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Recommendation X.75

PACKET-SWITCHED SIGNALLING SYSTEM
BETWEEN PUBLIC NETWORKS PROVIDING
DATA TRANSMISSION SERVICES

*(provisional, Geneva, 1978; amended at Geneva, 1980,
Malaga-Torremolinos, 1984, and Melbourne, 1988)*

The establishment in various countries of public networks providing packet-switched data transmission services creates a need to standardize 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, Recommendations X.25, X.28, X.29, X.31 and X.32 define DTE/DCE interface characteristics and Recommendation X.96 defines *call progress* signals;

(b) that the logical links A1 and G1 in an international connection are defined in Recommendation X.92 for packet-switched data transmission services;

(c) that Recommendations X.300, X.301 and X.302 define the general principles and arrangements for interworking between public data networks, and between public data networks and other public networks;

(d) that Recommendations X.320, X.322, X.323 and X.325 provide descriptions of interworking cases among networks;

(e) that Recommendation X.180 defines the administrative arrangements for International Closed User Groups and that Recommendation X.181 defines the administrative arrangements for the provision of international Permanent Virtual Circuits;

(f) that the necessary elements of the signalling terminal (STE) interface Recommendation at the gateway/transit data switching exchange should be defined independently as:

Physical layer – the mechanical, electrical, functional and procedural characteristics to activate, maintain and deactivate the physical link at the signalling terminal interface;

Link layer – the link layer procedures for data interchange across the interface between the signalling terminals;

Packet layer – the packet format and signalling procedures for the exchange of packets containing control information and user data at the signalling terminal interface;

(g) that Recommendations X.134, X.135, X.136 and X.137 define the quality of service parameters in public networks providing packet-switched data transmission services;

(h) that Recommendations X.110, X.121, X.122, E.164 and E.166 describe the routing principles and numbering plans for public networks including ISDNs;

unanimously declares

(1) that the basic system structure of the signalling and data transfer procedures in terms of

elements, should be as specified in the Introduction, *Basic system structure*;

(2) that the mechanical, electrical, functional and procedural characteristics to activate, maintain and deactivate the physical link at the signalling terminal interface should be as specified in § 1 below, *Physical layer – Characteristics of the signalling terminal/physical circuit interface*;

(3) that the link layer procedures which operate over the physical circuits and provide a mechanism for reliable transport of packets at the signalling terminal interface should be as specified in § 2 below, *Link layer procedures between signalling terminals*;

(4) that the packet signalling procedures for the exchange of call information and user data at the signalling terminal interface should be as specified in § 3 below, *Packet layer procedures between signalling terminals*;

(5) that the packet format for packets exchanged at the signalling terminal interface should be as specified in § 4 below, *Packet formats for virtual calls and permanent virtual circuits*;

(6) that the procedure and formats for user facilities and network utilities at the signalling terminal interface should be as specified in § 5 below, *Procedure and formats for user facilities and network utilities*.

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0 Introduction

0.1 General

This Recommendation defines the characteristics and operation of a signalling system for use on interconnecting links between various types of public networks to provide internetwork data transmission services. It permits the transfer of call control and network control information and user traffic.

The Recommendation applies to all links between packet-switched public data networks in different countries and also in a number of cases of international links with ISDNs as specified in Recommendation X.300. These include links between ISDNs and packet-switched public data networks and links between ISDNs providing packet-switched data transmission services as defined in Recommendation X.31. It may also be used on such links where the two public networks are in the same country.

Each internetwork link comprises two directly connected signalling terminals (STEs) each within a public network. Transmission facilities between the two STEs may comprise either one or a number of circuits. Each STE is associated with one end of one link and is part of an exchange or exchange function in the public network.

Certain parts of this Recommendation apply in only a limited range of interworking situations; these are clearly indicated in the text. Some concern links between public networks in the same country, and others concern links where at least one public network is not a packet-switched data network.

The protocol elements included in this Recommendation can be used to support the Network Layer Service for interworking situations.

0.2 Elements

The system is made up of communicating elements which function independently and are

therefore defined separately. These elements are:

- a) the physical circuits which comprise transmission facilities, and a set of mechanical, electrical, functional and procedural interface characteristics between the transmission facilities and the signalling terminals and which provide a mechanism for information transfer between two signalling terminals;
- b) the link layer procedures which operate over the physical circuits and provide a mechanism for reliable transport of packets between the two signalling terminals independently of the particular types of physical circuit in use;
- c) the packet layer procedures which use the link layer procedures and provide a mechanism for the exchange of call control information and user traffic between the two signalling terminals.

0.3 *Basic system structure*

The basic system structure of the signalling procedures, in terms of the elements, is shown in Figure 1/X.75.

Figure 1/X.75 - CCITT 19160

Note – Applicable to this Recommendation:

- a) STE–X denotes the STE of the exchange under consideration on the link concerned;
- b) STE–Y denotes the STE of the other exchange under consideration on the link;
- c) the STE–X/STE–Y interface is abbreviated to the X/Y interface;
- d) multiple X/Y interfaces may be used between two networks. In this case, each X/Y interface behaves according to the physical, link and packet layer formats and procedures within this Recommendation.

