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Information technology — Telecommunications and information exchange between systems — High-level data link control procedures — Description of the X.25 LAPB-compatible DTE data link procedures

Technologies de l'information — Télécommunications et échange d'information entre systèmes — Procédures de commande de liaison de données de haut niveau — Description des procédures de liaison de données ETTD compatibles X.25 LAPB

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Contents

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 7776 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

This second edition cancels and replaces the first edition (ISO 7776:1986), and consolidates Amendment 1:1992, as well as Technical Corrigenda 1, 2 and 3.

Annex A forms an integral part of this International Standard. Annex B is for information only.

Introduction

This document provides the ISO/IEC description of the ITU-T Recommendation X.25 LAPB interface operation as viewed by the DTE. It is the DTE counterpart of the X.25 LAPB DCE description.

This document also provides the ISO/IEC description of how two DTEs are capable of communicating directly with one another at the Data Link layer using the X.25 LAPB procedures without an intervening public data network.

The Data Link layer provides the DTE with three basic functions:

a) link initialization: necessary for the DTE to begin communication in a known state;

b) flow control: control of the flow of frames between the DTE and the other station (DCE or DTE) to ensure that they are not sent more quickly than they can be received; and

c) error control: provided in two forms:

   1) a cyclic redundancy check (CRC) using a 16-bit polynomial to detect mutilated frames, and

   2) use of sequence numbers to ensure against losing entire frames.

   (The Data Link layer endeavours to ensure correct receipt of all frames by retransmission of mutilated or missing frames.)

This International Standard repeats requirements of other International Standards. Annex B contains a list of these repeated requirements and references to the corresponding International Standards.

To evaluate conformance of a particular implementation, it is necessary to have a statement of which capabilities and options have been implemented. Such a statement is called a "Protocol Implementation Conformance Statement" (PICS), as defined in ISO/IEC 9646-1. This International Standard provides such a PICS proforma in compliance with the relevant requirements, and in accordance with the relevant guidance, given in ISO/IEC 9646-2.

Information technology — Telecommunications and information exchange between systems — High-level data link control procedures — Description of the X.25 LAPB-compatible DTE data link procedures

1 Scope

This International Standard defines an application of the following HDLC standards: ISO/IEC 3309, ISO/IEC 4335, ISO 7478, and ISO/IEC 7809. When there is difficulty in the interpretation of a reworded requirement from one of the other International Standards, the original requirement of ISO/IEC 3309, ISO/IEC 4335, ISO 7478 or ISO/IEC 7809 is definitive. It also defines the structure, elements and procedures for the operation of a DTE using the X.25 LAPB protocol as specified in ITU-T Recommendation X.25.[1)] The procedures are applicable to data interchange between a DTE and a DCE, or between two DTEs. The procedures are defined for use on duplex links, using synchronous transmission or start/stop transmission.

Clause 3 describes two frame structures: one for basic (modulo 8) operation and one for extended (modulo 128) operation. Basic (modulo 8) operation is the ISO/IEC balanced asynchronous class of procedure with optional functions 2 and 8 (BAC, 2, 8). Extended (modulo 128) operation is the ISO/IEC balanced asynchronous class of procedure with optional functions 2, 8 and 10 (BAC, 2, 8, 10). For those DTE/DCE connections that support both basic (modulo 8) operation and extended (modulo 128) operation, the choice is made at subscription-time only. For those DTE/remote DTE connections that support both basic (modulo 8) operation and extended (modulo 128) operation, the choice is made by bilateral agreement.

NOTE — The procedure herein described as basic (modulo 8) operation is the only one available in all public data networks.

Clause 3 also describes two methods for encoding the frames, as sequences of bits when synchronous transmission is used, and as sequences of octets when start/stop transmission is used. The start/stop encoding specifies optional mechanisms, for use in environments that are sensitive to transmission of octets with values that could be interpreted as ISO/IEC 646 control characters, and/or in environments that support transfer of only seven data bits per start/stop character. The choice of encoding is made by bilateral agreement, or other suitable means, to suit the data transmission characteristics of the environment.

Clause 4 describes the elements of procedures. Some aspects are only operable for the basic (modulo 8) operation and some for the extended (modulo 128) operation.

Clauses 5 and 6 describe the single link procedure (SLP) which is derived from the frame structure and the elements of procedures, and an optional multilink procedure (MLP), respectively. The SLP is used for data interchange over a single data link and the MLP is used for data interchange over a multiple of parallel SLPs. An MLP is required if the effects of individual SLP failures are not to disrupt the higher layer operation. An MLP can also be used over a single SLP by prior bilateral agreement. For DTE/DCE connections the choice of an MLP operation or not is made at subscription-time only. For DTE/remote DTE connections, the choice is made by bilateral agreement.

Where choices among alternative actions are indicated in the procedures, a recommended choice is usually indicated. Unless specifically stated otherwise, the choice of action does not affect interoperability with other implementations of this International Standard although efficiency of operation may be affected. Where such choices do affect interoperability, the procedures explicitly state that prior bilateral

1) Future revisions of this International Standard will be made in accordance with revisions of ITU-T Recommendation X.25. The present version is based on the 1993 ITU-T Recommendation X.25

agreement on the choice of procedure with the remote end is needed. An attempt has been made to minimize such choices consistent with the need to satisfy a broad range of applications. A basic requirement for all implementations of this International Standard is that they be capable of responding, as specified, to any actions taken at the remote end that are permitted by this International Standard (except possibly for those procedures whose use involves prior bilateral agreement.)

Clause 7 covers the Static Conformance requirements, the Dynamic Conformance requirements, and the Protocol Implementation Conformance Statement (PICS).

2 Normative references.

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO/IEC 646: 1991, *Information technology — ISO 7-bit coded character set for information interchange.*

ISO/IEC 3309: 1993, *Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures — Frame structure.*

ISO/IEC 4335: 1993, *Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures — Elements of procedure.*

ISO 7478: 1987, *Information processing systems — Data communication — Multilink procedures.*

ISO/IEC 7809: 1993, *Information technology — Telecommunications and information exchange between systems — High-level data link control procedures (HDLC) — Classes of procedures.*

ISO/IEC 9646-1:1994, *Information technology — Open Systems Interconnection — Conformance testing methodology and framework — Part 1: General concepts.*

ISO/IEC 9646-2:1994, *Information technology — Open Systems Interconnection — Conformance testing methodology and framework — Part 2: Abstract Test Suite specification.*

ITU-T 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.*

3 Frame structure

All transmissions on a SLP are in frames conforming to one of the formats of table 1 for basic (modulo 8) operation, or alternatively one of the formats of table 2 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.

All transmissions from the DCE/remote DTE are expected to use this frame structure.

Table 1 — 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	I	FCS	F
01111110	8-bits	8-bits	N-bits	16-bits	01111110

FCS = Frame Check Sequence

Table 2 — Frame formats — Extended (modulo 128) operation

Bit order of transmission

12345678	12345678	1 to *	16 to 1	12345678
Flag	Address	Control	FCS	Flag
F 01111110	A 8-bits	C *-bits	FCS 16-bits	F 01111110

FCS = Frame Check Sequence

Bit order of transmission

12345678	12345678	12345678		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 Check Sequence

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

3.1 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 hunts continuously for this sequence on a bit-by-bit basis, and thus uses the flag sequence for frame synchronization. The DTE/DCE/remote DTE may send one or more complete flag sequences between frames. The DTE shall only send complete eight-bit flag sequences when sending multiple flag sequences (see 3.10). A single flag may be used as both the closing flag for one frame and the opening flag for the next frame.

3.2 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 5.1.

3.3 Control field

For basic (modulo 8) operation, the control field shall consist of one octet. For extended (modulo 128) 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 4.1.

3.4 Information field

The information field of a frame, when present, follows the control field (see 3.3) and precedes the frame check sequence (see 3.6). (See 4.3.9 and 6.2 for the various codings and groupings of bits in the information field that are defined for use in this International Standard.) The coding and grouping of bits received from a higher layer are unrestricted, except for requirements that are imposed by the higher layer itself.

For start/stop transmission there shall be eight (8) information bits between the start element and the stop element: the information field is therefore constrained to be octet-aligned.

See 4.3.9 and 5.7.3 with regard to the maximum information field length.

3.5 Transparency

3.5.1 Synchronous transmission

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

3.5.2 Start/stop transmission

Two principal levels of transparency processing are specified for use with start/stop transmission. These are seven-bit data path transparency (SBDPT), specified in 3.5.2.1, and control-escape transparency, specified in 3.5.2.2. Control-escape transparency shall always be performed. SBDPT is an option, use or non-use of which is selected for a given data link by means outside the scope of this International Standard (for example, a priori knowledge, bilateral agreement, heuristic implementation techniques). The control-escape transparency processing may optionally be extended in its application in one of the two ways specified in 3.5.2.3; use or non-use of either of these for a given data link is again selected by means outside the scope of this International Standard.

3.5.2.1 Seven-bit data path transparency

When SBDPT is selected, the content of each frame — from Address field to FCS field inclusive — shall be transferred between sender and receiver as a frame-image derived from the original frame as follows.

The sequence of octets making up the frame content is considered as divided into a sequence of contiguous seven-octet segments, with possibly a final segment having length between one and six octets inclusive. These segments are referred to as *original segments*.

The frame-image consists of a sequence of image segments defined, in one-to-one correspondence with the original segments, as follows:

a) image segments occur in the same order as the corresponding original segments;

b) each image segment is one octet longer than its original segment;

c) the first part of each image segment is a copy of its original segment, but with the most significant bit (MSB) of each octet set to zero;

d) the remaining, final, octet of each image segment has its least significant bit set to the value of the MSB of the last octet of the original segment, its next to least significant bit set to the value of the MSB of the next to last octet (if any) of the original segment, and so on;

e) in the final octet of each image segment, all higher order bits for which no corresponding octet exists in the original segment are set to zero.

NOTES

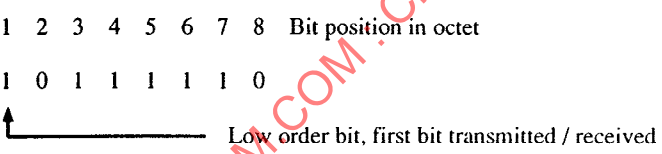
1 At the transmitter, the final octet of each image segment can be generated by shifting left the MSB of each octet in the original segment, in sequence, into an initially zero octet: this achieves the correct bit-positioning both for complete seven-octet segments and for any short segment at the end of a frame.

2 The MSB of each image-segment octet is defined as zero only for uniqueness of the mapping: because its value is known and plays no part in the reconstruction of the original segment at the receiver, it need not actually be transmitted as a zero bit value. This allows image segments to be transferred across data paths that, for example, force parity setting of the MSB of each octet.

3.5.2.2 Control-escape transparency

The following transparency mechanism shall be applied to each frame-image: a frame-image is as defined in 3.5.2.1 when SBDPT is selected, and otherwise is identical to the frame content from Address field to FCS field inclusive.

The control escape octet identifies an octet occurring within a frame-image to which the following transparency procedure is applied. The encoding of the control escape octet is:



The transmitter shall examine each octet of the frame-image between the two flag octets and shall:

a) upon the occurrence of the flag sequence or a control escape octet, complement the sixth bit of the octet, and

b) insert a control escape octet immediately preceding the octet resulting from the above, prior to transmission.

The receiver shall examine the frame-image between the two flag octets and shall, upon receipt of a control escape octet and prior to FCS calculation:

a) discard the control escape octet, and

b) restore the immediately following octet by complementing its sixth bit.

3.5.2.3 Extended transparency

The transmitter may apply the above control-escape transparency procedure (3.5.2.2) to octets in the groups defined below, in addition to the flag and control escape octets.

3.5.2.3.1 Flow-control transparency

The flow-control transparency option provide transparency processing for the DC1/XON and DC3/XOFF control characters defined in ISO/IEC 646: that is, for the octet values 1000100x and 1100100x, respectively, where the 8th bit "x" represents either "0" or "1". This has the effect of assuring that the octet stream does not contain values that could be interpreted by intermediate equipment as flow control characters (regardless of parity).

