International Standard 4335

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Data communication — High level data link control procedures — Elements of procedures

Téléinformatique — Procédures de commande de liaison de données à haut niveau — Éléments de procédure

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Descriptors : data processing, data transmission, control procedures, high-level data link control.

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FOREWORD

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4335 was developed by Technical Committee ISO/TC 97, *Computers and information processing*, and was circulated to the member bodies in September 1976.

It has been approved by the member bodies of the following countries :

Australia	Italy	Sweden
Belgium	Japan	Switzerland
Canada	Mexico	Turkey
Chile	Netherlands	United Kingdom
Czechoslovakia	Philippines	USA
Finland	Poland	USSR
France	Romania	Yugoslavia
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No member body expressed disapproval of the document.

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Data communication — High level data link control procedures — Elements of procedures

ADDENDUM 1

Addendum 1 to International Standard ISO 4335-1979 was developed by Technical Committee ISO/TC 97, *Computers and information processing*, and was circulated to the member bodies in June 1978.

It has been approved by the member bodies of the following countries :

Australia	Hungary	South Africa, Rep. of
Belgium	Italy	Spain
Canada	Japan	Sweden
Egypt, Arab Rep. of	Mexico	Switzerland
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France	Poland	USA
Germany, F. R.	Romania	Yugoslavia

No member body expressed disapproval of the document.

This addendum contains elements of procedures to be added to those already standardized in ISO 4335. It also contains some of the changes to be made to the text of ISO 4335 as a result of adopting these new elements.

The intention of this addendum is to standardize these new elements without the need to update ISO 4335 at this time. When ISO 4335 is eventually revised, the contents of this addendum will be incorporated into the new document.

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1 Definition of NDM, ADM and IM secondary modes

1.1 Disconnected modes

There are two link level disconnected modes : normal disconnected mode (NDM) and asynchronous disconnected mode (ADM). These modes differ from NRM[1] and ARM in that the secondary is logically disconnected from the data link, i.e. no information (I), unnumbered information (UI) or supervisory frames are transmitted or accepted.

These disconnected modes are provided to prevent a secondary from appearing on the link in a fully operational mode during unusual situations or exception conditions since such operation could cause :

— unintended contention in ARM;

— sequence number mismatch between the primary and secondary;

— ambiguity in the primary as to the secondary status.

A secondary shall be system predefined for the condition(s) that cause(s) it always to assume one of the two predetermined disconnected modes (NDM or ADM).

The secondary capability in either NDM or ADM shall be limited to :

— accepting one of the mode setting commands (SNRM, SARM, SNRME, SARME, SIM or DISC);

— accepting an XID command;

— transmitting a DM, XID, RIM or RD response frame at each respond opportunity.

In NDM or ADM, a secondary station, as a minimum capability, shall respond DM with the F bits set to "1" to a command frame received with the P-bit set to "1".

A secondary in NDM or ADM shall not establish a "command reject" exception condition.

If a secondary is in NDM or ADM and receives a DISC command, it shall respond with the DM response. If the secondary is in NRM, ARM or IM and receives a DISC command, it shall respond with the UA response if it is capable of actioning the command.

Examples of possible conditions (in addition to receiving a DISC command) which may cause a secondary to enter a disconnected mode are :

— the secondary power is turned on, or restored following a temporary loss of power;

— the secondary link level logic is manually reset;

— the secondary terminal is manually switched from a local (home) condition to a connected-on-the-link (on-line) condition.

1.1.1 Normal disconnected mode (NDM)

NDM is a secondary mode in which the secondary is logically disconnected from the data link and is therefore not in operational status. The secondary has normal mode respond opportunity and shall initiate a response transmission only as a result of receiving either a command frame with the P-bit set to "1" or a UP command.

In this mode, a secondary shall only action mode setting commands and the XID. A mode setting command or an XID command that cannot be actioned or any other command with the P-bit set to "1" shall cause a secondary in NDM to respond with a disconnected mode (DM) response or, if the secondary determines it is unable to function, a request for initialization (RIM). In the case where a mode setting command or an XID command has been received but cannot be actioned or a status condition is to be reported, a UP command with the P-bit set to "0" may cause a secondary in NDM to respond with DM or RIM, as appropriate.

Any commands with the P-bit set to "0", other than mode setting, the XID command or the UP command, shall be ignored by a secondary in NDM.

1.1.2 Asynchronous disconnected mode (ADM)

ADM is a secondary mode in which the secondary is logically disconnected from the data link and is therefore not in operational status. The secondary has asynchronous mode respond opportunity and may initiate a response transmission in two-way alternate exchange upon detection of an idle link state, and in two-way simultaneous exchange at any time. Such a response transmission shall only consist of a request for logical connection to the primary (DM), or a request for initialization (RIM) if the secondary determines it is unable to function.