1 **Physical layer – Characteristics of the signalling terminal/physical circuit interface**

The characteristics of the signalling terminal/physical circuit interface, defined as the physical layer element, shall be in accordance with Recommendation G.703, for physical circuits having a bearer rate of 64 kbit/s and optionally, by bilateral agreement, 2048 Mbit/s (see Note). In addition, Administrations may use for digital circuits any other recognized rate (e.g. 1544 Mbit/s, see Note) by bilateral agreement.

However, for an interim period by bilateral agreement, any other recognized rates could be used for analogue circuits, in which case the characteristics of the signalling terminal/physical circuit interface shall be in accordance with the appropriate V-Series Recommendations.

Each physical circuit of the link must be capable of supporting duplex operation.

In the case of international interworking between packet-switched public data networks, the link is assumed to be data link A1 and/or data link G1 in terms of the hypothetical reference connections defined in Recommendation X.92.

Note – It is for further study whether modifications to the link layer procedures are required for data signalling rates higher than 64 kbit/s in order to support high throughput.

2 Link layer procedures between signalling terminals

2.1 *Scope and field of application*

2.1.1 In order to provide a mechanism for the reliable transport of packets between two signalling terminals, it is necessary to define a procedure which can accept and deliver packets to the packet layer when either single or multiple physical circuits are employed. A multiplicity of physical circuits is required if the effects of circuit failures are not to disrupt the packet layer operation.

2.1.2 The Single link procedure (SLP) described in §§ 2.2 to 2.4 is used for data interchange over a single physical circuit, conforming to the description given in § 1, between two STEs. When multiple physical circuits are employed in parallel this single link procedure is used independently on each circuit and the Multilink procedure (MLP) described in § 2.5 is used for data interchange over these multiple parallel links. In addition, when only a single physical circuit is employed, Administrations may agree bilaterally to use this multilink procedure over the one link.

2.1.3 Each transmission facility is duplex.

2.1.4 The single link procedure is based upon the Link access procedure (LAPB) described in § 2 of Recommendation X.25. The procedure uses the principle and terminology of the High level data link control (HDLC) procedure specified by the International Organization for Standardization (ISO).

The multilink procedure is based on the principle and terminology of the multilink procedure specified by ISO.

2.1.5 For each SLP employed, either extended mode (modulo 128) or non-extended mode (modulo 8) may be used. The choice of the mode employed for such link procedures is independent of all others and of the choice of mode for the corresponding packet layer procedures. All choices are matters for bilateral agreement.

2.2 *Frame structure*

2.2.1 All transmissions are in frames conforming to one of the formats of Tables 1/X.75 and 2/X.75. The flag preceding the address field is defined as the opening flag. The flag following the Frame checking sequence (FCS) field is defined as the closing flag.

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 STE shall only send complete and distinct 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 below.

2.2.4 *Control field*

The control field shall consist of one or two octets. The content of this field is described in § 2.3.2 below.

TABLE 1/X.75

Frame formats (modulo 8)

Bit order of transmission 12345678 12345678 1 to 8 16 to 1 12345678

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

Bit order of transmission 12345678 12345678 1 to 8 16 to 1 12345678

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

FCS frame checking sequence

$0 \leq N \leq N1 - 32$

TABLE 2/X.75

Frame formats (modulo 128)

Bit order of transmission 12345678 12345678 1 to ^{a)} 16 to 1 12345678

Flag	Address	Control	FCS	Flag
F 01111110	A 8 bits	C bits ^{a)}	FCS 16 bits	F 01111110

Bit order of transmission 12345678 12345678 1 to ^{a)} 16 to 1 12345678

Flag	Address	Control	Information	FCS	Flag
F 01111110	A 8 bits	C bits ^{a)}	I N bits	FCS 16 bits	F 01111110

FCS frame checking sequence

$0 \leq N \leq N1 - 40$

a) Sixteen bits for frame formats that contain sequence numbers; 8 bits for frame formats that do not contain sequence numbers (see *Note*).

Note – For an interim period, frames that do not contain sequence numbers may alternatively have a 16 bit control field format as described in § 2.3.2.1.3.

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 (see § 2.2.7 below). See § 2.3.4.9, § 2.5.2 and § 4 for the various codings and groupings of bits in the information field as used in this Recommendation.

See §§ 2.3.4.9 and 2.4.8.5 with regard to the maximum information field length.

2.2.6 Transparency

The STE, 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 five contiguous 1 bits (including the last five bits of the FCS) to ensure that a flag sequence is not simulated. The STE, when receiving, shall examine the frame content and shall discard any 0 bit which directly follows five contiguous 1 bits.

2.2.7 Frame checking 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 $x^k (x^{15} + x^{14} + x^{13} + x^{12} + x^{11} + x^{10} + x^9 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x + 1)$ 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 the 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.

As 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 FCS, will be 0001110100001111 (x^{15} through x^0 , respectively) in the absence of transmission errors.

Note – Explanatory examples are given in Appendix 1 of Recommendation X.25.

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).

The order of transmitting bits within the information field is not specified under § 2. 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.75 and 2/X.75).

Note – In Tables 3/X.75, 4/X.75, 5/X.75, 6/X.75, 7/X.75, 8/X.75 and 10/X.75, 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 below.