3.5.2.3.2 Control-character octet transparency

The control-character octet transparency option provides transparency processing for all octets in which both the 6th and 7th bit are "0" (i.e., xxxxx00x, where each "x" represents either "0" or "1"), and for the DELETE character octet (i.e., 1111111x, where "x" represent "0" or "1"). This has the effect of assuring that the octet stream does not contain values that could be interpreted by intermediate equipment as the control characters or DELETE character defined by ISO/IEC 646 (regardless of parity).

3.6 Frame check sequence (FCS) field

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

a) 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 start and stop elements (start/stop transmission) and bits (synchronous transmission) or octets (start/stop transmission) inserted for transparency, and

b) 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 start and stop elements (start/stop transmission) and bits (synchronous transmission) or octets (start/stop transmission) 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 ones and is then modified by division by the generator polynomial (as described above) of 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 ones. 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

0001110100001111 (x^{15} through x^0, respectively)

in the absence of transmission errors.

3.7 Transmission considerations

3.7.1 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 specified for specific information field formats as defined elsewhere in this International Standard.

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 and 2).

NOTE — The low-order bit is defined as bit 1, as depicted in tables 1 to 8.

3.7.2 Start/stop transmission

For start/stop transmission, each octet is delimited by a start element and a stop element. Mark-hold (continuous logical "1" state) is used for inter-octet time fill if required. Typical octet transmission is as shown in Figure 1.

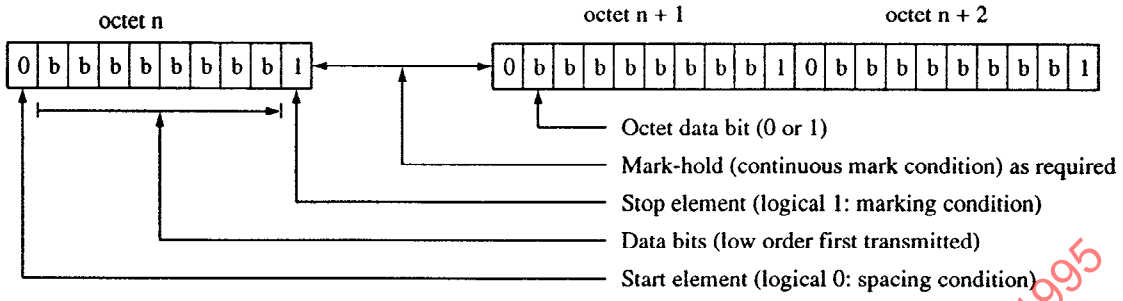


Figure 1 — Start/stop transmission

3.8 Invalid frames

3.8.1 Synchronous transmission

An invalid frame is defined as one which

a) is not properly bounded by two flags;

b) contains fewer than 32 bits between flags;

c) contains a Frame Check Sequence (FCS) error; or

d) contains an address field encoding other than that defined in 5.1.

NOTE — For those DTEs and DCEs that are octet-aligned, a detection of non-octet alignment may be made at the Data Link layer or in the higher layer. Detection at the Data Link layer, while not required, is accomplished 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.

3.8.2 Start/stop transmission

An invalid frame is one:

a) containing fewer than four octets between flags, excluding octets inserted for transparency;

b) in which octet framing is violated (i.e., a "0" bit occurs where a stop element is expected); or

c) ending with a control escape – closing flag sequence.

3.9 Frame abortion

3.9.1 Synchronous transmission

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

3.9.2 Start/stop transmission

Aborting a frame is performed by transmitting the two-octet sequence "control escape – closing flag".

3.10 Interframe time fill

3.10.1 Synchronous transmission

Interframe time fill is accomplished by transmitting contiguous flags between frames (i.e., multiple 8-bit flag sequences).

3.10.2 Start/stop transmission

Interframe time fill is accomplished by transmitting either successive flags (with mark-hold for inter-octet time fill if required) or a continuous mark condition (logical "1" state) between frames.

3.11 Data link channel states

3.11.1 Synchronous transmission

3.11.1.1 Active channel state

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

3.11.1.2 Idle channel state

The DTE outgoing channel is in an idle condition when the DTE causes a continuous "1" state that persists for at least 15 bit times. The DTE incoming channel is defined to be in an idle condition when the DTE detects that a continuous "1" state has persisted for at least 15 bit times.

The action to be taken by a DCE upon detection of the idle channel state is not defined at this time. The DTE, upon detection of the idle channel state, may interpret the idle condition as an indication that the DCE is not able to support set up of the data link.

NOTE — Upon detection of the idle channel state for at least T3, the DTE should consider the data link to be in the disconnected state. T3 is as defined in 5.7.1.3.

3.11.2 Start/stop transmission

3.11.2.1 Active channel state

The DTE outgoing channel is in active condition when the DTE is actively transmitting a frame, an abortion sequence, or interframe time fill consisting of flag octets separated by inter-octet time fill not greater than the timeout value for idle channel state (see 3.11.2.2). The DTE incoming channel is defined to be in an active condition when the DTE is actively receiving a frame, an abortion sequence, or interframe time fill as just specified for the outgoing channel.

3.11.2.2 Idle channel state

The DTE outgoing channel is in an idle condition when the DTE causes a continuous "1" state that persists for a period of time determined by the timeout value T5 at the DCE/remote DTE. The DTE incoming channel is defined to be in an idle condition when the DTE detects that a continuous "1" state has persisted for a period of time exceeding the DTE timeout value T5. T5 is as defined in 5.7.1.5.

The action to be taken by a DCE upon detection of the idle channel state is not defined at this time. The DTE, upon detection of the idle channel state, may interpret the idle condition as an indication that the DCE is not able to support set up of the data link.

NOTE — Upon detection of the idle channel state for at least T3, the DTE should consider the data link to be in the disconnected state. T3 is as defined in 5.7.1.3.

4 Elements of procedures

The elements of procedures are defined in terms of actions that occur at the DTE on receipt of commands from the DCE/remote DTE.

The elements of procedures specified below contain a selection of commands and response relevant to the data link and system configuration described in clause 1.

4.1 Control field formats and state variables

4.1.1 Control field formats

The control field indicates the type of commands or responses, and contains 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 and the control field formats for extended (modulo 128) operation are depicted in table 4.

Table 3 — Control field formats — Basic (modulo 8) operation

Control field format	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 — Control field formats — Extended (modulo 128) operation

Control field format	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 6 = 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)

4.1.1.1 Information transfer format — I

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

4.1.1.2 Supervisory format — S

The S format is used by the DTE to perform data link supervisory control functions such as acknowledging I frames, requesting retransmission of I frames, and requesting a temporary suspension of transmission of I frames. The functions of N(R) and P/F are independent; i.e., each supervisory frame shall have an N(R) which may or may not acknowledge additional I frames received by the DTE, and a P/F bit that may be set to "0" or "1".

4.1.1.3 Unnumbered format — U

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

4.1.2 Control field parameters

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

4.1.2.1 Modulus

Each I frame shall be sequentially numbered and may have the value 0 through modulus minus one (where "modulus" is the modulus of the sequence numbers). The modulus equals 8 or 128 and the sequence numbers cycle through the entire range.

4.1.2.2 Frame variables and sequence numbers

4.1.2.2.1 Send state variable V(S)

The DTE send state variable, V(S), denotes the sequence number of the next in-sequence I frame to be transmitted by the DTE. The send state variable can take on the value 0 through modulus minus one. The value of the DTE send state variable shall be incremented by one with each successive I frame transmission, but shall not exceed N(R) of the last received I or S frame by more than the maximum number of outstanding I frames (k). The value of k is defined in 5.7.4.

4.1.2.2.2 Send sequence number N(S)

Only I frames contain N(S), the send sequence number of transmitted I frames. Prior to transmission of an in-sequence I frame by the DTE, the value of N(S) shall be set equal to the value of the DTE send state variable.

4.1.2.2.3 Receive state variable V(R)

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

4.1.2.2.4 Receive sequence number N(R)

All I frames and supervisory frames shall contain N(R), the expected sequence number of the next received I frame. Prior to transmission of a frame of the above types by the DTE, the value of N(R) shall be set equal to the current value of the DTE receive state variable. N(R) indicates that the transmitter of the N(R) has correctly received all I frames numbered up to N(R) - 1 inclusive.

4.1.2.2.5 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 the P/F bit is referred to as the F bit.

4.2 Functions of the poll/final bit

The poll (P) bit set to "1" shall be used by the DTE to solicit (poll) a response from the DCE/remote DTE. The final (F) bit set to "1" shall be used by the DTE to indicate the response frame transmitted by the DTE as a result of a soliciting (poll) command received from the DCE/remote DTE.

The use of the P/F bit is described in 5.2.

4.3 Commands and responses

The commands and responses supported by the DTE are represented in table 5 for basic (modulo 8) operation and in table 6 for extended (modulo 128) operation. For purposes of this International Standard, the supervisory function bit encoding "11" and those encodings of the modifier function bits in tables 3 and 4 not identified in tables 5 and 6 are identified as "undefined or not implemented" command and response control fields. The commands and responses in tables 5 and 6 are defined as follows:

Table 5 — Commands and responses — Basic (modulo 8) operation

Format	Commands	Responses	Encoding							
			1	2	3	4	5	6	7	8
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
		UA (unnumbered acknowledge)	1	1	0	0	F	1	1	0
		DM (disconnected mode)	1	1	1	1	F	0	0	0
		FRMR (frame reject)	1	1	1	0	F	0	0	1

Table 6 — Commands and responses — Extended (modulo 128) operation

Format	Commands	Responses	Encoding									
			1	2	3	4	5	6	7	8	9	10 to 16
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)		1	1	1	1	P	1	1	0		
	DISC (disconnect)		1	1	0	0	P	0	1	0		
		UA (unnumbered acknowledge)	1	1	0	0	F	1	1	0		
		DM (disconnected mode)	1	1	1	1	F	0	0	0		
		FRMR (frame reject)	1	1	1	0	F	0	0	1		

4.3.1 Information (I) command

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

4.3.2 Receive ready (RR) command and response

The receive ready (RR) supervisory frame shall be used by the DTE to

a) indicate that the DTE is ready to receive an I frame, and

b) acknowledge previously received I frames numbered up to N(R) - 1 inclusive.

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 (DTE or DCE/remote DTE). In addition to indicating the DTE status, the RR command with the P bit set to "1" may be used by the DTE to ask for the status of the DCE/remote DTE.

4.3.3 Receive not ready (RNR) command and response

The receive not ready (RNR) supervisory frame shall be used by the 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 shall be acknowledged. I frame N(R) and subsequent I frames received, if any, shall not be acknowledged; the acceptance status of these I frames will be indicated in subsequent exchanges.

In addition to indicating the DTE status, the RNR command with the P bit set to "1" may be used to ask for the status of the DCE/remote DTE.

4.3.4 Reject (REJ) command and response

The reject (REJ) supervisory frame shall be used by the DTE to request retransmission of I frames starting with the frame numbered N(R). I frames numbered N(R) - 1 and below shall be 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 shall be cleared (reset) upon the receipt of an I frame with an N(S) equal to the N(R) of the REJ frame. (A REJ frame may be retransmitted, however, if the REJ exception condition is not cleared within the acknowledgement time-limit T1, see 4.4.2.2.)

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. In addition to indicating the DTE status, the REJ command with the P bit set to "1" may be used to ask for the status of the DCE/remote DTE.

4.3.5 Set asynchronous balanced mode (SABM) command/Set asynchronous balanced mode extended (SABME) command

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

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

NOTE — For DTE/DCE connections, the mode of operation of the data link [basic (modulo 8) or extended (modulo 128)] shall be determined at subscription time and shall only be changed by going through a new subscription process. For DTE/DTE connections, the mode of operation of the data link [basic (modulo 8) or extended (modulo 128)] shall be determined by bilateral agreement.

