer of the interface gives permission for this to happen. For Nonidentified DTE service, the PSPDN is the interface definer. Otherwise, the DTE identified by use of a prior-to-virtual-call method is the interface definer.

Other X.32 facilities are:

* Temporary location
* Secure dial-back.

PACKET LEVEL AND X.32 FACILITIES

- REGISTRATION
- NUI FACILITY
- NUI OVERRIDE PERMISSION FACILITY
- TEMPORARY LOCATION FACILITY
- SECURE DIAL-BACK FACILITY

SA008.036

SA019.036

IDENTIFICATION PROTOCOL

When DTE/DCE identification is done by either the XID or Registration method an "identification protocol" defines which pieces of identification and authentication information are used and in what order. Five pieces of information are defined, called "identification elements":

Identity (ID)
Signature (SIG)
Random number (RAND)
Signed response (SRES)
Diagnostic (DIAG)

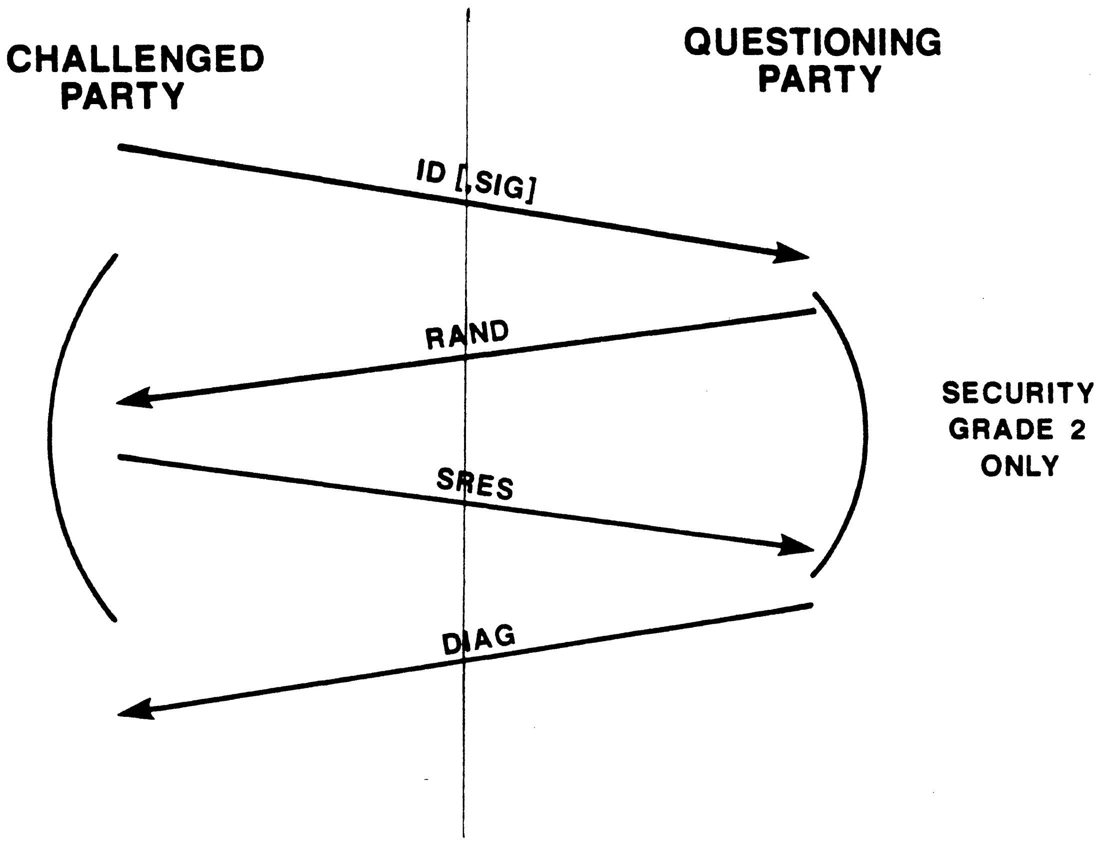
The identification elements are exchanged between the "challenged" party and the "questioning" party. The challenged party is the DTE or PSPDN that is giving its identity (i.e., the DTE in DTE identification; the PSPDN in DCE identification). The questioning party is the DTE or PSPDN that is checking the validity of the identity given (i.e., the PSPDN in DTE identification; the DTE in DCE identification).

Two grades of security are possible with the identification protocol. Grade 1 is a "password" technique. Grade 2 involves public key encryption.

The identification elements are coded the same way as facilities. In the XID method, an element is carried in the User Data Subfield of the Information field in an XID command frame. In the Registration method, an element is carried in the Registration field of a Registration Request or Registration Confirmation packet.

If both DTE identification and DCE identification are done, they may be done separately or at the same time (i.e., in the same packets or frames).

