

Recommendation X.25

INTERFACE BETWEEN DATA TERMINAL EQUIPMENT (DTE) AND DATA CIRCUIT-TERMINATING EQUIPMENT (DCE) FOR TERMINALS OPERATING IN THE PACKET MODE AND CONNECTED TO PUBLIC DATA NETWORKS BY DEDICATED CIRCUIT

(Geneva, 1976; amended at Geneva, 1980,
Malaga-Torremolinos, 1984 and Melbourne, 1988)

The establishment in various countries of public data networks providing packet switched data transmission services creates a need to produce standards to facilitate international interworking.

The CCITT,

considering

(a) that Recommendation X.1 includes specific user classes of service for data terminal equipments operating in the packet mode, Recommendation X.2 defines user facilities, Recommendation X.10 defines categories of access, Recommendations X.21 and X.21 *bis* define DTE/DCE physical layer interface characteristics, Recommendation X.92 defines the hypothetical reference connections for packet switched data transmission service and Recommendation X.96 defines *call progress* signals;

(b) that data terminal equipments operating in the packet mode will send and receive network control information in the form of packets;

(c) that certain data terminal equipments operating in the packet mode will use a packet interleaved synchronous data circuit;

(d) the desirability of being able to use a single data circuit to a Data Switching Exchange (DSE) for all user facilities;

(e) that Recommendation X.2 specifies which of the various data transmission services and optional user facilities described in the present Recommendation are “essential” and have thus to be made available internationally, and which are not;

(f) the need for defining an international Recommendation for the exchange between DTE and DCE of control information for the use of packet switched data transmission services;

(g) that this definition is made in Recommendation X.32 with regard to the access through a public switched telephone network, an integrated services digital network (ISDN), or a circuit switched public data network;

(h) that Recommendation X.31 defines the support of packet-mode terminal equipment by an integrated services digital network (ISDN);

(i) that, when this Recommendation is used to support the Network Service defined in Recommendation X.213, the physical, data link and packet layers correspond to the Physical, Data link and Network Layers respectively, as defined in Recommendation X.200;

(j) that this Recommendation includes all the features necessary to support the services included in Recommendation X.213 as well as other features; that Recommendation X.223 defines the use of X.25 packet layer protocol to provide the OSI connection mode Network service;

(k) that the necessary elements for an interface Recommendation should be defined independently as:

Physical layer – the mechanical, electrical, functional and procedural characteristics to activate, maintain and deactivate the physical link between the DTE and the DCE;

Data link layer – the link access procedure for data interchange across the link between the DTE and the DCE;

Packet layer – the packet format and control procedures for the exchange of packets containing control information and user data between the DTE and the DCE;

unanimously declares

that for public data networks accessed via dedicated circuits by data terminal equipments operating in the packet mode:

(1) the mechanical, electrical, functional and procedural characteristics to activate, maintain and deactivate the physical link between the DTE and the DCE should be as specified in § 1 below, *DTE/DCE interface characteristics*;

(2) the link access procedure for data interchange across the link between the DTE and the DCE should be as specified in § 2 below, *Link access procedure across the DTE/DCE interface*;

(3) the packet layer procedures for the exchange of control information and user data at the DTE/DCE interface should be as specified in § 3 below, *Description of the packet layer DTE/DCE interface*;

(4) the procedures for virtual call and permanent virtual circuit services should be as specified in § 4 below, *Procedures for virtual circuit services*;

(5) the format for packets exchanged between the DTE and the DCE should be as specified in § 5 below, *Packet formats*;

(6) the procedures for optional user facilities should be as specified in § 6 below, *Procedures for optional user facilities*;

(7) the formats for optional user facilities should be as specified in § 7 below, *Formats for facility fields and registration fields*.

Note – This Recommendation fully specifies the behaviour of the DCE. In addition, a minimum set of requirements is specified for the DTE. Additional guidance for the design of DTEs is available in ISO standards ISO 7776 (data link layer) and ISO 8208 (packet layer). It is not required by this Recommendation that these ISO standards be used. If using these ISO standards, note must be taken that their scope is expanded beyond that of just interfacing with packet switched public data networks.

It should also be noted that this Recommendation uses the term DTE to refer to the equipment to which the DCE interfaces. In ISO 8208, distinction is made between a DTE and a packet switched private data network, which are both considered as DTEs in this Recommendation.

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1 DTE/DCE interface characteristics (physical layer)

Administrations may offer one or more of the interfaces specified below. The exact use of the relevant points in these Recommendations is detailed below.

1.1 *X.21 interface*

1.1.1 *DTE/DCE physical interface elements*

The DTE/DCE physical interface elements shall be according to §§ 2.1 through 2.5 of Recommendation X.21.

1.1.2 *Procedures for entering operational phases*

The procedures for entering operational phases shall be as described in § 5.2 of Recommendation X.21. The data exchanged on circuits T and R when the interface is in states 13S, 13R and 13 of Figure A-3/X.21 will be as described in subsequent sections of this Recommendation.

The *not ready* states given in § 2.5 of Recommendation X.21 are considered to be *non-operational* states and may be considered by the higher layers to be *out of order* states (see § 4.6 below).

1.1.3 *Failure detection and test loops*

The failure detection principles shall be according to § 2.6 of Recommendation X.21. In addition, i = OFF may be signalled due to momentary transmission failures. Higher layers may delay for several seconds before considering the interface to be out of order.

The definitions of test loops and the principles of maintenance testing using the test loops are provided in Recommendation X.150.

A description of the test loops and the procedures for their use is given in § 7 of Recommendation X.21.

Automatic activation by a DTE of a test loop 2 in the DCE at the remote terminal is not possible. However, some Administrations may permit the DTE to control the equivalent of a test loop 2, at the local DSE, to verify the operation of the leased line or subscriber line and/or all or part of the DCE or line terminating equipment. Control of the loop, if provided, may be either manual or automatic, as described in Recommendations X.150 and X.21 respectively.

1.1.4 *Signal element timing*

Signal element timing shall be in accordance with § 2.6.3 of Recommendation X.21.

1.2 *X.21 bis interface*

1.2.1 *DTE/DCE physical interface elements*

The DTE/DCE physical interface elements shall be according to § 1.2 of Recommendation X.21 *bis*.

1.2.2 *Operational phases*

When circuit 107 is in the ON condition, and circuits 105, 106, 108 and 109, if provided, are in the ON condition, data exchange on circuits 103 and 104 will be as described in subsequent sections of this Recommendation.

When circuit 107 is in the OFF condition, or any of circuits 105, 106, 108 or 109, if provided, are in the OFF condition, this is considered to be in a *non-operational* state, and may be considered by the higher layers to be in an *out of order* state (see § 4.6 below).

1.2.3 *Failure detection and test loops*

The failure detection principles, the description of test loops and the procedures for their use shall be according to §§ 3.1 through 3.3 of Recommendation X.21 *bis*. In addition, circuits 106 and 109 may enter the OFF condition due to momentary transmission failures. Higher layers may delay for several seconds before considering the interface to be out of order.

Automatic activation by a DTE of test loop 2 in the DCE at the remote terminal is not possible. However, some Administrations may permit the DTE to control the equivalent of a test loop 2, at the local DSE, to verify the operation of the leased line or subscriber line and/or all or part of the DCE or line terminating equipment. Control of the loop, if provided, may be either manual or automatic, as described in Recommendations X.150 and X.21 *bis* respectively.

1.2.4 *Signal element timing*

Signal element timing shall be in accordance with § 3.4 of Recommendation X.21 *bis*.

1.3 *V-Series interface*

General operation with V-Series modems is as described in § 1.2 above. However, for specific details, particularly related to failure detection principles, loop testing, and the use of circuits 107, 109, 113 and 114, refer to the appropriate V-Series Recommendations.

The delay between 105-ON and 106-ON (when these circuits are present) will be more than 10 ms and less than 1 s. In addition, circuits 106 or 109 may enter the OFF condition due to momentary transmission failures or modem retraining. Higher layers may delay for several seconds before considering the interface to be out of order.

1.4 *X.31 interface*

1.4.1 *DTE/DCE physical interface*

The DTE/DCE physical interface shall coincide with the R reference point between the DTE and the Terminal Adaptor (TA). The purpose of the TA is to allow the operation of a DTE over an ISDN. The functionalities of such a TA when accessing a packet switched data transmission service through a semi-permanent ISDN connection (i.e., a non switched B-channel) are described in § 7 of Recommendation X.31.

Note 1 – This type of access is considered a dedicated access to a public switched data transmission service. Non dedicated access to a public switched data transmission service is defined in Recommendations X.32 and X.31.

Note 2 – The DTE and the TA functionalities may be implemented in the same piece of equipment in the case of a packet mode terminal TE1 conforming to the I-series Recommendations. In this case, this Recommendation covers layer 2 and layer 3 operation on the semi-permanent B-channel.

1.4.2 *Operational phases*

The operational phases are as described in § 7 of Recommendation X.31.