2.2.10 *Frame abortion*

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

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

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

2.3 *Elements of procedures*

2.3.1 *The elements of procedures are defined in terms of actions that occur on receipt of frames.*

A procedure is derived from these elements of procedures and is described in § 2.4 below. Together, §§ 2.2 and 2.3 form the general requirements for the proper management of the link.

2.3.2 *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 (see Tables 3/X.75 and 4/X.75) are used to perform numbered information transfer (I format), numbered supervisory functions (S format) and unnumbered control functions (U format).

TABLE 3/X.75

Control field formats (modulo 8)

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.75

a) Control field formats (modulo 128)

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		

b) Alternative U format, control field formats (modulo 128) (see Note)

Control field bits	1st Octet	2nd Octet
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
U Format	1	1	M	M	U	M	M	M	P/F	X	X	X	X	X	X	X	

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.

U Unspecified.

P/F Poll bit when issued as a command, final bit when issued as a response (1 = Poll/Final).

P Poll bit (1 = Poll).

Note – For an interim period, as described in § 2.3.2.1.3, Administrations may bilaterally agree to use an unnumbered format that consists of a 2-octet control field.

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/F are independent: i.e., each I frame has a N(S), a N(R) which may or may not acknowledge additional I frames received by the STE, and a P bit.

2.3.2.1.2 *Supervisory format – S*

The S format is used to perform link supervisory control functions such as acknowledge I frames, request transmission of I frames, and to request a temporary suspension of transmission of I frames. The function 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 STE, 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 link control functions. This format contains no

sequence number but does include a P/F bit that may be set to 0 to 1. The encoding of the unnumbered commands and responses is as defined in Tables 5/X.75 and 6/X.75. Unnumbered U frames make use of a single octet control field for both modulo 8 and extended modulo 128 operations. However, for an interim period and for extended modulo 128 operations only, some Administrations may choose after bilateral agreement, the 2 octet control field coding described in b) of Table 6/X.75.

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 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 denotes the sequence number of the next in-sequence I frame to be transmitted. The send state variable can take on the value 0 through modulus minus 1. The value of the send state variable is incremented by 1 with each successive I frame transmission, but cannot exceed $N(R)$ of the last received I or S format 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 frames. At the time of 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.

2.3.2.2.4 Receive state variable $V(R)$

The receive state variable denotes the sequence number of the next in-sequence I frame expected to be received. This receive state variable can take on the values 0 through modulus minus 1. The value of the receive state variable 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.

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. $N(R)$ indicates that the STE 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 (P/F) bit

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 STE to solicit (poll) a response from the other STE. The Final bit set to 1 is used by the STE to indicate the response frame transmitted by the other STE 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

The following commands and responses will be supported by the STE and are represented in Tables 5/X.75 and 6/X.75.

The supervisory function bit encoding 11, and those encodings of the modifier function bits in Tables 3/X.75 and 4/X.75 not identified in Tables 5/X.75 and 6/X.75, are identified as *undefined or not implemented* command and response control fields.

The commands and responses are as follows:

2.3.4.1 *Information (I) command*

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

2.3.4.2 Receive ready (RR) command and response

The Receive ready (RR) supervisory frame is used by the STE to:

- 1) indicate it is ready to receive an I frame;
- 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 STE. In addition to indicating the STE status, the RR command with the P bit set to 1 may be used by an STE to ask for the status of the other STE.

TABLE 5/X.75

Commands and responses (modulo 8)

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
		FRM (frame reject)	1 1 1 0	F	0 0 1
		UA (unnumbered acknowledgement)	1 1 0 0	F	1 1 0
		DM (disconnected mode)	1 1 1 1	F	0 0 0

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TABLE 6/X.75

a) Commands and responses (modulo 128)

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)

Supervisor y	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	
		FRMR (frame reject)	1 1 1 0 F 0 0 1	
		UA (un-numbered acknowledgement)	1 1 0 0 F 1 1 0	
		DM (disconnected mode)	1 1 1 1 F 0 0 0	

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b) Alternative unnumbered commands and responses (modulo 128) (see Note 2)

1234567891111111
0123456

Format	Command	Response	Encoding (Note 1)											
Unnumbered	SABM (set asynchronous balanced mode)		1	1	1	1	U	1	1	0	P	0	0	0
												0	0	0

	extended)						
	DISC (disconnect)		1 1 0 0	U	0 1 0	P	0 0 0 0 0 0 0
		FRMR (frame reject)	1 1 1 0	U	0 0 1	F	0 0 0 0 0 0 0
		UA (unnumbered acknowledgement)	1 1 0 0	U	1 1 0	F	0 0 0 0 0 0 0
		DM (disconnected mode)	1 1 1 1	U	0 0 0	F	0 0 0 0 0 0 0

Note 1 – Bit 5 of unnumbered format frames is unspecified in alternative b).

Note 2 – For an interim period, as described in § 2.3.2.1.3, Administrations may bilaterally agree to use a format that consists of a 2-octet control field.

2.3.4.3 Receive not ready (RNR) command and response

The Receive not ready (RNR) supervisory frame is used by the STE 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 frames.

In addition to indicating the STE status, the RNR command with the P bit set to 1 may be used by an STE to ask for the status of the other STE.

2.3.4.4 Reject (REJ) command and response

The reject (REJ) supervisory frame is used by the STE to request retransmission 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 STE. In addition to indicating the STE status, the REJ command with the P bit set to 1 may be used by an STE to ask for the status of the other STE.