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

Previously transmitted I frames that are unacknowledged when this command is actioned shall remain unacknowledged (i.e., they are not retransmitted following link set-up). It shall be the responsibility of a higher-layer protocol (for example, Network Layer or MLP) to recover from the possible loss of the contents (data units) of such I frames.

4.3.6 Disconnect (DISC) command

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

Previously transmitted I frames that are unacknowledged when this command is actioned shall remain unacknowledged (i.e., they are not retransmitted following link set-up). It shall be the responsibility of a higher-level protocol (for example, Network Layer or MLP) to recover from the possible loss of the contents (data units) of such I frames.

4.3.7 Unnumbered acknowledgment (UA) response

The UA unnumbered response shall be used by the DTE to acknowledge the receipt and acceptance of the SABM/SABME and DISC unnumbered commands. No information field shall be permitted with the UA response. The transmission of a UA response shall indicate the clearance of a busy condition that was reported by the earlier transmission of an RNR frame by the same station.

4.3.8 Disconnected mode (DM) response

The DM response shall be used by the DTE to report a status where the DTE is logically disconnected from the link, and is in the disconnected phase. The DM response may be sent in this phase to request a set mode command, or, if sent in response to the reception of a set mode command, to inform the DCE/remote DTE that the DTE is still in the disconnected phase and cannot action the set mode command. No information field shall be permitted with the DM response.

A DTE in the disconnected phase shall monitor received commands, react to a SABM/SABME command as outlined in 5.3 and respond with a DM response with the F bit set to "1" to any other command received with the P bit set to "1".

4.3.9 Frame reject (FRMR) response

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

a) the receipt of a command or response control field that is undefined or not implemented;

b) the receipt of an I frame with an information field which exceeds the maximum established length;

c) the receipt of an invalid N(R); or

d) the receipt of a frame with an information field which is not permitted or the receipt of a supervisory frame with incorrect length (comprising between 32 and 39 bits inclusive).

An undefined or not implemented control field shall be any of the control field encodings that are not identified in tables 5 or 6.

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) shall be within the range from the lowest send sequence number, N(S), of the still unacknowledged frame(s) to the current DTE send state variable inclusive.

An information field which immediately follows the control field, and consists of 3 octets [basic (modulo 8) operation] or 5 octets [extended (modulo 128) operation], shall be returned with this response to provide the reason for the FRMR response. These formats are given in table 7 and table 8.

Table 7 — FRMR information field format — Basic (modulo 8) operation

	Information field bits											
	1 to 8	9	10 to 12	13	14 to 16	17	18	19	20	21	22	23	24
Rejected frame control field		0	N(S)	C/R	N(R)	*w*	*x*	*y*	*z*	0	0	0	0

In Table 7:

a) Rejected frame control field shall be the control field of the received frame which caused the frame reject.

b) N(S) shall be the current send state variable value at the DTE or DCE reporting the rejection condition (bit 10 = low-order bit).

c) C/R set to "1" shall indicate that the frame which caused the rejection condition was a response frame. C/R set to "0" shall indicate that the frame which caused the rejection condition was a command frame.

d) N(R) shall be the current receive state variable value at the DTE or DCE reporting the rejection condition (bit 14 = low-order bit).

e) *w* set to "1" shall indicate that the control field received and returned in bits 1 to 8 was undefined or not implemented.

f) *x* set to "1" shall indicate that the control field received and returned in bits 1 to 8 was considered invalid because the frame contained an information field which is not permitted. Bit w shall be set to "1" in conjunction with this bit.

g) *y* set to "1" shall indicate that any information field received exceeded the maximum established capacity of the DTE or DCE reporting the rejection condition.

h) *z* set to "1" shall indicate that the control field received and returned in bits 1 to 8 contained an invalid N(R).

i) Bits 9 and 21 to 24 shall be set to "0".

The *w*, *x*, *y* and *z* bits in the information field of the FRMR response may all be set to "0", indicating an unspecified rejection condition of the frame for one or more of the conditions cited above.

Table 8 — 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	N(S)	C/R	N(R)	*w*	*x*	*y*	*z*	0	0	0	0

In Table 8:

a) Rejected frame control field shall be 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 shall be positioned in bit positions 1 to 8, with bits 9 to 16 set to "0".

b) N(S) shall be the current send state variable value at the DCE or DTE reporting the rejection condition (bit 18 = low-order bit).

c) C/R set to "1" shall indicate the rejected frame was a response. C/R set to "0" shall indicate the rejected frame was a command.

d) N(R) shall be the current receive state variable value at the DCE or DTE reporting the rejection condition (bit 26 = low-order bit).

e) *w* set to "1" shall indicate that the control field received and returned in bits 1 to 16 was undefined or not implemented.

f) *x* set to "1" shall indicate that the control field received and returned in bits 1 to 16 was considered invalid because the frame contained an information field which is not permitted or is a supervisory frame with incorrect length (comprising between 32 and 39 bits inclusive). Bit w shall be set to "1" in conjunction with this bit.

g) *y* set to "1" shall indicate that the information field received exceeded the maximum established capacity of the DTE or DCE reporting the rejection condition.

h) *z* set to "1" shall indicate that the control field received and returned in bits 1 to 16 contained an invalid N(R).

i) Bits 17 and 37 to 40 shall be set to "0".

The *w*, *x*, *y* and *z* bits in the information field of the FRMR response may all be set to "0", indicating an unspecified rejection condition of the frame for one or more of the conditions cited above.

4.4 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. The exception conditions described are those situations which may occur as the result of transmission errors, station malfunction or operational situations.

4.4.1 Busy condition

The busy condition shall result when the DTE is temporarily unable to continue to receive I frames due to internal constraints, for example, receive buffering limitations. In this case, an RNR frame shall be transmitted by the DTE. I frames pending transmission may be transmitted by the DTE prior to or following the RNR frame. An indication that the busy condition has cleared shall be communicated by the transmission of a UA (only in response to a SABM/SABME command), RR, REJ or SABM/SABME frame.

Upon receipt of an RNR frame from the DCE/remote DTE, the DTE shall terminate any transmission of I frames in progress and wait for an indication from the DCE/remote DTE that the busy condition has been cleared. If the DTE has I frames to send, it shall start a time-out function (Timer T1) when it receives the RNR frame, or if I frames become available to send while in the busy condition, the DTE shall start Timer T1 when the first I frame becomes available. If Timer T1 runs out before an indication of busy clearance is received, the DTE shall send a supervisory command frame with the P bit set to "1" to solicit the status of the DCE/remote DTE. The response received with the F-bit set to "1" shall report the busy/non-busy status of the DCE/remote DTE. The DTE shall repeatedly solicit status in this manner until either a non-busy response is received or it is determined that the data link layer should return information regarding the status of the information frames to the higher layer for subsequent disposition.

4.4.2 N(S) sequence error

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

An N(S) sequence exception condition occurs in the DTE when an I frame received contains an N(S) that is not equal to the DTE receive state variable. The DTE shall not acknowledge (i.e. increment its receive state variable) the I frame causing the sequence error, or any I frames which may follow, until an I frame with the correct N(S) is received.

A DTE which receives one or more I frames having sequence errors or subsequent supervisory frames (RR,RNR or REJ) shall accept the control information contained in the N(R) field and the P or F bit to perform link control functions; for example, to receive acknowledgment for I frames previously transmitted by the DTE and to respond (P bit set to "1").

The means specified in 4.4.2.1 to 4.4.2.3 shall be available for initiating the retransmission of lost or errored I frames following the occurrence of a N(S) sequence error condition.

4.4.2.1 Checkpoint recovery

Checkpoint recovery shall be based on a checkpoint cycle. For the DTE, a checkpoint cycle shall begin with the transmission of a command frame with the P bit set to "1" and end either

a) with the receipt of a response frame with an F bit set to "1", or

b) when the reply time-out function (Timer T1) runs out.

When the DTE receives the supervisory response frame with the F bit set to "1", after having transmitted an I, RR, RNR or REJ command frame with the P bit set to "1", it shall initiate retransmission of all unacknowledged I frames with sequence numbers less than the value of the send state variable V(S) at the time the command frame with the P bit set to "1" was transmitted. (In the case where the supervisory frame received is a RNR response, the DTE shall first wait for an indication of clearance of the busy condition at the DCE/remote DTE before initiating possible retransmission.) Retransmission shall start with the lowest numbered unacknowledged I frame. I frames shall be retransmitted sequentially. New I frames may be transmitted by the DTE if they become available. Such retransmission of I frames is known as checkpoint retransmission.

When the DTE detects the necessity for checkpoint retransmission, the retransmission shall be started either before or concurrent with transmission of the next command frame with the P bit set to "1".

NOTE — The DTE and the DCE/remote DTE may each initiate a checkpointing cycle independently of the other by the transmission of a command frame with the P bit set to "1". Therefore, since two independent checkpointing cycles may be in process simultaneously, the DTE will not initiate checkpoint retransmission upon the receipt of a command frame with the P bit set to "1", but only upon the receipt of a response frame with the F bit set to "1", that is the response to a command frame sent by the DTE with the P bit set to "1".

To prevent duplicate retransmissions, checkpoint retransmission of a specific I frame [same N(R) in the same numbering cycle] shall be inhibited for the current checkpoint cycle, if during the checkpoint cycle the DTE has previously received and actioned a REJ frame with the P bit set to "0" or "1", or an F bit set to "0".

Checkpoint retransmission shall also be inhibited if, after sending a command frame with the P bit set to "1", the DTE receives an acknowledgment for that frame before the next checkpoint occurs.

4.4.2.2 REJ recovery

The REJ frame shall be used by a receiving DTE to initiate recovery (retransmission) following the detection of an N(S) sequence error, earlier than might be possible with checkpointing.

Only one "sent REJ" exception condition from the DTE shall be established at a time. A "sent REJ" exception condition shall be cleared when the requested I frame is received. A REJ frame may be retransmitted (up to N2 transmissions) if the REJ exception condition is not cleared within time-out T1 following transmission of a REJ frame.

The DTE receiving a REJ frame from the DCE/remote DTE shall initiate 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. The DTE shall start the retransmission before or concurrent with transmission of the next command frame with the P bit set to "1".

If

a) DTE retransmission beginning with a particular frame occurs due to checkpointing (see 4.4.2.1), and

b) a REJ frame is received from the DCE before completion of the next checkpoint cycle which would also start retransmission with the same particular frame [as identified by the N(R) in the REJ frame],

the retransmission resulting from the REJ frame shall be inhibited by the DTE.

4.4.2.3 Time-out recovery

If the DCE/remote DTE, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frame 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 which transmitted the unacknowledged I frame(s) shall, following the completion of a system specified time-out period (see 5.7.1.1), take appropriate recovery action to determine at which I frame retransmission shall begin. The retransmitted I 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.

4.4.3 Invalid frame condition

Any frame received from the DCE/remote DTE which is invalid (see 3.8) shall be discarded by the DTE and no action shall be taken as a result of that frame.

4.4.4 Frame rejection condition

A frame rejection condition shall be established at the DTE upon the receipt of an error-free frame with one of the conditions listed in 4.3.9.

This frame rejection exception condition shall be reported by the DTE by a FRMR response frame for appropriate action by the DCE/remote DTE. Once the DTE has established such an exception condition, no additional I frames shall be accepted until the condition is reset by the DCE/remote DTE. The FRMR response may be repeated by the DTE at each opportunity, as specified in 5.6.2, until recovery is effected by the DCE/remote DTE and the data link is reset, or until the local DTE initiates its own recovery.

5 Description of the procedure

5.1 Procedure for addressing

The address field identifies a frame as either a command or a response. A command frame contains the address of the station to which the command is being sent. A response frame contains the address of the station 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 shall be 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 shall 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 shall 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	Bit
		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

The DTE shall discard all frames received with an address other than A or B (single link operation), or C or D (multilink operation).