1.4.3 *Maintenance*

The maintenance shall be made as described in § 7.6 of Recommendation X.31.

1.4.4 *Synchronization*

The synchronization shall be made as described in § 7 of Recommendation X.31.

2 **Link access procedures across the DTE/DCE interface**

2.1 *Scope and field of applications*

2.1.1 The Link Access Procedures (LAPB and LAP) are described as the Data Link Layer Element and are used for data interchange between a DCE and a DTE over a single physical circuit (LAPB and LAP), or optionally over multiple physical circuits (LAPB), operating in user classes of service 8 to 11 as indicated in Recommendation X.1. The optional, subscription-time selectable, multiple physical circuit operation with LAPB (known as multilink operation) is required if the effects of circuit failures are not to disrupt the Packet Layer operation.

The single link procedures (SLPs) described in §§ 2.2, 2.3 and 2.4 (LAPB) and in §§ 2.2, 2.6 and 2.7 (LAP) are used for data interchange over a single physical circuit, conforming to the description given in § 1, between a DTE and a DCE. When the optional multilink operation is employed with LAPB, a single link procedure (SLP) is used

independently on each physical circuit, and the multilink procedure (MLP) described in § 2.5 is used for data interchange over these multiple parallel LAPB data links. In addition, when only a single physical circuit is employed with LAPB, agreements may be made with the Administration to use this optional multilink procedure over the one LAPB data link.

2.1.2 The single link procedures (SLPs) use the principles and terminology of the High-level Data Link Control (HDLC) procedures specified by the International Organization for Standardization (ISO). The multilink procedure (MLP) is based on the principles and terminology of the Multilink Control Procedures specified by ISO.

2.1.3 Each transmission facility is duplex.

2.1.4 DCE compatibility of operation with the ISO balanced classes of procedure (Class BA with options 2, 8 and Class BA with options 2, 8, 10) is achieved using the LAPB procedure described in §§ 2.3 and 2.4. Of these classes, Class BA with options 2, 8 (LAPB modulo 8) is the basic service, and is available in all networks. Class BA with options 2, 8, 10 (LAPB modulo 128) is recognized as an optional, subscription-time selectable, extended sequence numbering service that may be available in those networks wishing to serve DTE applications having a need for modulo 128 sequence numbering.

DTE manufacturers and implementors must be aware that the procedure hereunder described as LAPB modulo 8 will be the only one available in all networks.

Likewise, a DTE may continue to use the LAP procedure described in §§ 2.2, 2.6 and 2.7 (in those networks supporting such a procedure), but for new DTE implementations, LAPB should be preferred. The LAP procedures are defined for modulo 8 basic service only.

Note – Other possible applications for further study are, for example:

- two-way alternate, asynchronous response mode;
- two-way simultaneous, normal response mode;
- two-way alternate, normal response mode.

2.1.5 For those networks that choose to support both the basic and extended LAPB sequence numbering services, the choice of either basic mode (modulo 8) or extended mode (modulo 128) may be made at subscription time. The choice of the mode employed for each data link procedure is independent of all others and of the choice of mode for the corresponding Packet Layer procedures. All choices are matters for agreement for a period of time with the Administration.

2.1.6 In the case of those networks that support both the LAPB procedure and the LAP procedure, the DCE will maintain an internal mode variable B, which it will set as follows:

- to 1, upon acceptance of an SABM/SABME (modulo 8/modulo 128) command from the DTE, or upon issuance of an SABM/SABME command by the DCE;
- to 0, upon acceptance of an SARM command from the DTE.

Whenever B is 1, the DCE will use the LAPB procedure described in §§ 2.2, 2.3 and 2.4 below, and is said to be in the LAPB (balanced) mode.

Whenever B is 0, the DCE will use the LAP procedure described in §§ 2.2, 2.6 and 2.7 below, and is said to be in the LAP mode.

Changes to the mode variable B by the DTE should occur only when the data link has been disconnected as described in §§ 2.4.4.3 or 2.7.3.3 below.

Should a DCE malfunction occur that negates the current setting of internal mode variable B, the DCE will, upon restoration of operation, not send either a SARM or SABM/SABME command. The DCE may send a DISC command or a DM response to notify the DTE that the DCE is in the disconnected phase. This will result in the DTE attempting to reinitialize the data link with what the DTE considers to be the proper mode-setting command (SARM or SABM/SABME). The DCE will then be able to set the internal mode variable B to its proper value.

2.2 *Frame structure*

2.2.1 All transmissions on an SLP are in frames conforming to one of the formats of Table 1/X.25 for basic (modulo 8) operation, or alternatively one of the formats of Table 2/X.25 for extended (modulo 128) operation. The flag preceding the address field is defined as the opening flag. The flag following the FCS field is defined as the closing flag.

TABLE 1/X.25

Frame formats – Basic (modulo 8) operation

Bit order of transmission 12345678 12345678 12345678 16 to 1 12345678

Flag	Address	Control	FCS	Flag
F	A	C	FCS	F
01111110	8-bits	8-bits	16-bits	01111110

FCS Frame check sequence

Bit order of transmission 12345678 12345678 12345678 16 to 1 12345678

Flag	Address	Control	Information	FCS	Flag
F	A	C	Info	FCS	F
01111110	8-bits	8-bits	N-bits	16-bits	01111110

FCS Frame check sequence

TABLE 2/X.25

Frame formats – Extended (modulo 128) operation

Bit order of transmission 12345678 12345678 1 to *) 16 to 1 12345678

Flag	Address	Control	FCS	Flag
F	A	C	FCS	F
01111110	8-bits	*)-bits	16-bits	01111110

FCS Frame check sequence

Bit order of transmission 12345678 12345678 1 to *) 16 to 1 12345678

Flag	Address	Control	Information	FCS	Flag
F	C	Info	FCS	F	
01111110	8-bits	*)-bits	N-bits	16-bits	01111110

FCS Frame check sequence

*) 16 for frame formats that contain sequence numbers; 8 for frame formats that do not contain sequence numbers.

2.2.2 *Flag sequence*

All frames shall start and end with the flag sequence consisting of one 0 bit followed by six contiguous 1 bits and one 0 bit. The DTE and DCE shall only send complete eight-bit flag sequences when sending multiple flag sequences (see § 2.2.11). A single flag may be used as both the closing flag for one frame and the opening flag for the next frame.

2.2.3 *Address field*

The address field shall consist of one octet. The address field identifies the intended receiver of a command frame and the transmitter of a response frame. The coding of the address field is described in § 2.4.2 (LAPB) and in § 2.7.1 (LAP) below.

2.2.4 *Control field*

For modulo 8 (basic) operation, the control field shall consist of one octet. For modulo 128 (extended) operation, the control field shall consist of two octets for frame formats that contain sequence numbers, and one octet for frame formats that do not contain sequence numbers. The content of this field is described in § 2.3.2 (LAPB) and in § 2.6.2 (LAP) below.

2.2.5 *Information field*

The information field of a frame, when present, follows the control field (see § 2.2.4 above) and precedes the frame check sequence field (see § 2.2.7 below).

See §§ 2.3.4.9, 2.5.2, 2.6.4.8 and 5 for the various codings and groupings of bits in the information field as used in this Recommendation.

See §§ 2.3.4.9, 2.4.8.5, 2.6.4.8 and 2.7.7.5 below with regard to the maximum information field length.

2.2.6 *Transparency*

The DCE or DTE, when transmitting, shall examine the frame content between the two flag sequences including the address, control, information and FCS fields and shall insert a 0 bit after all sequences of 5 contiguous 1 bits (including the last 5 bits of the FCS) to ensure that a flag sequence is not simulated. The DCE or DTE, when receiving, shall examine the frame content and shall discard any 0 bit which directly follows 5 contiguous 1 bits.

2.2.7 *Frame check sequence (FCS) field*

The notation used to describe the FCS is based on the property of cyclic codes that a code vector such as 1000000100001 can be represented by a polynomial $P(x) = x^{12} + x^5 + 1$. The elements of an n -element code word are thus the coefficients of a polynomial of order $n - 1$. In this application, these coefficients can have the value 0 or 1 and the polynomial operations are performed modulo 2. The polynomial representing the content of a frame is generated using the first bit received after the frame opening flag as the coefficient of the highest order term.

The FCS field shall be a 16-bit sequence. It shall be the ones complement of the sum (modulo 2) of:

- 1) the remainder of $xk(x^{15} + x^{14} + x^{13} + x^{12} + x^{11} + x^{10} + x^9 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x + 1)$ divided (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency, and
- 2) the remainder of the division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of the product of x^{16} by the content of the frame, existing between but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency.

As a typical implementation, at the transmitter, the initial content of the register of the device computing the remainder of the division is preset to all 1s and is then modified by division by the generator polynomial (as described above) on the address, control and information fields; the ones complement of the resulting remainder is transmitted as the 16-bit FCS.

