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SERIES V: DATA COMMUNICATION OVER THE TELEPHONE NETWORK

Interfaces and voiceband modems

Generic multiplexer using V.42 LAPM-based procedures

ITU-T Recommendation V.76

(Previously "CCITT Recommendation")

ITU-T V-SERIES RECOMMENDATIONS

DATA COMMUNICATION OVER THE TELEPHONE NETWORK

For further details, please refer to ITU-T List of Recommendations.

FOREWORD

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The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation V.76 was prepared by ITU-T Study Group 14 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 16th of August 1996.

NOTE

1 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

2 The status of annexes and appendices attached to the Series V Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

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GENERIC MULTIPLEXER USING V.42 LAPM-BASED PROCEDURES

(Geneva, 1996)

1 Scope

1.1 General

This Recommendation describes a set of procedures for use between peer stations for multiplexing multiple streams of information at the same time. These procedures are based on V.42 LAPM procedures but are independent of the application requiring multiplexing support. They provide two basic information-transfer modes known as Error Recovery Mode (ERM) and Unacknowledged Non Error-Recovery Mode (UNERM).

For each stream, an information-transfer mode is chosen independently of those selected for other streams; other characteristics can also be chosen in the same fashion. All streams use a common multiplexing platform.

1.2 Relationship to other international standards and Recommendations

The protocol defined in this Recommendation can be specified in terms of the High-Level Data Link Control (HDLC) formats and procedures. In particular, it makes use of the balanced asynchronous class (BAC) of HDLC procedures with the HDLC "optional functions" (1, 2, 4, 7, 8, 10, 18 and 19 for the basic features and 3.1, 3.3, 12, 14 and 20 as optional features).

2 Definitions

The following terms are used in this Recommendation as defined here:

2.1 initiator: A role taken on by a Multiplexing Function (MF) that determines how it operates for various functions. The information to determine that a station takes on this role is provided to the MF by means not specified in this Recommendation. The two stations involved in an instance of communication take on opposite roles.

2.2 responder: A role taken on by a Multiplexing Function (MF) that determines how it operates for various functions. The information to determine that a station takes on this role is provided to the MF by means not specified in this Recommendation. The two stations involved in an instance of communication take on opposite roles.

3 Abbreviations

For the purposes this Recommendation, the following abbreviations are used.

C/R	Command/Response
CRC	Cyclic Redundancy Check
DCE	Data Circuit-Terminating Equipment
DISC	Disconnect (frame)
DLC	Data Link Connection

DLCI	Data Link Connection Identifier
DM	Disconnect Mode (frame)
DTE	Data Terminal Equipment
EA	Address Extension
ERM	Error Recovery Mode
FCS	Frame Check Sequence
FRMR	Frame Reject (frame)
HDLC	High-Level Data Link Control
I	Information (frame)
LAPM	Link Access Procedure for Modems
MF	Multiplexing Function
m-SREJ	multi-Selective Reject (procedure)
REJ	Reject (frame)
RNR	Receive Not Ready (frame)
RR	Receive Ready (frame)
SABME	Set Asynchronous Balanced Mode Extended (frame)
SREJ	Selective Reject (frame)
s-SREJ	single-Selective Reject (procedure)
SU	Service User
UA	Unnumbered Acknowledgement (frame)
UI	Unnumbered Information (frame)
UNERM	Unacknowledged Non-Error Recovery Mode
XID	Exchange Identification (frame)

4 Overview of multiplexing operation and services

4.1 General

The multiplexing operation described in this Recommendation can be viewed as consisting of two parts:

a) a multiplex "platform" that provides a core set of functions of frame delimiting, protection from bit corruption and multiplexing and demultiplexing of multiple information streams known as Data Link Connections (DLCs);

b) one DLC entity per DLC to operate the procedures for setting up a DLC (including negotiation/indication of appropriate parameters and functions such as selection of ERM or UNERM); transfer of information in the selected mode; and release of the DLC.

The above division is depicted in Figure 1.

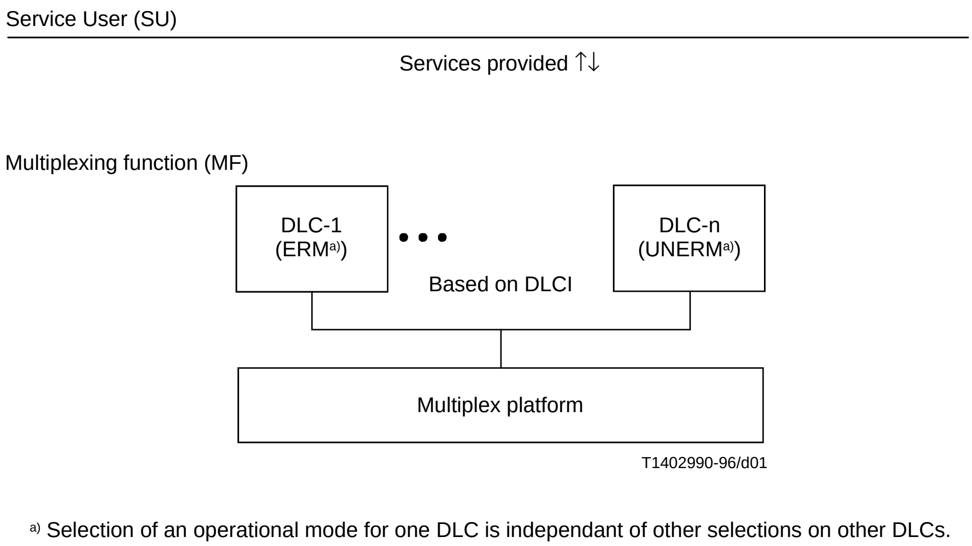


FIGURE 1/V.76

Division of multiplexing operation

The multiplex operations are provided by a Multiplexing Function (MF), which provides the resulting set of services to a "higher layer" called, for purposes of discussion here, the Service User (SU). It is the responsibility of the SU to request services of the MF in a meaningful way for a specific application.

4.2 Overview of the Service User (SU)

Specification of the SU for specific applications is beyond the scope of this Recommendation. However, it is described here in a generic way so as to provide a context in which the MF provides its services.

The SU is responsible for requesting services of the MF. The services that may be requested are:

a) establish a DLC between the station and its peer for the purposes of establishing a control channel or transferring information as characterized by various parameters – more than one DLC can be established (the maximum number is implementation-dependent);

b) transfer of information in ERM or UNERM;

c) release of a DLC.

The SU shall make known to the MF whether the station is to operate as an initiator or responder for various MF procedures.

The SU is also responsible for transferring supervisory/control information of two types. The first type affects a specific DLCI (e.g. break for a data channel) and is sent on that DLCI. The second type affects all DLCIs as a whole or is independent of any DLCI (e.g. orderly release of all DLCIs with one message); it is sent on a DLCI separate from those carrying user information. These SU functions are transparent to the MF.

4.3 Overview of the Multiplexing Function (MF)

The multiplexing procedures in this Recommendation provide for:

a) frame delimiting, alignment and transparency;

b) provision for multiple DLCs; discrimination between these connections is by means of a Data Link Connection Identifier (DLCI) contained in each frame;

c) detection of transmission errors;

d) initialization and orderly release of a DLC;

e) independent selection of ERM or UNERM for each DLC;

f) negotiation/indication of parameter values and optional procedures relating to DLC operation;

g) transfer of user information;

h) detection of format and operational errors;

i) transparent transfer of higher-layer information or protocols; and

j) when transferring information in ERM:

 – recovery from detected transmission, format and operational errors with notification of unrecoverable errors;

 – sequence control; and

 – flow control.

In terms of Figure 1, items a), b) and c) constitute the multiplex platform; the remaining items constitute the operation of each individual DLC.

4.4 Communication between the SU and the MF

Primitives are specified here for descriptive purposes only to illustrate, in an abstract fashion, how the capabilities of the MF are seen by the SU. The use of primitives is **not** meant to imply any requirements on implementations.

The primitives are provided in Table 1.

TABLE 1/V.76

Primitives for communication between the SU and MF

Service	Primitive	Types	Parameters[a)]
Establish a DLC between peer SUs	L-ESTABLISH	– request – indication – response – confirm	– user data – mode
Transfer data in ERM	L-DATA	– request – indication	– user data
Transfer data in UNERM	L-UNITDATA	– request – indication	– user data
Release a DLC	L-RELEASE	– request – indication	– user data
Transfer control information	L-SIGNAL	– request – indication – response[b)] – confirm[b)]	– user data
Negotiate/indicate parameter values and optional procedures	L-SETPARM	– request – indication – response – confirm	– user data
Conduct a loop-back test between SU entities	L-TEST	– request – indication	– user data

a) Primitives pertain to a specific DLC. Although not specified here as a parameter, a local mechanism is needed to map the DLC to a “connection endpoint identifier” understood by the SU.

b) The need for and use of the response and confirm forms of the L-SIGNAL primitive depend on the type of control information to be transferred.

5 Multiplexing platform and frame structure

The frame structure and general procedures for basic operation of the MF are specified below. Optional modifications to the basic operation are specified in Annex A and Appendix II.

5.1 Basic frame structure and fields

5.1.1 Basic frame structure

All communications using the basic frame format are accomplished using the structure shown in Figure 2. Depending on the frame type, an information field may also be present in the frame.

8	7	6	5	4	3	2	1	
0	1	1	1	1	1	1	0	
Opening flag								Octet 1
Address (Note 1)								2
Control (Note 2)								3
Information (Note 3)								
FCS (Note 4)								
0	1	1	1	1	1	1	0	
Closing flag								N

NOTES

1 The maximum size of this field is limited to two octets.

2 The control field is two octets for frame types with sequence numbers and one octet for frame types without sequence numbers, see 6.2.

3 Not all frame types have an information field.

4 The FCS field can be 8, 16 or 32 bits long.

FIGURE 2/V.76

Basic frame structure

5.1.2 Flag sequence and transparency

All frames using the basic frame structure are delimited by the unique bit pattern “01111110”, known as a flag. The flag preceding the address field is defined as the opening flag. The flag following the frame check sequence field is defined as the closing flag. The closing flag of one frame may also serve as the opening flag of the next frame.

Transparency is maintained by the transmitters examining the frame content between the opening and closing flags and inserting a “0” bit after all sequences of five contiguous “1” bits. The receiver examines the frame content between the opening and closing flags and discards any “0” bit that directly follows five contiguous “1” bits.

5.1.3 Address field

The primary purpose of the address field is to identify, by means of a DLCI, an individual stream of information and the DLC entity associated with it. The format of this field is defined in 6.1.

5.1.4 Control field

The control field is used to distinguish between different frame types. This field is further described in 6.2.

5.1.5 Information field

Depending on the frame type, an information field may also be present in the frame. The maximum number of octets in this field is governed by parameter N401 (see 9.3). When an information field is present, it need not be of the maximum size of N401 octets. Different maximum values may apply to each DLC.

5.1.6 Frame Check Sequence (FCS) field

This field uses a CRC polynomial to guard against bit errors.

If support for specific FCS lengths has been indicated by both stations, then all received frames shall be checked against all the supported lengths. See 7.1.2.1.

5.1.6.1 8-bit frame check sequence

The FCS field shall be the 8-bit sequence preceding the closing flag. The 8-bit FCS shall be the 1's complement of the sum (modulo 2) of:

a) the remainder of x^k ($x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + 1$) divided (modulo 2) by the generator polynomial $x^8 + x^2 + x + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency; and

b) the remainder of the division (modulo 2) by the generator polynomial $x^8 + x^2 + x + 1$, of the product of x^8 by the content of the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency.

As a typical implementation at the transmitter, the initial content of the register of the device computing the remainder of the division is preset to all 1s and is then modified by division by the generator polynomial (as described above) of the address, control and information fields; the 1's complement of the resulting remainder is transmitted as the 8-bit FCS.

As a typical implementation at the receiver, the initial content of the register of the device computing the remainder is preset to all 1s. The final remainder, after multiplication by x^8 and then division (modulo 2) by the generator polynomial $x^8 + x^2 + x + 1$ of the serial incoming protected bits and the FCS, will be 11110011 (x^7 through x^0, respectively) in the absence of transmission errors.

5.1.6.2 16-bit frame check sequence

The FCS field shall be the 16-bit sequence preceding the closing flag. The 16-bit FCS shall be the 1's complement of the sum (modulo 2) of:

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

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 bits inserted for transparency.

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

As a typical implementation at the receiver, the initial content of the register of the device computing the remainder is preset to all 1s. The final remainder, after multiplication by x^{16} and then division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of the serial incoming protected bits and the FCS, will be "0001 1101 0000 1111" (x^{15} through x^0, respectively) in the absence of transmission errors.

5.1.6.3 32-bit frame check sequence

The FCS shall be the 32-bit sequence preceding the closing flag. The 32-bit FCS shall be the 1's complement of the sum (modulo 2) of:

a) the remainder of $x^k (x^{31} + x^{30} + x^{29} + x^{28} + x^{27} + x^{26} + x^{25} + x^{24} + x^{23} + x^{22} + x^{21} + x^{20} + x^{19} + x^{18} + x^{17} + x^{16} + x^{15} + x^{14} + x^{13} + x^{12} + x^{11} + x^{10} + x^9 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + 1)$ divided (modulo 2) by the generator polynomial $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency; and

b) the remainder of the division (modulo 2) by the generator polynomial $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$, of the product of x^{32} by the content of the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency.

As a typical implementation at the transmitter, the initial content of the register of the device computing the remainder of the division is preset to all 1s and is then modified by division by the generator polynomial (as described above) of the address, control and information fields; the 1's complement of the resulting remainder is transmitted as the 32-bit FCS.

As a typical implementation at the receiver, the initial content of the register of the device computing the remainder is preset to all 1s. The final remainder, after multiplication by x^{32} and then division (modulo 2) by the generator polynomial $x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$ of the serial incoming protected bits and the FCS, will be "1100 0111 0000 0100 1101 1101 0111 1011" (x^{31} through x^0, respectively) in the absence of transmission errors.

5.2 Format conventions

5.2.1 Numbering convention

The basic convention used in this Recommendation is illustrated in Figure 3. The bits are grouped into octets. The bits of an octet are shown horizontally and are numbered from 1 to 8. Multiple octets are shown vertically and are numbered from 1 to n.

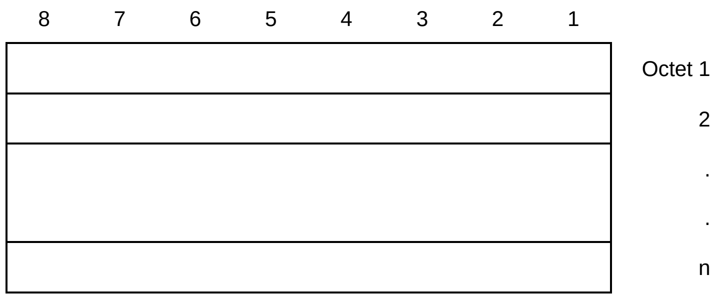


FIGURE 3/V.76

Format convention

5.2.1.1 Order of bit transmission

The octets are transmitted in ascending numerical order; inside an octet, bit 1 is the first bit to be transmitted.