IDENTIFICATION PROTOCOL



SA019.036

INITIAL DEFAULT VALUES

The initial configuration of the DTE/DCE interface before any DTE identification is done has been defined as a very simple one and is the configuration for the Nonidentified DTE service if that is offered. The direction of the logical channel is the same as the switched access (i.e., one-way outgoing for dial-in access; one-way incoming for dial-out access). Networks may allow non-identified DTEs to change this configuration, possibly even enlarge its capabilities, using Registration.

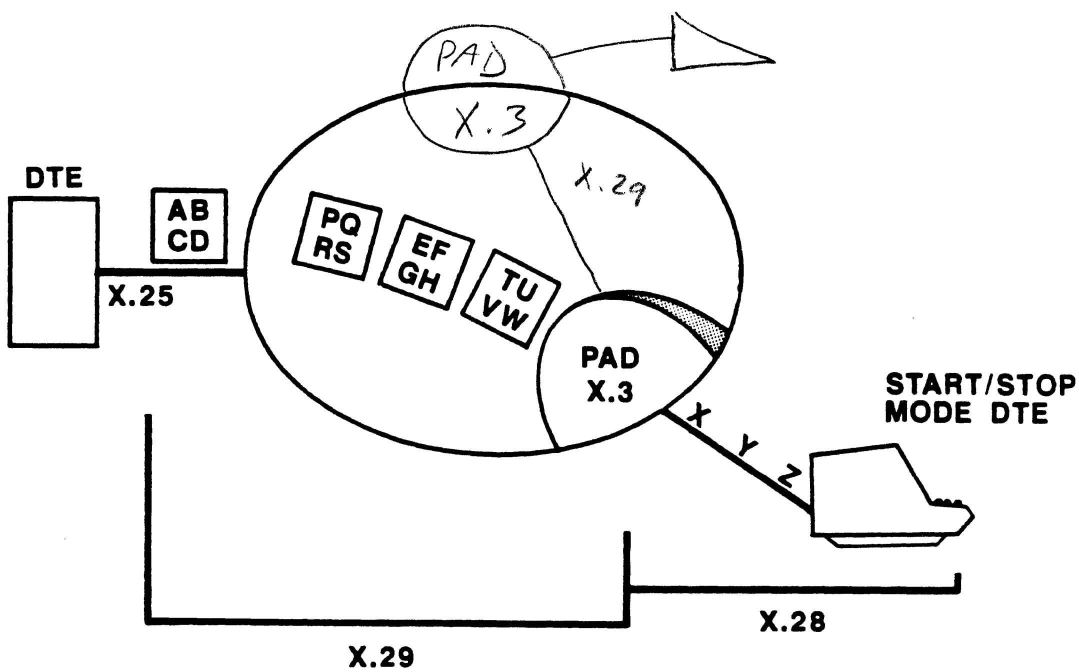
NONIDENTIFIED DTE SERVICE

- 1 ONE-WAY CHANNEL
- NO ENTIRE INTERFACE FACILITIES IN EFFECT
- PACKET = 128
- WINDOW = 2
- THROUGHPUT CLASS = SPEED
- LOCAL CHARGING PREVENTION

SA017.026

NOTES

PAD: X.28 - X.3 - X.29



PD000.016

PD007.044

FUNCTIONS OF THE PAD

The PAD must perform some basic functions to enable a start/stop DTE to interact with a packet network. These include the following:

* Assembly of characters into packets and disassembly of packets into serial character streams

* Performing the operations necessary for establishing

* Resetting, and clearing a virtual circuit

* The operations for interrupts and generation of service signals.

The PAD must also provide mechanisms for forwarding packets, for transmitting data toward the start/stop DTE, and for handling the break signal. Finally, the PAD must include procedures that will enable the operator to use a limited subset of editing functions.

PAD FUNCTIONS

- ●ASSEMBLY OF PACKETS
- ●DISASSEMBLY OF PACKETS
- ●PACKET FORWARDING
- ●CHARACTER TRANSMISSION
- ●CALL ESTABLISHMENT
- ●CALL CLEARING
- ●VIRTUAL CIRCUIT RESETTING
- ●VIRTUAL CIRCUIT INTERRUPTS
- ●SERVICE SIGNALS
- ●BREAK HANDLING
- ●EDITING

PD007.125

PD008.122

PAD PARAMETERS

The PAD is the functional unit that interfaces the packet-switched network with the start/stop DTE. It is defined such that it may be a unit within the network or a unit on the customer's premises serving as a relay between one or more terminals and the X.25 access. A number of "statistical multiplexers" are on the market that fulfill this purpose.

There are a number of operations defined that are performed by the PAD. These can be dynamically modified by either the start/stop DTE side or the X.25 network side. A basic family of parameters are defined that can take a number of different values to provide the characteristics needed for operation of the start/stop terminal.