At the receiver, the initial content of the register of the device computing the remainder is preset to all 1s. The final remainder, after multiplication by x^{16} and then division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of the serial incoming protected bits and the FCS, will be 000110100001111 (x^{15} through x^0 , respectively) in the absence of transmission errors.

Note – Examples of transmitted bit patterns by the DCE and the DTE illustrating application of the transparency mechanism and the frame check sequence to the SABM command and the UA response are given in Appendix I.

2.2.8 *Order of bit transmission*

Addresses, commands, responses and sequence numbers shall be transmitted with the low-order bit first (for example, the first bit of the sequence number that is transmitted shall have the weight 2^0). The order of transmitting bits within the information field is not specified under § 2 of this Recommendation. The FCS shall be transmitted to the line commencing with the coefficient of the highest term, which is found in bit position 16 of the FCS field (see Tables 1/X.25 and 2/X.25).

Note – In Tables 1/X.25 to 13/X.25, bit 1 is defined as the low-order bit.

2.2.9 *Invalid frames*

The definition of an invalid frame is described in § 2.3.5.3 (LAPB) and in § 2.6.5.3 (LAP) below.

2.2.10 *Frame abortion*

Aborting a frame is performed by transmitting at least seven contiguous 1 bits (with no inserted 0 bits).

2.2.11 *Interframe time fill*

Interframe time fill is accomplished by transmitting contiguous flags between frames, i.e. multiple eight-bit flag sequences (see § 2.2.2).

2.2.12 *Link channel states*

A link channel as defined here is the means for transmission for one direction.

2.2.12.1 *Active channel state*

The DCE incoming or outgoing channel is defined to be in an active condition when it is receiving or transmitting, respectively, a frame, an abortion sequence or interframe time fill.

2.2.12.2 *Idle channel state*

The DCE incoming or outgoing channel is defined to be in an idle condition when it is receiving or transmitting, respectively, a continuous 1s state for a period of at least 15 bit times.

See § 2.3.5.5 for a description of DCE action when an idle condition exists on its incoming channel for an excessive period of time.

2.3 *LAPB elements of procedures*

2.3.1 The LAPB elements of procedures are defined in terms of actions that occur on receipt of frames at the DCE or DTE.

The elements of procedures specified below contain the selection of commands and responses relevant to the LAPB data link and system configurations described in § 2.1 above. Together, §§ 2.2 and 2.3 form the general requirements for the proper management of a LAPB access data link.

2.3.2 *LAPB control field formats and parameters*

2.3.2.1 *Control field formats*

The control field contains a command or a response, and sequence numbers where applicable.

Three types of control field formats are used to perform numbered information transfer (I format), numbered supervisory functions (S format) and unnumbered control functions (U format).

The control field formats for basic (modulo 8) operation are depicted in Table 3/X.25.

The control field formats for extended (modulo 128) operation are depicted in Table 4/X.25.

TABLE 3/X.25

LAPB control field format – Basic (modulo 8) operation

Control field bits	1	2	3	4	5	6	7	8
I format	0	N(S)			P	N(R)		
S format	1	0	S	S	P/F	N(R)		
U format	1	1	M	M	P/F	M	M	M

N(S) Transmitter send sequence number (bit 2 = low-order bit)

N(R) Transmitter receive sequence number (bit 6 = low-order bit)

S Supervisory function bit

M Modifier function bit

P/F Poll bit when issued as a command, final bit when issued as a response

(1 = Poll/Final)

P Poll bit (1 = Poll)

TABLE 4/X.25

LAPB control field formats – Extended (modulo 128) operation

Control field bits	1st octet								2nd octet							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I format	0	N(S)							P	N(R)						
S format	1	0	S	S	X	X	X	X	P/F	N(R)						
U format	1	1	M	M	P/F	M	M	M								

N(S) Transmitter send sequence number (bit 2 = low-order bit)

N(R) Transmitter receive sequence number (bit 10 = low-order bit)

S Supervisory function bit

M Modifier function bit

X Reserved and set to 0

P/F Poll bit when issued as a command, final bit when issued as a response

(1 = Poll/Final)

P Poll bit (1 = Poll)

2.3.2.1.1 Information transfer format – I

The I format is used to perform an information transfer. The functions of N(S), N(R) and P are independent; i.e., each I frame has an N(S), an N(R) which may or may not acknowledge additional I frames received by the DCE or DTE, and a P bit that may be set to 0 or 1.

2.3.2.1.2 Supervisory format – S

The S format is used to perform data link supervisory control functions such as acknowledge I frames, request retransmission of I frames, and to request a temporary suspension of transmission of I frames. The functions of N(R) and

P/F are independent; i.e., each supervisory frame has an N(R) which may or may not acknowledge additional I frames received by the DCE or DTE, and a P/F bit that may be set to 0 or 1.

2.3.2.1.3 *Unnumbered format – U*

The U format is used to provide additional data link control functions. This format contains no sequence numbers, but does include a P/F bit that may be set to 0 or 1. The unnumbered frames have the same control field length (one octet) in both basic (modulo 8) operation and extended (modulo 128) operation.

2.3.2.2 *Control field parameters*

The various parameters associated with the control field formats are described below.

2.3.2.2.1 *Modulus*

Each I frame is sequentially numbered and may have the value 0 through modulus minus 1 (where “modulus” is the modulus of the sequence numbers). The modulus equals either 8 or 128 and the sequence numbers cycle through the entire range.

2.3.2.2.2 *Send state variable V(S)*

The send state variable V(S) denotes the sequence number of the next in-sequence I frame to be transmitted. V(S) can take on the values 0 through modulus minus 1. The value of V(S) is incremented by 1 with each successive I frame transmission, but cannot exceed the N(R) of the last received I or supervisory frame by more than the maximum number of outstanding I frames (k). The value of k is defined in § 2.4.8.6 below.

2.3.2.2.3 *Send sequence number N(S)*

Only I frames contain N(S), the send sequence number of transmitted I frames. At the time that an in-sequence I frame is designated for transmission, the value of N(S) is set equal to the value of the send state variable V(S).

2.3.2.2.4 *Receive state variable V(R)*

The receive state variable V(R) denotes the sequence number of the next in-sequence I frame expected to be received. V(R) can take on the values 0 through modulus minus 1. The value of V(R) is incremented by 1 by the receipt of an error-free, in-sequence I frame whose send sequence number N(S) equals the receive state variable V(R).

2.3.2.2.5 *Receive sequence number N(R)*

All I frames and supervisory frames contain N(R), the expected send sequence number of the next received I frame. At the time that a frame of the above types is designated for transmission, the value of N(R) is set equal to the current value of the receive state variable V(R). N(R) indicates that the DCE or DTE transmitting the N(R) has received correctly all I frames numbered up to and including N(R) – 1.

2.3.2.2.6 *Poll/Final bit P/F*

All frames contain P/F, the Poll/Final bit. In command frames, the P/F bit is referred to as the P bit. In response frames, it is referred to as the F bit.

2.3.3 *Functions of the Poll/Final bit*

The Poll bit set to 1 is used by the DCE or DTE to solicit (poll) a response from the DTE or DCE, respectively. The Final bit set to 1 is used by the DCE or DTE to indicate the response frame transmitted by the DTE or DCE, respectively, as a result of the soliciting (poll) command.

The use of the P/F bit is described in § 2.4.3 below.

2.3.4 *Commands and responses*

For basic (modulo 8) operation, the commands and responses represented in Table 5/X.25 will be supported by the DCE and the DTE.

For extended (modulo 128) operation, the commands and responses represented in Table 6/X.25 will be supported by the DCE and the DTE.

For purposes of the LAPB procedures, the supervisory function bit encoding “11” and those encodings of the modifier function bits in Tables 3/X.25 and 4/X.25 not identified in Tables 5/X.25 or 6/X.25 are identified as “undefined or not implemented” command and response control fields.

The commands and responses in Tables 5/X.25 and 6/X.25 are defined as follows:

2.3.4.1 Information (I) command

The function of the information (I) command is to transfer across a data link a sequentially numbered frame containing an information field.