2.3.4.5 Set asynchronous balanced mode (SABM) command and set asynchronous balanced mode extended (SABME) command

The SABM unnumbered command is used to place the addressed STE in the asynchronous balanced mode (AMB) 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 STE in the asynchronous balanced mode information transfer phase, where numbered command/response control fields will be two octets in length and unnumbered command response fields will be one octet in length (see *Note*).

No information field is permitted with the SABM and 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 STE. The STE confirms acceptance of SABM/SABME (modulo 8/modulo 128) by the transmission at the first opportunity of an UA response. Upon acceptance of this command both the send state variable and the receive state variable are set to 0.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged.

Note – For an interim period, as described in § 2.3.2.1.3, Administrations may bilaterally agree to use a format that consists of a 2-octet control field.

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 STE receiving the DISC command that the STE sending the DISC command is suspending operation. No information field is permitted with the DISC command. Prior to actioning the DISC command, the addressed STE confirms the acceptance of DISC by the transmission of an UA response. The STE sending the DISC 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.

2.3.4.7 *Unnumbered acknowledge (UA) response*

The UA unnumbered response is used by the STE to acknowledge the receipt and acceptance of the mode-setting commands. Received mode-setting commands are not activated until the UA response is transmitted. The transmission of an UA response indicates the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by that same STE. 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 STE is logically disconnected from the link, and is in the disconnected phase. The DM response is sent in this phase in response to the reception of a set mode command, to inform the STE that the STE is still in disconnected phase and cannot action a set mode command. No information field is permitted with the DM response.

An STE 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 STE 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 a 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);
- 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;
- 5) the receipt of a supervisory frame with the F bit set to 1, except during a timer recovery condition as described in § 2.4.5.9 or except as a reply to a command sent with the P bit set to 1;
- 6) the receipt of an unexpected UA or DM response;
- 7) the receipt of an invalid N(S).

An invalid N(R) is defined as one which points to an I frame which has previously been transmitted and acknowledged or to an I frame which has not been transmitted and is not the next sequential I frame awaiting transmission. 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 STE send state variable included (or to the current internal variable x if the STE is in the timer recovery condition as described in § 2.4.5.9). This constraint applies even if the STE is in a frame rejection condition.

An invalid N(S) is defined as an N(S) which is equal to the last transmitted N(R) + k and is equal to the received state variable V(R), where k is the maximum number of outstanding information frames (see § 2.4.8.6 below).

An information field which immediately follows the control field, and consists of 3 octets (modulo 8) or 5 octets (modulo 128), is returned with this response and provides the reason for the FRMR response. This format is given in Tables 7/X.75 and 8/X.75.

For condition 4) listed above, bits W and X should be set to 1.

For conditions 5), 6) and 7) listed above, bit W should be set to 1.

In all cases, the STE receiving the FRMR should examine the contents of the rejected frame control field for further clarification of the cause of the error before recording this error.

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 link layer are described below. Exception conditions described are those situations which may occur as the result of transmission errors, STE malfunction or operational situations.

2.3.5.1 Busy condition

The busy condition results when an STE 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 STE. I frames pending transmission may be transmitted from the busy STE prior to or following the RNR frame. An indication that the busy condition has cleared is communicated by the transmission of an UA (only in response to a SABM/SABME command), RR, REJ or SABM/SABME (modulo 8/modulo 128) frame.

TABLE 7/X.75

FRMR information field format (modulo 8) **Information field bits**

1 2 3 4 5 6 7 8 9 10 11 13 14 15 1 1 1 2 2 2 2 2
 12 16 7 8 9 0 1 2 3 4

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 STE 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 STE 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 invalid 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 1 indicates the control field received and returned in bits 1 through 8 contained an invalid N(R).

Bits 9 and 21 through 24 shall be set to 0.

TABLE 8/X.75

FRMR information field format (modulo 128)**Information field bits**

1 to 16	1	18 to	25	26 to	3	3	3	3	3	3	3	4
	7	24		32	3	4	5	6	7	8	9	0

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. If, however, the interim solution mentioned in § 2.3.2.1.3 is adopted, the 2-octet control field will be placed in bit positions 1–16.

V(S) is the current send state variable value at the STE 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 STE 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 invalid 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 1 indicates the control field received and returned in bits 1 through 16 contained an invalid N(R).

Bits 17 and 37 through 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.

An STE 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/F bit to perform link control functions; e.g., to receive acknowledgement of previously transmitted I frames, and to cause the STE to respond (P bit sent to 1).

2.3.5.2.1 REJ recovery

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

With respect to each direction of transmission on the link, only one *sent REJ* exception condition from an STE is established at a time. A *sent REJ* exception condition is cleared when the

requested I frame is received.

An STE receiving REJ initiates sequential (re-)transmission of I frames starting with the I frame indicated by the N(R) obtained in the REJ frame.

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 I frame(s).

2.3.5.2.2 *Time-out recovery*

If an STE, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frames in a sequence of I frames, it will not detect an N(S) sequence error condition and therefore will not transmit an REJ frame. The STE which transmitted the unacknowledged I frame(s) shall, following the completion of a system specified time-out period (see §§ 2.4.5.9 and 2.4.8.1 below), take appropriate recovery action to determine at which I frame retransmission must begin. 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.