X.3 PARAMETERS

PARAMETER REFERENCE NUMBER	PARAMETER DESCRIPTION
1	PAD RECALL
2	ECHO
3	DATA FORWARDING SIGNALS
4	IDLE TIMER
5	ANCILLARY DEVICE CONTROL
6	PAD SERVICE SIGNAL
7	ACTION ON BREAK
8	DISCARD OUTPUT
9	PADDING AFTER CARRIAGE RETURN
10	LINE FOLDING
11	SIGNALLING RATE
12	FLOW CONTROL OF PAD
13	LINEFEED INSERTION
14	LINEFEED PADDING
15	EDITING
16	CHARACTER DELETE
17	LINE DELETE
18	LINE DISPLAY
19	EDITING PAD SERVICE SIGNALS
20	ECHO MASK
21	PARITY TREATMENT
22	PAGE WAIT

PD008.016

Added in 1984

X.3 PARAMETER VALUES

REFERENCE	VALUES	
1 PAD recall	0	not possible
	1	Character DLE (default)
	32-126	user defined characters
2 Echo	0	no echo
	1	echo (default)
3 Data forwarding	0	full packet only
	1	alphanumerics
	2	carriage return (default)
	4	ESC, BEL, ENQ, ACK
	6	carriage return, ESC, BEL, ENQ, ACK
	8	DEL, CAN, DC2
	16	EXT, EOT
	18	carriage return, EOT, ETX
	32	HT, LT, VT, FF
	126	all other characters in col 1 & 2, IA5
4 Idle timer delay	0	no timer
	1-255	delay value in twentieths of a second (all possible values not always available in some networks)
5 Ancillary device control	0	not operational
	1	X-ON (DC1)/X-OFF (DC3) - data transfer
	2	X-ON/X-OFF - data transfer and command
6 Control of PAD service sigs	0	no service signals
	1	transmit service signals
	5	transmit service and prompt signals
	8-15	network dependent format service signals
7 Operation on break	0	no action
	1	interrupt packet
	2	reset packet
	4	indication of break service signal
	5	interrupt and indication of break
	8	escape from data transfer state
	16	discard output to start/stop DTE
	21	1 + 4 + 16 combined
8 Discard output	0	normal data delivery
	1	discard output to start/stop DTE
9 Carriage return padding	0	no padding
	1-7	number of padding character inserted
10 Line folding	0	no line folding
	1-255	number of characters per line

X.3 PARAMETERS VALUES (cont)

Parameter	Value	Meaning
11 Binary speed	0	110 bit/s
Signalling rate	1	134.5 bit/s
	2	300 bit/s
	3	1200 bit/s
	4	600 bit/s
	5	75 bit/s
	6	150 bit/s
	7	1800 bit/s
	8	200 bit/s
	9	100 bit/s
	10	50 bit/s
	11	75/1200 bit/s
	12	2400 bit/s
	13	4800 bit/s
	14	9600 bit/s
	15	19200 bit/s
	16	48000 bit/s
	17	56000 bit/s
	18	64000 bit/s
12 Flow control of PAD	0	not operational
	1	use X-on (DC1) and X-off (DC3)
13 Linefeed insertion	0	None
	1	after carriage return to DTE
	2	after carriage return from DTE
	4	after echoed carriage return
	5	values 1 + 4
	6	values 2 + 4
	7	values 1 + 2 + 4 (data transfer only)
14 Linefeed padding	0	none
	1-7	number of pads inserted (data transfer
	8-255	optional extension only)
15 Editing	0	off
	1	on
16 Character delete	127	DEL character
	0-126	other characters from IA5 (optional)
17 Line delete	24	CAN character
	0-23, 25-127	other characters from IA5 (optional)
18 Line display	18	DC2 character
	0-17, 19-127	other characters from IA5 (optional)

PD009b.044

X.3 PARAMETER VALUES (cont.)

NOTE: The following parameters were added in the 1984 version.

19 Editing PAD service sigs	0	no editing
	1	editing for printing terminals
	2	editing for display terminals
	8	editing using characters from range 32-126
20 Echo mask	0	all characters echoed
	1	no echo of carriage return
	2	no echo of LF
	4	no echo of VT HT, FF
	8	no echo of BEL, BS
	16	no echo of ESC, ENQ
	32	no echo of ACK,NAK,STX,SOH,EOT,ETB,ETX
	64	no echo of editing characters
	128	no echo of all characters in columns 1 and 2 plus DEL
21 Parity treatment	0	no parity detection or generation
	1	parity checking
	2	parity generation
	3	value 1 + 2
22 Page wait	0	no page wait
	23	number of linefeed characters before waiting (mandatory value)
	1-22, 24-255	optional values

NOTES

PD010.122

X.28 PROCEDURES

X.28 defines the procedures for operation between the start/stop DTE and the PAD. It covers the establishment of access to the PAD, establishment of the virtual call through the packet network, arrangement of the PAD parameters, and transfer of data in both directions.