TABLE 5/X.25

LAPB commands and responses – Basic (modulo 8) operation

				1	2	3	4	5	6	7	8
Format	Command		Response		Encoding						
Information transfer	I	(information)		0	N(S)			P	N(R)		
Supervisory	RR	(receive ready)	RR (receive ready)	1	0	0	0	P/F	N(R)		
	RNR	(receive not ready)	RNR (receive not ready)	1	0	1	0	P/F	N(R)		
	REJ	(reject)	REJ (reject)	1	0	0	1	P/F	N(R)		
Unnumbered	SABM	(set asynchronous balanced mode)		1	1	1	1	P	1	0	0
	DISC	(disconnect)		1	1	0	0	P	0	1	0
		DM (disconnect mode)		1	1	1	1	F	0	0	0
		UA (unnumbered acknowledgment)		1	1	0	0	F	1	1	0
		FRMR (frame reject)		1	1	1	0	F	0	0	1

TABLE 6/X.25

LAPB commands and responses – Extended (modulo 128) operation

			1	2	3	4	5	6	7	8	9	10 to 16
Format	Command	Response	Encoding									
Information transfer	I (information)		0	N(S)								P N(R)
Supervisory	RR (receive ready)	RR (receive ready)	1	0	0	0	0	0	0	0	P/F	N(R)
	RNR (receive not ready)	RNR (receive not ready)	1	0	1	0	0	0	0	0	P/F	N(R)
	REJ (reject)	REJ (reject)	1	0	0	1	0	0	0	0	P/F	N(R)
Unnumbered	SABME (set asynchronous balanced mode extended)		1	1	1	1	P	1	1	0		
	DISC (disconnect)		1	1	0	0	P	0	1	0		
		DM (disconnected mode)	1	1	1	1	F	0	0	0		
		UA (unnumbered acknowledgment)	1	1	0	0	F	1	1	0		
		FRMR (frame reject)	1	1	1	0	F	0	0	1		

2.3.4.2 Receive ready (RR) command and response

The receive ready (RR) supervisory frame is used by the DCE or DTE to:

- 1) indicate it is ready to receive an I frame; and
- 2) acknowledge previously received I frames numbered up to and including $N(R) - 1$.

An RR frame may be used to indicate the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by that same station (DCE or DTE). In addition to indicating the DCE or DTE status, the RR command with the P bit set to 1 may be used by the DCE or DTE to ask for the status of the DTE or DCE, respectively.

2.3.4.3 Receive not ready (RNR) command and response

The receive not ready (RNR) supervisory frame is used by the DCE or DTE to indicate a busy condition; i.e. temporary inability to accept additional incoming I frames. I frames numbered up to and including $N(R) - 1$ are acknowledged. I frame $N(R)$ and any subsequent I frames received, if any, are not acknowledged; the acceptance status of these I frames will be indicated in subsequent exchanges.

In addition to indicating the DCE or DTE status, the RNR command with the P bit set to 1 may be used by an DCE or DTE to ask for the status of the DTE or DCE, respectively.

2.3.4.4 *Reject (REJ) command and response*

The reject (REJ) supervisory frame is used by the DCE or DTE to request transmission of I frames starting with the frame numbered N(R). I frames numbered N(R) – 1 and below are acknowledged. Additional I frames pending initial transmission may be transmitted following the retransmitted I frame(s).

Only one REJ exception condition for a given direction of information transfer may be established at any time. The REJ exception condition is cleared (reset) upon the receipt of an I frame with an N(S) equal to the N(R) of the REJ frame.

An REJ frame may be used to indicate the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by that same station (DCE or DTE). In addition to indicating the DCE or DTE status, the REJ command with the P bit set to 1 may be used by the DCE or DTE to ask for the status of the DTE or DCE, respectively.

2.3.4.5 *Set asynchronous balanced mode (SABM) command/Set asynchronous balanced mode extended (SABME) command (subscription time option)*

The SABM unnumbered command is used to place the addressed DCE or DTE in an asynchronous balanced mode (ABM) information transfer phase where all command/response control fields will be one octet in length.

The SABME unnumbered command is used to place the addressed DCE or DTE in an asynchronous balanced mode (ABM) information transfer phase where numbered command/response control fields will be two octets in length, and unnumbered command/response control fields will be one octet in length.

No information field is permitted with the SABM or SABME command. The transmission of a SABM/SABME command indicates the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by that same station (DCE or DTE). The DCE or DTE confirms acceptance of SABM/SABME [modulo 8 (basic) operation/modulo 128 (extended) operation] command by the transmission, at the first opportunity, of a UA response. Upon acceptance of this command, the DCE or DTE send state variable V(S) and receive state variable V(R) are set to 0.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. It is the responsibility of a higher layer (e.g. Packet Layer or MLP) to recover from the possible loss of the contents (e.g. packets) of such I frames.

Note – The mode of operation of a data link [basic (modulo 8) or extended (modulo 128)] is determined at subscription time and is only changed by going through a new subscription process.

2.3.4.6 *Disconnect (DISC) command*

The DISC unnumbered command is used to terminate the mode previously set. It is used to inform the DCE or DTE receiving the DISC command that the DTE or DCE sending the DISC command is suspending operation. No information field is permitted with the DISC command. Prior to actioning the DISC command, the DCE or DTE receiving the DISC command confirms the acceptance of the DISC command by the transmission of a UA response. The DTE or DCE sending the DISC command enters the disconnected phase when it receives the acknowledging UA response.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. It is the responsibility of a higher layer (e.g. Packet Layer or MLP) to recover from the possible loss of the contents (e.g., packets) of such I frames.

2.3.4.7 *Unnumbered acknowledgement (UA) response*

The UA unnumbered response is used by the DCE or DTE to acknowledge the receipt and acceptance of the mode-setting commands. Received mode-setting commands are not actioned until the UA response is transmitted. The transmission of a UA response indicates the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by that same station (DCE or DTE). No information field is permitted with the UA response.

2.3.4.8 Disconnected mode (DM) response

The DM unnumbered response is used to report a status where the DCE or DTE is logically disconnected from the data link, and is in the disconnected phase. The DM response may be sent to indicate that the DCE or DTE has entered the disconnected phase without benefit of having received a DISC command, or, if sent in response to the reception of a mode setting command, is sent to inform the DTE or DCE that the DCE or DTE, respectively, is still in the disconnected phase and cannot execute the set mode command. No information field is permitted with the DM response.

A DCE or DTE in a disconnected phase will monitor received commands and will react to an SABM/SABME command as outlined in § 2.4.4 below, and will respond with a DM response with the F bit set to 1 to any other command received with the P bit set to 1.

2.3.4.9 Frame reject (FRMR) response

The FRMR unnumbered response is used by the DCE or DTE to report an error condition not recoverable by retransmission of the identical frame; i.e. at least one of the following conditions, which results from the receipt of a valid frame:

- 1) the receipt of a command or response control field that is undefined or not implemented;
- 2) the receipt of an I frame with an information field which exceeds the maximum established length;
- 3) the receipt of an invalid N(R); or
- 4) the receipt of a frame with an information field which is not permitted or the receipt of a supervisory or unnumbered frame with incorrect length.

An undefined or not implemented control field is any of the control field encodings that are not identified in Tables 5/X.25 or 6/X.25.

A valid N(R) must be within the range from the lowest send sequence number N(S) of the still unacknowledged frame(s) to the current DCE send state variable inclusive (or to the current internal variable x if the DCE is in the timer recovery condition as described in § 2.4.5.9).

An information field which immediately follows the control field, and consists of 3 or 5 octets [modulo 8 (basic) operation or modulo 128 (extended) operation, respectively], is returned with this response and provides the reason for the FRMR response. These formats are given in Tables 7/X.25 and 8/X.25.

2.3.5 Exception condition reporting and recovery

The error recovery procedures which are available to effect recovery following the detection/occurrence of an exception condition at the Data Link Layer are described below. Exception conditions described are those situations which may occur as the result of transmission errors, DCE or DTE malfunction, or operational situations.

2.3.5.1 Busy condition

The busy condition results when the DCE or DTE is temporarily unable to continue to receive I frames due to internal constraints, e.g. receive buffering limitations. In this case an RNR frame is transmitted from the busy DCE or DTE. I frames pending transmission may be transmitted from the busy DCE or DTE prior to or following the RNR frame.

An indication that the busy condition has cleared is communicated by the transmission of a UA (only in response to a SABM/SABME command), RR, REJ or SABM/SABME (modulo 8/modulo 128) frame.

TABLE 7/X.25

LAPB FRMR information field format – Basic (modulo 8) operation

Information field bits

1	2	3	4	5	6	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
7	8																				
Rejected frame control field						0	V(S)			C/R	V(R)			W	X	Y	Z	0	0	0	0

- Rejected frame control field is the control field of the received frame which caused the frame reject.
- V(S) is the current send state variable value at the DCE or DTE reporting the rejection condition (bit 10 = low-order bit).
- C/R set to 1 indicates the rejected frame was a response. C/R set to 0 indicates the rejected frame was a command.
- V(R) is the current receive state variable value at the DCE or DTE reporting the rejection condition (bit 14 = low-order bit).
- W set to 1 indicates that the control field received and returned in bits 1 through 8 was undefined or not implemented.
- X set to 1 indicates that the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this frame or is a supervisory or unnumbered frame with incorrect length. Bit W must be set to 1 in conjunction with this bit.
- Y set to 1 indicates that the information field received exceeded the maximum established capacity.
- Z set to indicates the control field received and returned in bits 1 through 8 contained an invalid N(R).

Note – Bits 9 and 21 to 24 shall be set to 0.