2.3.5.3 *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 non-extended (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.

Note – Or fewer than 40 bits (modulo 128) if 2-octet control field is used as alternative b during the interim period (see § 2.3.2.1.3).

- c) contains a Frame check sequence (FCS) error;
- 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 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 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.

This frame rejection exception condition is reported by sending an FRMR response for appropriate STE action.

Once an STE has established a frame rejection condition, no additional I or S format frames are accepted until the condition is reset 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 other STE or until the STE initiates its own recovery in case the other STE 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 STE 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 STE shall notify the MLP or the packet layer of the excessive idle channel state condition, but shall not take any action that would preclude the other STE from establishing the link by normal link set-up procedures.

The value of T3 is a system parameter and is agreed bilaterally.

2.4 *Description of the procedures*

2.4.1 *Extended and non-extended modes of operation*

Changing from non-extended operation to extended operation, or vice versa, requires bilateral agreement and is not supported dynamically.

Table 5/X.75 indicates the command and response control field formats used with the non-extended (modulo 8) service. The mode setting command employed to initialize (set up) or reset the non-extended mode is the SABM command. Table 6/X.75 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 *Procedure for addressing*

Commands are sent with the remote STE address and responses are sent with the local STE address.

In order to allow differentiation between single link operation and multilink operation for diagnostic and/or maintenance reasons, different address pair encodings shall be assigned to links operating with the multilink procedure (MLP) compared to links operating with the single link procedure (SLP). These STE 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	C	1	1	1	1	0	0	0	0

operation

D 1 1 1 0 0 0 0 0

A and B, or C and D, are assigned by bilateral agreement between the Administrations.

2.4.3 Procedure for the use of the P/F bit

The STE 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 STE to an SABM/SABME or DISC command with the P bit set to 1 will be an UA or DM response with the F bit set to 1. The response frame returned by the STE 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 STE 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 to an I frame or supervisory frame with the P bit set to 1, received in the disconnected phase, will be a DM with F bit set to 1.

The P bit may be used by the STE in conjunction with the time-out recovery condition (see § 2.4.5.9 below).

When not used the P/F bit is set to 0.

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

2.4.4 Procedures for link set up and disconnection

2.4.4.1 Link set up

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

Either STE may initialize the link by sending SABM/SABME (modulo 8/modulo 128) and starting Timer T1 in order to determine when too much time has elapsed waiting for a reply. The opposite STE upon receiving SABM/SABME correctly, sends UA and resets both its state variables to 0. If UA is received correctly, then the link is set up and the initiating STE resets both its state variables to 0 and stops Timer T1.

If, upon receipt of SABM/SABME correctly, the STE determines that it cannot enter the indicated phase, it sends the DM response.

When receiving the DM response, the STE which has transmitted an SABM/SABME stops its Timer T1 and does not enter the information transfer phase.

The STE sending SABM/SABME will ignore and discard any frames except

SABM/SABME, DISC, UA and DM from the other STE.

Frames other than UA and DM in response to a received SABM/SABME will be sent only after the link is set up and if no outstanding SABM/SABME exists.

If an SABM/SABME or DISC command, UA or DM response is not received correctly, the result will be that the Timer T1 will run out in the STE which originally sent the SABM/SABME and that the STE may resend SABM/SABME and restart Timer T1.

After transmission of SABM/SABME N2 times by the STE, appropriate 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 STE will accept and transmit I and supervisory frames according to the procedures described in § 2.4.5 below.

When receiving an SABM/SABME (modulo 8/modulo 128) command while in the information transfer phase, the STE will conform to the resetting procedure described in § 2.4.7 below.

2.4.4.3 Link disconnection

During the information transfer phase, either STE shall indicate a request for disconnecting the link by transmitting a DISC command, and it shall start Timer T1 (see § 2.4.8.1 below).

The STE, on correctly receiving a DISC command, will send a UA response and enter the disconnected phase. The STE, on receiving a UA or DM response to a sent DISC command, stops its timer, and enters the disconnected phase. If a UA or DM response is not received correctly, this will result in the expiration of the Timer T1 in the STE which originally sent the DISC command. If Timer T1 runs out, this STE will retransmit a DISC command and restart Timer T1. This action will continue until a UA response or a DM response is correctly received or until recovery takes place at a higher layer after transmission of DISC N2 times. 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 and returned a UA response, or having received the UA response to a transmitted DISC command, the STE will enter the disconnected phase.

In the disconnected phase, the STE may initiate link set up. In the disconnected phase, the STE 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 frame (defined, or undefined or not implemented) with the P bit set to 1, the STE will transmit a DM response with the F bit set to 1. Other frames received in the disconnected phase will be ignored.

2.4.4.4.2 After recovery from an internal malfunction, the STE may either initiate a resetting procedure (see § 2.4.7 below) or disconnect the link (see § 2.4.4.3 above) prior to a 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, each STE shall send the UA response at the earliest possible opportunity. Each STE shall enter the indicated phase after receiving a UA response.

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

2.4.5 *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 1 frames*

When the STE 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, it will increment its send state variable V(S) by 1.

If the 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) the STE 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 STE is in a busy condition, it may still transmit I frames provided that the other STE is not busy. When in the frame rejection condition, the STE will stop transmitting I frames.