5.2.1.2 Field mapping convention

When a field is contained within a single octet, the lowest bit number of the field represents the lowest-order value.

When a field spans more than one octet, the order of bit values within each octet progressively decreases as the octet number increases. The lowest bit number associated with the field represents the lowest-order value.

For example, a bit number can be identified as a couple (o, b) where o is the octet number and b is the relative bit number within the octet. Figure 4 illustrates a field that spans from bit (1, 3) to bit (2, 7). The high-order bit of the field is mapped on bit (1, 3) and the low-order bit is mapped on bit (2, 7).

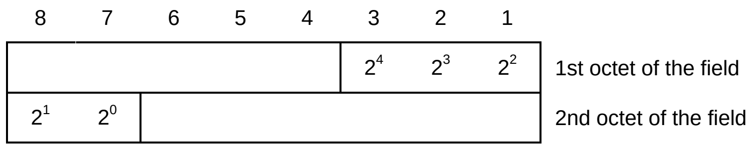


FIGURE 4/V.76

Field mapping convention

An exception to the preceding field mapping convention is the FCS field, which spans one, two or four octets. In this case, as shown in Figure 5:

a) the high-order bit is bit 1 of the first octet for all FCS lengths;

b) the low-order bit is bit 8 of the first octet (for 8-bit FCS), bit 8 of the second octet (for 16-bit FCS) or bit 8 of the fourth octet (for 32-bit FCS).

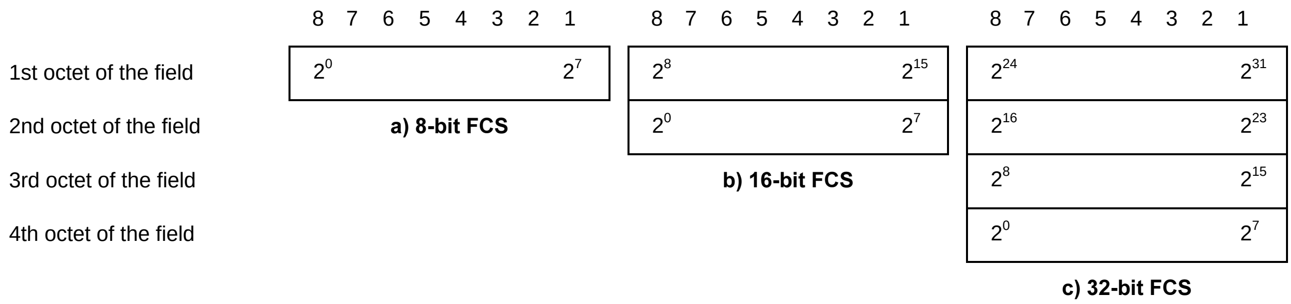


FIGURE 5/V.76

FCS mapping convention

5.3 Invalid frames

An invalid frame when using the basic frame format is one which meets any one (or more) of the following conditions:

a) is not properly bounded by two flags; or

b) does not have at least the number of octets between flags as follows:

	# Octets in invalid frame	
	Frames with sequence numbers	**Frames without sequence numbers**
8-bit FCS	< 4	< 3
16-bit FCS	< 5	< 4
32-bit FCS	< 7	< 6

c) does not consist of an integral number of octets prior to 0-bit insertion or following 0-bit extraction;

d) indicates presence of a transmission error in that all of the supported FCSs fail the corresponding check as given in 5.1.6.1 through 5.1.6.3; or

e) contains an address field with more than two octets.

Invalid frames shall be discarded without notification to the sender (however, see 8.4.1). Actions taken by the MF to indicate reception of an invalid frame to the SU are left to implementors. However, an indication that a frame with an FCS error [invalid frame condition d) above], has been received, may be of use to the SU when supporting DLCs for voice/audio.

5.4 Frame abort

When using the basic frame format, receipt of seven or more contiguous 1 bits shall be interpreted as an abort and the MF shall ignore the frame currently being received.

5.5 Interframe time fill

Interframe time fill is accomplished by transmitting contiguous flags between frames, i.e. multiple 8-bit flag sequences (see 5.1.2).

6 Elements of procedure and field formats

The elements of procedures define the commands and responses that are used. Procedures, which are derived from these elements of procedures, are described in subsequent subclauses.

6.1 Address field format

The format of the address field is shown in Figure 6. The address field contains the Data Link Connection Identifier (DLCI), the C/R bit and the address field extension (EA) bit.

8	7	6	5	4	3	2	1	
DLCI						C/R	EA	Octet 2
DLCI							EA	2A

FIGURE 6/V.76

Address field format

6.1.1 Data Link Connection Identifier (DLCI)

The DLCI is used to identify an individual user information stream as well as to identify SU-to-SU connections. Multiple DLCIs shall be supported but the number is implementation-specific.

Selection of a new DLCI value shall be as follows:

a) the initiator shall select DLCI values for new DLCs with increasing values starting from 0;

b) the responder shall select DLCI values for new DLCs with decreasing values starting from 63 when using one-octet address fields or 8191 when using two-octet address fields.

The role of initiator or responder shall be made known to the MF by the SU. The means of doing so is beyond the scope of this Recommendation.

Use of the second address-field octet is optional. All DLC entities shall be able to receive frames with a two-octet address field.

Regardless of role, DLCI values freed as a result of releasing a DLC shall be reused prior to new values being allocated. In case of collision (i.e. the same DLCI value being selected), the responder shall back off its attempt to establish a new DLC (i.e. it shall inform its SU of failure to establish the DLC it attempted and continue with the DLC establishment attempt by the initiator).

The DLCI used on a given DLC is mapped to/from an internal “connection endpoint identifier” for communication between the MF and the SU.

6.1.2 Command/Response (C/R) bit

Figure 6 shows the location of the C/R bit in the address field. The C/R (command/response) bit identifies the frame as either a command or a response. In conformance with HDLC rules, a command frame contains the "address" of the data link connection entity to which it is transmitted while a response frame contains the "address" of the data link connection entity transmitting the frame. For a given DLC, the DLCI value of the address field remains the same but the C/R bit changes, as shown in Table 2.

TABLE 2/V.76

Command/response bit usage

Command/response	Direction			C/R value
Command	Initiator	⟶	Responder	1
	Responder	⟶	Initiator	0
Response	Initiator	⟶	Responder	0
	Responder	⟶	Initiator	1

6.1.3 Address field extension (EA) bit

According to the rules of HDLC, the range of the address field may be extended by reserving the first transmitted bit of each octet of this field to indicate whether the octet is the last one of the field. Within the scope of this Recommendation, the address field is limited to a maximum of two octets.

When the EA bit is set to 1 in an octet, it signifies that this octet is the last octet of the address field. When the EA bit is set to 0, it signifies that another octet of the address field follows.

6.2 Control field format

The control field identifies the type of frame, which will be a command or response. The control field will contain sequence numbers, where applicable.

Three types of control field formats are specified: numbered information transfer (I format), supervisory functions (S format) and unnumbered information transfers and control functions (U format). The control field formats are shown in Table 3.

6.2.1 Information transfer (I) format

The I format shall be used to perform an error-protected information transfer between data link connection entities. The functions of N(S), N(R) and P are independent; that is, each I frame has an N(S) sequence number, an N(R) sequence number that may or may not acknowledge additional I frames received by the data link connection entity and a P bit that may be set to 0 or 1.

6.2.2 Supervisory (S) format

The S format shall be used to perform supervisory control procedures on the data link connection, such as acknowledge I frames, request retransmission of one or more I frames and request temporary suspension of transmission of I frames. The functions of N(R) and P/F are independent; that is, each supervisory frame has an N(R) sequence number that may or may not acknowledge additional I frames received by the data link connection entity and a P/F bit that may be set to 0 or 1.

6.2.3 Unnumbered (U) format

The U format shall be used to provide additional connection control procedures and unnumbered information transfers. The U format does not include sequence numbers but does include a P/F bit that may be set to 0 or 1.

TABLE 3/V.76

Control field formats

Format	Control field bits (modulo 128)								
	8	7	6	5	4	3	2	1	
I format	N(S)							0	Octet 3
	N(R)							P	4
S format	X	X	X	X	S	S	0	1	3
	N(R)							P/F	4
U format	M	M	M	P/F	M	M	1	1	3

N(S) Transmitter send sequence number
N(R) Transmitter receive sequence number
S Supervisory function bits
M Modifier function bits
P/F Poll bit when issued as a command
Final bit when issued as a response
X Reserved and set to 0

6.3 Control field parameters and associated state variables

The various parameters associated with the control field formats are described in this subclause. The coding of the bits within these parameters is such that the lowest numbered bit within the parameter field is the least-significant bit.

6.3.1 Poll/final (P/F) bit

All frames contain the poll/final (P/F) bit. The P/F bit serves a function in both command frames and response frames. In command frames, the P/F bit is referred to as the P bit. In response frames, it is referred to as the F bit. The P bit set to 1 is used by a data link connection entity to solicit (poll) a response frame from the peer data link connection entity. The F bit set to 1 is used by a data link connection entity to indicate the response frame transmitted as a result of a soliciting (poll) command.

6.3.2 Variables and sequence numbers

The variables and sequence numbers of the control field apply only to operation in ERM.

6.3.2.1 Modulus

Each I frame is sequentially numbered and may have the value 0 through n minus 1 (where n is the modulus of the sequence numbers). The modulus equals 128 and the sequence numbers cycle through the entire range, 0 through 127.

NOTE – All arithmetic operations on state variables and sequence numbers contained in this Recommendation are affected by the modulus operation.

6.3.2.2 Send state variable V(S)

Each connection shall have an associated V(S) when using I frame commands. V(S) denotes the sequence number of the next I frame to be transmitted. V(S) can take on the value 0 through n minus 1. The value of V(S) shall be incremented by 1 with each successive I frame transmission, and shall not exceed V(A) by more than the maximum number of outstanding I frames, *k*. The value of *k* may be in the range of $1 \leq k \leq 127$.

6.3.2.3 Acknowledge state variable V(A)

Each connection shall have an associated V(A) when using I frame commands and supervisory frame commands/responses. V(A) identifies the last frame that has been acknowledged by its peer [V(A) – 1 equals the N(S) of the last acknowledged I frame]. V(A) can take on the value 0 through n minus 1. The value of V(A) shall be updated by the valid N(R) values received from its peer (see 6.3.2.6). A valid N(R) value is one that is in the range V(A) ≤ N(R) ≤ V(S).

6.3.2.4 Send sequence number N(S)

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

6.3.2.5 Receive state variable V(R)

Each connection shall have an associated V(R) when using I frame commands and supervisory frame commands/responses. V(R) denotes the sequence number of the next in-sequence I frame expected to be received. V(R) can take on the value 0 through n minus 1. The value of V(R) shall be incremented by one with the receipt of an error-free, in-sequence I frame whose N(S) equals V(R).

6.3.2.6 Receive sequence number N(R)

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

6.4 Frame types

6.4.1 Commands and responses

The command and response frames listed in Table 4 are used by either data link connection entity. For purposes of this Recommendation, those frame types not identified in Table 4 are classified as undefined command and/or response control fields; the actions to be taken are specified in 8.4.2.

The commands and responses in Table 4 are defined in 6.4.2 through 6.4.14. An additional optional command and response are described in Appendix II.

6.4.2 Information (I) command

The function of the information (I) command is to transfer, across a data link connection, sequentially numbered frames containing data provided by the SU.

6.4.3 Set Asynchronous Balanced Mode Extended (SABME) command

The SABME unnumbered command is used to place the addressed data link connection entity into the connected state.

An information field is permitted with the SABME command. A data link connection entity confirms acceptance of an SABME command by the transmission at the first opportunity of a UA response. Upon acceptance of this command, the data link connection entity's V(S), V(A) and V(R) are set to 0. The transmission of an SABME command indicates the clearance of all exception conditions.

Previously-transmitted I frames that are unacknowledged when this command is processed remain unacknowledged and are discarded.

6.4.4 Disconnect (DISC) command

The DISC unnumbered command is used to return to the disconnected state.

An information field is permitted with the DISC command. The data link connection entity receiving the DISC command confirms the acceptance of a DISC command by the transmission of a UA response. The data link connection entity sending the DISC command terminates the data link connection when it receives the acknowledging UA or DM response.

Previously-transmitted I frames that are unacknowledged when this command is processed remain unacknowledged and are discarded.

TABLE 4/V.76

Commands and responses

Format	Commands	Responses	Control field encoding 8	7	6	5	4	3	2	1	
Information transfer	I (information)		N(S)							0	Octet 3
			N(R)							P	
Supervisory	RR (receive ready)	RR (receive ready)	0	0	0	0	0	0	0	1	
			N(R)							P/F	
	RNR (receive not ready)	RNR (receive not ready)	0	0	0	0	0	1	0	1	
			N(R)							P/F	
	REJ (reject)	REJ (reject)	0	0	0	0	1	0	0	1	
			N(R)							P/F	
	SREJ (selective reject)	SREJ (selective reject)	0	0	0	0	1	1	0	1	
			N(R)							P/F	
Unnumbered	SABME (set asynchronous balanced mode extended)		0	1	1	P	1	1	1	1	
		DM (disconnected mode)	0	0	0	F	1	1	1	1	
	UI (unnumbered information)	UI (unnumbered information)	0	0	0	P/F	0	0	1	1	
	DISC (disconnect)		0	1	0	P	0	0	1	1	
		UA (unnumbered acknowledgement)	0	1	1	F	0	0	1	1	
		FRMR (frame reject)	1	0	0	F	0	1	1	1	
	XID (exchange identification)	XID (exchange identification)	1	0	1	P/F = 0	1	1	1	1	
	TEST (test)		1	1	1	P = 0	0	0	1	1	

6.4.5 Unnumbered information (UI) command/response

An unnumbered information (UI) frame is used to send information that the MF will not recover if lost (the SU, however, may try to ensure that the information is successfully transmitted to the remote station). The UI frame may be used in either ERM (in conjunction with I frames) or UNERM.

No sequence numbers are contained within the control field of a UI frame. The P/F bit of a UI frame is set to 0.

6.4.6 Receive ready (RR) command/response

The RR supervisory frame is used by a data link connection entity to:

a) indicate it is ready to receive an I frame;

b) acknowledge previously-received I frames numbered up to and including N(R) – 1 (as defined in 8.1.3.1); and

c) clear a busy condition that was indicated by the earlier transmission of an RNR frame by that same data link connection entity.

In addition to indicating the status of a data link connection entity, the RR command with the P bit set to 1 may be used by the data link connection entity to ask for the status of its peer data link connection entity.