For DTE/DTE use (point-to-point non-switched applications), the assignment of A/B (single link operation) or C/D (multilink operation) addresses shall be made prior to initialization and should be capable of being fixed at system generation time.

NOTE — The mechanism for ascertaining DTE address allocation in the case of point-to-point switched applications for both DTE/DCE cases and DTE/DTE cases is not covered by this International Standard.

5.2 Procedure for the use of the P/F bit

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

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

The P bit shall be used in conjunction with the timer recovery condition (see 5.4.9). The P bit may also be used by the DTE to initiate a checkpoint mechanism (see 4.4.2.1) at any time.

5.3 Procedures for link set-up and disconnection

5.3.1 Link set-up

A DCE shall indicate that it is able to set up the link by transmitting contiguous flags (active channel state) to the DTE.

Either the DTE or a DCE/remote DTE may initiate link set-up. Prior to initiation of link set-up, either the DTE or the DCE/remote DTE may initiate link disconnection for the purpose of ensuring that the DTE and the DCE/remote DTE are in the same phase. The DTE may also transmit an unsolicited DM response to request the DCE/remote DTE to initiate link set-up.

The DCE/remote DTE shall initialize the link by transmitting a SABM/SABME command to the DTE. If, on receiving correctly the SABM/SABME command, the DTE can enter the information transfer phase, it shall return a UA response, set its send and receive state variables, V(S) and V(R), to "0", and consider the link set up. If, on receiving correctly the SABM/SABME command, the DTE cannot enter the information transfer phase, it shall return a DM response as a denial to the link set-up initialization and consider the link not set up.

The DTE shall initiate link set-up by transmitting a SABM/SABME command to the DCE/remote DTE and starting Timer T1 in order to determine when too much time has elapsed waiting for a reply (see 5.7.1.1). If the DCE/remote DTE can enter the information transfer phase, it shall return a UA response, reset its send and receive state variables, V(S) and V(R), to "0", and consider the link set up. The DTE, on receiving correctly a UA response, shall stop Timer T1, have its send and receive state variables, V(S) and V(R), set to zero, and consider the link set up. If the DCE/remote DTE cannot enter the information transfer phase, it shall return a DM response as a denial to the link set-up initialization. The DTE, on receiving correctly a DM response, shall stop Timer T1 and consider the link not set up. In order to avoid misinterpretation of a DM response received during link set-up, the DTE shall always send its SABM/SABME command with the P bit set to "1". It will then be possible to differentiate a DM response from the DCE/remote DTE intended as a denial to link set-up (F bit set to "1") from a DM response from the DCE/remote DTE that was issued in an unsolicited sense (F bit set to "0") as a request for a mode-setting command (as described in 5.5). The DTE may decide to re-initiate link set-up at any time.

The DTE, having sent a SABM/SABME command, shall ignore and discard any frames except a SABM/SABME, DISC, UA or DM frame

received from the DCE/remote DTE. The receipt of a SABM/SABME or DISC frame from the DCE/remote DTE will result in a collision situation that is resolved per 5.3.5. Frames from the DTE other than the UA frame and the DM frame sent in response to a received SABM/SABME or DISC frame from the DCE/remote DTE shall be sent only after the link is set up and no outstanding SABM/SABME exists.

After the DTE sends the SABM/SABME command, if a UA or DM response is not received correctly, Timer T1 will run out in the DTE. The DTE shall then resend the SABM/SABME command and restart Timer T1. After N2 attempts to set up the link, the DTE shall initiate appropriate higher layer recovery action. The value of N2 is defined in 5.7.2.

5.3.2 Information transfer phase

After having transmitted the UA response to a SABM/SABME command or having received the UA response to a transmitted SABM/SABME command, the DTE shall accept and transmit I frames and supervisory frames according to the procedures described in 5.4.

During the information transfer phase, whenever there has been no activity on the data link for a period of time T4, it is strongly recommended that the DTE transmit an appropriate supervisory command frame with the P bit set to "1" to query the status of the DCE/remote DTE. Receipt of a response with the F bit set to "1" will indicate both the existence of a working physical link and the logical status of the responding DCE/remote DTE.

When receiving a SABM/SABME command while in the information transfer phase, the DTE shall conform to the link resetting procedure described in 5.6.

While in the information transfer phase, either the DTE or the DCE/remote DTE may initiate a disconnect of the data link according to the procedures described in 5.3.3.

5.3.3 Link disconnection

The DCE/remote DTE shall initiate a disconnect of the data link by transmitting a DISC command to the DTE. The DTE, on receiving correctly a DISC command in the information transfer phase, shall send a UA response and shall enter the disconnected phase. The DTE, on receiving correctly a DISC command in the disconnected phase, shall send a DM response and remain in the disconnected phase.

The DTE shall initiate a disconnect of the data link by transmitting a DISC command to the DCE/remote DTE and starting Timer T1. Upon reception of a UA response from the DCE/remote DTE, the DTE shall stop Timer T1 and enter the disconnected phase. Upon reception of a DM response from the DCE/remote DTE as an indication that the DCE/remote DTE was already in the disconnected phase, the DTE shall stop Timer T1 and enter the disconnected phase. In order to avoid misinterpretation of a DM response received during link disconnect, the DTE shall always send its DISC command with the P bit set to "1". It will then be possible to differentiate a DM response from the DCE/remote DTE intended as an indication that the DCE/remote DTE was already in the disconnected phase (F bit set to "1") from a DM response from the DCE/remote DTE that was issued in an unsolicited sense (F bit set to "0") as a request for a mode-setting command (as described in 5.5).

The DTE, having sent a DISC command, shall ignore and discard any frames except a SABM/SABME, DISC, UA or DM frame received from the DCE/remote DTE. The receipt of a SABM/SABME or DISC command from the DCE/remote DTE will result in a collision situation that is resolved per 5.3.5.

After the DTE sends a DISC command, if a UA or DM response is not received correctly, Timer T1 will run out in the DTE. The DTE shall then resend the DISC command and restart Timer T1. After N2 attempts to disconnect the data link, the DTE shall initiate appropriate higher layer recovery action.

5.3.4 Disconnected phase

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

In the disconnected phase, either the DTE or the DCE/remote DTE may initiate link set-up.

In the disconnected phase, the DTE shall react to the receipt of a SABM/SABME command as described in 5.3.1, and shall transmit a DM response in answer to a received DISC command. When receiving any other command frame with the P bit set to "1", the DTE shall transmit a DM response with the F bit set to "1". In the disconnected phase, the DTE shall react to the receipt of an unsolicited DM response by initiating a link set-up procedure in accordance with 5.3.1, provided that it is able to set up the link. Other frames received in the disconnected phase shall be ignored.

When the DTE enters the disconnected phase after detecting error conditions as listed in 5.5, or after an internal malfunction, it may indicate this by sending a DM response rather than a DISC command. In these cases, the DTE shall transmit the DM response and start Timer T1. If Timer T1 runs out before the reception of a SABM/SABME or DISC command, the DTE may retransmit the DM response and restart Timer T1. After transmission of the DM response N2 times, the DTE may remain in the disconnected phase and appropriate recovery action shall be initiated by a higher layer. Alternatively, after an internal malfunction, the DTE may either initiate a link resetting procedure (see 5.6) or disconnect the data link (see 5.3.3) prior to initiating a link set-up procedure (see 5.3.1).

5.3.5 Collision of unnumbered commands

Collision situations shall be resolved in the following way.

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

a) after receiving the UA response;

b) after sending the UA response; or

c) after timing out waiting for the UA response having sent a UA response.

In the case of (b), the DTE shall accept a subsequent UA response to the unnumbered command it issued without considering it an unsolicited UA response if received within the time-out interval.

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

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

When a DM response is issued by the DCE/remote DTE as an unsolicited response to request the DTE to issue a mode-setting command as described in 5.3.4, a collision between a SABM/SABME or DISC command transmitted by the DTE and the unsolicited DM response may occur. In order to avoid misinterpretation of the DM response received, the DTE shall always send its SABM/SABME or DISC command with the P bit set to "1".

5.3.7 Collision of DM responses

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

5.4 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 one higher than 6 and 0 is one higher than 7 for modulo 8 series, and 127 is one higher than 126 and 0 is one higher than 127 for modulo 128 series.

5.4.1 Sending I frames

When the DTE has an I frame to transmit (i.e. an I frame not already transmitted, or an I frame that has to be retransmitted as described in 5.4.6), it shall 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 shall increment its send state variable V(S) by one.

The DTE Timer T1, if not running at the time of transmission of an I frame, shall be started.

If the DTE 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 5.7.4) the DTE shall not transmit any new I frame, but may retransmit an old I frame as described in 5.4.6 or 5.4.9.

In order to ensure security of information transfer, the DTE shall not transmit any I frame if its send state variable V(S) is equal to the last value of N(R) it has received from the DCE/remote DTE plus 7 in basic (modulo 8) operation or 127 in extended (modulo 128) operation.

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

5.4.2 Receiving an I frame

When the DTE is not in a busy condition and receives a valid I frame whose send sequence number is equal to the DTE receive state variable V(R), the DTE shall accept the information field of this frame, increment by one its receive state variable V(R), and take one of the following actions:

a) if the DTE is still not in a busy condition:

1) if an I frame is available for transmission, the DTE shall act as described in 5.4.1 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 DTE receive state variable V(R), or the DTE shall acknowledge the received I frame by transmitting an RR frame with the N(R) equal to the value of the DTE receive state variable V(R);

2) if no I frame is available for transmission, the DTE shall transmit an RR frame with the N(R) equal to the value of the DTE

receive state variable V(R).

b) If the DTE is now in a busy condition, it shall transmit an RNR frame with N(R) equal to the value of the DTE receive state variable V(R) (see 5.4.8).

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

5.4.3 Reception of invalid frames

When the DTE receives an invalid frame (see 3.8), this frame shall be discarded.

5.4.4 Reception of out-of-sequence frames

When the DTE receives a valid I frame whose send sequence number is incorrect, i.e., not equal to the current DTE receive state variable V(R), it shall 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 shall 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 DTE shall then discard the information field of all I frames received until the expected I frame is received correctly. When receiving the expected I frame, the DTE shall then acknowledge the I frame as described in 5.4.2. The DTE shall use the N(R) and P bit information in the discarded I frames as described in 4.4.2.

5.4.5 Receiving acknowledgment

When correctly receiving an I frame or a supervisory frame (RR, RNR or REJ), even in the busy condition, the DTE shall 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 DTE shall stop the 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 a REJ frame with an N(R) equal to the last received N(R).

If Timer T1 has been stopped by the receipt of an I, RR os RNR frame, and if there are outstanding I frames still unacknowledged, the DTE shall start Timer T1. If Timer T1 then runs out, the DTE shall follow the recovery procedure (see 5.4.9) with respect to the unacknowledged I frames. If Timer T1 has been reset by the receipt of a REJ frame, the DTE shall follow the retransmission procedures in 5.4.6.

5.4.6 Receiving a REJ frame

When receiving a REJ frame, the DTE shall set its send state variable V(S) to the N(R) received in the REJ frame control field. It shall transmit the corresponding I frame as soon as it is available or retransmit it, in accordance with the procedure described in 5.4.1. (Re)transmission shall conform to the following:

a) If the DTE is transmitting a supervisory command or response when it receives the REJ frame, it shall complete that transmission before commencing transmission of the requested I frame.

b) If the DTE is transmitting an unnumbered command or response when it receives the REJ frame, it shall ignore the request for retransmission.

c) If the DTE is transmitting an I frame when it receives the REJ frame, it may abort the I frame and commence transmission of the requested I frame immediately after aborting the frame.

d) If the DTE is not transmitting any frame when it receives the REJ frame, it shall 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 shall be retransmitted by the DTE following the retransmission of the requested I frame.

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

Other I frames not yet transmitted may be transmitted following the retransmitted I frame.