2.4.5.2 *Receiving an I frame*

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

- a) If the STE is still not in a busy condition:
 - i) If an I frame is available for transmission by the STE, 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 STE receive state variable V(R). The STE may also acknowledge the received I frame by transmitting an RR with the N(R) equal to the value of the STE receive state variable V(R).
 - ii) If no I frame is available for transmission by the STE, it will transmit an RR with the N(R) equal to the value of the STE receive state variable V(R).
- b) If the STE is now in a busy condition, it will transmit an RNR frame with N(R) equal to the value of the STE receive state variable V(R) (see § 2.4.5.8).

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

2.4.5.3 *Reception of invalid frames*

When the STE 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 STE receives a valid I frame whose send sequence number is incorrect, i.e., not equal to the current STE receive state variable $V(R)$, it will discard the information field of the frame and transmit a 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 STE 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 STE will then acknowledge the I frame as described in § 2.4.5.2 above. The STE will use the $N(R)$ and P bit information in the discard 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 except in the frame rejection condition, the STE 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 STE 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 reset and if there are outstanding I frames still unacknowledged, Timer T1 will be restarted. If Timer T1 then runs out, the STE will follow the retransmission procedure (in § 2.4.5.9 below) with respect to the unacknowledged I frames.

2.4.5.6 *Receiving an REJ frame*

When receiving an REJ frame, the STE 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 STE 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 STE is transmitting an unnumbered command or response when it receives the REJ frame, it will ignore the request for retransmission.
- iii) If the STE 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 STE 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 have already been transmitted following the one indicated in the REJ frame, then those I frames will be retransmitted by the STE 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 other STE as a command with the P bit set to 1, the STE 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 STE 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 the Timer T1 as it does. After receiving an RNR frame whose N(R) indicates a previously transmitted frame, the STE 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 STE will follow the procedure described in § 2.4.5.9 below. In any case, the STE will not transmit any other I frames before receiving an RR or REJ frame or before the completion of a link resetting procedure.

2.4.5.8 *STE busy condition*

When the STE 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 response frame. While in the busy condition, the STE 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 STE 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*

If Timer T1 runs out waiting for the acknowledgement from the other STE for an I frame transmitted, the STE 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 STE will then restart Timer T1, set its send state variable to the last value of N(R) received from the other STE 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 STE receives a valid supervisory frame with the F bit set to 1.

If, while in the timer recovery condition, the STE 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 STE correctly receives an I frame or a supervisory frame with the P/F bit set to 0 and with a valid N(R) (see § 2.3.4.9) within the range from its current send state variable V(S) to x included, 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 STE may decide to keep the last transmitted I frame in store (even if it is acknowledged) in order to be able to retransmit it when the P bit set to 1 when Timer T1 runs out at a later time.

If Timer T1 runs out in the timer recovery condition, the STE 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 STE will initiate a link resetting procedure as described in § 2.4.7.2 below. N2 is a system parameter (see § 2.4.8.4 below).

2.4.6 Conditions for link resetting or link reinitialization (link set-up)

2.4.6.1 When the STE 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 STE will request the other STE to initiate a link resetting procedure by transmitting an FRMR response as described in § 2.4.7.3.

2.4.6.2 When the STE receives, during the information transfer phase, an FRMR response from the other STE, the STE will initiate the link resetting procedures as described in § 2.4.7.2.

2.4.7 Procedure for link resetting

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

2.4.7.2 The link resetting procedure indicates a clearance of the busy condition, if present.

The STE will initiate a link resetting by transmitting an SABM/SABME command to the other STE and starting its Timer T1 (see § 2.4.8.1 below). Upon reception of a UA response from the other STE, the STE 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 link resetting request, the STE will stop its Timer T1 and will enter the disconnected phase.

If upon receipt of the SABM/SABME command correctly, the STE determines that it can continue in the information transfer phase, it will return a UA response, 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 receipt of the SABM/SABME command correctly, the STE 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 STE, having sent an SABM/SABME command, will ignore and discard any frames except an SABM/SABME or DISC command, UA or DM response received. The receipt of an SABM/SABME or DISC command from the other STE 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 link is reset and if no outstanding SABM/SABME command exists.

After the STE sends the SABM/SABME command, if a UA or DM response is not received correctly, Timer T1 will run out. The STE will then resend the SABM/SABME command and will restart Timer T1. After N2 attempts to reset the link, the STE 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 STE may ask the other STE to reset the link by transmitting an FRMR response (see § 2.4.6.1 above).

After transmitting an FRMR response, the STE will enter the frame rejection condition. The frame rejection condition is cleared when the STE receives or transmits an SABM/SABME or DISC command. Any other frame received while in the frame rejection condition will cause the STE to

retransmit the FRMR response with the same information field as originally transmitted.

The STE may start Timer T1 on transmission of the FRMR response. If Timer T1 runs out before the frame rejection condition is cleared the STE may retransmit the FRMR response, and restart Timer T1. After N2 attempts to get the other STE to reset the link, the STE may reset the 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. Also, received I frames and supervisory frames will be discarded by the STE except for the observance of a P bit set to 1. When an additional FRMR response must be transmitted 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 a FRMR response (even during a frame rejection condition), the STE will initiate a resetting procedure by transmitting a SABM/SABME command as described in § 2.4.7.2 above.