6.4.7 Reject (REJ) command/response

The REJ supervisory frame is used by a data link connection entity to request retransmission of I frames starting with the frame numbered N(R). The value of N(R) in the REJ frame acknowledges I frames numbered up to and including N(R) – 1. New I frames pending initial transmission shall be transmitted following the retransmitted I frame(s).

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

The transmission of an REJ frame shall also indicate the clearance of any busy condition within the sending data link connection entity that was reported by the earlier transmission of an RNR frame by that same data link connection entity.

In addition to indicating the status of a data link connection entity, the REJ command with the P bit set to 1 may be used by the data link connection entity to ask for the status of its peer data link connection entity.

6.4.8 Selective reject (SREJ)

6.4.8.1 Selective reject (SREJ) command/response (for use with s-SREJ procedure)

Implementation of the single-Selective Reject (s-SREJ) procedure is optional; if implemented it shall use the SREJ frame as described here. When implemented, it is used by a data link connection entity to request retransmission of the single I frame numbered N(R). The P/F bit of an SREJ frame is always set to 0. In this case, the N(R) of the SREJ frame does not indicate acknowledgement of any I frames.

Each SREJ exception condition is cleared upon receipt of the I frame with an N(S) equal to the N(R) of the SREJ frame. A data link connection entity may transmit one or more SREJ frames, each containing a different N(R), with the P/F bit set to 0 before one or more earlier SREJ exception conditions have been cleared.

I frames that may have been transmitted following the I frame indicated by the SREJ frame shall not be retransmitted as the result of receiving an SREJ frame. Additional I frames awaiting initial transmission may be transmitted following the retransmission of the specific I frame requested by the SREJ frame.

6.4.8.2 Selective reject (SREJ) response (for use with m-SREJ procedure)

Implementation of the multi-selective reject (m-SREJ) procedure is optional; if implemented it shall use the SREJ response frame as described here. When implemented, it is used by a DLC entity to initiate error recovery by requesting retransmission of one or more (not necessarily contiguous) lost I frames. The N(R) field of the control field of the SREJ frame shall contain the sequence number of the earliest I frame to be retransmitted and the information field shall contain the sequence numbers of additional I frames(s), if any, in need of retransmission.

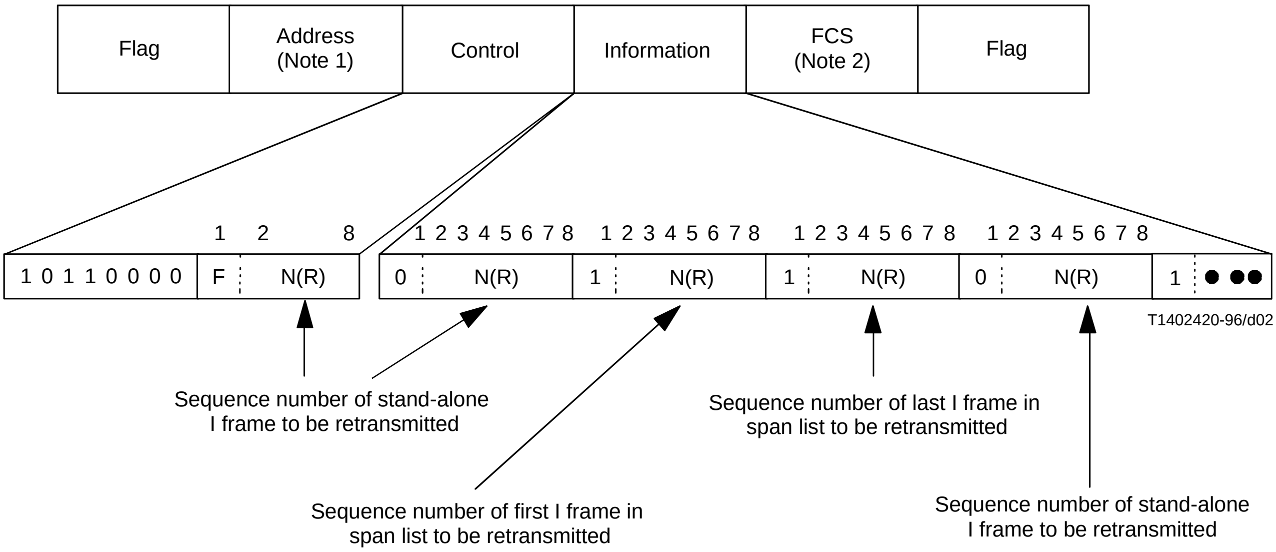
The data link connection entity shall create a list of sequence numbers N(X), N(X) + 1, N(X) + 2, N(Y), N(Z) + 3, N(Z) + 4, …, N(S) – 1, where N(X) is greater than or equal to V(R) and none of the I frames N(X) to N(S) – 1 have been received. The N(R) field of the SREJ frame shall be set to N(X) and the information field set to the list N(X) + 1, …, N(S) – 1. The information field shall be encoded such that there is one octet for each I frame in need of retransmission. The sequence number of each designated I frame shall occupy bit positions 2-8 of an octet, as depicted in Figure 7.

If the list of sequence numbers is too large to fit in the information field of the SREJ frame, then the list shall be truncated to fit in one SREJ frame, by including only the earliest sequence numbers. The truncated sequence numbers may be transmitted in another SREJ frame. The number of bits in the information field of an SREJ frame shall not exceed the value of parameter N401, the maximum number of octets in the information field of a frame.

If the F bit in an SREJ frame is set to 1, then I frames numbered up to N(R) – 1 inclusive are considered as acknowledged. If the F bit in an SREJ frame is set to 0, then the N(R) in the control field of the SREJ frame does not indicate acknowledgement of I frames.

Each SREJ exception condition is cleared upon receipt of the I frame(s) with an N(S) equal to the N(R) identified in the SREJ frame control field and, if present, information field. A data link connection entity may transmit one or more SREJ response frames with their F bit set to 0, each containing one or more different N(R) values before earlier exception conditions have been cleared.

I frames that may have been transmitted following an I frame indicated in an SREJ frame shall not be transmitted as the result of receiving an SREJ frame. Additional I frames awaiting initial transmission may be transmitted following the retransmission of a specific I frame(s) requested by an SREJ frame.



NOTES

1 The maximum size of this field is limited to 2 octets.

2 The FCS field can be either 8-, 16-, or 32-bits in length.

FIGURE 7/V.76

Control and information field encoding of SREJ frame for m-SREJ procedure

6.4.9 Receive not ready (RNR) command/response

The RNR supervisory frame is used by a data link connection entity to indicate a busy condition – that is, a temporary inability to accept additional incoming I frames. The value of N(R) in the RNR frame acknowledges I frames numbered up to and including N(R) – 1.

In addition to indicating the status of a data link connection entity, the RNR command with the P bit set to 1 may be used by the data link connection entity to ask for the status of its peer data link connection entity.

6.4.10 Unnumbered Acknowledgement (UA) response

The UA unnumbered response is used by a data link connection entity to acknowledge the receipt and acceptance of the mode-setting commands (SABME or DISC). Received mode-setting commands are not processed until the UA response is transmitted. An information field is permitted with the UA response. The transmission of the UA response indicates the clearance of any busy condition that was reported by the earlier transmission of an RNR frame by that same data link connection entity.

6.4.11 Disconnected Mode (DM) response

The DM unnumbered response is used by a data link connection entity to report to its peer that the data link connection entity is in the disconnected state and/or unable or unwilling to enter the connected state. An information field is permitted with the DM response.

6.4.12 Frame reject (FRMR) response

The FRMR unnumbered response may be received by a data link connection entity as a report of an error condition not recoverable by retransmission of the identical frame, i.e. at least one of the following error conditions resulting 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 a supervisory or unnumbered frame with incorrect length;

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

d) the receipt of a frame with an information field which exceeds the maximum established length.

An undefined control field is any of the control field encodings not identified in Table 4.

A valid N(R) value is one that is in the range $V(A) \leq N(R) \leq V(S)$.

An information field which immediately follows the control field and consists of five octets is returned with this response and provides the reason for the FRMR response. This information field format is given in Figure 8.

6.4.13 Exchange identification (XID) command/response

XID frames are used to exchange general identification information as provided by the SU. No sequence numbers are contained within the control field of an XID frame. The P/F bit of an XID frame is set to 0.

6.4.14 Test (TEST) command

Implementation of the TEST command frame is optional. When implemented, it is used to conduct a loop-back test between the two SUs. No sequence numbers are contained within the control field of a TEST frame. The P bit of a TEST command frame is set to 0.

An information field, not specified by this Recommendation, is also included in the frame. The SU initiating a loop-back test chooses the contents of the information field. The SU responding to a loop-back test returns the information field received from the originator.

6.5 Use of timers

For various functions in the following subclauses, timers are used to ensure proper operation of the protocol. In these clauses, the following terminology is used to describe timer operations:

a) to start or restart a timer both imply that the timer is set to run from a predefined value;

b) to stop a timer implies that it no longer runs and that the value of the timer at the time it is stopped is of no significance.

7 DLC procedures

When sending the first protocol frame following establishment of the physical connection (e.g. an SABME or XID frame), the originator may first need to transmit flag patterns for a period of time sufficient to guarantee the transmission of at least 16 flag patterns.

8	7	6	5	4	3	2	1	
Rejected frame control field								Octet 4
								5
V(S)							0	6
V(R)							C/R	7
0	0	0	0	W	X	Y	Z	8

NOTES

1 Rejected frame control field is the control field of the received frame which caused the frame reject. When the rejected frame is an unnumbered frame, the control field of the rejected frame is positioned in octet 4, with octet 5 set to 00000000.

2 V(S) is the current send state variable value of the data link connection entity reporting the rejection condition.

3 C/R is set to 1 if the frame rejected was a response and is set to 0 if the frame rejected was a command.

4 V(R) is the current receive state variable value of the data link connection entity reporting the rejection condition.

5 W set to 1 indicates that the control field received and returned in octets 4 and 5 was undefined or not implemented.

6 X set to 1 indicates that the control field received and returned in octets 4 and 5 was considered invalid because the frame contained an information field which is not permitted with this frame or is a supervisory or unnumbered frame with incorrect length. Bit W must be set to 1 in conjunction with this bit.

7 Y set to 1 indicates that the information field received exceeded the maximum established information field length (N401) of the data link connection entity reporting the rejection condition.

8 Z set to 1 indicates that the control field received and returned in octets 4 and 5 contained an invalid N(R).

9 Octet 6, bit 1 and octet 8, bits 5 through 8 shall be set to 0.

FIGURE 8/V.76

FRMR information field format

7.1 Establishment of a data link connection

7.1.1 General

The procedures for DLC establishment in this clause apply to both ERM and UNERM.

The procedures in this clause are used to establish a data link connection (i.e. go from a disconnected to a connected state) to allow the transfer of user data.

On receipt of an L-ESTABLISH request primitive from its SU, the MF shall attempt to establish the data link connection. The data link connection entity transmits an SABME frame; any user-data contained in the L-ESTABLISH request primitive is included in the information field of the SABME frame. All frames other than U-format frames received at this time shall be ignored.

7.1.2 Detailed procedures

7.1.2.1 Establishment procedures

A request to establish the data link connection is initiated by the transmission of the SABME command. All existing exception conditions shall be cleared, the retransmission counter shall be reset, and timer T401 shall then be started (timer T401 is defined in 9.1).

When transmitting an SABME frame, it shall contain the appropriate FCS length as instructed by the SU. All subsequent frames transmitted on the DLC shall contain the same FCS length as the SABME.

To avoid misinterpretation of a received DM response frame, the SABME frame shall always be transmitted with its P bit set to 1.

A data link connection entity receiving an SABME command, if it is able to establish the data link connection (as indicated by receipt of an L-ESTABLISH response primitive from the SU in response to an L-ESTABLISH indication primitive), shall:

- respond with a UA response with the F bit set to the same binary value as the P bit in the received SABME command;
- set V(S), V(R) and V(A) to 0;
- consider the data link connection as established and enter the connected state;
- clear all existing exception conditions;
- clear any existing peer-receiver busy condition; and
- start timer T403 (timer T403 is defined in 9.6) if implemented.

NOTE – When a repeated SABME frame is received during link establishment, indicating that the originating station may not have received the UA response, any unacknowledged I frames remain unacknowledged with respect to the MF. Responsibility for the contents of the information fields of such I frames reverts to the SU. Whether or not the contents of these information fields are reassigned to the MF is decided by the SU.

If the SU is unable to accept establishment of the data link connection (as indicated by an L-RELEASE request primitive from the SU in response to an L-ESTABLISH indication primitive), the data link connection entity shall respond to the SABME command with a DM response with the F bit set to the same binary value as the P bit in the received SABME command.

When returning a UA or DM frame, the DLC entity shall use the same FCS length as present in the received SABME frame. If a UA frame was returned, all subsequent frames transmitted on this DLC shall contain this same FCS length.

Upon reception of the UA response with the F bit set to 1, the originator of the SABME command shall:

- stop timer T401;
- start timer T403 if implemented;
- set V(S), V(R), and V(A) to 0; and
- consider the data link connection as established (i.e. enter the connected state) and inform the SU by using the L-ESTABLISH confirm primitive.

Upon reception of a DM response with the F bit set to 1, the originator of the SABME command shall inform its SU of a failure to establish the data link connection (by issuing an L-RELEASE indication primitive) and stop timer T401. DM responses with the F bit set to 0 shall be ignored in this case.

Upon receipt of an I frame or a supervisory frame, the originator of the SABME command may assume that the responding data link connection entity has received and accepted the SABME command and sent a UA response, but that the UA response was lost in transmission. It may proceed as though a UA response has been received, and perform the actions noted above for reception of the UA response before processing the received I frame or supervisory frame.

7.1.2.2 Procedure on expiry of timer T401

If timer T401 expires before the UA or DM response with the F bit set to 1 is received, the data link connection entity shall:

- retransmit the SABME command as above;
- restart timer T401; and
- increment the retransmission counter (N400).

After retransmission of the SABME command N400 times and failure to receive a response, the data link connection entity shall indicate this to the SU by means of the L-RELEASE indication primitive. Any data in queue shall be discarded.

The value of N400 is defined in 9.2.

7.2 Information transfer

The procedures for information transfer in ERM and UNERM are provided in clause 8 below.

7.3 Orderly release of a DLC

7.3.1 General

The procedures for DLC release in this subclause apply to both ERM and UNERM.

These procedures shall be used to return a DLC to the disconnected state. The SU requests release of a DLC by use of the L-RELEASE request primitive.

All outstanding L-DATA and L-SIGNAL request primitives and all associated frames in queue shall be discarded. The data link connection entity transmits a DISC frame; any user-data contained in the L-RELEASE request primitive is included in the information field of the DISC frame. All frames other than U-format frames received at this time shall be ignored.