Many of the OSI layers of operation are involved in the PAD. From the Physical Layer, there is access using the V-series Recommendations (RS-232-C) as well as the X.20 public data network circuit switched access.

The Data Link Layer is ultrasimple using only the start/stop character synchronization.

The Network Layer procedures involve the two steps of access to the PAD and circuit establishment through the packet network.

The remaining functions relate to the upper four layers - transport, session, presentation, and application functions. The dividing lines between these layers are not clear, but the functions are considered collectively for this purpose.

ACCESS TO PAD FROM START/STOP MODE DTE

VIA LEASED OR SWITCHED PUBLIC TELEPHONE CIRCUIT

- CCITT V.21 (UP TO 300BPS)
- CCITT V.24/V.28 (RS 232C)

VIA LEASED OR SWITCHED PUBLIC DATA NETWORK CIRCUIT

- CCITT X.20
- CCITT X.24/X.26/X.27

PD010.125

PD001.122

STATE DIAGRAM

A state diagram is used to define the pad operations and sequence of events. The ellipses represent a specific state that has certain signals associated with it. The rectangle represents a family of signals from which a specific signal can be selected. Each state is essentially an instantaneous snap-shot of the interface showing the signals that originate from the DTE and the PAD. The transition between states is caused by either the DTE or the PAD presenting a different signal (see legend below).

NOTES:

1. States 3A and 3B are represented for convenience. They are functionally equivalent.
2. State 8 is used to represent a state during which all PAD Service Signals are transmitted.
3. When parameter 6 is set to 0, the change in state occurs when the PAD receives an indication that the virtual call to the packet-mode DTE has been established.
4. When parameter 6 is set to 0, states 4 and 8 are bypassed.
5. The PAD will permit entry to the PAD Waiting state N times before performing PAD clearing.
6. Under certain circumstances DTE Clearing is performed by disconnecting the access information path.
7. Some networks may allow states 2 to 4 to be bypassed.

LEGEND -

D - DTE to DTE data signal

0 or **1** - Steady binary conditions

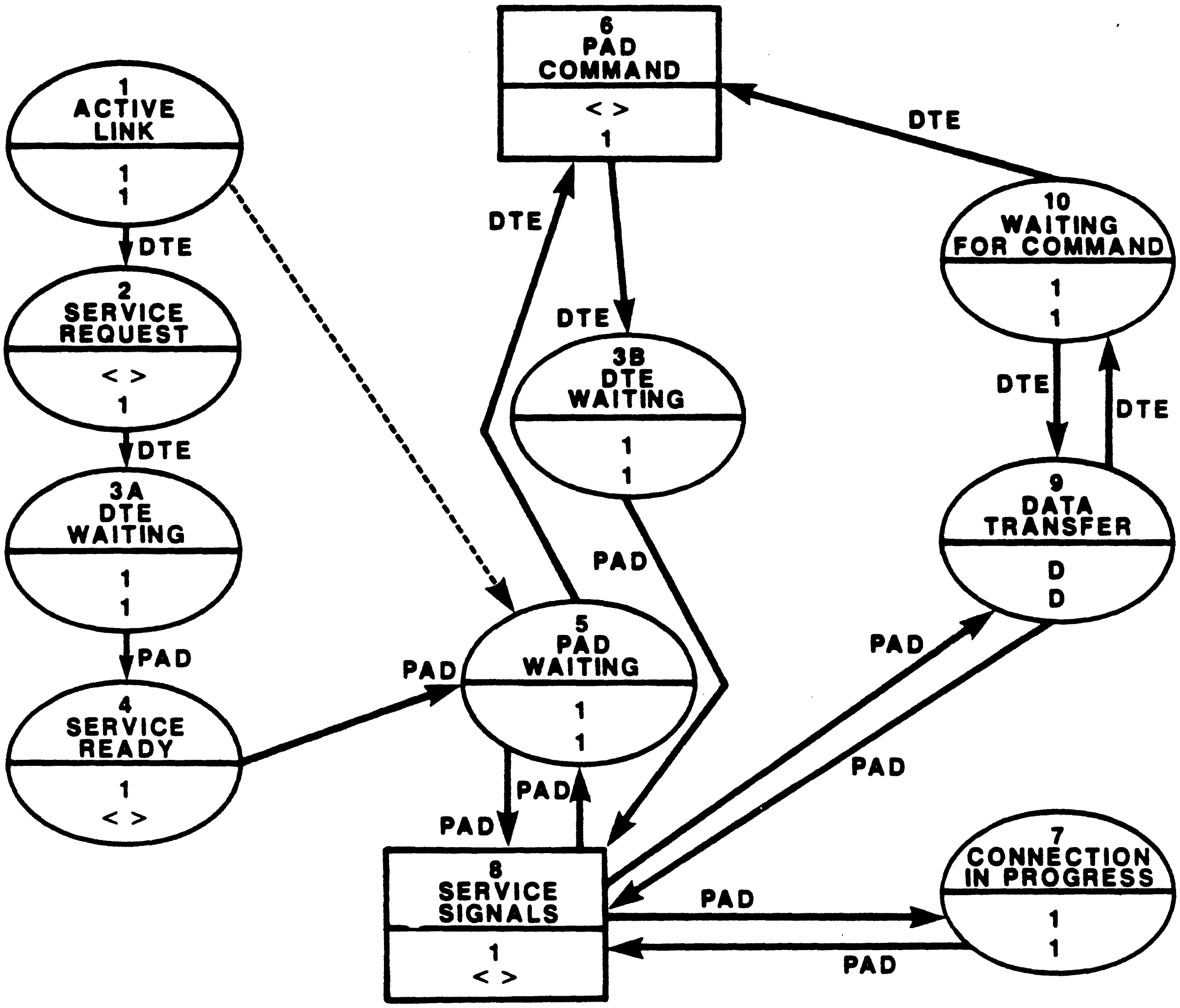
< > - An International Alphabet No 5 (ASCII) character sequence