2.4.8 *List of system parameters*

The system parameters are as follows:

2.4.8.1 *Timer T1*

The period of Timer T1, at the end of which transmission of a frame may be initiated, is a system parameter agreed for a period of time between the Administrations.

The period of Timer T1 will take into account whether the timer is started at the beginning or end of transmission of the frame in the STE.

The proper operation of the procedure requires that the transmitter's Timer T1 be greater than the maximum time between transmission of a frame (SABM/SABME, DISC, I for 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 STE 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 STE will not delay the response or acknowledging frame returned to one of the above frames by more than a period T2.

2.4.8.2 *Parameter T2*

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

2.4.8.3 *Timer T3*

The STE shall support a Timer T3 system parameter, the value of which shall be made known to both STEs.

The period of Timer T3, at the end of which an indication of an observed excessively long idle channel state condition is passed to the packet layer or the MLP, shall be sufficiently greater than the period of the Timer T1 (i.e., $T3 > T1$) so that the expiration of T3 provides the desired level of assurance that the link channel is in a non-active, non-operational state, and is in need of link set up before normal link operation can resume.

2.4.8.4 *Maximum number of attempts to complete a transmission, N2*

The value of the maximum number N2 of transmission and retransmissions of a frame following the running out of Timer T1 is a system parameter agreed for a period of time between Administrations. The value of N2 can be different in STE–X and STE–Y.

2.4.8.5 *Maximum number of bits in an I frame, N1*

The maximum number of bits in an I frame (excluding flags and 0 bits inserted for transparency) is a system parameter which depends upon the maximum length of the information fields transferred across the X/Y interface.

Note – When multilink procedures are used, N1 shall allow for the multilink control field (MLC). See § 2.5.2 below. Appendix II of Recommendation X.25 provides additional information on N1. The utility field has to be added.

2.4.8.6 *Maximum number of outstanding I frames, k*

The maximum number (k) of sequentially numbered I frames that the STE may have outstanding (i.e., unacknowledged) at any given time is a system parameter which can never exceed 7/127 (modulo 8/modulo 128). It shall be agreed for a period of time between Administrations and shall have the same value for both the STEs.

2.5 *Multilink procedures (MLP)*

The multilink procedure (MLP) exists as an added upper sublayer of the data link layer, operating between the packet layer and a multiplicity of single data link protocol functions (SLPs) in the data link layer (see Figure 2/X.75).

Figure 2/X.75 - T0702220-87

A multilink procedure (MLP) must perform the functions of distributing across the available SLPs, packets which are to be transmitted to the remote STE and of resequencing packets received from the remote STE for delivery to the packet layer.

Note 1 – In § 2.5.4.4 (MT1 expiry) and § 2.5.4.5 (retransmission), other mechanisms can be envisaged to achieve the same functions.

Note 2 – In § 2.5.5.4 (MN1), § 2.5.5.1 (MT1) and § 2.5.5.2 (MT2) other mechanisms can be envisaged to achieve the same functions.

2.5.1 *Field of application*

The optional multilink procedure (MLP) described below is used for data interchange over one or more single link procedures (SLPs), each conforming to the description in §§ 2.2, 2.3 and 2.4, in parallel between two STEs. The multilink procedure provides the following general features:

- a) achieve economy and reliability of service by providing multiple SLPs between two STEs;
- b) permit addition and deletion of SLPs without interrupting the service provided by the multiple SLPs;

- c) optimize bandwidth utilization of a group of SLPs through load sharing;
- d) achieve graceful degradation of service when an SLP(s) fails;
- e) provide each multiple SLP group with a single logical data link layer appearance to the packet layer, and
- f) provide sequencing of the received packets prior to delivering them to the packet layer.

2.5.2 *Multilink frame structure*

All information transfers over an SLP are in multilink frames conforming to one of the formats shown in Table 9/X.75.

Table 9/X.75 - CCITT 34731

2.5.2.1 *Multilink control field*

The multilink control field (MLC) consists of two octets and its contents are described in § 2.5.3.

2.5.2.2 *Multilink information field*

The information field of a multilink frame, when present, follows the MLC. See § 2.5.3.2.3, § 2.5.3.2.4 and § 4 for the various codings and grouping of bits in the multilink information field.

2.5.3 *Multilink control field format and parameters*

2.5.3.1 *Multilink control field format*

The relationship shown in Table 10/X.75 exists between the order of bits delivered to/received from an SLP and the coding of the fields in the multilink control field.

2.5.3.2 *Multilink control field parameters*

The various parameters associated with the multilink control field format are described below. See Table 10/X.75 and Figure 2/X.75.

2.5.3.2.1 *Void sequencing bit (V)*

The void sequencing bit (V) indicates if a received multilink frame shall be subjected to sequencing constraints. V set to 1 means sequencing shall not be required. V set to 0 means sequencing shall be required.

Note – For the purpose of this Recommendation, this bit shall be set to 0.

2.5.3.2.2 *Sequence check option bit (S)*

The sequence check option bit (S) is only significant when V is set to 1 (indicating that sequencing of received multilink frames shall not be required). S set to 1 shall mean no MN(S)

number has been assigned. S set to 0 shall mean an MN(S) number has been assigned, so that although sequencing shall not be required, a duplicate multilink frame check may be made, as well as a missing multilink frame identified.