7.3.2 Release procedure

A data link connection entity shall initiate a request for release of the connection by transmitting the disconnect (DISC) command.

To avoid misinterpretation of a received DM response frame, the DISC frame shall always be transmitted with its P bits set to 1.

Timer T401 shall then be started and the retransmission counter reset.

A data link connection entity receiving a DISC command while in the connected state shall transmit a UA response with the F bit set to the same binary value as the P bit in the received DISC command. An L-RELEASE indication primitive shall be passed to the SU, and the disconnected state shall be entered.

If the originator of the DISC command receives either:

- a UA response with the F bit set to 1; or
- a DM response with the F bit set to 1, indicating that the peer data link connection entity is already in the disconnected state,

it shall enter the disconnected state and stop timer T401.

The data link connection entity that issued the DISC command is now in the disconnected state and will notify its SU. The conditions relating to this state are defined in 7.4.

7.3.3 Procedure on expiry of timer T401

If timer T401 expires before a UA or DM response with its F bit set to 1 is received, the data link connection entity shall:

- retransmit the DISC command as above;
- restart timer T401; and
- increment the retransmission counter (N400).

If the data link connection entity has not received the correct response as defined in 7.3.2, after N400 attempts to recover, the data link connection entity shall enter the disconnected state and notify its SU.

7.4 Disconnected state

The disconnected state applies to each DLC.

While in the disconnected state:

- the receipt of a DISC command shall result in the transmission of a DM response with F bit set to the value of the received P bit;
- on receipt of an SABME command, the procedures defined in 7.1 shall be followed;
- on receipt of an unsolicited DM response with the F bit set to 0, the data link connection entity shall, if it is able to and the SU is willing, initiate the data link connection establishment procedures by the transmission of an SABME (see 7.1.2.1); otherwise, the DM shall be ignored; and
- all other frame types shall be discarded.

7.5 Collision of unnumbered commands and responses

7.5.1 Identical transmitted and received mode-setting commands

If transmitted and received unnumbered mode-setting commands (SABME or DISC) are the same, the data link connection entities shall send the UA response at the earliest possible opportunity. The indicated state (the connected state if the commands were SABMEs, or the disconnected state if they were DISCs) shall be entered after receiving the UA response. The data link connection entity shall notify its SU by means of the appropriate primitive.

7.5.2 Different transmitted and received mode-setting commands

If the transmitted and received unnumbered mode-setting commands (SABME or DISC) are different, the data link connection entities shall issue a DM response at the earliest possible opportunity. Upon receipt of a DM response with the F bit set to 1, the data link connection entity shall enter the disconnected state and notify its SU by means of an L-RELEASE indication primitive.

7.5.3 Unsolicited DM response and SABME or DISC command

A DM response with its F bit to 0 colliding with an SABME or DISC command shall be ignored.

7.6 Exchange identification procedures

7.6.1 General

Upon receipt of an L-SETPARM request primitive from its SU, a data link connection entity shall initiate exchange identification procedures using XID frames (e.g. to indicate parameter values and optional procedures with the remote station).

NOTE – Procedures for renegotiating parameter values and/or use of optional values, once a DLC has been opened, are for further study.

7.6.2 Exchange identification procedure

Upon receipt of an L-SETPARM request primitive, the data link connection entity shall transmit an XID command frame. The information field of this frame shall contain the user data parameter of this primitive. Timer T401 shall then be started and the retransmission counter, N400, reset.

On receipt of an XID command frame, the data link connection entity shall issue an L-SETPARM indication primitive to its SU, passing it the contents of the information field.

On receipt of an L-SETPARM response primitive from its SU, a data link connection entity shall return the indicated user data in the information field of an XID response frame.

On receipt of an XID response frame, the data link connection entity shall inform its SU by an L-SETPARM confirm primitive of the values contained in the information field.

7.6.3 Procedure on expiry of timer T401

If timer T401 expires before receipt of the XID response frame, the data link connection entity shall:

- retransmit the XID command as above;
- restart timer T401; and
- increment the retransmission counter (N400).

After retransmission of the XID command N400 times and failure to receive an XID response, the data link connection entity shall notify the SU that the exchange identification procedure did not complete.

The value of N400 is defined in 9.2.

7.7 Loop-back test

Upon receipt of an L-TEST request primitive from its SU, the data link connection entity shall transmit a TEST command frame with its P bit set to 0. The information field of the TEST frame shall be used to convey the information provided by the SU. Its receipt does not affect the flow of other frames.

On receipt of a TEST command frame with its P bit set to 0, the data link connection entity shall issue an L-TEST indication primitive to its SU that also conveys the contents of the information field from the received TEST frame.

8 Information transfer modes

Having either transmitted the UA response to a received SABME command or received the UA response to a transmitted SABME command, information transfer may commence. This clause deals with the transfer of user data.

8.1 Error recovery mode

8.1.1 Transmitting I frames

Data received by the data link connection entity from the SU by means of an L-DATA request primitive shall be transmitted in an I frame. The control field parameters N(S) and N(R) shall be assigned the values V(S) and V(R), respectively. V(S) shall be incremented by 1 at the end of the transmission of the I frame.

If timer T401 is not running at the time of transmission of an I frame, it shall be started. If timer T401 expires, the procedures defined in 8.1.8 shall be followed.

If V(S) is equal to V(A) plus *k* (where *k* is the maximum number of outstanding I frames – see 9.4), the data link connection entity shall not transmit any new I frames, but may retransmit an I frame as a result of the error-recovery procedures as described in 8.1.4 and 8.1.5.

When a data link connection entity is in an own-receiver busy condition, it may still transmit I frames, provided that a peer-receiver busy condition does not exist.

NOTE – L-DATA request primitives received while in the timer-recovery condition (see 8.1.11) shall be queued.

8.1.2 Receiving I frames

Independent of a timer-recovery condition, when a data link connection entity is not in an own-receiver busy condition and receives a valid I frame whose N(S) is equal to the current V(R), the data link connection entity shall:

- pass the information field of this frame to the SU using the L-DATA indication primitive;
- increment by 1 its V(R) and act as indicated below.

8.1.2.1 P bit set to 1

If the P bit of the received I frame was set to 1, the data link connection entity shall respond to its peer in one of the following ways:

- if the data link connection entity receiving the I frame is still not in an own-receiver busy condition, it shall send an RR response with the F bit set to 1;
- if the data link connection entity receiving the I frame enters the own-receiver busy condition upon receipt of the I frame, it shall send an RNR response with the F bit set to 1.

8.1.2.2 P bit set to 0

If the P bit of the received I frame was set to 0 and:

a) if the data link connection entity is still not in an own-receiver busy condition:
   - if no I frame is available for transmission or if an I frame is available for transmission but a peer-receiver busy condition exists, the data link connection entity shall transmit an RR response with the F bit set to 0; or
   - if an I frame is available for transmission and no peer-receiver busy condition exists, the data link connection entity shall transmit the I frame with the value of N(R) set to the current value of V(R) as defined in 8.1.1; or

b) if, on receipt of this I frame, the data link connection entity is now in an own-receiver busy condition, it shall transmit an RNR response with the F bit set to 0.

When the data link connection entity is in an own-receiver busy condition, it shall process any received I frame according to 8.1.7.

8.1.3 Sending and receiving acknowledgements

8.1.3.1 Sending acknowledgements

Whenever a data link connection entity transmits an I frame or an RR, RNR or REJ supervisory frame, N(R) shall be set equal to V(R).

8.1.3.2 Receiving acknowledgements

On receipt of a valid I frame or an RR, RNR or REJ supervisory frame, even in the own-receiver busy or the timer recovery condition, the data link connection entity shall treat the N(R) contained in this frame as an acknowledgement for all the I frames it has transmitted with an N(S) up to and including the received N(R) – 1. V(A) shall be set to N(R). The data link connection entity shall stop the timer T401 on receipt of a valid I frame or an RR, RNR or REJ supervisory frame with the N(R) higher than V(A) (actually acknowledging some I frames), or an REJ frame with an N(R) equal to V(A). The data link connection entity shall stop the timer T401 on receipt of an SREJ supervisory frame with an N(R) equal to or higher than V(A), even though there is no acknowledgement function associated with the N(R) contained in the SREJ frame.

NOTES

1 If an RR, RNR or REJ supervisory frame with P bit set to 1 has been transmitted and not acknowledged, timer T401 shall not be stopped.

2 Upon receipt of a valid I frame, timer T401 shall not be stopped if the data link connection entity is in the peer-receiver busy condition (i.e. the remote data link connection entity had indicated a busy condition).

If timer T401 has been stopped by the receipt of an I, RR or RNR frame, and if there are outstanding I frames still unacknowledged, the data link connection entity shall restart timer T401. If timer T401 then expires, the data link connection entity shall follow the recovery procedure as defined in 8.1.8 with respect to the unacknowledged I frames.

If timer T401 has been stopped by the receipt of an REJ frame, the data link connection entity shall follow the retransmission procedures in 8.1.4.

If timer T401 has been stopped by the receipt of an SREJ frame, the data link connection entity shall follow the selective retransmission in 8.1.5 and start timer T401. If timer T401 then expires, the data link connection entity shall follow the recovery procedure defined in 8.1.8 with respect to the unacknowledged I frames.

8.1.4 Receiving REJ frames

On receipt of a valid REJ frame, the data link connection entity shall act as follows:

a) if it is not in the timer-recovery condition:

   – clear an existing peer-receiver busy condition;

   – set its V(S) and its V(A) to the value of the N(R) contained in the REJ frame control field;

   – stop timer T401;

   – start timer T403 if implemented;

   – if it was an REJ command frame with the P bit set to 1, transmit an appropriate supervisory response frame (see Note 2 in 8.1.6) with the F bit set to 1;

   – transmit the corresponding I frame as soon as possible, as defined in 8.1.1, taking into account the items 1) to 3) below and the paragraph following items 1) to 3); and

   – note that a protocol violation has occurred if the received frame was an REJ response frame with the F bit set to 1;

b) if it is in the timer-recovery condition and it was an REJ response frame with the F bit set to 1:

   – clear an existing peer-receiver busy condition;

   – set its V(S) and its V(A) to the value of the N(R) contained in the control field of the REJ frame;

   – stop timer T401;

   – start timer T403 if implemented; and

   – transmit the corresponding I frame as soon as possible, as defined in 8.1.1, taking into account the items 1) to 3) below and the paragraph following items 1) to 3);

c) if it is in the timer-recovery condition and it was an REJ frame other than an REJ response frame with the F bit set to 1:

   – clear an existing peer-receiver busy condition;

   – set its V(A) to the value of the N(R) contained in the control field of the REJ frame; and

   – if it was an REJ command frame with the P bit set to 1, transmit an appropriate supervisory response frame with the F bit set to 1 (see Note 2 in 8.1.6).

Transmission of I frames shall take account of the following:

1) if the data link connection entity is transmitting a supervisory frame when it receives the REJ frame, it shall complete that transmission before commencing transmission of the requested I frame;

2) if the data link connection entity is transmitting an SABME command, a DISC command, a UA response, or a DM response when it receives the REJ frame, it shall ignore the request for retransmission; and

3) if the data link connection entity is not transmitting a frame when the REJ is received, it shall immediately commence transmission of the requested I frame.

All outstanding unacknowledged I frames, commencing with the I frame identified in the received REJ frame shall be transmitted. Other I frames not yet transmitted may be transmitted following the retransmitted I frames.

8.1.5 Receiving SREJ frames

8.1.5.1 Single-SREJ procedure

If the optional selective retransmission procedure has been agreed for use on the data link connection, then receipt of an SREJ frame results in the retransmission of the I frame whose N(S) is equal to the N(R) in the SREJ frame. No other I frames shall be retransmitted as a result of receiving the SREJ frame (however, I frames pending initial transmission may be transmitted).

Transmission of I frames shall take account of the following:

1) if the data link connection entity is transmitting a supervisory frame when it receives the SREJ frame, it shall complete that transmission before commencing transmission of the requested I frame;

2) if the data link connection entity is transmitting an SABME command, a DISC command, a UA response, or a DM response when it receives the SREJ frame, it shall ignore the request for retransmission; and

3) if the data link connection entity is not transmitting a frame when the SREJ is received, it shall immediately commence transmission of the requested I frame.

If the optional selective retransmission procedure has not been agreed for use, then receipt of an SREJ frame shall be treated as an unrecognized command/response control field (see 8.4.2).

8.1.5.2 Multi-SREJ procedure

8.1.5.2.1 SREJ response frame with F bit = 0

When receiving an SREJ response frame with its F bit set to 0, the data link connection entity shall retransmit all I frames whose sequence numbers are indicated in the N(R) field and the information field of the SREJ frame, in the order specified in the SREJ frame. Retransmission shall conform to the following:

a) if the data link connection entity is transmitting a supervisory or I frame when it receives the SREJ frame, it shall complete that transmission before commencing transmission of the requested I frame(s);

b) if the data link connection entity is transmitting an unnumbered command or response when it receives the SREJ frame, it shall ignore the request for retransmission; and

c) if the data link connection entity is not transmitting any frame when it receives the SREJ frame, it shall commence transmission of the requested I frames immediately.

If there is no outstanding poll condition, then a poll shall be sent either by transmitting an RR command (or RNR command if the data link connection entity is in the busy condition) with the P bit set to 1 or by setting the P bit in the last retransmitted I frame. Timer T401 shall be restarted.

If there is an outstanding poll condition, then timer T401 shall not be restarted.

8.1.5.2.2 SREJ response frame with F bit = 1

When receiving an SREJ response frame with its F bit set to 1, the data link connection entity shall retransmit all I frames whose sequence numbers are indicated in the N(R) field and the information field of the SREJ frame, in the order specified in the SREJ frame, except those I frames that were sent subsequent to the frame with the P bit set to 1 was sent. Retransmission shall conform to the following:

a) if the data link connection entity is transmitting a supervisory or I frame when it receives the SREJ frame, it shall complete that transmission before commencing transmission of the requested I frames;

b) if the data link connection entity is transmitting an unnumbered command or response when it receives the SREJ frame, it shall ignore the request for retransmission; and

c) if the data link connection entity is not transmitting any frame when it receives the SREJ frame, it shall commence transmission of the requested I frames immediately.

If any frames are retransmitted, then a poll shall be sent either by transmitting an RR command (or RNR command if the data link connection entity is in the busy condition) with the P bit set to 1 or by setting the P bit in the last retransmitted I frame.

Timer T401 shall be restarted.

8.1.6 Receiving RNR frames

After receiving a valid RNR command or response, if the data link connection entity is not engaged in a mode-setting operation (i.e. not transmitting an SABME or DISC frame), it shall set a peer-receiver busy condition and then:

- if it was an RNR command with the P bit set to 1, it shall respond with an RR response with the F bit set to 1 if the data link connection entity is not in an own-receiver busy condition, and shall respond with an RNR response with the F bit set to 1 if the data link connection entity is in an own-receiver busy condition; and

- if it was an RNR response with the F bit set to 1, an existing timer-recovery condition shall be cleared and the N(R) contained in this RNR response shall be used to update V(S).