5.4.7 Receiving an RNR frame

After receiving an RNR frame, the DTE shall stop transmission or retransmission of I frames until an RR or REJ frame is received, or until TImer T1 runs out, see 4.4.1. When Timer T1 runs out before receipt of a busy clearance indication, the DTE shall follow the procedure described below. In any case, the DTE shall not transmit any other I frames before receiving an RR or REJ frame, or before completion of a link resetting procedure.

After Timer T1 runs out, the DTE shall transmit a supervisory command frame (RR, RNR or REJ) with the P bit set to "1" and shall restart Timer T1, in order to determine if there is any change in the receive status of the DCE/remote DTE. The DCE/remote 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 frame) or clearance of the busy condition (RR or REJ frame). Upon receipt of the DCE/remote DTE response, Timer T1

shall be stopped.

a) If the response is an RR or REJ frame, the busy condition shall be assumed to be cleared and the DTE may transmit I frames beginning with the I frame identified by the N(R) in the received response frame.

b) If the response is still an RNR frame, the busy condition shall be assumed still to exist, and the DTE after a period of time (for example, the length of Timer T1) shall repeat the enquiry of the DCE/remote DTE receive status.

If Timer T1 runs out before a status response is received, the enquiry process above shall be repeated. If N2 attempts to get a status response fail, the DTE shall initiate a link resetting procedure as described in 5.6.

If, at any time during the enquiry process, an unsolicited RR or REJ frame is received from the DCE/remote DTE, it shall 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" shall be transmitted before the DTE may resume transmission of I frames. If Timer T1 is running, the DTE shall wait for the non-busy response with the F bit set to "1", or wait for Timer T1 to run out, and then resume transmission of I frames beginning with the I frame identified by the N(R) in the received RR or REJ frame.

5.4.8 DTE busy condition

When the DTE enters a busy condition, it shall transmit an RNR frame at the earliest opportunity. The RNR frame shall 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 DTE shall accept and process supervisory frames, accept and process the contents of the N(R) field of I frames, and 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 DTE shall transmit either an REJ frame or an RR frame, with N(R) set to the current receive state variable V(R) (for example, the choice of frame depends on whether or not the DTE discarded information fields of correctly received I frames). The REJ frame or the RR frame shall 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 RR frame may be either a command or a response frame.

5.4.9 Waiting acknowledgement

If Timer T1 runs out waiting for the acknowledgment from the DCE/remote DTE for an I frame transmitted, the DTE shall restart TImer T1 and transmit an appropriate supervisory command frame (RR, RNR or REJ) with the P bit set to "1". If the DTE receives correctly a supervisory response frame with the F bit set to "1" and with an N(R) within the range from the last N(R) received to the last N(S) sent plus one, the DTE shall reset Timer T1 and set its send state variable V(S) to the received N(R) and then resume with I frame transmission or retransmission, as appropriate. If, on the other hand, the DTE receives correctly a supervisory response frame with the F bit set to "0", or an I frame or supervisory command frame with the P bit set to "0" or "1", and with an N(R) within the range from the last N(R) received to the last N(S) sent plus one, the DTE shall not reset Timer T1, but use the received N(R) as an indication of acknowledgement of transmitted frames up to and including I frame numbered N(R) - 1.

If Timer T1 runs out before a supervisory response frame with the F bit set to "1" is received, the DTE shall retransmit an appropriate supervisory command frame (RR, RNR or REJ) with the P bit set to "1" and restart Timer T1. After N2 expirations of Timer T1 following transmission of an I frame, without a supervisory response frame with the F bit set to "1" having been received from the DCE/remote DTE, the DTE shall initiate a link resetting procedure as described in 5.6.

5.5 Conditions for link resetting or link re-initialization (link set-up)

When the DTE receives, during the information transfer phase, a frame which is not invalid (see 3.8) with one of the conditions listed in 4.3.9, it shall report the error condition and request the DCE/remote DTE to initiate a link resetting procedure by transmitting an FRMR response (see 5.6.2).

When the DTE receives, during the information transfer phase, an FRMR response, it shall either initiate the link resetting procedures (see 5.6.1) or return a DM response to ask the DCE/remote DTE to initiate the link set-up (initialization) procedure. After transmitting a DM response, the DTE shall enter the disconnected phase.

When the DTE receives, during the information transfer phase, a UA response, or an unsolicited response with the F bit set to "1", it may either initiate the link resetting procedures or return a DM response to ask the DCE/remote DTE to initiate the link set-up (initialization) procedure. After transmitting a DM response, the DTE shall enter the disconnected phase.

When the DTE receives, during the information transfer phase, a DM response, the DTE shall either initiate the link set-up (initialization) procedures or return a DM response to ask the DCE/remote DTE to initiate the link set-up procedures. After transmitting a DM response, the DTE shall enter the disconnected phase.

5.6 Procedure for link resetting

5.6.1 Link reset

The link resetting procedure shall be 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.

Either the DTE or the DCE/remote DTE may initiate the link resetting procedure. The link resetting procedure shall indicate a clearance of the DTE and/or the DCE/remote DTE busy condition, if present.

The DCE/remote DTE shall initiate a link resetting by transmitting a SABM/SABME command to the DTE. If, on correct receipt of the SABM/SABME command, the DTE determines that it can continue in the information transfer phase, it shall return a UA response to the DCE/remote DTE, reset its send and receive state variables, V(S) and V(R), to "0", and remain in the information transfer phase. If, on correct receipt of the SABM/SABME command, the DTE determines that it cannot remain in the information transfer phase, it shall return a DM response as a denial to the resetting request and enter the disconnected phase.

The DTE shall initiate a link resetting by transmitting a SABM/SABME command to the DCE/remote DTE and starting its Timer T1. The DTE, on receiving a UA response from the DCE/remote DTE, shall reset its send and receive variables, V(S) and V(R), to "0", stop its Timer T1, and remain in the information transfer phase. The DTE, on receiving a DM response from the DCE/remote DTE as a denial to the link resetting request, shall stop its Timer T1 and enter the disconnected phase.

The DTE, having sent a SABM/SABME command, shall ignore and discard any frames except a SABM/SABME or DISC command or a UA or DM response received from the DCE/remote DTE. The receipt of a SABM/SABME or DISC command from the DCE/remote DTE shall result in a collision situation that is resolved as in 5.3.5. Frames other than the UA or DM response sent in response to a received SABM/SABME or DISC command shall be sent only after the data link is reset and no outstanding SABM/SABME command exists.

After the DTE sends the SABM/SABME command, if a UA or DM response is not received correctly, Timer T1 will run out in the DTE. The DTE shall then send the SABM/SABME command again and start Timer T1. After N2 attempts to reset the link, the DTE shall initiate appropriate higher layer recovery action and enter the disconnected phase.

5.6.2 Request for link reset

The DTE may ask the DCE/remote DTE to reset the data link by transmitting an FRMR response (see 5.5).

After transmitting an FRMR response, the DTE shall enter the frame rejection condition. The frame rejection condition shall be cleared when the DTE receives or transmits a SABM/SABME or DISC command or a DM response. Any other command received while in the frame rejection condition shall cause the DTE to retransmit the FRMR response with the same information field as originally transmitted.

The DTE may start Timer T1 on transmission of the FRMR response. If Timer T1 runs out before the reception of a SABM/SABME or DISC command or a DM response from the DCE/remote DTE, the DTE shall retransmit the FRMR response and start Timer T1. After N2 attempts to get the DCE/remote DTE to reset the link, the DTE shall reset the link itself as described in 5.6.1.

In the frame rejection condition, I frames and supervisory frames shall not be transmitted by the DTE. Also, the DTE shall ignore and discard the N(S) and information fields of any received I frames, and the N(R) fields of any received I frames or supervisory frames. When an additional FRMR response has to be transmitted by the DTE as a result of the receipt of a command frame while Timer T1 is running, Timer T1 shall continue to run. The DTE on receiving an FRMR response (even during a frame rejection condition) shall initiate a resetting procedure by transmitting a SABM/SABME command as described in 5.6.1, or shall transmit a DM response to ask the DCE/remote DTE to initiate the link set-up procedure as described in 5.3.1 and enter the disconnected phase.

5.7 List of system parameters

The system parameters shall be as follows:

5.7.1 Timers

5.7.1.1 Timer T1

The value of the DTE Timer T1 system parameter may be different from the value of the DCE/remote DTE Timer T1 system parameter. These values shall be made known to both the DTE and the DCE/remote DTE and agreed to for a designated period of time.

The period of Timer T1, at the end of which retransmission of a frame may be initiated according to the procedures described in 5.3 to 5.4 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 (DTE or DCE/remote DTE) Timer T1 be greater than the maximum time between transmission of frames (SABM/SABME, DM, DISC, FRMR, I, supervisory commands or REJ response) and the reception of the corresponding frame returned as an answer to this frame (UA, DM or acknowledging frame). Therefore, the receiver (DTE or DCE/remote DTE) should not delay the response or acknowledging frame returned to the above frames by more than a value T2, where T2 is a system parameter (see 5.7.1.2).

5.7.1.2 Parameter T2

The value of DTE parameter T2 may be different from the value of the DCE/remote DTE parameter T2.

T2 is the amount of time available at the DTE or DCE/remote DTE before the acknowledging frame must be initiated in order to ensure its receipt by the DCE/remote DTE or DTE, respectively, prior to Timer T1 running out at the DCE/remote DTE or DTE. T2 < T1.

5.7.1.3 Timer T3

The period of optional Timer T3 shall provide an adequate interval of time to justify considering the data link to be in a disconnected (out of service) state. T3 >> T4.

5.7.1.4 Parameter T4

The parameter T4 is a system parameter which represents the maximum time a DTE will allow without frames being exchanged on the data link. The value of T4 should be greater than T1 and may be very large for applications which are not concerned with early detection of faulty data link or physical link conditions. T4 >> T1.

5.7.1.5 Parameter T5

The optional parameter T5 applies only to operation in a start/stop environment. The value of DTE parameter T5 may be different from the value of the DCE/remote DTE parameter T5.

T5 is the length of time for which the DTE or DCE/remote DTE will receive a continuous mark condition (logical "1" state) without considering its incoming channel to be in the idle channel state (see 3.11.2.2)

5.7.2 Maximum number of transmissions N2

The value of the DTE N2 system parameter may be different from the value of the DCE/remote DTE N2 system, parameter. These values shall be made known to both the DTE and the DCE/remote DTE and agreed to for a designated period of time.

The value of N2 shall indicate the maximum number of attempts that shall be made by the DTE or DCE/remote DTE to complete the successful transmission of a frame to the DCE/remote DTE or DTE, respectively.

5.7.3 Maximum number of bits in an I frame N1

The value of the DTE N1 system parameter may be different from the value of the DCE/remote DTE N1 system parameter. These values shall be made known to both the DTE and the DCE/remote DTE.

The value of N1 shall indicate the maximum number of bits in an I frame (excluding flags and "0" bits inserted for transparency) that the DTE or DCE/remote DTE is willing to accept from the DCE/remote DTE or DTE, respectively.

In order to support universal DCE operation, a DTE shall support a value of DTE N1 which is not less than 1 080 bits (135 octets). DCEs shall offer to DTEs that require it a value of DCE N1 which is greater than or equal to the maximum length of agreed to call set-up and clearing packets plus the length of the address, control and FCS fields at the DTE/DCE interface, and greater than or equal to the maximum length of the data packets which may cross the DTE/DCE interface plus the length of the address, control and FCS fields at the DTE/DCE interface.

5.7.4 Maximum number of outstanding I frames *k*

In the case of DTE/DCE operation, the value of the DTE *k* system parameter shall be the same as the value of the DCE *k* system parameter. This value shall be agreed to for a designated period of time by both the DTE and the DCE. In the case of DTE/remote DTE operation, the value of the DTE *k* system parameter may be different from the value of the remote DTE *k* system parameter. These values shall be agreed to fo a designated period of time by both the DTE and the remote DTE.