TABLE 8/X.25

LAPB FRMR information field format – Extended (modulo 128) operation

Information field bits

1 to 16	17	18 to 24	25	26 to 32	33	34	35	36	37	38	39	40
Rejected frame control field	0	V(S)	C/R	V(R)	W	X	Y	Z	0	0	0	0

- Rejected frame control field is the control field of the received frame which caused the frame reject. When the rejected frame is an unnumbered frame, the control field of the rejected frame is positioned in bit positions 1–8, with 9–16 set to 0.
- V(S) is the current send state variable value at the DCE or DTE reporting the rejection condition (bit 18 = low-order bit).
- C/R set to 1 indicates the rejected frame was a response. C/R set to 0 indicates the rejected frame was a command.
- V(R) is the current receive state variable value at the DCE or DTE reporting the rejection condition (bit 26 = low-order bit).
- W set to 1 indicates that the control field received and returned in bits 1 through 16 was undefined or not implemented.
- X set to 1 indicates that the control field received and returned in bits 1 through 16 was considered invalid because the frame contained an information field which is not permitted with this frame or is a supervisory or unnumbered frame with incorrect length. Bit W must be set to 1 in conjunction with this bit.
- Y set to 1 indicates that the information field received exceeded the maximum established capacity.
- Z set to indicates the control field received and returned in bits 1 through 16 contained an invalid N(R).

Note – Bits 17 and 37 to 40 shall be set to 0.

2.3.5.2 *N(S) sequence error condition*

The information field of all I frames received whose N(S) does not equal the receive state variable V(R) will be discarded.

An N(S) sequence error exception condition occurs in the receiver when an I frame received contains an N(S) which is not equal to the receive state variable V(R) at the receiver. The receiver does not acknowledge (increment its receive state variable) the I frame causing the sequence error, or any I frame which may follow, until an I frame with the correct N(S) is received.

A DCE or DTE which receives one or more valid I frames having sequence errors or subsequent supervisory frames (RR, RNR and REJ) shall accept the control information contained in the N(R) field and the P or F bit to perform data link control functions; e.g. to receive acknowledgement of previously transmitted I frames and to cause the DCE or DTE to respond (P bit set to 1).

The means specified in §§ 2.3.5.2.1 and 2.3.5.2.2 shall be available for initiating the retransmission of lost or errored I frames following the occurrence of an N(S) sequence error condition.

2.3.5.2.1 *REJ recovery*

The REJ frame is used by a receiving DCE or DTE to initiate a recovery (retransmission) following the detection of an N(S) sequence error.

With respect to each direction of transmission on the data link, only one “sent REJ” exception condition from a DCE or DTE, to a DTE or DCE, is established at a time. A “sent REJ” exception condition is cleared when the requested I frame is received.

A DCE or DTE receiving a REJ frame initiates sequential (re-)transmission of I frames starting with the I frame indicated by the N(R) contained in the REJ frame. The retransmitted frames may contain an N(R) and a P bit that are updated from, and therefore different from, the ones contained in the originally transmitted I frames.

2.3.5.2.2 *Time-out recovery*

If a DCE or DTE, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frame(s) in a sequence of I frames, it will not detect an N(S) sequence error condition and, therefore, will not transmit a REJ frame. The DTE or DCE which transmitted the unacknowledged I frame(s) shall, following the completion of a system specified time-out period (see §§ 2.4.5.1 and 2.4.5.9 below), take appropriate recovery action to determine at which I frame retransmission must begin. The retransmitted frame(s) may contain an N(R) and a P bit that is updated from, and therefore different from, the ones contained in the originally transmitted frame(s).

2.3.5.3 *Invalid frame condition*

Any frame which is invalid will be discarded, and no action is taken as the result of that frame. An invalid frame is defined as one which:

- a) is not properly bounded by two flags;
- b) in basic (modulo 8) operation, contains fewer than 32 bits between flags; in extended (modulo 128) operation, contains fewer than 40 bits between flags of frames that contain sequence numbers or 32 bits between flags of frames that do not contain sequence numbers;
- c) contains a Frame Check Sequence (FCS) error; or
- d) contains an address other than A or B (for single link operation) or other than C or D (for multilink operation).

For those networks that are octet aligned, a detection of non-octet alignment may be made at the Data Link Layer by adding a frame validity check that requires the number of bits between the opening flag and the closing flag, excluding bits inserted for transparency, to be an integral number of octets in length, or the frame is considered invalid.

2.3.5.4 *Frame rejection condition*

A frame rejection condition is established upon the receipt of an error-free frame with one of the conditions listed in § 2.3.4.9 above.

At the DCE or DTE, this frame rejection exception condition is reported by an FRMR response for appropriate DTE or DCE action, respectively. Once a DCE has established such an exception condition, no additional I frames are accepted until the condition is reset by the DTE, except for examination of the P bit. The FRMR response may be

repeated at each opportunity, as specified in § 2.4.7.3, until recovery is effected by the DTE, or until the DCE initiates its own recovery in case the DTE does not respond.

2.3.5.5 *Excessive idle channel state condition on incoming channel*

Upon detection of an idle channel state condition (see § 2.2.12.2 above) on the incoming channel, the DCE shall wait for a period T3 (see § 2.4.8.3 below) without taking any specific action, waiting for detection of a return to the active channel state (i.e., detection of at least one flag sequence). After the period T3, the DCE shall notify the higher layer (e.g. the Packet Layer or the MLP) of the excessive idle channel state condition, but shall not take any action that would preclude the DTE from establishing the data link by normal data link set-up procedures.

Note – Other actions to be taken by the DCE at the Data Link Layer upon expiration of period T3 is a subject for further study.

2.4 *Description of the LAPB procedure*

2.4.1 *LAPB basic and extended modes of operation*

In accordance with the system choice made by the DTE at subscription time, the DCE will either support modulo 8 (basic) operation or will support modulo 128 (extended) operation. Changing from basic operation to extended operation, or vice versa, in the DCE requires resubscription by the DTE for the desired service, and is not supported dynamically.

Table 5/X.25 indicates the command and response control field formats used with the basic (modulo 8) service. The mode-setting command employed to initialize (set up) or reset the basic mode is the SABM command. Table 6/X.25 indicates the command and response control field formats used with the extended (modulo 128) service. The mode-setting command employed to initialize (set up) or reset the extended mode is the SABME command.

2.4.2 *LAPB procedure for addressing*

The address field identifies a frame as either a command or a response. A command frame contains the address of the DCE or DTE to which the command is being sent. A response frame contains the address of the DCE or DTE sending the frame.

In order to allow differentiation between single link operation and the optional multilink operation for diagnostic and/or maintenance reasons, different address pair encodings are assigned to data links operating with multilink procedure compared to data links operating with the single link procedure.

Frames containing commands transferred from the DCE to the DTE will contain the address A for the single link operation and address C for the multilink operation.

Frames containing responses transferred from the DCE to the DTE will contain the address B for the single link operation and address D for the multilink operation.

Frames containing commands transferred from the DTE to the DCE shall contain the address B for the single link operation and address D for the multilink operation.

Frames containing responses transferred from the DTE to the DCE shall contain the address A for the single link operation and address C for the multilink operation.

These addresses are coded as follows:

Address 1 2 3 4 5 6 7 8

Single link operation	A	1 1 0 0 0 0 0 0
	B	1 0 0 0 0 0 0 0
Multilink operation	C	1 1 1 1 0 0 0 0
	D	1 1 1 0 0 0 0 0

Note – The DCE will discard all frames received with an address other than A or B (single link operation), or C or D (multilink operation).

2.4.3 LAPB procedure for the use of the P/F bit

The DCE or DTE receiving an SABM/SABME, DISC, supervisory command or I frame with the P bit set to 1 will set the F bit to 1 in the next response frame it transmits.

The response frame returned by the DCE to an SABM/SABME or DISC command with the P bit set to 1 will be a UA or DM response with the F bit set to 1. The response frame returned by the DCE to an I frame with the P bit set to 1, received during the information transfer phase, will be an RR, REJ, RNR or FRMR response with the F bit set to 1. The response frame returned by the DCE to a supervisory command with the P bit set to 1, received during the information transfer phase, will be an RR, REJ, RNR or FRMR response with the F bit set to 1. The response frame returned by the DCE to an I frame or supervisory frame with the P bit set to 1, received during the disconnected phase, will be a DM response with the F bit set to 1.

The P bit may be used by the DCE in conjunction with the timer recovery condition (see § 2.4.5.9 below).

Note – Other use of the P bit by the DCE is a subject for further study.

2.4.4 LAPB procedure for data link set-up and disconnection

2.4.4.1 Data link set-up

The DCE will indicate that it is able to set up the data link by transmitting contiguous flags (active channel state).

Either the DTE or the DCE may initiate data link set-up. Prior to initiation of data link set-up, either the DCE or the DTE may initiate data link disconnection (see § 2.4.4.3) for the purpose of insuring that the DCE and the DTE are in the same phase. The DCE may also transmit an unsolicited DM response to request the DTE to initiate data link set-up.