n - State number

Dwg. goes here

t - Value on interchange circuit 103 when access is via X.20bis or V.21; or on T interchange circuit when access is via X.20.

r - Value on interchange circuit 104 when access is via X.20bis or V.21; or on R interchange circuit when access is via X.20.



6
PAD
COMMAND
< >
1
1
ACTIVE
LINK
1
1
DTE
2
SERVICE
REQUEST
< >
1
DTE
3A
DTE
WAITING
1
1
PAD
4
SERVICE
READY
1
< >
DTE
DTE
3B
DTE
WAITING
1
1
PAD
5
PAD
WAITING
1
1
PAD
PAD
PAD
8
SERVICE
SIGNALS
1
< >
DTE
10
WAITING
FOR COMMAND
1
1
DTE
DTE
9
DATA
TRANSFER
D
D
PAD
PAD
7
CONNECTION
IN PROGRESS
1
1
PAD
PAD

PD001.016

PD002.026

PAD COMMAND SIGNALS

The PAD will accept and respond to PAD command signals when the start/stop DTE is in PAD command mode. The commands are:

COMMAND	DESCRIPTION	RESPONSE
STAT	Request status	ENGAGED FREE
CLR	Clear VC	CLR CONF CLR ERR
PAR?params	List current values	PAR dd:dd,....
SET?params	Set and read values	PAR dd:dd,....
SET params	Set values	Acknowledgement
PROF ident	Set standard values	Acknowledgement
RESET	Reset VC	Acknowledgement
INT or INTD	Interrupt	Acknowledgement
Selection*	Establish Virtual Call	Acknowledgement

* facility,facility,..-.Abbreviated address,full address D user data

PAD SERVICE SIGNALS

The PAD service signals include the following:

FORMAT	EXPLANATION
Reset DTE	Remote DTE has reset the VC
Reset ERR	Reset due to local procedure error
Reset NC	Reset due to network congestion
Reset RPE	Reset due to remote procedure error
Incoming call	For further study
COM	Indication of call connected
PAD ID.....	Selected by administration
XXX	Indication of line delete
ENGAGED	Response to PAD status command when call has already been established
FREE	Response to PAD status command when call has not been established
PAR	Response to set and read PAD command signal
ERR	PAD command signal is in error
CLR	Indication of clearing
CLR CONF	Confirmation of Clearing
*	Prompt PAD service signal
Format effector	Acknowledgement PAD service signal
Network dependent	PAD identification
\	Indication of character delete function (printer)
PAGE	Page wait indication
BS SP BS	Indication of character delete function (video)
TRANSFER DTE	Indication of DTE reselection

PD012.122

CLEAR INDICATION PAD SERVICE SIGNALS

CAUSE	MNEMONIC	EXPLANATION
Number busy	OCC	Called number engaged
Network congestion	NC	Temporary condition due to heavy traffic or nodal failure
Invalid fac req	INV	Facility request invalid
Access barred	NA	Called DTE not permitted connection to DTE
Local procedure err	ERR	Error due to DTE connected to PAD
Remote proc. err	RPE	Error due to distant DTE
Not obtainable	NP	Destination number not assigned
Out of order	DER	Destination out of order
PAD clearing	PAD	Call cleared by local PAD in response to remote DTE
DTE clearing	DTE	Remote DTE cleared the call
Reverse charging acceptance not subscribed	RNA	Called DTE has not subscribed to reverse charging acceptance