The DTE value of *k* shall indicate the maximum number of sequentially numbered I frames that the DTE may have outstanding (i.e., unacknowledged) at any given time. The value of *k* shall never exceed 7 for modulo 8 operation, or 127 for modulo 128 operation.

NOTE — All DCEs will support a value of seven. Other values (less than and greater than seven) may also be supported by DCEs.

6 Multilink procedure (MLP)

For DTE/DCE operation, use of the multilink procedure is a subscription-time selectable option. For DCE/remote DTE operation, use of the multilink procedure shall be a subject for bilateral agreement.

The DTE multilink procedure (MLP) performs the functions of

— distributing across the available DTE/SLPs packets which are to be transmitted to the DCE/remote DTE, and

— resequencing DCE/remote DTE packets received from the DTE SLPs for delivery to the DTE higher layer.

6.1 Field of application

The optional multilink procedure (MLP) described below shall be used for data interchange over one or more single link procedures (SLPs), each conforming to the description in clauses 3, 4 and 5, in parallel between a DTE and a DCE/remote DTE.

6.2 Multilink frame structure

All information transfers over an SLP shall be in multilink frames conforming to one of the formats shown in figure 2.

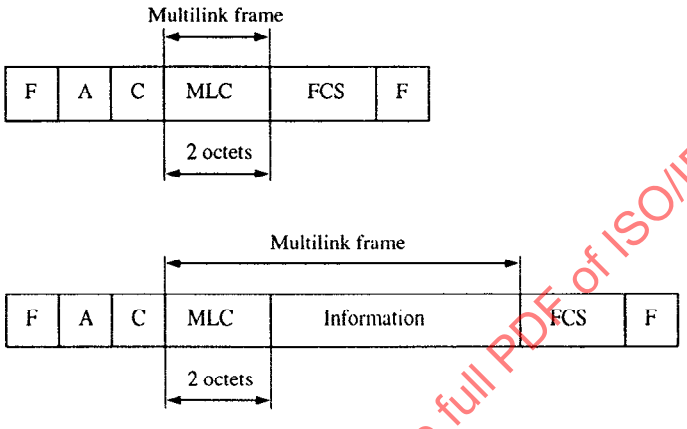


Figure 2 — Multilink frame formats

The multilink control field (MLC), the contents of which are described in 6.3, shall consist of two octets. The information field of the multilink frame, when present, shall follow the MLC (see 6.3.2.3 for the codings and groupings of bits in the multilink frame information field that are imposed by this International Standard).

6.3 Multilink control field format and parameters

6.3.1 Multilink control field format

The relationship shown in figure 3 shall exist between the order of bits delivered to/received from an SLP and the coding of the fields in the multilink control field.

6.3.2 Multilink control field parameters

The various parameters associated with the multilink control field format are described below (see figure 4).

6.3.2.1 Void sequencing bit (V)

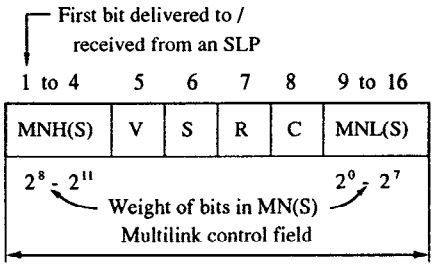
The void sequencing bit (V) shall indicate whether a received multilink frame shall be subject to sequencing constraints. V set to "1" shall mean sequencing shall not be required. V set to "0" shall mean sequencing shall be required.

NOTE — This bit shall be set to "0". The procedure with V set to "1" will form the subject of further study.

6.3.2.2 Sequence check option bit (S)

The sequence check option bit (S) shall only be significant when V is set to "1" (indicating that sequencing of received multilink frames shall not be required). S set to "1" shall mean that no MN(S) number has been assigned. S set to "0" shall mean that 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 — This bit shall be set to "0". The procedure with S set to "1" will form the subject of further study.



Legend

MNH(S) = bits 9 to 12 of 12-bit multilink send sequence number MN(S)
MNL(S) = bits 1 to 8 of 12-bit multilink send sequence number MN(S)
V = void sequencing bit
S = sequence check option bit
R = MLP reset request bit
C = MLP reset confirmation bit

Figure 3 — Multilink control field format

6.3.2.3 MLP reset request bit (R)

The MLP reset request bit shall be used to request a reset of the MLP state variables (see 6.4.2). The R bit set to "0" shall be used in normal communication; i.e., no request for reset. The R bit set to "1" shall be used by the DTE MLP or the DCE/remote DTE MLP to indicate a request for the reset of the DCE/remote DTE or the DTE MLP state variables, respectively. In this R = 1 case, the multilink frame information field shall not contain higher 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 will form the subject of further study.

6.3.2.4 MLP reset confirmation bit (C)

The MLP reset confirmation bit shall be used in reply to the R bit set to "1" to confirm that all of the MLP state variables have been reset. The C bit set to "0" shall be used in normal communication; i.e., no reset request has been activated. The C bit set to "1" shall be used by the DTE MLP or DCE/remote DTE MLP in reply to a DCE/remote DTE MLP or DTE MLP multilink frame, respectively, with the R bit set to "1", and shall indicate that the DTE MLP or DCE/remote DTE MLP state variable reset process has been completed by the DTE MLP or DCE/remote DTE MLP, respectively. In this C = 1 case, the multilink frame shall be used without an information field.

6.3.2.5 Multilink send state variable MV(S)

The multilink send state variable MV(S) shall denote the sequence number of the next in-sequence multilink frame to be assigned to an SLP. This variable can take on the value 0 to 4095 (modulo 4096). The value of MV(S) shall be incremented by one with each successive multilink frame assignment.

6.3.2.6 Multilink sequence number MN(S)

Multilink frames shall contain the multilink sequence number MN(S). Prior to the assignment of an in-sequence multilink frame to an available SLP, the value of MN(S) shall be set equal to the value of the multilink send state variable MV(S). The multilink sequence number shall be 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 higher layer.

6.3.2.7 Transmitted multilink frame acknowledged state variable MV(T)

MV(T) is the state variable at the transmitting DTE MLP or DCE/remote DTE MLP that shall denote the oldest multilink frame which is awaiting an indication that a DTE SLP or DCE/remote DTE SLP has received an acknowledgment from its DCE/remote DTE SLP or DTE SLP, respectively. This variable can take on values 0 to 4095 (modulo 4096). Some multilink frames with sequence numbers higher than MV(T) may already have been acknowledged.

6.3.2.8 Multilink receive state variable MV(R)

The multilink receive state variable MV(R) shall denote the sequence number at the receiving DTE MLP or DCE/remote DTE MLP of the next in-sequence multilink frame to be received and delivered to the higher layer. This variable can take on the value 0 to 4095 (modulo 4096). The value of MV(R) shall be updated as described in 6.4.3.2. Multilink frames with higher sequence numbers in the DTE MLP or DCE/remote DTE MLP receive window may already have been received.

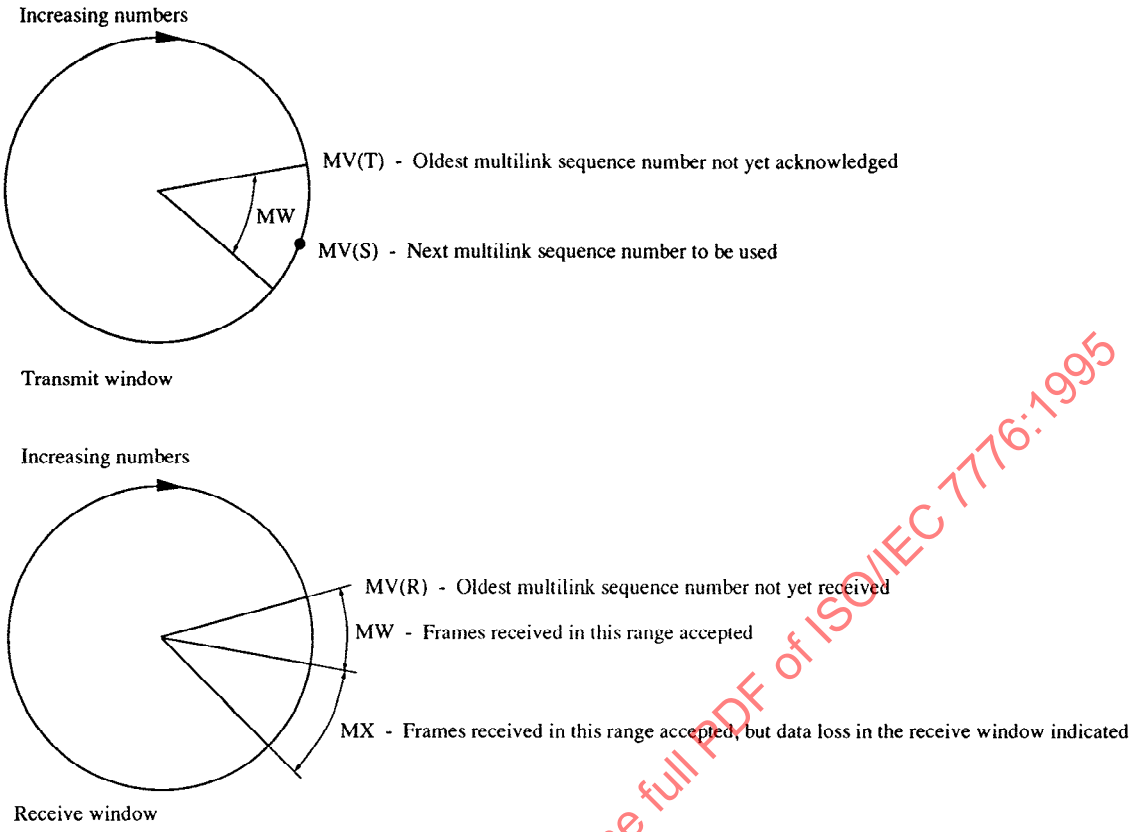


Figure 4 — MLP parameters

6.3.2.9 Multilink window size MW

MW shall be the maximum number of sequentially numbered multilink frames that the DTE MLP or DCE/remote DTE MLP may transfer to its SLPs beyond the lowest numbered multilink frame which has not yet been acknowledged. MW is a system parameter which can never exceed 4095 - MX. The value of MW shall be agreed for a period of time with the DCE/remote DTE and shall have the same value for both the DTE MLP and the DCE/remote DTE MLP for a given direction of information transfer.

NOTE — Factors which shall 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 single link parameters N2, T1 and *k*.

The MLP transmit window shall contain the sequence numbers MV(T) to MV(T) + MW - 1 inclusive.

The MLP receive window shall contain the sequence numbers MV(R) to MV(R) + MW - 1 inclusive. Any multilink frame received within this window shall be delivered to the higher layer when its MN(S) becomes the same as MV(R).

6.3.2.10 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.

NOTE — A number of methods may be selected in calculating a value for the guard region MX.

a) In a system where the transmitting 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 the $h_i + 1 - h_{min}$, 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

$$\sum_{i=1}^{L} h_i + 1 - h_{min}$$

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 will form the subject of further study.

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

6.4 Description of multilink procedure (MLP)

The procedure below is presented from a DTE perspective as a transmitter and receiver of multilink frames. It should be noted that the DCE/ remote DTE can follow these same general procedures when acting as a transmitter and receiver of multilink frames.

The arithmetic is performed modulo 4096.

6.4.1 Initialization

The DTE shall perform MLP initialization by first resetting MV(S), MV(T) and MV(R) to "0" and then initializing each of its SLPs. Upon successful initialization of at least one of the SLPs, the DTE may initiate the interchange of multilink frames. An SLP initialization shall be performed in accordance with 5.3.1.

NOTE — An SLP that cannot be initialized should be declared out of service and appropriate recovery action should be taken.

Alternatively, MLP initialization can be accomplished by performing the multilink resetting procedure as described in 6.4.2.