The data link connection entity shall take note of the peer-receiver busy condition and not transmit any I frames to the remote data link connection entity.

NOTE 1 – The N(R) in any RR or RNR command frame (irrespective of the setting of the P bit) will not be used to update the send state variable V(S).

The data link connection entity shall then:

- treat the N(R) contained in the received RNR frame as an acknowledgement for all the I frames that have been (re)transmitted with an N(S) up to and including N(R) – 1, and set its V(A) to the value of the N(R) contained in the RNR frame; and

- restart timer T401 unless a supervisory response frame with F bit set to 1 is still expected.

If timer T401 expires, the data link connection entity shall:

- if it is not yet in a timer-recovery condition, enter the timer-recovery condition and reset the retransmission count variable; or

- if it is already in a timer-recovery condition, add one to its retransmission count variable.

The data link connection entity shall then:

a) if the value of the retransmission count variable is less than N400:

   - transmit an appropriate RR, RNR or REJ supervisory command (see Note 2) with P bit set to 1;

   - restart timer T401; and

b) if the value of the retransmission count variable is equal to N400, initiate a termination procedure as defined in 8.4.6.

The data link connection entity receiving the RR, RNR or REJ supervisory frame with the P bit set to 1 shall respond, at the earliest opportunity, with an RR, RNR or REJ supervisory response frame (see Note 2) with the F bit set to 1 to indicate whether or not its own-receiver busy condition still exists.

Upon receipt of the supervisory response with the F bit set to 1, the data link connection entity shall stop timer T401, and:

- if the response is an RR, REJ or SREJ response, the peer-receiver busy condition is cleared and the data link connection entity may transmit new I frames or retransmit I frames as defined in 8.1.1 or 8.1.4, respectively; or

- if the response is an RNR response, the data link connection entity receiving the response shall proceed according to the first paragraph of this subclause.

If a supervisory command (RR, RNR or REJ) with the P bit set to 0 or 1, or a supervisory response frame (RR, RNR or REJ) with the F bit set to 0 is received during the inquiry process, the data link connection entity shall:

- if the supervisory frame is an RR or REJ command frame or an RR, REJ or SREJ response frame, clear the peer-receiver busy condition and if the supervisory frame received was a command with the P bit set to 1, transmit the appropriate supervisory response frame (see Note 2) with the F bit set to 1. However, the transmission or retransmission of I frames shall not be undertaken until the appropriate supervisory response frame with the F bit set to 1 is received or until the expiry of timer T401; or

– if the supervisory frame is an RNR command frame or an RNR response frame, retain the peer-receiver busy condition and if the supervisory frame received was an RNR command with P bit set to 1, transmit the appropriate supervisory response frame (see Note 2) with the F bit set to 1.

NOTE 2 – If the data link connection entity is not in an own-receiver busy condition and is in a reject-exception condition [that is, an N(S) sequence error has been detected and an REJ frame has been transmitted, but the requested I frame has not been received], the appropriate supervisory frame is the RR frame.

– If the data link connection entity is not in an own-receiver busy condition but is in an N(S) sequence error exception condition [that is, an N(S) sequence error has been detected but an REJ frame has not been transmitted], the appropriate supervisory frame is the REJ frame;

– if the data link connection entity is in its own-receiver busy condition, the appropriate supervisory frame is the RNR frame;

– otherwise, the appropriate supervisory frame is the RR frame.

8.1.7 Own-receiver busy condition

When the data link connection entity enters an own-receiver busy condition, it shall transmit an RNR frame at the earliest opportunity.

The RNR frame may be either:

– an RNR frame with the F bit set to 0; or

– if this condition is entered on receiving a command frame with the P bit set to 1, an RNR response with the F bit set to 1; or

– if this condition is entered on expiry of timer T401, an RNR command with the P bit set to 1.

All received I frames with the P bit set to 0 shall be discarded, after updating V(A).

All received RR, RNR and REJ supervisory frames with the P/F bit set to 0 shall be processed, including updating V(A).

All received SREJ supervisory frames with the P/F bit set to 0 shall be processed as specified in 8.1.5.

All received I frames with the P bit set to 1 shall be discarded, after updating V(A). However, an RNR response frame with the F bit set to 1 shall be transmitted.

All received RR, RNR and REJ supervisory frames with the P bit set to 1 shall be processed, including updating V(A). An RNR response with the F bit set to 1 shall be transmitted.

To indicate to the peer data link connection entity the clearance of the own-receiver busy condition, the data link connection entity shall transmit an RR frame or, if a previously-detected N(S) sequence error has not yet been reported, an REJ frame with its N(R) set to the current value of V(R) or an SREJ frame (if agreed for use).

8.1.8 Waiting acknowledgement

The data link connection entity shall maintain an internal retransmission count variable.

If timer T401 expires, the data link connection entity shall:

– if it is not yet in the timer-recovery condition, enter the timer-recovery condition and reset the retransmission count variable; or

– if it is already in the timer-recovery condition, add one to its retransmission count variable.

The data link connection entity shall then:

a) if the value of the retransmission count variable is less than N400, restart timer T401 and transmit an appropriate supervisory command (see Note 2 in 8.1.6) with the P bit set to 1; or

b) if the value of the retransmission count variable is equal to N400, initiate a termination procedure as defined in 8.4.6.

The time-recovery condition is cleared when the data link connection entity receives a valid RR, RNR or REJ supervisory response frame with the F bit set to 1. If the received RR, RNR or REJ supervisory frame N(R) is within the range from its current V(A) to its current V(S), inclusive, it shall set its V(S) to the value of the received N(R). If the received SREJ supervisory frame N(R) is within the range from the current V(A) to V(S), inclusive, it shall follow the procedures outlined in 8.1.5.2.1 or 8.1.5.2.2 depending on the setting of the F bit. Timer T401 shall be stopped if the received supervisory frame response is an RR or REJ response, and then the data link connection entity shall resume with I frame transmission or retransmission, as appropriate. Timer T401 shall be stopped and restarted if the received supervisory response is an RNR response, to proceed with the inquiry process according to 8.1.6.

8.1.9 N(S) sequence error

An N(S) sequence error exception condition occurs in the receiver when a valid I frame is received containing an N(S) value that is not equal to the V(R) at the receiver. Methods for recovering from N(S) sequence error exception conditions are:

a) use of REJ frames (mandatory);

b) use of SREJ frames – single frame (s-SREJ) recovery (optional and requires negotiation; see clause 10);

c) use of SREJ frames – multiple frame (m-SREJ) recovery (optional and requires negotiation; see clause 10).

The action of the receiver depends on whether or not the optional selective-retransmission (either single or multi) procedure has been agreed for use on the data link connection. If it has, the information field of I frames whose N(S) is not equal to the V(R) at the receiver shall be held for subsequent delivery to the SU until the expected I frame [i.e. the I frame with its N(S) = V(R)] is received. If the selective-retransmission procedure has not been agreed for use, the information field of all I frames whose N(S) does not equal the V(R) shall be discarded.

In either case, the receiver shall not acknowledge [nor increment its V(R)] the I frame causing the sequence error, nor any I frames which may follow, until an I frame with the correct N(S) is received.

A data link connection entity that receives one or more I frames having sequence errors but which are otherwise error-free, or subsequent supervisory frames, shall use the N(R) and P/F bit setting contained in the control field to perform connection-control functions; for example, to receive acknowledgement of previously-transmitted I frames and to cause the data link connection entity to respond if the P bit is set to 1. Therefore, the retransmitted I frame may contain an N(R) value and P bit that are updated from, and therefore different from, the ones contained in the originally transmitted I frame.

Either the REJ frame or the SREJ frame (either for the s-SREJ procedure or the m-SREJ procedure) is used by a receiving data link connection entity to initiate an exception condition recovery (retransmission) following the detection of an N(S) sequence error.

For a given direction of information transfer:

– only one REJ exception condition shall be established at a time;

– when using the s-SREJ procedure, any number of SREJ exception conditions may be established at a time;

– when using the m-SREJ procedure, any number of SREJ exception conditions with F = 0 may be established at a time; only one SREJ condition with F = 1, in response to a poll, may be established.

A data link connection entity receiving an REJ command or response frame shall initiate sequential transmission (retransmission) of I frames starting with the I frame indicated by the N(R) contained in the REJ frame.

A data link connection entity receiving an SREJ command or response frame shall initiate retransmission of the I frame indicated by the N(R) and, if present, the information field contained in the SREJ frame.

An REJ or SREJ exception condition is cleared when the requested I frame(s) is received or when an SABME or DISC command is received.

Neither REJ or SREJ frames may be retransmitted [in case of loss of either, the expiration of timer T401 in the remote data link connection entity will eventually cause resending of the requested I frame(s)]. However, if examination of received I frames indicates that retransmission of the requested frame has occurred without having satisfied the reject condition, a new REJ or SREJ condition may optionally be established and the REJ or SREJ frame repeated.

8.1.10 N(R) sequence error

An N(R) sequence error exception condition occurs in the transmitter when a valid supervisory frame or I frame is received that contains an invalid N(R) value.

A valid N(R) is one that is in the range $V(A) \leq N(R) \leq V(S)$.

The information field contained in an I frame that is correct in sequence and format may be delivered to the SU by means of the L-DATA indication primitive.

The data link connection entity shall initiate termination according to 8.4.6.2.

8.1.11 Timer-recovery condition

If a data link connection entity, due to a transmission error, does not receive a single I frame or the last I frame(s) in a sequence of I frames, it will not detect an out-of-sequence exception condition and, therefore, will not transmit an REJ or SREJ frame.

The data link connection entity that transmitted the unacknowledged I frame(s) shall, on the expiry of timer T401, take appropriate recovery action as defined in 8.1.8 to determine at which I frame retransmission must begin.

8.2 Unacknowledged non-error recovery mode

On receipt of an L-UNITDATA request primitive, the MF shall transmit a UI command frame with its P bit set to 0 and with its information field containing the data.

On receipt of a UI command frame with its P bit set to 0, the MF shall signal an L-UNITDATA indication primitive to the SU with the data contained in the information field.

8.3 Transfer of user-control information

Transfer of user-control information occurs through the SU's invocation of the appropriate MF primitives (e.g. L-UNITDATA or L-DATA).

See Annex B for procedures and encoding of user-control messages to signal breaks.

8.4 Additional information-transfer procedures

8.4.1 Invalid frame condition

Any frame received that is invalid shall be discarded (but see 5.3).

As an optional procedure in response to an invalid frame in ERM, a DLC entity may transmit an REJ frame. Otherwise, the frame is ignored and no action is taken.

8.4.2 Frame-rejection condition

A frame-rejection condition results from one of the conditions described in 6.4.1 (first paragraph) or 6.4.12, items b), c) and d).

Upon occurrence of a frame-rejection condition while a DLC is established, the data link connection entity shall initiate termination (see 8.4.6.2). At other times, the frame causing the condition shall be discarded.

NOTE – For satisfactory operation, it is essential that a receiver is able to discriminate between invalid frames, as defined in 5.3, and I frames with an information field that exceeds the maximum established length [see item d) in 6.4.12]. An unbounded frame may be assumed and, thus, discarded if two times the longest-permissible frame plus two octets are received without a flag detection.

8.4.3 Receipt of an FRMR response frame

Upon receipt of an FRMR response frame in the connected state, the data link connection entity shall initiate termination (see 8.4.6, 8.4.6.2).

8.4.4 Unsolicited response frames

The action to be taken on the receipt of an unsolicited response frame is defined in Table 5.

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Actions taken on receipt of unsolicited response frames

Unsolicited response frame	Disconnected state	Awaiting connection establishment	Awaiting connection release	Connected state	
				Not in timer-recovery condition	In timer-recovery condition
UA response F = 1	Ignore*	(Solicited)	(Solicited)	Ignore*	Ignore*
UA response F = 0	Ignore*	Ignore*	Ignore*	Ignore*	Ignore*
DM response F = 1	Ignore	(Solicited)	(Solicited)	Ignore*	(Solicited)
DM response F = 0	Establish connection	Ignore	Ignore	Terminate connection	Terminate connection
RR, RNR and REJ response: F = 1	Ignore	Ignore	Ignore	Ignore*	(Solicited)
RR, RNR and REJ response: F = 0	Ignore	Ignore	Ignore	(Solicited)	(Solicited)
SREJ response F = 1	Ignore	Ignore	Ignore	Terminate connection	Terminate connection
SREJ response F = 0	Ignore	Ignore	Ignore	(Solicited)	(Solicited)

NOTES

1 For ignore-cases marked with an asterisk (*), the data link connection entity shall inform the SU of a protocol violation.

2 Cases marked as (solicited) represent proper protocol operation.

8.4.5 Monitoring function

8.4.5.1 General

This function, if implemented, may be operated over one or many DLCIs.

The procedural elements defined in the earlier parts of clause 8 allow for the supervision of the data link connection. This describes procedures that may be used to provide this monitoring function. The use of this function is optional.

8.4.5.2 Supervision during the connected state

The connection verification is a service provided by the data link connection entity to its SU. This implies that the SU is informed in case of a failure only. Furthermore, the procedure may be incorporated in the "normal" exchange of information and may become more efficient than a procedure based on the involvement of the SU.

The procedure is based on supervisory command frames (RR command, RNR command) and timer T403, and operates during the connected state as follows.

If there are no frames being exchanged on the data link connection (neither new nor outstanding I frames, nor supervisory frames with a P bit set to 1), there is no means to detect a faulty DLC condition. Timer T403 represents the maximum time allowed without frames being exchanged.

If timer T403 expires, a supervisory command with a P bit set to 1 is transmitted. Such a procedure is protected against transmission errors by making use of timer T401 and the N400 retransmission count.

8.4.5.3 Connection verification procedures

8.4.5.3.1 Start timer T403

The timer T403 is started:

- when the connected state is entered; and
- in the connected state whenever timer T401 is stopped.

Upon receiving an I or supervisory frame, timer T403 will be restarted if timer T401 is not to be started.

8.4.5.3.2 Stop timer T403

The timer T403 is stopped:

- when, in the connected state, the timer T401 is started; and
- upon leaving the connected state.

8.4.5.3.3 Expiry of timer T403

If timer T403 expires, the data link connection entity will act as follows (it should be noted that timer T401 is neither running nor expired):

a) set the retransmission count variable to 0;

b) enter the timer-recovery condition (see 8.1.11);

c) transmit a supervisory command with the P bit set to 1 as follows:
   - if there is not an own-receiver busy condition, transmit an RR command; or
   - if there is an own-receiver busy condition, transmit an RNR command;

d) start timer T401; and

e) inform the SU after N400 retransmissions.