EXAMPLE CALL

DTE	DCE
V.25 AUTO CALL	
	BINARY 1
BINARY 1	
SET? 12:1 (cr)	
	PAR 12:1
FACILITY, "REVERSE CHARGE" - ADDRESS D DATA (cr)	
	COM
[DATA TRANSFER]	
DLE (return to PAD control)	
CLR (cr)	
	CLR CONF

PD012.036

PD013.122

STANDARD PAD PROFILES

Profiles are available whereby the X.3 parameters pre-set when communication commences between a start/stop DTE and a PAD. These settings can either be one of the two standardized profiles or one of the numerous profiles that networks offer users to meet a wide variety of configurations. Once the communication is established, profiles can be altered if they allow for recall of the PAD for control purposes.

The two X.3 standard profiles are 1) the Transparent and 2) the Simple profile. The Transparent profile is most basic and does not allow PAD recall to change any of the parameter values. The Simple profile is general purpose, but is not optimized for any specific application. Most Public Data Networks offer a large variety of profiles to accommodate the numerous configurations that are in actual application by users.

X.3 STANDARD PROFILES

standardized

PARAMETERS REFERENCE NUMBER	PARAMETER DESCRIPTION	TRANSPARENT PROFILE ID=91	SIMPLE PROFILE ID=90
1	RECALL	0 NOT POSSIBLE	1 DLE
2	ECHO	0 NO ECHO	1 ECHO
3	DATA FORWARD	0 NONE	126 SIGNAL CHAR
4	IDLE TIMER	20 ONE SEC	0 NO TIMEOUT
5	ANC. DEVICE	0 NO XON/XOFF	1 XON/XOFF
6	SERVICE SIG	0 NONE	1 SIGNALS SENT
7	BREAK	2 RESET	2 RESET
8	DISCARD	0 NORMAL DELIVERY	0 NORMAL
9	CR PADDING	0 NONE	0 NONE
10	LINE FOLD	0 NO	0 NO
11	SPEED(AUTO)	0 110 BPS 2 300 BPS 8 200 BPS	0 110 BPS 2 300 BPS 8 200 BPS
12	XON/XOFF	0 NO	1 XON/XOFF
13	LF INSERT	0 NO	0 NO

PD013A.026

X.3 STANDARD PROFILES

PARAMETER REFERENCE NUMBER	PARAMETER DESCRIPTION	TRANSPARENT PROFILE ID=91	SIMPLE PROFILE=90
14	LF PADDING	0 NONE	0 NO
15	EDITING	0 OFF	0 OFF
16	CHAR DEL	127 DEL	127 DEL
17	LINE DEL	24 CAN	24 CAN
18	LINE DSPL	18 DC2	18 DC2
19	EDIT SERV SIG	1 PRINTER	1 PRINTER
20	ECHO MASK	0 ECHO ALL	0 ECHO ALL
21	PARITY	0 NONE	0 NONE
22	PAGE WAIT	0 DISABLED	0 DISABLED

PD013B.026

PD014.026

X.29 PROCEDURES

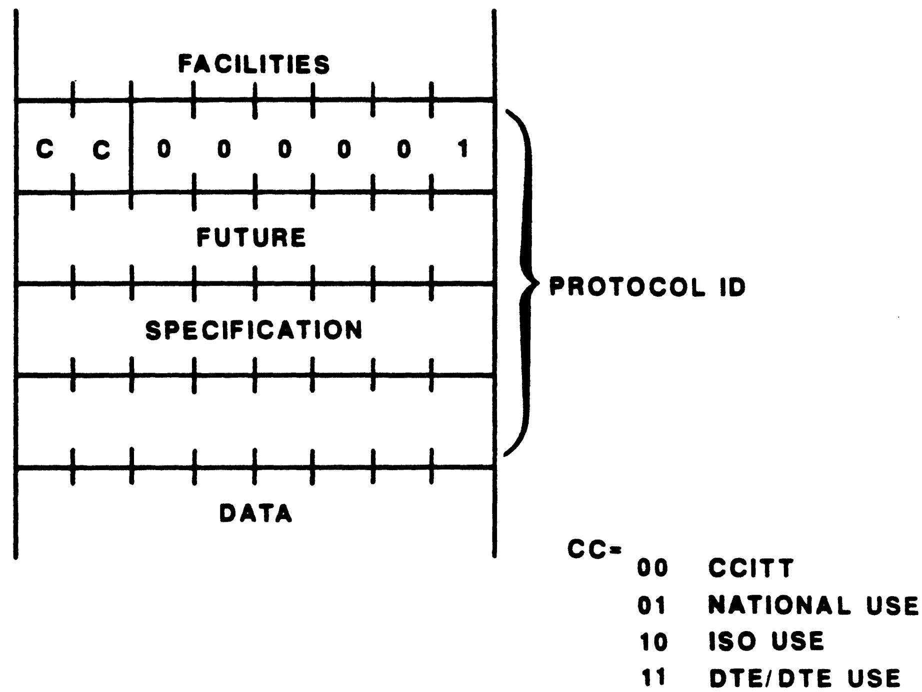
X.29 defines the procedures for the exchange of control information and user data between a packet mode DTE and a PAD. During call establishment, the protocol ID field is used to convey protocol identification information between the end-points.