The DTE shall initiate data link set-up by transmitting an SABM/SABME command to the DCE. If, upon receipt of the SABM/SABME command correctly, the DCE determines that it can enter the information transfer phase, it will return a UA response to the DTE, will reset its send and receive state variables V(S) and V(R) to zero, and will consider that the data link is set up. If, upon receipt of the SABM/SABME command correctly, the DCE determines that it cannot enter the information transfer phase, it will return a DM response to the DTE as a denial to the data link set-up initialization and will consider that the data link is *not* set up. In order to avoid misinterpretation of the DM response received, it is suggested that the DTE always sends its SABM/SABME command with the P bit set to 1. Otherwise, it is not possible to differentiate a DM response intended as a denial to data link set-up from a DM response that is issued in a separate unsolicited sense as a request for a mode-setting command (as described in § 2.4.4.4.2).

The DCE will initiate data link set-up by transmitting an SABM/SABME command to the DTE and starting its Timer T1 in order to determine when too much time has elapsed waiting for a reply (see § 2.4.8.1 below). Upon reception of a UA response from the DTE, the DCE will reset its send and receive state variables V(S) and V(R) to zero, will stop its Timer T1, and will consider that the data link is set up. Upon reception of a DM response from the DTE as a denial to the data link set-up initialization, the DCE will stop its Timer T1 and will consider that the data link is *not* set up.

The DCE, having sent the SABM/SABME command, will ignore and discard any frames except an SABM/SABME or DISC command, or a UA or DM response received from the DTE. The receipt of an SABM/SABME or DISC command from the DTE will result in a collision situation that is resolved per § 2.4.4.5 below. Frames other than the UA and DM responses sent in response to a received SABM/SABME or DISC command will be sent only after the data link is set up and if no outstanding SABM/SABME command exists.

After the DCE sends the SABM/SABME command, if a UA or DM response is not received correctly, Timer T1 will run out in the DCE. The DCE will then resend the SABM/SABME command and will restart Timer T1. After transmission of the SABM/SABME command N2 times by the DCE, appropriate higher layer recovery action will be initiated. The value of N2 is defined in § 2.4.8.4 below.

2.4.4.2 Information transfer phase

After having transmitted the UA response to the SABM/SABME command or having received the UA response to a transmitted SABM/SABME command, the DCE will accept and transmit I and supervisory frames according to the procedures described in § 2.4.5 below.

When receiving the SABM/SABME command while in the information transfer phase, the DCE will conform to the data link resetting procedure described in § 2.4.7 below.

2.4.4.3 *Data link disconnection*

The DTE shall initiate a disconnect of the data link by transmitting a DISC command to the DCE. On correctly receiving a DISC command in the information transfer phase, the DCE will send a UA response and enter the disconnected phase. On correctly receiving a DISC command in the disconnected phase, the DCE will send a DM response and remain in the disconnected phase. In order to avoid misinterpretation of the DM response received, it is suggested that the DTE always sends its DISC command with the P bit set to 1. Otherwise, it is not possible to differentiate a DM response intended as an indication that the DCE is already in the disconnected phase from a DM response that is issued in a separate unsolicited sense as a request for a mode-setting command (as described in § 2.4.4.4.2).

The DCE will initiate a disconnect of the data link by transmitting a DISC command to the DTE and starting its Timer T1 (see § 2.4.8.1 below). Upon reception of an UA response from the DTE, the DCE will stop its Timer T1 and will enter the disconnected phase. Upon reception of a DM response from the DTE as an indication that the DTE was already in the disconnected phase, the DCE will stop its Timer T1 and will enter the disconnected phase.

The DCE, having sent the DISC command, will ignore and discard any frames except an SABM/SABME or DISC command, or a UA or DM response received from the DTE. The receipt of an SABM/SABME or DISC command from the DTE will result in a collision situation that is resolved per § 2.4.4.5 below.

After the DCE sends the DISC command, if a UA or DM response is not received correctly, Timer T1 will run out in the DCE. The DCE will then resend the DISC command and will restart Timer T1. After transmission of the DISC command N2 times by the DCE, appropriate higher layer recovery action will be initiated. The value of N2 is defined in § 2.4.8.4 below.

2.4.4.4 *Disconnected phase*

2.4.4.4.1 After having received a DISC command from the DTE and returned a UA response to the DTE, or having received the UA response to a transmitted DISC command, the DCE will enter the disconnected phase.

In the disconnected phase, the DCE may initiate data link set-up. In the disconnected phase, the DCE will react to the receipt of an SABM/SABME command as described in § 2.4.4.1 above and will transmit a DM response in answer to a received DISC command. When receiving any other command (defined, or undefined or not implemented) with the P bit set to 1, the DCE will transmit a DM response with the F bit set to 1. Other frames received in the disconnected phase will be ignored by the DCE.

2.4.4.4.2 When the DCE enters the disconnected phase after detecting error conditions as listed in § 2.4.6 below, or after an internal malfunction, it may indicate this by sending a DM response rather than a DISC command. In these cases, the DCE will transmit a DM response and start its Timer T1 (see § 2.4.8.1 below).

If Timer T1 runs out before the reception of an SABM/SABME or DISC command from the DTE, the DCE will retransmit the DM response and restart Timer T1. After transmission of the DM response N2 times, the DCE will remain in the disconnected phase and appropriate recovery actions will be initiated. The value of N2 is defined in § 2.4.8.4 below.

Alternatively, after an internal malfunction, the DCE may either initiate a data link resetting procedure (see § 2.4.7 below) or disconnect the data link (see § 2.4.4.3 above) prior to initiating a data link set-up procedure (see § 2.4.4.1 above).

2.4.4.5 *Collision of unnumbered commands*

Collision situations shall be resolved in the following way:

2.4.4.5.1 If the sent and received unnumbered commands are the same, the DCE and the DTE shall each send the UA response at the earliest possible opportunity. The DCE shall enter the indicated phase either,

- 1) after receiving the UA response,
- 2) after sending the UA response, or
- 3) after timing out waiting for the UA response having sent a UA response.

In the case of 2) above, the DCE will accept a subsequent UA response to the mode-setting command it issued without causing an exception condition if received within the time-out interval.

2.4.4.5.2 If the sent and received unnumbered commands are different, the DCE and the DTE shall each enter the disconnected phase and issue a DM response at the earliest possible opportunity.

2.4.4.6 Collision of DM response with SABM/SABME or DISC command

When a DM response is issued by the DCE or DTE as an unsolicited response to request the DTE or DCE, respectively, to issue a mode-setting command as described in § 2.4.4.4, a collision between an SABM/SABME or DISC command and the unsolicited DM response may occur. In order to avoid misinterpretation of the DM response received, the DTE always sends its SABM/SABME or DISC command with the P bit set to 1.

2.4.4.7 Collision of DM responses

A contention situation may occur when both the DCE and the DTE issue a DM response to request a mode-setting command. In this case, the DTE will issue an SABM/SABME command to resolve the contention situation.

2.4.5 LAPB procedures for information transfer

The procedures which apply to the transmission of I frames in each direction during the information transfer phase are described below.

In the following, “number one higher” is in reference to a continuously repeated sequence series, i.e., 7 is 1 higher than 6 and 0 is 1 higher than 7 for modulo 8 series, and 127 is 1 higher than 126 and 0 is 1 higher than 127 for modulo 128 series.

2.4.5.1 Sending I frames

When the DCE has an I frame to transmit (i.e. an I frame not already transmitted, or having to be retransmitted as described in § 2.4.5.6 below), it will transmit it with an N(S) equal to its current send state variable V(S), and an N(R) equal to its current receive state variable V(R). At the end of the transmission of the I frame, the DCE will increment its send state variable V(S) by 1.

If Timer T1 is not running at the time of transmission of an I frame, it will be started.

If the send state variable V(S) is equal to the last value of N(R) received plus k (where k is the maximum number of outstanding I frames – see § 2.4.8.6 below), the DCE will not transmit any new I frames, but may retransmit an I frame as described in §§ 2.4.5.6 or 2.4.5.9 below.

When the DCE is in the busy condition, it may still transmit I frames, provided that the DTE is not busy. When the DCE is in the frame rejection condition, it will stop transmitting I frames.

2.4.5.2 Receiving an I frame

2.4.5.2.1 When the DCE is not in a busy condition and receives a valid I frame whose send sequence number N(S) is equal to the DCE receive state variable V(R), the DCE will accept the information field of this frame, increment by one its receive state variable V(R), and act as follows:

- a) If the DCE is still not in a busy condition:
 - i) If an I frame is available for transmission by the DCE, it may act as in § 2.4.5.1 above and acknowledge the received I frame by setting N(R) in the control field of the next transmitted I frame to the value of the DCE receive state variable V(R). Alternatively, the DCE may acknowledge the received I frame by transmitting an RR frame with the N(R) equal to the value of the DCE receive state variable V(R).
 - ii) If no I frame is available for transmission by the DCE, it will transmit an RR frame with N(R) equal to the value of the DCE receive state variable V(R).
- b) If the DCE is now in a busy condition, it will transmit an RNR frame with N(R) equal to the value of the DCE receive state variable V(R) (see § 2.4.5.8).