8.4.6 Termination of the data link connection

8.4.6.1 Criteria for termination

The criteria for termination of a data link connection are defined in this subclause by the following conditions:

- the occurrence of N400 retransmission failures while in the timer recovery condition (see 8.1.8);
- the occurrence of a frame-rejection condition as identified in 8.4.2;
- the receipt, while in the connected state, of an FRMR response frame (see 8.4.3);
- the receipt, while in the connected state, of an unsolicited DM response with the F bit set to 0 (see 8.4.4);
- the receipt, while in the timer recovery condition, of a DM response with the F bit set to 1.

NOTE – It is for further study whether receipt, while in the connected state, of an SABME frame should be included in the above list of termination conditions (recognizing the need to accommodate the possibility that the SABME frame may have been retransmitted due to a lost UA response).

8.4.6.2 Procedures

In all termination situations, an L-RELEASE indication primitive shall be passed to the SU, and the disconnected state shall be entered.

9 System parameters of the multiplex function

This clause specifies the parameters needed for proper operation of the MF. The values to be used for these parameters are made known to the DLC entity through local means. See Annex C.

All parameters, except window size, apply to both ERM and UNERM.

9.1 Acknowledgement timer (T401)

The acknowledgement timer governs the amount of time that a data link connection entity will wait for an acknowledgement before resorting to other action (e.g. transmitting a frame). The two data link connection entities associated with a connection may operate with a different value of T401.

NOTE – This timer should be regarded as a logical parameter. That is, there can be one acknowledgement timer associated with each MF function (e.g. transmitting an I frame, sending a frame with its P bit set to 1) that requires an acknowledgement to be received before expiration of this timer. This does not necessarily imply separate timer circuits.

9.2 Maximum number of retransmissions (N400)

N400 governs the maximum number of times that a data link connection entity will re-attempt a procedure requiring a response. The two data link connection entities associated with a connection may operate with a different value of N400.

9.3 Maximum number of octets in an information field (N401)

N401 governs the maximum number of octets that can be carried in the information field of an I frame, an SREJ frame (m-SREJ procedure only), an XID frame, a UI frame, a UIH frame (see Appendix II), an SABME frame, a UA frame, a DISC frame, a DM frame, or a TEST frame transmitted by a data link connection entity. A default value for a DLC may be expressed as a specific value (e.g. 128) or implied by certain characteristics pertaining to the operation of the DLC (e.g. the maximum size block associated with the coder selected for an audio channel). There may also be frame-specific maxima for a DLC that may apply for certain procedures (e.g. a maximum information-field size for UI frames different than the maximum for the SABME frame). This parameter consists of two subparameters – one for each direction of transmission (i.e. a maximum information-field size in the direction from the DLC-opener to the remote station and a maximum from the remote station to the DLC-opener). Identical values need not be used for each direction.

9.4 Window size (*k*)

k governs the maximum number of I frames that a data link connection entity can have outstanding (i.e. unacknowledged). This parameter consists of two subparameters – one for each direction of transmission (i.e. a maximum window size in the direction from the DLC-opener to the remote station and a maximum from the remote station to the DLC-opener). Identical values need not be used for each direction.

9.5 Reply delay timer (T402) – Optional

T402 is the maximum amount of time the data link connection entity may wait, following receipt of any frame requiring a reply, before it initiates transmission of an appropriate reply in order to ensure that the reply frame is received by the remote data link connection entity prior to expiration of the remote data link connection entity's T401 timer. If this timer expires, then the reply that would have been returned prior to its expiration shall not be sent.

NOTE – The necessity for an operation of such a timer remains for further study.

9.6 Inactivity timer (T403) – Optional

T403 represents the maximum amount of time a data link connection entity will allow to elapse without frames being exchanged on the data link connection. The two data link connection entities associated with a connection may operate with a different value of T403. While no default value is specified for T403, it should take on relatively small values so that faults can be detected early.

9.7 DLCI values

The DLCI value in the address field of a frame transmitted by the error control function serves to identify the connection between two peer data link connection entities.

9.8 Operational mode

This parameter indicates whether the DLC shall be used to support ERM or UNERM. The station initiating establishment of the DLCI shall select the mode of operation and convey this to the remote station. There is no negotiation of this parameter.

10 Negotiation of optional procedures

The following procedures are optional for MF operation (see Annex C):

a) in place of the REJ-recovery procedure for ERM operation, one of:
   - s-SREJ procedure for selective retransmission using an SREJ frame with no information field to provide retransmission of only a single I frame; or
   - m-SREJ procedure for selective retransmission using an SREJ frame with an optional information field for span-list encoding to allow retransmission of one or more I frames;

b) loop-back test, where the SU can determine whether its peer is operational;

c) in place of 16-bit FCS, selection of one of the alternative 8-bit FCS or 32-bit FCS;

d) suspend/resume operation (see Annex A) and whether an address field is present;

e) in place of UI frames, use of the unnumbered information with header check feature, including the number of initial octets after the opening flag that are protected by the FCS (see Appendix II).

The SU is responsible for determining, with its peer, whether to use an optional procedure. Use of any optional procedure requires agreement/support by both stations. If both stations support an option, then the MF is informed, through a means beyond the scope of this Recommendation, if the procedure is selected for use.

Annex A

Optional suspend/resume operation

A.1 Introduction

The bit streams that are multiplexed using the procedures of this Recommendation, based on their DLCI values, can be considered as falling into one of two classes:

– **real-time**, or delay-sensitive traffic; speech/audio falls into this class; or

– **non-real-time**, or delay-insensitive traffic; data falls into this class.

For real-time (RT) traffic, the quality as perceived by the receiving user is degraded as the end-to-end delay increases. For non-real-time (NRT) traffic, this is generally not the case as long as the overall delay does not exceed some (relatively large) bound.

Consider a scenario in which a NRT frame is in the process of being transmitted when an RT frame is ready to be sent. With the basic frame format defined in this Recommendation, the RT frame must wait until transmission of the NRT frame is complete or the NRT frame must be aborted. The delay seen by the RT frame can be as long as it takes to transmit a complete maximum-length NRT frame. For an information-field length of 128 octets, this delay is about 70 msec at 14.4 kbit/s. The delay can clearly be reduced by employing a smaller maximum frame length; however, this will increase the multiplexing overhead.

Suspend/resume is an enhancement to the multiplex platform that minimizes the delay seen by RT frames. Basically, suspend/resume permits the transmission of an NRT frame to be interrupted if an RT frame becomes ready to be sent; transmission of the NRT frame is resumed from the point at which it was interrupted once transmission of the RT frame is complete.

A.2 Abbreviations

The following additional abbreviations apply to this annex.

NRT Non-real-time

RF Resume Flag

RT Real-time

S/R Suspend/Resume

SF Suspend Flag

A.3 Operation of suspend/resume

This defines the normal operation of a suspend/resume (S/R) entity using the procedures defined in this annex. Interoperability of the S/R option with the basic multiplex platform is discussed below.

Two classes of traffic, real-time (RT) and non-real-time (NRT), are distinguished as noted above. A given DLC is an RT DLC or NRT DLC, depending on the class of traffic it carries. The traffic-class of an information stream is specified when the DLC is established. RT frames are distinguished from NRT frames by their DLCI values.

Each DLC has its own value of maximum frame length. The maximum length of all NRT frames is designated as $N401_{NRT}$ while all RT frames have a maximum frame length $N401_{RT}$.

In addition to the basic-format flag ("01111110") as defined in 5.1.2, two new delimiters are defined: the **suspend flag** ("011111110"); and the **resume flag** ("0111111110"). When using S/R, the abort sequence (see 5.4) is redefined to be at least *nine* consecutive 1-bits. The possible frame formats are illustrated below.

NRT (data) frame	F	A	C	C	I (max N401NRT)	FCS	FCS

RT (voice) frame (talkspurt)	SF	A	I (max N401RT)	FCS

RT (voice) frame (silence)	SF	A	I	FCS	RF

NOTES

1 The use of an address field is optional and made known to the S/R entity through means outside the scope of this Recommendation.

2 The RT frames are shown using an 8-bit FCS.

3 The RT frames do not have an explicit control field; the treatment of RT frames is as if they were UI frames.

There are three states associated with S/R operation: the **normal** state; the **suspend** state; and the **abort** state. The abort state is employed for handling error conditions, as described below. Operation in the normal and suspend states, and transitions between them, is as follows:

a) In normal state, a sending S/R entity transmits frames in the usual way, separated by normal flags; except:

 – If an RT frame becomes ready to be sent while transmission of an NRT frame is in progress, the S/R entity stops transmission of the NRT frame, transmits a single suspend flag, and then commences transmission of the RT frame; at this point, the S/R entity has entered suspend state.

b) For a sending S/R entity in suspend state, when transmission of an RT frame is completed:

 – If another RT frame is ready to be sent, the S/R entity transmits a single suspend flag followed by this RT frame, and remains in suspend state.

 – If there is no RT frame ready to be sent, then:

  i) If the RT frame whose transmission was just completed was **not** a maximum length RT frame (i.e. its information field was less than N401RT), then the S/R entity transmits a single RF and then resumes transmission of the suspended NRT frame from the point at which it was interrupted. At this point, the S/R entity returns to normal state.

  ii) If the RT frame whose transmission was just completed was a maximum length RT frame, then the S/R entity resumes transmission of the suspended NRT frame from the point at which it was interrupted. At this point, the S/R entity returns to normal state. Note that the next octet of the NRT frame is transmitted immediately following the FCS field of the RT frame, with no intervening RF.

c) In normal state, a receiving S/R entity receives frames in the usual way, separated by normal flags; except:

 – If an SF is received in the midst of an NRT frame, receipt of the NRT frame is suspended, the frame that follows the SF is treated as an RT frame, and the S/R entity enters suspend state.

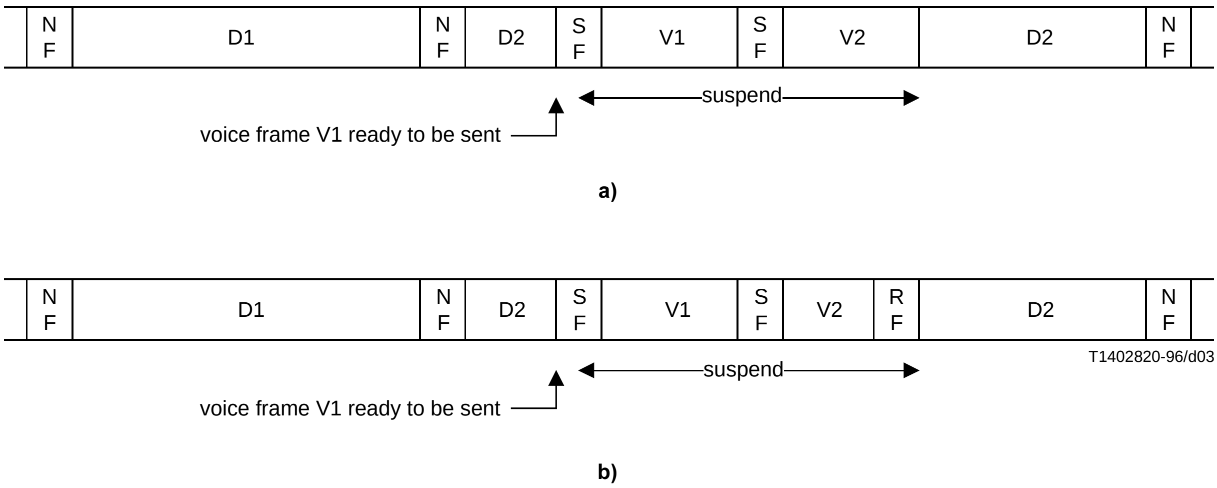
d) A receiving S/R entity in suspend state will count octets following the address field, if agreed to be used, of the frame being received.

 – If an SF is received with the octet count less than or equal to N401RT plus the length of the FCS field, then receipt of the RT frame completes normally, the next frame is treated as an RT frame, and the S/R entity remains in suspend state.

– If an RF is received with the octet count less than or equal to N401RT plus the length of the FCS field, then receipt of the RT frame completes normally, receipt of the suspended NRT frame continues with the octet immediately following the flag, and the S/R entity returns to normal state.

– If the octet count is equal to N401RT plus the length of the FCS field and the bit pattern that follows immediately is neither an SF nor an RF, then receipt of the RT frame is completed as a maximum-length RT frame, receipt of the suspended NRT frame continues with the octet immediately following the FCS field of the completed RT frame, and the S/R entity returns to normal state.

Error conditions are discussed below. A simple example is depicted.



Two simple suspend/resume examples: Data frames D1 and D2 are NRT frames. Voice frames V1 and V2 are RT frames. "NF" is a normal flag, "SF" is a suspend flag, and "RF" is a resume flag. In a), frame V2 is a maximum-length RT frame. In b), frame V2 is not a maximum-length RT frame. In both cases, frame V2 is ready to be sent before transmission of frame V1 is complete.

The following properties of suspend/resume will be noted:

– An RT frame that would suspend transmission of an NRT frame does not carry an HDLC control field[1].
– Only RT frames are sent and received in suspend state.
– Only normal flags are sent and received within normal state.
– Only suspend flags are sent and received within suspend state.
– RT frames are never suspended.
– An NRT frame may be suspended and resumed several times.

A.4 Error conditions with suspend/resume

For S/R entities, the definition and handling of invalid frames and S/R violations are as defined in this subclause.

Note that the receipt of an abort sequence is considered to be an error condition and as such is also discussed in this subclause.

[1] A frame other than an RT "UI" frame (e.g. a DISC for releasing an RT DLC) is not considered an RT frame and would not suspend the transmission of an NRT frame.

A.4.1 Invalid frames

An NRT frame is invalid if it meets the conditions for invalid frames specified in 5.3, with the clarification that the flags that bound the frame are the normal flags that mark the beginning and the end of the frame. In addition, any NRT frame for which some S/R error condition (e.g. invalid RT frame, S/R violation, abort state) occurs between its opening and closing flags is considered to be an invalid frame.

An RT frame is invalid if it meets one of the following conditions:

a) it has zero octets between the address field, if agreed to be used, and the FCS field;

b) it has more than N401RT octets between the address field, if agreed to be used, and the FCS field;

c) it does not consist of an integral number of octets following zero-bit extraction;

d) it contains a frame check sequence error;

e) it contains an address field, if agreed to be used, that is not identified with an RT DLCI.

A.4.2 Suspend/resume violations

The following S/R protocol violations are identified:

a) an SF is followed immediately by a normal, suspend or resume flag;

b) an RF is followed immediately by a normal, suspend or resume flag;

c) a normal flag is received in suspend state;

d) an RF is received in normal state;

e) a normal flag is followed immediately by a suspend or resume flag.