The categories of settings are identified by bits 7 and 8 of the first octet of the user data field of the call request packet:

00 CCITT use
01 national use
10 ISO use
11 DTE use

During the data transfer phase, the data field of data packets is used to transfer user data and X.29 control information. The determination of content is made based on the setting of the Q-bit in the GFI. When Q=1 the data field contains PAD control information, and when Q=0 the data field contains data to or from the PAD.

CALL REQUEST PACKET



PD014.016

PD015.122

PAD CONTROL PACKETS

When a PAD receives a packet with the Q-bit set to one, it will deliver all data to the start/stop DTE, forward any packets, and then interrogate the first data byte of the immediately received packet. If it does not recognize the command code, it will return an error PAD message with the appropriate code.

There are eight PAD control messages defined:

SET PAD MESSAGE — Indicates to the PAD to set the parameters specified in the packet to the given profiles.

READ PAD MESSAGE — Instructs the PAD to read the specified parameters and return a parameter indication message.

SET & READ PAD MESSAGE — Instructs the PAD to first set the selected parameters and then return the parameters requested.

PARAMETER INDICATION — Provides an indication of the parameter settings

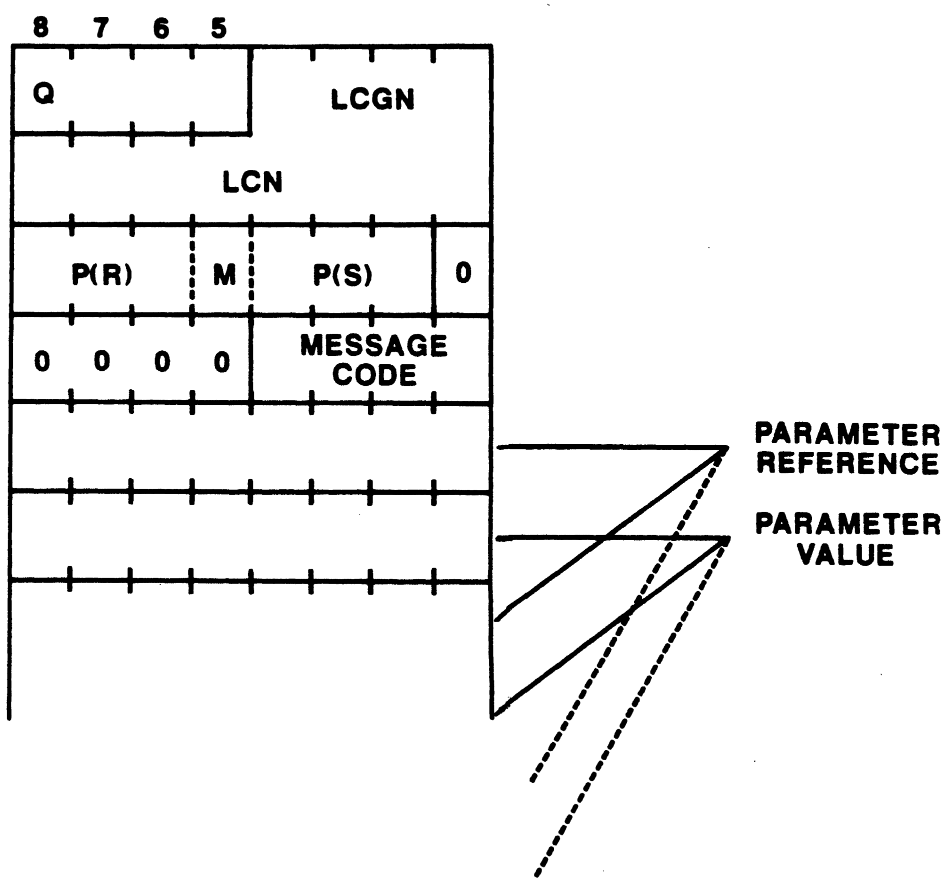
INVITATION TO CLEAR — To avoid the loss of data during clearing, the PAD can be notified when all data has been sent so clearing can be initiated from the receiving end.

INDICATION OF BREAK — When parameter 7 is set to value 21, the PAD will transmit an interrupt packet followed by a break PAD message to indicate that the PAD is discarding all data designated for the start/stop DTE. The PAD message will indicate in its parameter field that parameter 8 has been set to 1.