2.4.5.2.2 When the DCE is in a busy condition, it may ignore the information field contained in any received I frame.

2.4.5.3 Reception of invalid frames

When the DCE receives an invalid frame (see § 2.3.5.3), this frame will be discarded.

2.4.5.4 Reception of out-of-sequence I frames

When the DCE receives a valid I frame whose send sequence number N(S) is incorrect, i.e., not equal to the current DCE receive state variable V(R), it will discard the information field of the I frame and transmit an REJ frame

with the N(R) set to one higher than the N(S) of the last correctly received I frame. The REJ frame will be a command frame with the P bit set to 1 if an acknowledged transfer of the retransmission request is required; otherwise the REJ frame may be either a command or a response frame. The DCE will then discard the information field of all I frames received until the expected I frame is correctly received. When receiving the expected I frame, the DCE will then acknowledge the I frame as described in § 2.4.5.2 above. The DCE will use the N(R) and P bit information in the discarded I frames as described in § 2.3.5.2 above.

2.4.5.5 *Receiving acknowledgement*

When correctly receiving an I frame or a supervisory frame (RR, RNR or REJ), even in the busy condition, the DCE will consider the N(R) contained in this frame as an acknowledgement for all I frames it has transmitted with an N(S) up to and including the received N(R)–1. The DCE will stop Timer T1 when it correctly receives an I frame or a supervisory frame with the N(R) higher than the last received N(R) (actually acknowledging some I frames), or an REJ frame with an N(R) equal to the last received N(R).

If Timer T1 has been stopped by the receipt on an I, RR or RNR frame, and if there are outstanding I frames still unacknowledged, the DCE will restart Timer T1. If Timer T1 then runs out, the DCE will follow the recovery procedure (§ 2.4.5.9 below) with respect to the unacknowledged I frames. If Timer T1 has been stopped by the receipt of an REJ frame, the DCE will follow the retransmission procedures in § 2.4.5.6 below.

2.4.5.6 *Receiving an REJ frame*

When receiving an REJ frame, the DCE will set its send state variable V(S) to the N(R) received in the REJ control field. It will transmit the corresponding I frame as soon as it is available or retransmit it in accordance with the procedures described in § 2.4.5.1 above. (Re)transmission will conform to the following procedure:

- i) if the DCE is transmitting a supervisory command or response when it receives the REJ frame, it will complete that transmission before commencing transmission of the requested I frame;
- ii) if the DCE is transmitting an unnumbered command or response when it receives the REJ frame, it will ignore the request for retransmission;
- iii) if the DCE is transmitting an I frame when the REJ frame is received, it may abort the I frame and commence transmission of the requested I frame immediately after abortion;
- iv) if the DCE is not transmitting any frame when the REJ frame is received, it will commence transmission of the requested I frame immediately.

In all cases, if other unacknowledged I frames had already been transmitted following the one indicated in the REJ frame, then those I frames will be retransmitted by the DCE following the retransmission of the requested I frame. Other I frames not yet transmitted may be transmitted following the retransmitted I frames.

If the REJ frame was received from the DTE as a command with the P bit set to 1, the DCE will transmit an RR, RNR or REJ response with the F bit set to 1 before transmitting or retransmitting the corresponding I frame.

2.4.5.7 *Receiving an RNR frame*

After receiving an RNR frame whose N(R) acknowledges all frames previously transmitted, the DCE will stop Timer T1 and may then transmit an I frame, with the P bit set to 0, whose send sequence number is equal to the N(R) indicated in the RNR frame, restarting Timer T1 as it does. After receiving an RNR frame whose N(R) indicates a previously transmitted frame, the DCE will not transmit or retransmit any I frame, Timer T1 being already running. In either case, if the Timer T1 runs out before receipt of a busy clearance indication, the DCE will follow the procedure described in § 2.4.5.9 below. In any case, the DCE will not transmit any other I frames before receiving an RR or REJ frame, or before the completion of a link resetting procedure.

Alternatively, after receiving an RNR frame, the DCE may wait for a period of time (e.g., the length of the Timer T1) and then transmit a supervisory command frame (RR, RNR or REJ) with the P bit set to 1, and start Timer T1, in order to determine if there is any change in the receive status of the DTE. The DTE shall respond to the P bit set to 1 with a supervisory response frame (RR, RNR or REJ) with the F bit set to 1 indicating either continuance of the busy condition (RNR) or clearance of the busy condition (RR or REJ). Upon receipt of the DTE response, Timer T1 is stopped.

- 1) If the response is the RR or REJ response, the busy condition is cleared and the DCE may transmit I frames beginning with the I frame identified by the N(R) in the received response frame.
- 2) If the response is the RNR response, the busy condition still exists, and the DCE will after a period of time (e.g. the length of Timer T1) repeat the enquiry of the DTE receive status.

If Timer T1 runs out before a status response is received, the enquiry process above is repeated. If N2 attempts to get a status response fail (i.e. Timer T1 runs out N2 times), the DCE will initiate a data link resetting procedure as described in § 2.4.7.2 below or will transmit a DM response to ask the DTE to initiate a data link set-up procedure as described in § 2.4.4.1 and enter the disconnected phase. The value of N2 is defined in § 2.4.8.4 below.

If, at any time during the enquiry process, an unsolicited RR or REJ frame is received from the DTE, it will be considered to be an indication of clearance of the busy condition. Should the unsolicited RR or REJ frame be a command frame with the P bit set to 1, the appropriate response frame with the F bit set to 1 must be transmitted before the DCE may resume transmission of I frames. If Timer T1 is running, the DCE will wait for the non-busy response with the F bit set to 1 or will wait for Timer T1 to run out and then either may reinitiate the enquiry process in order to realize a successful P/F bit exchange or may resume transmission of I frames beginning with the I frame identified by the N(R) in the received RR or REJ frame.

2.4.5.8 *DCE busy condition*

When the DCE enters a busy condition, it will transmit an RNR frame at the earliest opportunity. The RNR frame will be a command frame with the P bit set to 1 if an acknowledged transfer of the busy condition indication is required; otherwise the RNR frame may be either a command or a response frame. While in the busy condition, the DCE will accept and process supervisory frames, will accept and process the contents of the N(R) fields of I frames, and will return an RNR response with the F bit set to 1 if it receives a supervisory command or I command frame with the P bit set to 1. To clear the busy condition, the DCE will transmit either an REJ frame or an RR frame, with N(R) set to the current receive state variable V(R), depending on whether or not it discarded information fields of correctly received I frames. The REJ frame or the RR frame will be a command frame with the P bit set to 1 if an acknowledged transfer of the busy-to-non-busy transition is required, otherwise the REJ frame or the RR frame may be either a command or a response frame.

2.4.5.9 *Waiting acknowledgement*

The DCE maintains an internal transmission attempt variable which is set to 0 when the DCE sends a UA response, when the DCE receives a UA response or an RNR command or response, or when the DCE correctly receives an I frame or supervisory frame with the N(R) higher than the last received N(R) (actually acknowledging some outstanding I frames).

If Timer T1 runs out waiting for the acknowledgement from the DTE for an I frame transmitted, the DCE will enter the timer recovery condition, add one to its transmission attempt variable and set an internal variable x to the current value of its send state variable V(S). The DCE will then restart Timer T1, set its send state variable V(S) to the last value of N(R) received from the DTE and retransmit the corresponding I frame with the P bit set to 1, or transmit an appropriate supervisory command frame (RR, RNR or REJ) with the P bit set to 1.

The timer recovery condition is cleared when the DCE receives a valid supervisory frame with the F bit set to 1.

If, while in the timer recovery condition, the DCE correctly receives a supervisory frame with the F bit set to 1 and with the N(R) within the range from its current send state variable V(S) to x included, it will clear the timer recovery condition (including stopping Timer T1) and set its send state variable V(S) to the value of the received N(R), and may then resume with I frame transmission or retransmission, as appropriate.

If, while in the timer recovery condition, the DCE correctly receives an I or supervisory frame with the P/F bit set to 0 and with a valid N(R) (see § 2.3.4.9), it will not clear the timer recovery condition. The value of the received N(R) may be used to update the send state variable V(S). However, the DCE may decide to keep the last transmitted I frame in store (even if it is acknowledged) in order to be able to retransmit it with the P bit set to 1 when Timer T1 runs out at a later time.

If the received supervisory frame with the P/F bit set to 0 is an REJ frame with a valid N(R), the DCE may either immediately initiate (re)transmission from the value of the send state variable V(S), or it may ignore the request for retransmission and wait until the supervisory frame with the F bit set to 1 is received before initiating (re)transmission of frames from the value identified in the N(R) field of the supervisory frame with the F bit set to 1. In the case of immediate retransmission, in order to prevent duplicate retransmissions following the clearance of the timer recovery condition, the DCE shall inhibit retransmission of a specific I frame [same N(R) in the same numbering cycle] if the DCE has retransmitted that I frame as the result of a received REJ frame with the P/F bit set to 0.