A.4.3 Abort state

The abort state is used primarily when, as a result of an error condition, the proper state for an S/R entity cannot be determined.

For a receiving S/R entity in abort state:

a) If a normal flag is received, the S/R entity is placed in normal state.

b) If an SF is received, the S/R entity is placed in suspend state, and the frame that follows is taken to be an RT frame. Note that any NRT frame that would then be "resumed" will be considered an invalid frame.

c) If an RF is received, the S/R entity remains in abort state, and the NRT frame being "resumed" is considered an invalid frame.

A.4.4 Handling of error conditions

Error conditions are handled by an S/R entity as follows:

a) If an abort sequence is received, the frame being received is discarded, and the S/R entity is placed in abort state.

b) If an invalid NRT frame is received, the frame is discarded. If the frame was terminated by a normal flag, the S/R entity remains in normal state; otherwise, the S/R entity is placed in abort state.

c) If an invalid RT frame is received, the frame is discarded. If the frame was terminated by a normal flag, the S/R entity remains in normal state; otherwise, the S/R entity is placed in abort state.

d) If a normal flag is received in suspend state, the frame being received is discarded, and the S/R entity is placed in abort state.

e) If an RF is received in normal state, the frame being received is discarded, and the S/R entity is placed in abort state.

f) If a suspend or resume flag is followed immediately by a normal, suspend or resume flag, the frame received prior to the flag is discarded, and the S/R entity is placed in abort state.

Note that there are several error conditions that will result in an NRT frame being declared invalid at some point during its reception, e.g. while it is suspended.

A.5 Interoperability of suspend/resume with basic frame format

A key property of the S/R protocol is that a station with S/R capability interoperates directly with a station without S/R capabilities.

If S/R operation has not been selected, a station capable of supporting S/R will clearly never send suspend or resume flags, and will treat such flags if received as abort sequences. In other words, a station with S/R capability behaves exactly like a station without this capability while S/R is not enabled.

A.6 Error-recovery performance

At issue here is the ability of an S/R entity to recover to the proper state following an error condition. Consider two examples:

a) An NRT frame being sent is suspended, a single maximum-length RT frame is sent, and the NRT frame is resumed. The SF is corrupted at the receiver and not detected. The closing flag of the NRT frame is correctly received:

   – The receiving S/R entity will see the RT frame as part of the NRT frame, i.e. the NRT frame will be seen as consisting of all the octets between the opening and closing flags of the NRT frame. The invalidity of the received frame will be detected, primarily by FCS check (in this respect, the scenario is almost identical to the case of a corrupted normal flag). The receiving S/R entity is correctly in normal state after receiving the normal flag that closes the NRT frame.

b) An NRT frame being sent is suspended, a single short RT frame is sent, followed by an RF and the remainder of the NRT frame. The RF is corrupted at the receiver and not detected:

   – Assume that the octet count for the RT frame being received expires before the closing flag of the NRT frame is detected. The invalidity of the RT frame will be detected, primarily by FCS check. As a result, the suspended NRT frame will also be declared invalid and discarded. The normal closing flag of the NRT frame will cause the receiving S/R entity to correctly return to normal state.

   – Assume that the normal closing flag of the NRT frame is received before the RT octet count expires. This is an S/R violation, and the RT frame is declared invalid and discarded. The suspended NRT frame will also be declared invalid and discarded. The receiving entity is placed in abort state, and the next flag received will determine its proper state.

Annex B

Procedures and encoding for conveying break signals

B.1 Procedures for transfer of break signals

B.1.1 General

Upon receipt of an L-SIGNAL request primitive from its SU, a DLC entity shall transmit a UI command frame with its P bit set to 0. The information field of the UI command frame shall be encoded to indicate a break (BRK) message and shall contain the break-handling option as indicated by the SU. If the L-SIGNAL request primitive includes a break length, it shall also be encoded in the information field of the UI frame.

On receipt of a UI command frame indicating a BRK, the DLC entity shall issue an L-SIGNAL indication primitive to its SU, conveying the break-handling option and, if present, the break length. On receipt of an L-SIGNAL response primitive from its SU, a DLC entity shall transmit a UI response frame as soon as possible with its F bit set to the same binary value as the received UI command frame. The information field of the UI response frame shall be encoded to indicate a break acknowledgement (BRKACK) message.

On receipt of a UI response frame with a BRKACK message in reply to a UI command frame conveying a BRK message, a DLC entity shall issue an L-SIGNAL confirm primitive to its SU.

NOTE – The exchange of UI frames, in and of itself, does not provide a confirmed service. The confirmed nature of the L-SIGNAL service provided to the SU, as described here, comes about through the association and interpretation of the contents of the information fields of the UI frames exchanged and not the association of a UI response frame with a previously-transmitted UI command frame.

B.1.2 State variables and parameters

B.1.2.1 Send and receive sequence numbers

To distinguish between unique and duplicate UI frames carrying break information, a DLC entity shall perform a sequencing operation, modulo 2, on the information field of the UI frame. Bit 8 of the first octet of the information field shall be used for this purpose. As such, bit 8 serves as a break send sequence number, N(SB), in BRK message while it serves as a break receive sequence number, N(RB), in BRKACK messages.

B.1.2.2 Send state variable V(SB)

The DLC entity shall maintain the break send state variable V(SB). V(SB) denotes the value of N(SB) in the next BRK message sent as a result of receiving an L-SIGNAL request primitive from the SU. V(SB) is complemented each time a transmitted BRK message is correctly acknowledged by a BRKACK message. Initially when a DLC is established, V(SB) is set to zero.

B.1.2.3 Receive state variable V(RB)

The DLC entity shall maintain the break receive state variable V(RB). V(RB) denotes the expected value of N(SB) in the next BRK message to be received. If N(SB) in the next received BRK message is equal to V(RB), then V(RB) shall be complemented prior to sending the BRKACK message. Initially when a DLC is established, V(RB) is set to zero.

B.1.3 Break procedures

B.1.3.1 Transmitting a BRK message

On receipt of an L-SIGNAL request primitive, the DLC entity shall transmit a BRK message in a UI command frame with its P bit set to 0. The DLC entity shall set N(SB) to the current value of V(SB), start the acknowledgement timer T401 (see 9.1) and set the retransmission counter N400 (see 9.2) to zero.

B.1.3.2 Receiving a BRK message

When receiving a BRK message in a UI command frame, the DLC entity shall check whether N(SB) is equal to the current value of V(RB). If it is, the DLC entity shall issue an L-SIGNAL indication primitive to the SU, passing it the break-handling option and, if present, the length of break information. The DLC entity shall also complement the value of V(RB).

Upon receipt of an L-SIGNAL response primitive, the DLC entity shall transmit a BRKACK message in a UI response frame with N(RB) equal to the value of V(RB). The F bit of the UI response frame shall be set to the same binary value as the received UI command frame.

If N(SB) in the received BRK message is not equal to V(RB), then the DLC entity shall discard the BRK message and retransmit the previous BRKACK message with N(RB) equal to the current value of V(RB). No L-SIGNAL indication primitive shall be issued to the SU.

B.1.3.3 Receiving a BRKACK message

When receiving a BRKACK message in a UI response frame, the DLC entity shall check whether N(RB) is equal to V(SB) + 1. If it is, the DLC entity shall complement V(SB), stop the acknowledgement timer T401, and issue an L-SIGNAL confirm primitive to the SU. If N(RB) is not equal to V(SB) + 1, the DLC entity shall ignore the BRKACK message.

B.1.3.4 Expiration of the acknowledgement timer

If T401 expires before a BRKACK message is received to acknowledge the last BRK message transmitted, the DLC entity shall retransmit the BRK message with N(SB) equal to the current value of V(SB). No more than N400 retransmissions shall occur. Failure to receive a BRKACK after N400 retransmissions shall be reported to the SU.

B.2 Encoding of break information

The encoding of BRK and BRKACK messages is shown in Figure B.1.

Bits (8 7 6 5 4 3 2 1)	Octet	Present In
Break Message Type (see B.2.1 and Table B.1)	1	BRK, BRKACK
Break Handling (see B.2.2 and Table B.2)	2	BRK
Break Length (see B.2.3)	3	BRK

FIGURE B.1/V.76

Format of BRK and BRKACK messages

B.2.1 Message type

The encoding of octet 1, the message type, is given in Table B.1.

TABLE B.1/V.76

Coding of message types

Message type	Bits 8	7	6	5	4	3	2	1
BRK	X	1	0	0	0	0	0	0
BRKACK	X	1	1	0	0	0	0	0

NOTES

1 Encodings not shown above are reserved.

2 X is used as the break sequence number as discussed in B.1.2.

B.2.2 Break handling option

The encoding of octet 2, the break handling option, is given in Table B.2.

TABLE B.2/V.76

Coding of break handling option

Bit	Meaning
8	Data discard (D) bit: 0: no discarding of data 1: discarding of data not yet delivered
7	Data sequencing (S) bit: 0: break delivered in sequence with respect to data 1: break precedes data received but not delivered
6-1	Reserved

B.2.3 Break length

The break length, which is optional, is binary-coded in octet 3 in units of 10 ms. Bit 1 is the low-order bit. The value of “11111111” shall be used to indicate a break longer than 2.54 seconds. Absence of a break length field or a value of zero shall be interpreted as a break of default length.

Annex C

Parameter values and optional procedures for operation with Recommendation V.70

The following table shows the parameter values and optional procedures for use with Recommendation V.70. All "default/mandatory" values shall be supported.

Feature	Default/ mandatory value	Reference	Selectable operation (Note 1)	Reference	Additional information (Note 2)
Multiplex Platform: 1) Flag; Abort	 "0111 1110"; ≥ 7 ones	 5.1.2 5.4	 Suspend/resume flags and abort	 Annex A	 One value applicable to all DLCs
2) Max address-field size	1 octet	6.1	2 octets	6.1	
3) FCS length	2 octets	5.1.6.2	1 or 4 octets	10; 5.1.6.1 or 5.1.6.3	
DLC Parameters: 4) Operational Mode	 none		 ERM or UNERM	 8.1 or 8.2	 Select one mode per DLC; both modes shall be supported
5) Recovery for ERM	REJ	6.4.7	SREJ: s-SREJ or SREJ: m-SREJ	10; 6.4.8.1 or 6.4.8.2	
6) Control messages for ERM	UI frames	6.4.5	UIH frames	10; Appendix II	UIH frames with first 4 octets protected by FCS
7) Transport for UNERM	UI frames	6.4.5	UIH frames	10; Appendix II	UIH frames with first 4 octets protected by FCS
8) Acknowledgment timer (T401)	system-defined value	9.1	none		Rec. V.75 not used
9) Max number of retransmissions (N400)	system-defined value (≥ 1)	9.2	none		Rec. V.75 not used
10) Max information field size (N401)	(Note 3)	9.3	1-4095	9.3	(Note 4)
11) Max window size (k)	15	9.4	1-127	9.4	(Note 4); applies to ERM only
12) Reply delay timer (T402)	system-defined value	9.5	none		For further study; Rec. V.75 not used
13) Inactivity timer (T403)	system-defined value	9.6	none		Rec. V.75 not used
14) DLCI range	0-63 for 1-octet address fields	6.1.1	0-8191 for 2-octet address fields	6.1.1	(Note 5)

Feature	Default/ mandatory value	Reference	Selectable operation (Note 1)	Reference	Additional information (Note 2)
15) DLCI value	low⇒high for initiator; high⇒low for responder	6.1.1	none		(Note 5)
16) Loop-back test	not used	–	add TEST frame	10; 6.4.14	
17) Channel type	non-real-time	Annex A	real-time	Annex A	
18) Address-field present for real-time DLCs	one DLC: absent		one DLC: may be present; > one DLC: present	Annex A	(Note 6)

NOTES

1 In case of a default method of operation, the selectable method shows an alternative that may be chosen in place of the default. In case of no default method, one of the selectable methods shall be chosen.

2 Unless otherwise noted, Recommendation V.75 is used by the DLC-opener to indicate operating characteristics for each feature of the DLC. These characteristics are chosen from among the default/mandatory value or the selectable values. It is noted that, other than for feature No. 4, operational mode, selectable values need not be supported by the remote station.

3 The maximum value specified for this feature is the size of the largest frame to be transmitted on the DLC. The default maximum information field size is either 128 octets or as implied by other operational characteristics of the DLC. It should be noted that certain DLC procedures may imply a frame-specific maximum value less than the DLC-maximum. For example, an audio DLC may have an audio-speech block size implied by the audio coder for UI/UIH frames (e.g. 10 octets) and a control frame (e.g. SABME, DISC, etc.) maximum of 128.

4 Each parameter consists of two subparameters – one for each direction of transmission (i.e. a maximum window-size in the direction from the DLC-opener to the remote station and a maximum from the remote station to the DLC-opener; similarly for maximum information field size). Identical values need not be used for each direction.

5 The DLCI range depends on the maximum address-field size (see feature No. 2). When the 2-octet address-field size is available for use, a 1-octet address-field size may also be used. The selection of an address-field size is made by the DLC-opener. DLCI values of 0-63 may be encoded in either 1- or 2-octet address fields.

6 Left for further study is whether one real-time DLC can operate without an address field when multiple real-time DLCs are open.

Appendix I

Data retransmission

I.1 Introduction

This Recommendation provides two capabilities for retransmission of information in ERM (there is no retransmission in UNERM): REJ and SREJ. Just as in the original forwarding of information, there are additional considerations applying to retransmission given the support for different types of information transfer. This appendix provides some further considerations for retransmission. It should be noted that these considerations depend on the method of recovery (REJ or SREJ) but no attempt is made here to limit selection to one or a specific set of choices.

I.1.1 Use of SREJ

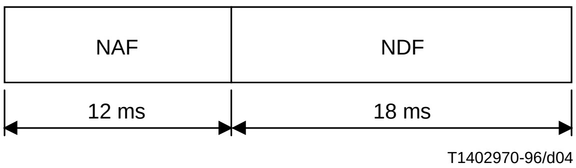
When multiplexing the information from several DLCIs, such as an audio and a data stream, the multiplexing protocol is required to treat these two information types differently. Data must be delivered error-free, but does not carry the same real-time urgency that voice does. On the other hand, voice frames must be delivered on a periodic basis, but these frames can be dropped occasionally without material impact on intelligibility. Thus, there is generally no requirement to retransmit dropped audio frames.

The data throughput in ERM may be improved when SREJ error recovery is used, as opposed to REJ, particularly when significant delay is involved. Efficiency is further improved when an audio encoder is allowed to represent silent intervals in speech with special short frames. However, a problem arises when these two features are implemented together.

Consider the following assumptions:

- 30 ms audio frame rate, single audio packet per frame;
- 24 000 bit/s data link;
- 8000 bit/s audio encoder output;
- short audio frames are sent to indicate silence.

A normal 30 ms interval consisting of one Normal Audio Frame (NAF) and one Normal Data Frame (NDF)is depicted below.