RESELECTION PAD — Instructs the PAD to clear the existing call and to establish a new call to the DTE given in the PAD message using any facilities and call user data included.

ERROR PAD MESSAGE — If the PAD can not interrupt a PAD command or a parameter value is invalid, it will respond with an ERR PAD message.

DATA PACKET



PD015.016

PD016.026

PAD MESSAGES

TYPE	CODE
SET	0 0 0 0 0 0 1 0
READ	0 0 0 0 0 1 0 0
SET & READ	0 0 0 0 0 1 1 0
PARAMETER INDICATION	0 0 0 0 0 0 0 0
INVITATION TO CLEAR	0 0 0 0 0 0 0 1
INDICATION OF BREAK	0 0 0 0 0 0 1 1
RESELECTION	0 0 0 0 0 1 1 1
ERROR	0 0 0 0 0 1 0 1

PD017.026

PAD ERROR CODES

TYPE	CODE
MESSAGE LESS THAN 8 BITS	0 0 0 0 0 0 0 0
INVALID MESSAGE CODE	0 0 0 0 0 0 0 1
PARAMETER FIELD INVALID OR INCOMPATIBLE WITH CODE	0 0 0 0 0 0 1 0
NOT AN INTEGRAL NUMBER OF OCTETS	0 0 0 0 0 0 1 1
PARAMETER INDICATION PAD MESSAGE WAS UNSOLICITED	0 0 0 0 0 1 0 0
RECEIVED PAD MESSAGE TOO LONG	0 0 0 0 0 1 0 1

PD018.054

RELATIONSHIP TO THE OPEN SYSTEMS INTERCONNECTION REFERENCE MODEL

The Open Systems Interconnection (OSI) reference model defines a seven-layer architecture for distributed information systems applications. (A tutorial on OSI is presented in Transmission 1 of the Open Systems Data Transfer in the Open Systems Handbook - see reference documents). Each layer performs a defined set of functions to facilitate communications among remotely located open systems.

The PAD Recommendations were developed before the establishment of the OSI reference model. Therefore a direct mapping of the PAD functions to specific OSI layers has not been clear, and has been a topic of some controversy.

While the PAD does not perform many of the defined OSI services, it is possible to identify the placement of the various PAD functions.

The Physical Layer functions of X.28 are readily apparent and the Data Link functions are very minimal, if not non-existent. Each of the functions defined by X.3 is classified by layer in the facing table. In general, the PAD is viewed as providing Network Layer services. Only when user data, which is being transmitted end-to-end, is modified in format (syntax) does the Presentation Layer functionality apply. The analogy can be made that X.3 parameters specify Network Layer functions provided by the PAD in the same sense that X.25 facilities specify many of the Network functions provided by a DCE. PAD command and service signals may be viewed as Network Layer protocol mechanisms that allow functions to be selected.

The X.29 PAD messages that are transmitted in the data qualified packets (Q=1) provide the function that can also be placed in the Network Layer functionality. It is the setting of the Q-bit that distinguishes between user data flowing end-to-end from Network Layer control information flowing between a PAD and X.25 DTE or another PAD. (This contradicts some past views that X.29 is a Transport or higher layer protocol, while the X.25 packet serves only the Network function.)

RELATION OF PAD PARAMETERS WITH OSI

PARAMETER	NAME	APPLICABLE OSI LAYER
1	PAD RECALL	NETWORK
2	ECHO	NETWORK
3	DATA FORWARDING	NETWORK
4	IDLE TIMER DELAY	NETWORK
5	ANCILLARY DEVICE CONTROL	NETWORK
6	PAD SERVICE SIGNALS	NETWORK
7	BREAK HANDLING	NETWORK
8	DISCARD OUTPUT	NETWORK
9	PADDING AFTER CR	NETWORK
10	LINE FOLDING	PRESENTATION

PD018A.016

RELATION OF PAD PARAMETERS WITH OSI

PARAMETER	NAME	APPLICABLE OSI LAYER
11	SIGNALLING RATE	NETWORK
12	FLOW CONTROL OF PAD	NETWORK
13	LINEFEED INSERTION AFTER CR	NETWORK - VALUES 0 (OFF) OR 4 (IN ECHOED SIGNAL) PRESENTATION - ALL OTHER VALUES (WHEN IN END-TO-END USER DATA STREAM)
14	PADDING AFTER LF	NETWORK
15	EDITING	NETWORK - WHEN USED IN PAD CONTROL MODE PRESENTATION/APPLICATION - WHEN USED FOR END-TO-END USER DATA STREAM
16,17,18	EDITING CHARACTERS	ACCORDING TO USE OF PAR 15
19	EDITING PAD SERVICE SIGNALS	NETWORK
20	ECHO MASK	NETWORK
21	PARITY TREATMENT	DATA LINK
22	PAGE WAIT	NETWORK

PD018B.016