6.4.2 Multilink resetting procedure

The multilink resetting procedure shall provide the mechanism for synchronizing the multilink sequence numbers for the interconnected MLPs. Following a successful multilink resetting procedure, the multilink sequence numbering in each direction shall begin with the value 0. A multilink frame with R = 1 shall be used to request multilink reset, and a multilink frame with C = 1 shall confirm that the multilink reset process has been completed. A MLP shall reset MV(S) and MV(T) to "0" on transfer of a multilink frame with R = 1; and reset MV(R) to "0" on receipt of a multilink frame with R = 1.

When a DTE MLP initiates the resetting procedure, it shall remove all of the unacknowledged multilink frames that are held in that MLP and its associated SLPs, and retain control of these frames. Hereafter, the initiating MLP shall not transfer a multilink frame with R = C = 0 until the reset process is completed. (One method to remove multilink frames in the SLP is to disconnect the data link of the SLP.) The initiating MLP shall then reset its multilink send state variable MV(S) and its transmitted multilink frame acknowledged state variable MV(T) to "0". The initiating MLP shall then transfer a multilink frame with R = 1 as a reset request on one of its SLPs and start Timer MT3. The value of the MN(S) field in the R = 1 frame may be any value, since when R = 1 the MN(S) field shall be ignored by the receiving MLP. The initiating MLP shall continue to receive and process multilink frames from the remote MLP until it receives a multilink frame with R = 1 from the remote MLP.

A MLP which has received a multilink frame with R = 1 (reset request) in the normal communication status from an initiating MLP shall start the operation as described above; that MLP should receive no multilink frame with R = C = 0 from the initiating MLP until the reset process is completed. Any such multilink frame received shall be discarded. When a MLP has already initiated its own multilink resetting procedure and has transferred the multilink frame with R = 1 to one of its SLPs for transfer, that MLP shall not repeat the above operation upon receipt of a multilink frame with R = 1 from the other MLP.

Receipt of a multilink frame with R = 1 (reset request) shall cause the receiving MLP to deliver to the higher layer those multilink frame information fields (packets) already received and to identify those packets assigned to SLPs but unacknowledged.

The higher layer may be informed of the loss of the I frame content at the original value of MV(R) and at any subsequent value(s) of MV(R) for which there has been no multilink frame received up to and including the highest numbered multilink frame received. The receiving MLP shall then reset its multilink receive state variable MV(R) to "0".

After a MLP assigns a multilink frame with R = 1 to one of its SLPs, it shall receive indication of successful or unsuccessful transmission from the SLP as one of the conditions before transferring a multilink frame with C = 1; when the initiating MLP then receives a multilink frame with R = 1, and has completed the multilink state variable resetting operation described above, the initiating MLP shall transfer a multilink frame with C = 1 (reset confirmation) to the other MLP. When a MLP has

a) received a multilink frame with R = 1;

b) transferred a multilink frame with R = 1; and

c) completed the multilink state variable resetting operation described above,

it shall then transfer a multilink frame with C = 1 (reset confirmation) to the other MLP as soon as possible, given that indication of the successful or unsuccessful transmission of the R = 1 multilink frame has been received from that MLP's SLP. The C = 1 multilink frame is a reply to the multilink frame with R = 1. The value of the MN(S) field in the above C = 1 frame may be any value, since when C = 1 the MN(S) field shall be ignored by the receiving MLP. The multilink sequence number MN(S) received in each direction following multilink reset shall begin with the value 0.

When a MLP uses only one SLP to transmit the multilink frame with R = 1 and the multilink frame with C = 1, it can transfer the multilink frame with C = 1 immediately after the multilink frame with R = 1, without waiting for SLP indication of transmission completion. A MLP shall not retransmit a multilink frame with R = 1 or a multilink frame with C = 1 unless Timer MT3 runs out. A MLP may use two different SLPs as long as one is used for transmitting the multilink frame with R = 1 and the other is used for transmitting the multilink frame with C = 1 following receipt of the SLP indication of successful transmission of the R = 1 multilink frame. A multilink frame with R = C = 1 shall never be used.

When a MLP receives the multilink frame with C = 1, the MLP shall stop its Timer MT3. The transfer of the multilink frame with C = 1 to a remote MLP and the reception of a multilink frame with C = 1 from the remote MLP shall complete the multilink resetting procedure for a MLP. The first multilink frame transferred with R = C = 0 shall have a multilink sequence number MN(S) value of 0. After a MLP transfers a multilink frame with C = 1 to a SLP, the MLP may receive one or more multilink frames with R = C = 0. After a MLP receives a multilink frame with C = 1, the MLP may transfer one or more multilink frames with R = C = 0 to its SLPs.

When a MLP additionally receives one or more multilink frames with R = 1 between receiving a multilink frame with R = 1 and transferring a multilink frame with C = 1, the MLP shall discard the extra multilink frames with R = 1.

When a MLP receives a multilink frame with C = 1, which is not a reply to a multilink frame with R = 1, the MLP shall discard the multilink frame with C = 1.

After a MLP transfers a multilink frame with C = 1 on one of its SLPs, the MLP may receive a multilink frame with R = 1 from the other MLP. The MLP shall regard the multilink frame with R = 1 as a new reset request and shall start the multilink resetting procedure from the beginning. When a MLP which has not received a multilink frame with R = 1 transfers a multilink frame with R = 1 and therefore receives a multilink frame with C = 1, the MLP shall restart the resetting procedure from the beginning.

When the Timer MT3 runs out, the MLP shall restart the multilink resetting procedure from the beginning. The value of Timer MT3 shall be large enough to include the transmission, retransmission, and propagation delays in the SLPs, and the operation time of the MLP that receives a multilink frame with R = 1 and responds with a multilink frame with C = 1.

6.4.3 Transmitting multilink frames

When the transmitting DTE MLP accepts a data unit from the higher layer, it shall place the packet in a multilink frame, set the MN(S) equal to MV(S), assure that MN(S) is not assigned outside the transmit window (MW), set V, S, R and C to "0", and then increment MV(S) by 1.

In the following, incrementing send and receive state variables is in reference to a continuously repeated sequence series, i.e., 4095 is one higher than 4094, and 0 is one higher than 4095 for modulo 4096 series.

NOTE 1 — The use of V and/or S bit set to "1" will form the subject of further study.

If the MN(S) is less than MV(T) + MW, and the DCE/remote DTE MLP has not indicated a busy condition on all available DCE/remote DTE SLPs, the transmitting DTE MLP may then assign the new multilink frame to an available DTE SLP. The transmitting DTE MLP shall always assign the lowest MN(S) unassigned multilink frame first. Also, the transmitting DTE MLP may assign a multilink frame to more than one DTE SLP. When the DTE SLP successfully completes the transmission of a multilink frame(s) by receiving an acknowledgement from the DCE/remote DTE SLP, it shall indicate this to the transmitting DTE MLP. The transmitting DTE MLP may then discard the acknowledged multilink frame(s). As the transmitting DTE MLP receives new indications of acknowledgements from the DTE SLPs, MV(T) shall be advanced to denote the lowest numbered multilink frame not yet acknowledged.

Whenever a DTE SLP indicates that it has attempted to transmit a multilink frame N2 times, the DTE MLP shall then assign the multilink frame to the same or one or more other DTE SLPs, unless the MN(S) has been acknowledged on some previous DTE SLP. The DTE MLP shall always assign the lowest MN(S) multilink frame first.

NOTE 2 — If a DTE MLP implementation is such that a multilink frame is assigned to more than one DTE SLP (for example, to increase the probability of successful delivery) there is a possibility that one of these multilink frames (i.e., a duplicate) may be delivered to the DCE/remote DTE MLP after an earlier one has been acknowledged [the earlier multilink frame would have resulted in the receiving DCE/remote DTE MLP having incremented its MV(R) and the transmitting DTE MLP having incremented its MV(T)]. To ensure that an old duplicate multilink frame is not mistaken for a new frame by the receiving DCE/remote DTE MLP, it is required that the transmitting DTE MLP should never assign to a DTE SLP a new multilink frame with MN(S) equal to MN(S)′ - MW - MX, where MN(S)′ is associated with a duplicate multilink frame that was earlier assigned to other DTE SLPs, until all such DTE SLPs have either successfully transmitted multilink frame MN(S)′ or have attempted the transmission the maximum number of times. Alternatively, the incrementing of MV(T) may be withheld until all DTE SLPs that were assigned multilink frame MN(S)′ have either successfully transferred multilink frame MN(S)′ or have attempted the transmission the maximum number of times. These and other alternatives will form the subject of further study.

Flow control of the DTE MLP is achieved by the window size parameter MW, and through busy conditions being indicated by the DCE/

remote DTE SLPs.

The DTE MLP shall not assign a multilink frame with an MN(S) greater than MV(T) + MW - 1. At the point where the next DTE multilink frame to be assigned has an M(S) = MV(T) + MW, the DTE MLP shall hold this and subsequent multilink frames until an indication of acknowledgment advancing MV(T) is received from the DTE SLPs.

The DCE/remote DTE MLP may exercise flow control of the DTE MLP by indicating a busy condition over one or more DCE/remote DTE SLPs. The number of SLPs made busy will determine the degree of DTE MLP flow control realized. When the DTE MLP receives an indication of a DCE/remote DTE SLP busy condition from one or more of its DTE SLPs, the DTE MLP may reassign any unacknowledged multilink frames that were assigned to those DTE SLPs. The DTE MLP shall assign the multilink frames containing the lowest MN(S) to an available DTE SLP as specified above.

In the event of a circuit failure, a DTE SLP reset, or a DTE SLP or DCE/remote DTE SLP disconnection, all DTE MLP multilink frames that were unacknowledged on the affected DTE SLPs shall be assigned to an operational DTE SLP(s) which is (are) not in the busy condition.

NOTES

3 The action to be taken on the receipt of an RNR frame by the DTE SLP whose unacknowledged multilink frames have been removed will form the subject of further study.

4 The means of detecting transmitting DTE MLP malfunctions (for example, sending more than MW multilink frames) and the actions to be taken will form the subject of further study.

6.4.4 Receiving multilink frames

Any multilink frame less than two octets in length shall be discarded by the receiving DTE MLP.

NOTE — The procedures to be followed by the receiving DTE MLP when V and/or S is equal to "1" will form the subject of further study. The procedures to be followed by the receiving DTE MLP when R or C is equal to "1" are as described in 6.4.2.

When the DTE MLP receives multilink frames from one of the DTE SLPs, the DTE MLP shall compare the multilink sequence number MN(S) of the received multilink frame to its multilink receive state variable MV(R), and act on the multilink frame as follows:

a) If the received MN(S) is equal to the current value of MV(R), i.e., is the next expected in-sequence multilink frame, the DTE MLP shall deliver the data unit to the higher layer.

b) If the MN(S) is greater than the current value of MV(R) but less than MV(R) + MW + MX, the DTE MLP shall keep the received multilink frame until condition (a) is met, or discard it if it is a duplicate.

c) If the MN(S) is other than in (a) and (b) above, the multilink frame shall be discarded.

On receipt of a multilink frame, MV(R) shall be incremented by the DTE MLP in the following way:

1) If MN(S) is equal to the current value of MV(R), MV(R) shall be incremented by the number of consecutive in-sequence multilink frames that have been received. If additional multilink frames are awaiting delivery pending receipt of a multilink frame with MN(S) equal to the updated MV(R), then Timer MT1 (see 6.5.1) shall be restarted; otherwise, Timer MT1 shall be stopped.

2) If MN(S) is greater than the current value of MV(R) but less than MV(R) + MW, MV(R) shall remain unchanged. Timer MT1 shall be started, if not already running.

3) If MN(S) is greater than or equal to MV(R) + MW but less than MV(R) + MW + MX, MV(R) shall be incremented to MN(S) - MW + 1, and then the higher layer may be informed of the data unit loss at the original value of MV(R). As MV(R) is being incremented, if any multilink frame with MN(S) = MV(R) has not been received, the higher layer may also be informed of that data unit loss; if the multilink frame with MN(S) = MV(R) has been received, it shall be delivered to the higher layer.