The audio coder could be producing short blocks during intervals of silence. These frames would consist of a Short Audio Frame (SAF) and a Long Data Frame (LDF):

There are two areas of concern:

1) If SREJ is used for retransmitting an LDF and the next opportunity for resending it is of NAF/NDF type, the LDF will not "fit" without affecting the timing of the subsequent frame.

2) If an NDF is rejected and the next available frame is of SAF/LDF type, some bandwidth will be wasted.

There are numerous solutions. An implementation may select one or more of the solutions below:

1) Use the optional suspend/resume feature (see Annex A). In this case, any LDF is "broken apart" across voice frames as needed. Therefore, there is no issue concerning "fitting" data frames between voice frames – either during initial transmission or any retransmission.

2) Send the LDF during the next available time-slot and delay the subsequent audio frame. The transmitter can set a limit on maximum permissible audio delay and drop the audio frame if the limit is exceeded. The audio codec is already required to survive dropped frames, if it is used on a modem link, and the addition of an occasional intentionally dropped frame would probably not have much effect. The receiver would probably also be set up with a delay limit and would automatically notify the audio decoder of the lost frame condition if the delay threshold was exceeded.

3) The next available frame for retransmission can be forced to the SAF/LDF format and the current audio data can be ignored. A fairly high percentage of the audio frames are SAF anyway (estimates run as high as 60%). An occasional SAF should have little effect on a well-designed audio codec.

4) The next frame can contain a special Dropped Audio Frame (DAF), which would serve to preserve audio timing, and tell the audio decoder to use a special error concealment technique. The audio decoder would generate an interpolated output rather than silence.

5) Instead of SAF/LDF, introduce a new Short Data Frame (SDF) for a sequence of SAF/SDF/NDF.

6) Hold the LDF for the duration of the window waiting for an appropriate frame. Before the window is closed, invoke 2) above.

7) The receiver can double buffer the audio frames, creating one entire frame (30 ms) of jitter tolerance. This extra delay in the audio path is not noticeable in many applications. Jitter tolerance can be further increased by building double audio frames at a 60 ms rate. This also reduces protocol overhead.

8) A "maximum variable audio delay" parameter can be exchanged for the audio DLCI. The receiver knows how much delay buildout is allowed. This parameter can be modified as a function of application and data rate.

I.1.2 Use of REJ

Recovery of lost information using the SREJ procedure may necessitate additional mechanisms to utilize bandwidth efficiently, as discussed above. Moreover, it also requires the receiver to buffer received frames until missing frames are recovered. Use of the REJ procedures, on the other hand, relieves the receiver of this burden but may introduce unnecessary retransmission requirements leading to inefficient use of bandwidth. This subclause examines the issue of bandwidth utilization for the two recovery schemes. It also shows how REJ recovery can be used for the silent-interval issue discussed above.

I.1.2.1 First-order comparison

Consider the simple case where station A is sending frames on a particular DLCI to station B and a single frame error occurs. Let the sent frames be numbered 1, 2 and 3.

If frame 1 is lost, station B will notice that frame 2 is out of sequence. When using REJ recovery, station B will discard frame 2. If station B is not already sending a frame, it can immediately send an REJ frame to ask station A to retransmit frames starting at frame 1. If station B is currently transmitting a frame, it will send the REJ after it completes sending its current frame (or it can abort the frame currently being transmitted). The REJ frame will usually reach station A while it is sending frame 3; however, this may be further delayed depending on actual operating conditions (e.g. round trip delay).

When using REJ recovery, station B must discard all received frames until it receives frame 1 correctly. Then station B can begin keeping good frames. If station B is able to send an REJ as soon as one is needed, then the total number of frames that station B will discard is 2 (frames 1 and 2) plus the number of frames that are sent during one round trip delay time. If station B must wait to send the REJ, then the number of discarded frames will increase by an average of 1/2 frame (assuming both stations are sending the same size frames). Note that frame 1 must be retransmitted in any case but that frame 2 and any subsequent frames would not be retransmitted when using SREJ.

At station A, frame 3 can be aborted when the REJ frame is received since it will need to be retransmitted again (station B will discard it until frames 1 and 2 are received correctly). With SREJ, frame 3 would not be truncated in order to resend frame 1.

Suppose the frame error probability is low (the analysis requires more possibilities at high frame error probabilities). Then the average efficiency of REJ and SREJ is:

$$\text{REJ efficiency} = 1/(1 + p(2 + T \cdot R/F))$$

where p is the frame error probability, T is the line data rate, R is the round trip delay, and F is the frame size.

$$\text{SREJ efficiency} = 1/(1 + p)$$

If $T \cdot R/F$ is no larger than 1, then REJ efficiency is bounded from below by $1/(1 + 3p)$.

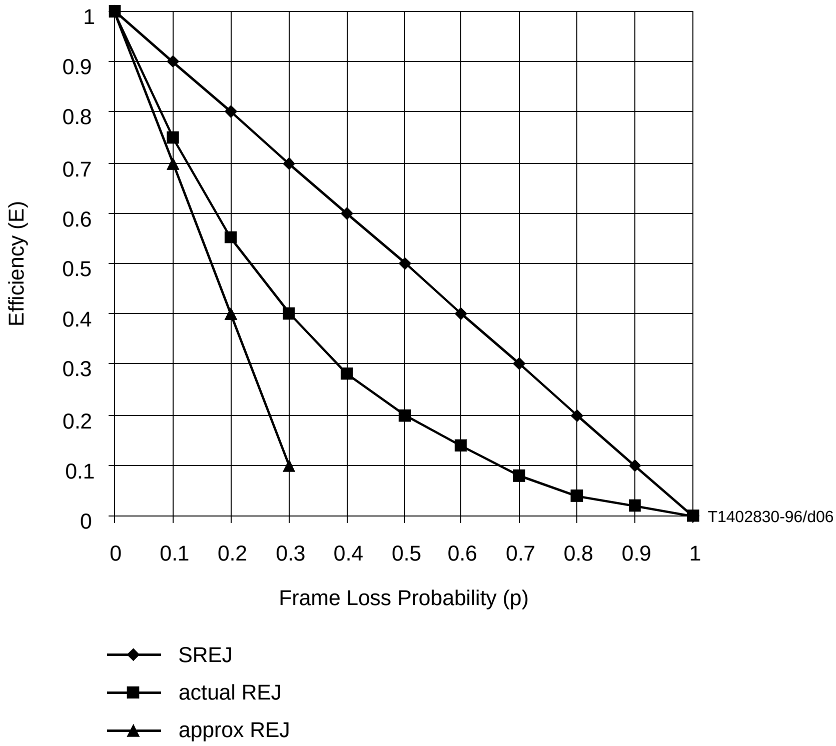
The efficiency calculations can be approximated for small values of p by:

$$\text{REJ efficiency} \approx 1 - 3p \qquad \text{for } (T \cdot R)/F \leq 1$$

and

$$\text{SREJ efficiency} \approx 1 - p$$

The following graph shows the efficiency of the recovery schemes.



If p is 0.01, then REJ efficiency is about 0.97 and SREJ efficiency is about 0.99. The difference is less than 0.02. If several frame errors occur consecutively, then REJ and SREJ both produce lower efficiency.

I.1.2.2 Use of REJ with silent intervals

Consider a stream of octets on a DLCI used to carry data in ERM that is multiplexed with audio frames. As depicted in I.1.1, these octets are carried by data frames (NDF) using appropriate data-forwarding conditions and interspersed with audio frames (NAF). During silent intervals, an LDF may be sent with an SAF. Subclause I.1.1 discussed strategies concerning use of an LDF and the possible need for retransmission using SREJ. In this case, the initial grouping of octets into data frames, as derived from the data forwarding conditions, must be maintained to ensure unique delivery of all octets.

When using REJ for recovery, the stream of octets initially transmitted must still be delivered but it need **not** be delivered in the same frame numbers. Since REJ is a "Go-Back-N" approach to recovery, then the original "packaging" of octets during retransmission is not important.

For example, consider a stream of 300 octets originally sent by station A as frames 1, 2 and 3 consisting of 150 (LDF), 75 (NDF) and 75 (NDF) octets, respectively. Suppose station B does not receive frame 1; it then sends an REJ for frame 1 when it receives frame 2. Station B will then discard frames 2 and 3. Station A must retransmit frames starting with frame 1. While it is required that the first octet of the retransmitted frame 1 be the same as in the originally-transmitted frame 1, it is **not** required that frame 1 be of the same length as originally transmitted. Frame 1 may, for example, contain 75 octets (NDF) while the retransmitted frames 2 and 3 each contain 150 octets (LDF). In the case of frame 3, it now carries octets not originally transmitted.

Appendix II

Additions for "Unnumbered information with header check" feature

II.1 Introduction

The unnumbered information with header check (UIH) feature is an option that allows frames to be transmitted without error recovery and flow control like UI frames (see 6.4.5). Unlike UI-frame operation, the UIH feature provides for protection from bit corruption only for a number of octets immediately following the opening flag of a frame (including a suspend flag when using the suspend/resume feature of Annex A). Applications where this is useful include:

- data applications where a higher-layer protocol provides protection against bit corruption;
- voice applications where bit errors in the voice-related bits can be tolerated (as opposed to discarding the frame and introducing either silence or some background noise);
- applications that may add their own forward error correction so that it is only necessary to protect a few octets of the "enveloping" protocol.

The number of octets to be protected is made known to the DLC entity through a local mechanism when a DLC is opened.

When agreeing to use of the UIH option, a UIH frame is used in place of the UI frame in either ERM or UNERM.

II.2 Abbreviation

The following additional abbreviation applies to this appendix.

UIH Unnumbered Information with Header Check (frame or feature)

II.3 Changes for UIH feature

When using the UIH feature, the text of this Recommendation should be read with the following changes applied.

a) Subclause 5.1.6: Add at the end of the existing sentence the following text:

"… guard against bit errors.] Unless otherwise noted, the frame check sequence is calculated for the entire length of the frame, excluding the opening flag, the FCS itself, any bits inserted for transparency and the closing flag. In those instances where the FCS is calculated over an agreed-to, designated portion of the entire frame, then the calculation shall begin immediately after the opening flag and continue over the designated portion of the entire frame, excluding any bits inserted for transparency."

NOTE – Selection of an FCS length is independent of whether the FCS covers the entire frame or only part of the frame.

b) Subclauses 5.1.6.1, 5.1.6.2, and 5.1.6.3 (descriptions of 8-, 16- and 32-bit FCSs, respectively):

Change all 3 subclauses in the same ways as follows:

– In Paragraph 1, item a):

change “where *k* is the number of bits … inserted for transparency; and”

to “where *k* is the number of bits being protected by the FCS; and”

– In Paragraph 1, item b):

change “by the content of the frame … inserted for transparency.”

to “by the content of the *k* bits being protected.”

– In Paragraph 2:

change “of the address, control and information fields;”

to “of the address, control and any remaining bits of the designated *k* bits being protected;”

c) Subclause 6.4.1, Paragraph 2: change ”6.4.14” at the end of the sentence to ”6.4.15”.

d) Subclause 6.4.1, Table 4/V.76: add a new row after the UI row as follows:

	UIH (unnumbered information with header check)	UIH (unnumbered information with header check)	1	1	1	P/F	1	1	1	1

e) Add a new subclause 6.4.15 as follows:

“**6.4.15 Unnumbered information with header check (UIH) command/response**

An unnumbered information with header check (UIH) frame is used to send information that the MF will not recover if lost and where the integrity of the information being transferred is of lesser importance than its delivery to the SU (the SU, however, may try to ensure that the information is successfully transmitted to the remote station).

For the UIH frame, the FCS shall be calculated over only the initial octets of the frame, not including bits inserted for transparency, starting after the opening flag. This number of octets shall be made known to the DLC entity through a local mechanism when a DLC is opened.

The UIH frame may be used in either ERM (in conjunction with I frames) or UNERM.”

f) Subclause 8.2:

– Paragraphs 1 and 2: change “UI command frame” to “UI/UIH command frame”.

– Add a new third paragraph as follows:

“The use of either the UI command frame or the UIH command frame for the DLC is determined during its connection establishment.”

g) Subclause 8.3: add the following text as a new second sentence: “When UI frames are used for the transfer of user-control information, the UIH frame shall be used in its place if such usage was agreed when the DLC was opened.”

h) Subclause A.3:

– Add to the end of Note 3: [… as if they were UI frames] or, if its use in place of UI frames has been agreed, UIH frames.

– Add a new Note 4 as follows: "4 When use of UIH frames has been agreed for a DLCI, then the partial FCS coverage spans the initial octets starting after the suspend flag, excluding any bits inserted for transparency. The absence of the explicit control field and, optionally, the address field does not change this fixed value of coverage."

i) Subclause B.1.1: Add a new fourth paragraph as follows: "The UIH command and response frames shall be used in place of the respective UI frames if such usage was agreed when the DLC was opened."

Appendix III

Cross-reference between Recommendations V.76 and V.42

The MF of this Recommendation is based on V.42 LAPM. Therefore, there is technical alignment between the procedures used here for the ERM with those in Recommendation V.42. Editorially, terminology may differ – for example, LAPM uses the phrase *error-correcting entity* whereas this Recommendation uses the phrase *data link connection entity*.

The table below shows the clauses in Recommendations V.76 and V.42 that have some commonality.

Recommendation V.76	Recommendation V.42
4.4	6.4
5.1.1	8.1.1.1
5.1.2	8.1.1.2
5.1.3	8.1.1.3
5.1.4	8.1.1.4
5.1.5	8.1.1.5
5.1.6.2	8.1.1.6.1
5.1.6.3	8.1.1.6.2
5.2 and subclauses	8.1.2 and subclauses
5.3	8.1.3
5.4	8.1.4
5.5	8.1.5
6	8.2
6.1 and subclauses	8.2.1 and subclauses
6.2 and subclauses	8.2.2 and subclauses
6.3 and subclauses	8.2.3 and subclauses

Recommendation V.76	Recommendation V.42
6.4 and subclauses	8.2.4 and subclauses
6.5	8.2.5
7.1 and subclauses	8.3 and subclauses
7.3 and subclauses	8.7 and subclauses
7.4	8.8
7.5 and subclauses	8.9 and subclauses
7.6 and subclauses	8.10 and subclauses
7.7	8.11
8	8.4
8.1 and subclauses	8.4.1 through 8.4.8, 8.5.1 through 8.5.3
8.3	8.6
8.4.1	8.5.4
8.4.2	8.5.5
8.4.3	8.5.6
8.4.4	8.5.7
8.4.5	8.12
8.4.6	8.4.9
9.1	9.2.1
9.2	9.2.2
9.3	9.2.3
9.4	9.2.4
9.5	9.2.5
9.6	9.2.6
9.7	9.2.7
10	10
Annex B	8.13, 12.3

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