Note – For the purpose of this Recommendation, this bit shall be set to 0.

Tableau 10/X.75 - CCITT 34740

2.5.3.2.3 *MLP reset request bit (R)*

The MLP reset request bit (R) is used to request a multilink reset (see § 2.5.4.2). R set to 0 is used in normal communication; i.e., no request for a multilink reset. R set to 1 is used by the STE MLP to request the reset of the remote MLP state variables. In this R = 1 case, the multilink information field does not contain packet layer information, but may contain an optional 8-bit cause field that incorporates the reason for the reset.

Note – The encoding of the cause field is a subject for further study.

2.5.3.2.4 *MLP reset confirmation bit (C)*

The MLP reset confirmation bit (C) is used in reply to an R bit set to 1 (see § 2.5.3.2.3) to confirm the resetting of the multilink state variables (see § 2.5.4.2). C set to 0 is used in normal communication; i.e., no multilink reset request has been activated. C set to 1 is used by the STE MLP in reply to a multilink frame from the remote STE with R set to 1, and indicates that the MLP state variable reset process has been completed. In this C = 1 case, the multilink frame is used without an information field.

2.5.3.2.5 *Multilink send state variable MV(S)*

The multilink send state variable MV(S) denotes the sequence number of the next in-sequence multilink frame to be assigned to an SLP. The variable can take on the value 0 through 4095 (modulus 4096). The value of MV(S) is incremented by 1 with each successive multilink frame assignment.

2.5.3.2.6 *Multilink sequence number MN(S)*

Multilink frames contain the multilink sequence number MN(S). Prior to the assignment of an in-sequence multilink frame, the value of MN(S) is updated to equal the value of the multilink send state variable MV(S). The multilink sequence number is used to resequence and to detect missing and duplicate multilink frames at the receiver before the contents of a multilink frame information field is delivered to the packet layer.

Figure 3/X.75 - CCITT 34750

2.5.3.2.7 Transmitted multilink acknowledged state variable $MV(T)$

$MV(T)$ is the state variable at the transmitting STE denoting the oldest multilink frame which is awaiting an indication that a local SLP has received an acknowledgement from its remote SLP. This variable $MV(T)$ can take on the value 0 through 4095 (modulus 4096). Some multilink frames with sequence numbers higher than $MV(T)$ may already have been acknowledged.

2.5.3.2.8 Multilink receive state variable $MV(R)$

The multilink receive state variable $MV(R)$ denotes the sequence number at the receiving STE of the next in-sequence multilink frame to be received and delivered to the packet layer. This variable $MV(R)$ can take on the value 0 through 4095 (modulus 4096). The value of $MV(R)$ is updated as described in § 2.5.4.4 below. Multilink frames with higher sequence numbers in the MLP receive window may already have been received.

2.5.3.2.9 Multilink window size MW

MW is the maximum number of sequentially numbered multilink frames that the STE may transfer to its SLPs beyond the lowest numbered multilink frame which has not as yet been acknowledged. MW is a system parameter which can never exceed $(4095 - MX)$.

The value of MW shall be agreed between Administrations and shall have the same value for both STEs for a given direction of information transfer.

Note – Factors which will affect the value of parameter MW include, but are not limited to single link transmission and propagation delays, the number of links, the range of multilink frame lengths, and SLP parameters $N2$, $T1$ and k .

The MLP transmit window contains the sequence numbers $MV(T)$ to $[MV(T) + MW - 1]$ inclusive.

The MLP receive window contains the sequence numbers $MV(R)$ to $[MV(R) + MW - 1]$ inclusive. Any multilink frame received within this window shall be delivered to the packet layer when its $MN(S)$ is the same as $MV(R)$.

2.5.3.2.10 Receive MLP window guard region MX

MX is a system parameter which defines a guard region of multilink sequence numbers of fixed size beginning at $[MV(R) + MW]$. The range of MX shall be large enough for the receiving MLP to recognize the highest $MN(S)$ outside of its receive window that it may legitimately receive after a multilink frame loss has occurred.

A multilink frame with sequence number $MN(S) = Y$ received in this guard region indicates that those missing multilink frame(s) in the range $MV(R)$ to $[Y - MW]$ has(have) been lost. $MV(R)$ is then updated to $[Y - MW + 1]$.

Note – A number of methods may be selected in calculating a value for the guard region MX :

- a) In a system where the transmission MLP assigns h_i in-sequence contiguous multilink frames at a time to the i^{th} SLP, MX should be greater than or equal to the sum of $[h_i + 1 - h_{min}]$, where h_{min} equals the smallest h_i encountered. Where there are L SLPs in the multilink group, MX should be greater than or equal to:

; or

- b) In a system where the transmitting MLP assigns on a rotation basis h in-sequence, contiguous multilink frames at a time to each SLP, MX at the receiving MLP should be greater than or equal to $[h(L - 1) + 1]$, where L is the number of SLPs in the multilink group; or
- c) MX should be no larger than MW.

Additional methods of selecting MX values are for further study.

2.5.4 *Description of multilink procedure (MLP)*

The procedure below is presented from the perspective of the transmitter and receiver of multilink frames.

The arithmetic is performed modulo 4096.