If, while in the timer recovery condition, the DCE receives a REJ command with the P bit set to 1, the DCE will respond immediately with an appropriate supervisory response with the F bit set to 1. The DCE may then use the value of the N(R) in the REJ command to update the send state variable V(S), and may either immediately begin (re)transmission from the value N(R) indicated in the REJ frame or ignore the request for retransmission and wait until

the supervisory frame with the F bit set to 1 is received before initiating (re)transmission of I frames from the value identified in the N(R) field of the supervisory frame with the F bit set to 1. In the case of immediate retransmission, in order to prevent duplicate retransmissions following the clearance of the timer recovery condition, the DCE shall inhibit retransmission of a specific I frame [same N(R) in the same numbering cycle] if the DCE has retransmitted that I frame as the result of the received REJ command with the P bit set to 1.

If Timer T1 runs out in the timer recovery condition, and no I or supervisory frame with the P/F bit set to 0 and with a valid N(R) has been received, or no REJ command with the P bit set to 1 and with a valid N(R) has been received, the DCE will add one to its transmission attempt variable, restart Timer T1, and either retransmit the I frame sent with the P bit set to 1 or transmit an appropriate supervisory command with the P bit set to 1.

If the transmission attempt variable is equal to N2, the DCE will initiate a data link resetting procedure as described in § 2.4.7.2 below, or will transmit a DM response to ask the DTE to initiate a data link set-up procedure as described in § 2.4.4.1 above and enter the disconnected phase. N2 is a system parameter (see § 2.4.8.4 below).

Note – Although the DCE may implement the internal variable x, other mechanisms do exist that achieve the identical function.

2.4.6 *LAPB conditions for data link resetting or data link re-initialization (data link set-up)*

2.4.6.1 When the DCE receives, during the information transfer phase, a frame which is not invalid (see § 2.3.5.3) with one of the conditions listed in § 2.3.4.9 above, the DCE will request the DTE to initiate a data link resetting procedure by transmitting an FRMR response to the DTE as described in § 2.4.7.3.

2.4.6.2 When the DCE receives, during the information transfer phase, an FRMR response from the DTE, the DCE will either initiate the data link resetting procedures itself as described in § 2.4.7.2 or return a DM response to ask the DTE to initiate the data link set-up (initialization) procedure as described in § 2.4.4.1. After transmitting a DM response, the DCE will enter the disconnected phase as described in § 2.4.4.4.2.

2.4.6.3 When the DCE receives, during the information transfer phase, a UA response, or an unsolicited response with the F bit set to 1, the DCE may either initiate the data link resetting procedures itself as described in § 2.4.7.2, or return a DM response to ask the DTE to initiate the data link set-up (initialization) procedure as described in § 2.4.4.1. After transmitting a DM response, the DCE will enter the disconnected phase as described in § 2.4.4.4.2.

2.4.6.4 When the DCE receives, during the information transfer phase, a DM response from the DTE, the DCE will either initiate the data link set-up (initialization) procedures itself as described in § 2.4.4.1, or return a DM response to ask the DTE to initiate the data link set-up (initialization) procedures as described in § 2.4.4.1. After transmitting a DM response, the DCE will enter the disconnected phase as described in § 2.4.4.4.2.

2.4.7 *LAPB procedure for data link resetting*

2.4.7.1 The data link resetting procedure is used to initialize both directions of information transfer according to the procedure described below. The data link resetting procedure only applies during the information transfer phase.

2.4.7.2 Either the DTE or the DCE may initiate the data link resetting procedure. The data link resetting procedure indicates a clearance of a DCE and/or DTE busy condition, if present.

The DTE shall initiate a data link resetting by transmitting an SABM/SABME command to the DCE. If, upon correct receipt of the SABM/SABME command, the DCE determines that it can continue in the information transfer phase, it will return a UA response to the DTE, will reset its send and receive state variables V(S) and V(R) to zero, and will remain in the information transfer phase. If, upon correct receipt of the SABM/SABME command, the DCE determines that it cannot remain in the information transfer phase, it will return a DM response as a denial to the resetting request and will enter the disconnected phase.

The DCE will initiate a data link resetting by transmitting an SABM/SABME command to the DTE and starting its Timer T1 (see § 2.4.8.1 below). Upon reception of a UA response from the DTE, the DCE will reset its send and receive state variables V(S) and V(R) to zero, will stop its Timer T1, and will remain in the information transfer phase. Upon reception of a DM response from the DTE as a denial to the data link resetting request, the DCE will stop its Timer T1 and will enter the disconnected phase.

The DCE, having sent an SABM/SABME command, will ignore and discard any frames received from the DTE except an SABM/SABME or DISC command, or a UA or DM response. The receipt of an SABM/SABME or DISC command from the DTE will result in a collision situation that is resolved per § 2.4.4.5 above. Frames other than the UA or DM response sent in response to a received SABM/SABME or DISC command will be sent only after the data link is reset and if no outstanding SABM/SABME command exists.

After the DCE sends the SABM/SABME command, if a UA or DM response is not received correctly, Timer T1 will run out in the DCE. The DCE will then resend the SABM/SABME command and will restart Timer T1. After N2

attempts to reset the data link, the DCE will initiate appropriate higher layer recovery action and will enter the disconnected phase. The value of N2 is defined in § 2.4.8.4 below.

2.4.7.3 The DCE may ask the DTE to reset the data link by transmitting an FRMR response (see § 2.4.6.1 above). After transmitting an FRMR response, the DCE will enter the frame rejection condition.

The frame rejection condition is cleared when the DCE receives an SABM/SABME command, a DISC command, a FRMR response, or a DM response; or if the DCE transmits an SABM/SABME command, a DISC command, or a DM response. Other commands received while in the frame rejection condition will cause the DCE to retransmit the FRMR response with the same information field as originally transmitted.

The DCE may start Timer T1 on transmission of the FRMR response. If Timer T1 runs out before the frame rejection condition is cleared, the DCE may retransmit the FRMR response, and restart T1. After N2 attempts (time outs) to get the DTE to reset the data link, the DCE may reset the data link itself as described in § 2.4.7.2 above. The value of N2 is defined in § 2.4.8.4 below.

In the frame rejection condition, I frames and supervisory frames will not be transmitted by the DCE. Also, received I frames and supervisory frames will be discarded by the DCE except for the observance of a P bit set to 1. When an additional FRMR response must be transmitted by the DCE as a result of the receipt of a P bit set to 1 while Timer T1 is running, Timer T1 will continue to run. Upon reception of an FRMR response (even during a frame rejection condition), the DCE will initiate a resetting procedure by transmitting an SABM/SABME command as described in § 2.4.7.2 above, or will transmit a DM response to ask the DTE to initiate the data link set-up procedure as described in § 2.4.4.1 and enter the disconnected phase.

2.4.8 *List of LAPB system parameters*

The DCE and DTE system parameters are as follows:

2.4.8.1 *Timer T1*

The value of the DTE Timer T1 system parameter may be different than the value of the DCE Timer T1 system parameter. These values shall be made known to both the DTE and the DCE, and agreed to for a period of time by both the DTE and the DCE.

The period of Timer T1, at the end of which retransmission of a frame may be initiated (see § 2.4.4 and § 2.4.5 above for the DCE), shall take into account whether T1 is started at the beginning or the end of the transmission of a frame.

The proper operation of the procedure requires that the transmitter's (DCE or DTE) Timer T1 be greater than the maximum time between transmission of a frame (SABM/SABME, DISC, I or supervisory command, or DM or FRMR response) and the reception of the corresponding frame returned as an answer to that frame (UA, DM or acknowledging frame). Therefore, the receiver (DCE or DTE) should not delay the response or acknowledging frame returned to one of the above frames by more than a value T2, where T2 is a system parameter (see § 2.4.8.2).

The DCE will not delay the response or acknowledging frame returned to one of the above DTE frames by more than a period T2.

2.4.8.2 *Parameter T2*

The value of the DTE parameter T2 may be different than the value of the DCE parameter T2. These values shall be made known to both the DTE and the DCE, and agreed to for a period of time by both the DTE and the DCE.

The period of parameter T2 shall indicate the amount of time available at the DCE or DTE before the acknowledging frame must be initiated in order to ensure its receipt by the DTE or DCE, respectively, prior to Timer T1 running out at the DTE or DCE (parameter T2 < Timer T1).

Note – The period of parameter T2 shall take into account the following timing factors: the transmission time of the acknowledging frame, the propagation time over the access data link, the stated processing times at the DCE and the DTE, and the time to complete the transmission of the frame(s) in the DCE or DTE transmit queue that are neither displaceable or modifiable in an orderly manner.

Given a value for Timer T1 for the DTE or DCE, the value of parameter T2 at the DCE or DTE, respectively, must be no larger than T1 minus 2 times the propagation time over the access data link, minus the frame processing time at the DCE, minus the frame processing time at the DTE, and minus the transmission time of the acknowledging frame by the DCE or DTE, respectively.