   MV(R), on reaching MN(S) - MW + 1, shall be incremented further [as in (1) above] until the first unacknowledged MN(S) is encountered.

4) If the MN(S) is other than in (1), (2) and (3) above, MV(R) shall remain unchanged.

If Timer MT1 runs out, MV(R) shall be incremented to the MN(S) of the next multilink frame awaiting delivery to the higher layer and then the higher layer may be informed of the data unit loss at the original MV(R). The procedure shall follow (a) and (1) above as long as there are consecutive in-sequence multilink frames which have been received.

When flow control of the DCE/remote DTE MLP is desired, one or more DTE SLPs may be made to indicate a busy condition. The number of DTE SLPs made busy shall determine the degree of flow control realized.

If the DTE MLP can exhaust its receive buffer capacity before resequencing can be completed, Timer MT2 (see 6.5.2) shall be implemented. Whenever a busy condition is indicated by the DTE MLP on all DTE SLPs, and multilink frames at the DTE MLP are awaiting

resequencing, Timer MT2 shall be started. When the busy condition is cleared on one or more DTE SLPs by the DTE MLP, Timer MT2 shall be stopped.

If Timer MT2 runs out, the multilink frame with MN(S) = MV(R) is blocked and shall be considered lost. MV(R) shall be incremented to the next sequence number not yet received, and the data units contained in multilink frames with intervening multilink sequence numbers shall be delivered to the higher layer. Timer MT2 shall be restarted if the busy condition remains in effect on all DTE SLPs and more multilink frames are awaiting resequencing.

6.4.5 Taking an SLP out of service

A DTE SLP shall be taken out of service by disconnecting at either the Physical layer or the Data Link layer. Any outstanding DTE MLP multilink frames shall be reassigned to one or more other DTE SLPs, unless the MN(S) has been previously acknowledged on some other DTE SLP. The usual procedure for taking a DTE SLP out of service at the Data Link layer would be to flow control the DCE/remote DTE SLP with an RNR frame, and then logically disconnect (see 5.3.3).

A DTE SLP may be taken out of service for maintenance, traffic, or performance considerations.

If the DTE SLP Timer T1 has run out N2 times and the DTE SLP link resetting procedure is unsuccessful, then the DTE SLP shall enter the disconnected phase, taking the DTE SLP out of service (see 5.4.9 and 5.6).

6.5 List of multilink system parameters

6.5.1 Lost-frame timer MT1 (multilink)

Timer MT1 shall be used at a receiving DTE MLP to provide a means of identifying during low traffic periods the loss of the multilink frame with MN(S) equal to MV(R).

6.5.2 Group busy Timer MT2 (multilink)

Timer MT2 shall be provided at a receiving DTE MLP in order to identify a "blocked" multilink frame condition (for example, a buffer exhaust situation) that occurs before required resequencing can be accomplished. MT2 shall be started when all DTE SLPs are busy and there are multilink frames awaiting resequencing. If MT2 runs out before the "blocked" multilink frame MV(R) is received, the "blocked" multilink frame(s) shall be declared lost. MV(R) shall be incremented to the value of the next in-sequence multilink frame to be received, and any data units in intervening multilink frames shall be delivered to the higher layer.

NOTE — MT2 may be set to infinity; for example, when the receiving DTE always has sufficient storage capacity.

6.5.3 MLP reset confirmation timer MT3 (multilink)

Timer MT3 shall be used by the DTE MLP to provide a means of identifying the the DCE/remote DTE MLP multilink frame with the C bit set to "1" that is expected following the transmission of the DTE MLP multilink frame with the R bit set to "1" has not been received.

7 Conformance

7.1. Static conformance

7.1.1. General requirements

A DTE that claims conformance to this International Standard shall implement:

a) Single link operation;

b) operation with DTE address A (ie, A sent in response frames);

c) either basic (modulo 8) operation or extended (modulo 128) operation, and may implement both (3);

d) either synchronous transmission or start/stop transmission, and may implement both (3.5.1, 3.5.2);

e) link set-up as initiator (5.3.1, 5.3.4), and as responder to a set-up initiated by the DCE/remote DTE (5.3.1);

f) link disconnection as responder to a disconnection initiated by the DCE/remote DTE (5.3.3);

g) link reset as responder to a reset initiated by the DCE/remote DTE (5.6.1);

h) information transfer, in both directions (5.2, 5.4, 5.4.1, 5.4.2, 5.4.3, 5.4.4, 5.4.5, 5.4.6, 5.4.7, 5.4.9);

j) sending of FRMR response on receipt of a valid frame with an error condition not recoverable by retransmission of the identical frame (4.3.9, 5.5);

k) responding to receipt of a FRMR response in the information transfer phase either by initiating link reset, or by transmitting a DM response and entering the disconnected phase (5.5);

l) timer T1 (5.7.1.1), and parameter N2 (5.7.2);

m) if synchronous transmission is implemented, interframe time fill by contiguous flags (3.10.1).

NOTE — Support for initiation of link set-up is mandatory only because it is required on reception of an unsolicited DM response frame in disconnected phase, as specified in 5.3.4. Support for initiation of link set-up in other situations is not required.

7.1.2 Options

A DTE that claims conformance to this International Standard may implement:

a) multilink operation (clause 6);

b) operation with DTE address B for DTE/DTE applications;

c) if start/stop transmission is supported, one or more of the transparency options for flow-control transparency (3.5.2.3.1), control-character octet transparency (3.5.2.3.2), and seven-bit data path transparency (3.5.2.1);

d) link disconnection as initiator (5.3.3);

e) link reset as initiator (5.6.1);

f) DTE busy condition (5.4.8);

g) timers T3 (5.7.1.3), T4 (5.7.1.4) and T5 (5.7.1.5);

h) transmission of unsolicited DM response frames in disconnected phase (5.3.4);

j) transmission of DISC frames prior to link set-up (5.3.1).

NOTE — Caution is needed in choosing not to implement link disconnection, (d) above, if an implementation might be used in a DTE/DTE environment: two such implementations communicating with each other in DTE/DTE mode would be unable to disconnect the link, since neither would be capable of initiating the disconnection.

7.2. Dynamic conformance

For each function that the PICS states to be supported, the implementation shall exhibit external behaviour consistent with the implementation of

a) the corresponding data link layer procedures, and

b) the encoding specified in 3.4.1, 4.3, 4.3.9 and 5.1 for all relevant fields of any transmitted frames,

as specified in the clauses to which the PICS proforma entry for the function refers.

7.3 Protocol Implementation Conformance Statement

The supplier of a protocol implementation that is claimed to conform to this International Standard shall complete a copy of the PICS proforma in annex A, including the information necessary to identify fully both the supplier and the implementation.

Annex A *
(normative)

PICS Proforma

A.1 Introduction

The supplier of a protocol implementation which is claimed to conform to ISO/IEC 7776 shall complete the following Protocol Implementation Conformance Statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can have a number of uses, including use:

— by the protocol implementor, as a check-list to reduce the risk of failure to conform to the standard through oversight;

— by the supplier and acquirer — or potential acquirer — of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;

— by the user — or potential user — of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICS's);

— by a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A.2 Abbreviations and special symbols

A.2.1 Status symbols

M	mandatory
O	optional
O.*n*	optional, but support of at least one of the group of options labelled by the same numeral *n* is required
X	prohibited
<item>:	conditional symbol, status is dependent on the support marked for <item> (see A.3.4)

A.2.2 General abbreviations

N/A	not applicable
PICS	Protocol Implementation Conformance Statement

A.2.3 Item references

The following is a list of the item references used in the PICS proforma

Major capabilities, A.5:	Ls, Lm, Lc, Lt, Lta
Basic / extended operation, A.6.1:	M8, M128
Synchronous and start/stop transmission, A.6.1:	Tsy, Tss, Tfc, Tcc, Tsb
Link setup, A.6.2:	LSI1, LSI2, LSI3, LSA, LSD, LSR
Link disconnection and disconnected phase, A.6.2:	LD1, LD2, LDP
Link reset, A.6.2:	LRI1, LRIb, LRIc, LRId, LRRa, LRRb, LRRc, LRRd, LRA, LRD
Collision resolution for U frames, A.6.2:	LCRa, LCRb, LCRc, LCRd, LCRe
I-frame transmission, A.6.3:	IT, ITs, ITCi, ITCs, ITRJ, ITB
I-frame reception, A.6.3:	IR, IRs, IRRJ, IRB
Frame rejection, A.6.3:	FR1, FR2
Frame formats, A.6.4:	F1a, F1b, F1c, F2, F2a, F2b, F2c, F2d, F2e, F3, F4, FD, FA, FF
Timers, etc., A.6.5:	T1a, T1b, T1c, T1d, T1e, T1f, T1g, N2a, N2b, T3, T4, T5a, T5b
System parameters, A.6.6:	SPT1, SPT2, SPT3, SPT4, SPT5a, SPT5b, SPN2, SPN1, SPk

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*) **Copyright release for PICS proformas**

Users of this International Standard may freely reproduce the PICS proforma in this annex so that it can be used for the intended purpose and may further publish the completed PICS.

Multilink procedure, initialization, A.7.1:	ML1
Multilink resetting, A.7.1:	MLRi, MLRr, MLRCi, MLRCr, MLLNrs
Multilink procedure for taking an SLP out of service:	MLSOS
Multilink frame transmission, A.7.1:	MLFT, MLFTrf, MLFTrb
Multilink frame reception, A.7.1:	MLFR, MLFRbs, MLFRfc, MLLNt1, MLMT2
Multilink frames, A.7.1:	MLFS, MLFF, MLFVS, MLFSC
Multilink system parameters, A.7.2:	SPMT1, SPMT2, SPMT3, SPMWT, SPMWR, SPMX

A.3 Instructions for completing the PICS proforma

A.3.1 General structure of the PICS proforma

The first part of the PICS proforma — Implementation Identification and Protocol Summary — is to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed-format questionnaire, divided into several subclauses each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No), or by entering a value or a set or range of values. (Note that there are some items where two or more choices from a set of possible answers can apply: all relevant choices are to be marked.)

Each item is identified by an item reference in the first column; the second column contains the question to be answered; the third column contains the reference or references to the material that specifies the item in the main body of ISO/IEC 7776. The remaining columns record the status of the item — whether support is mandatory, optional or conditional — and provide the space for the answers: see also A.3.4 below.

A supplier may also provide — or be required to provide — further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labelled A*i* or X*i* respectively for cross-referencing purposes, where *i* is any unambiguous identification for the item (eg, simply a numeral): there are no other restrictions on its format and presentation.

A completed PICS proforma, including any Additional Information and Exception Information, is the Protocol Implementation Conformation Statement for the implementation in question.

NOTE — Where an implementation is capable of being configured in more than one way, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's configuration capabilities, in case that makes for easier and clearer presentation of the information.

A.3.2 Additional Information

Items of Additional Information allow a supplier to provide further information intended to assist the interpretation of the PICS. It is not intended or expected that a large quantity will be supplied, and a PICS can be considered complete without any such information. Examples might be an outline of the ways in which a (single) implementation can be set up to operate in a variety of environments and configurations; or a brief rationale — based perhaps upon specific application needs — for the exclusion of features which, although optional. are commonly present in implementations of the ISO/IEC 7776 protocol.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

A.3.3 Exception Information

It may occasionally happen that a supplier will wish to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No pre-printed answer will be found in the Support column for this: instead, the supplier shall write the missing answer into the Support column, together with an X*i* reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception item itself.

An implementation for which an Exception item is required in this way does not conform to ISO/IEC 7776.

NOTE — A possible reason for the situation described above is that a defect in ISO/IEC 7776 has been reported, a correction for which is expected to change the requirement not met by the implementation.

A.3.4 Conditional items

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply — mandatory or optional — are dependent upon whether or not certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the questionnaire if the "Not Applicable" answer is selected. Otherwise,