In this mode a secondary, if capable, shall action only mode setting commands and XID.

Other valid commands with the P-bit set to "1" shall cause a secondary in ADM to respond with a "disconnected mode" response or, if the secondary determines that it is unable to function, a request for initialization (RIM). Other valid commands with the P-bit set to "0" shall be ignored by the secondary.

1.2 Initialization mode (IM)

IM is the secondary mode of operation in which the secondary link control program may be initialized or regenerated by primary action, or in which other parameters to be used in the operational mode may be exchanged. IM is invoked when a primary concludes that a secondary is operating abnormally and needs its link control program corrected, and for remote

1) See ISO 4335 for all abbreviations not defined in this addendum.

upgrading of the secondary's link control program. In a similar manner, a secondary may determine it is unable to function due to program checks and request IM to obtain a good program from the primary.

A secondary shall enter the IM upon sending a UA (at its system predefined respond opportunity) in response to the receipt of a set initialization mode (SIM) command. The secondary may request SIM by sending a request initialization mode (RIM). In IM, the primary and secondary may exchange information in the predetermined manner specified for that secondary, for example UI or I frames.

IM is terminated when the secondary receives and acknowledges (via a UA response) one of the other mode setting command.

2 Definition of additional commands

The following list contains the bit encodings of the defined commands.

Command	Low-to-high bit encoding
SIM	1110P000
UP	1100P100
UI	1100P000
XID	1111P101

2.1 Set initialization mode (SIM) command

The SIM command causes the addressed secondary to initiate a station-specified procedure (or procedures) to initialize its link level control functions.

No information field is permitted with the SIM command. The secondary shall confirm acceptance of SIM by the transmission of a UA. Upon acceptance of this command, the secondary station send and receive state variables shall be set to zero.

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

2.2 Unnumbered poll (UP) command

The UP command is used to solicit response frames from a group of secondaries (group poll) or from a single secondary (individual poll). In the case of a group poll, the mechanism employed to control response transmissions schedule (to avoid simultaneous transmissions) is not defined in this addendum. The UP command does not acknowledge receipt of any response frames that may have been previously transmitted by the secondary (or secondaries). No information is permitted with the UP command.

The secondary (or secondaries) which receives UP with a group address shall respond in the same manner as when polled using an individual address. The response frame (or frames) shall contain the sending secondary (or secondaries) individual address, plus N(S) and N(R) numbers as required by the particular response (or responses). The continuity of each secondary (or secondaries) N(S) shall be maintained. If the UP has the P-bit set to "1", each individual secondary shall respond with at least one frame, the last frame having the F-bit set to "1". If the UP has the P-bit set to "0", each individual secondary may or may not respond depending on the status of the secondary; secondary responses sent in reply to this command shall have the F-bit set to "0" in all frames of each secondary's response. A secondary which receives a UP with the P-bit set to "0" shall respond when it has :

— an I/UI frame (or frames) to send;

— an I frame to resend because it did not receive an acknowledgement;

— received but not acknowledged an I frame (or frames);

— experienced an exception condition or change of status that has not been reported;

— a status that must be reported again (for example DM, CMDR).

If idle (15 ones) is detected following receipt of a frame (or frames), or no response is received within a given period of time, it is assumed the secondary has completed, or will not initiate, transmission.

2.3 Unnumbered information (UI) command

The UI command is used to send information (for example status, operation interruption, temporal data, link level programs or parameters) to a secondary (or secondaries) without impacting the V(S) or V(R) variables at any station. There is no specified secondary response required to the UI command.

2.4 Exchange identification (XID) command

The XID command is used to cause the addressed secondary station to identify itself, and optionally to provide primary station identification and/or characteristics to the addressed secondary. An information field is optional with the XID command; if present, the information field shall contain the primary station identification. A secondary receiving an XID command shall, if capable, action the XID in any mode unless a set mode response (UA) is pending transmission, or a CMDR condition exists.

If in an operational mode (NRM, ARM) a CMDR condition may be established if the received XID information field exceeds the maximum defined storage capability of the secondary.

3 Definition of additional responses

The following list contains the bit encodings of the defined responses.

Response	Low-to-high bit encoding
DM	1111F000
RD	1100F010
RIM	1110F000
UI	1100F000
XID	1111F101

3.1 Disconnect mode (DM) response

The DM response is used to report a status where the secondary is logically disconnected from the link; and is, by system definition, in NDM or ADM.

The DM response is sent by the secondary in NDM or ADM, to inform the primary that it is still in NDM/ADM and cannot action the set mode command. No information field is permitted with the DM response.

On a switched network where the call is initiated by a secondary, the DM shall be sent to request a mode setting command. On a non-switched line, a secondary in ADM may send a DM response at any respond opportunity.

A secondary in NDM or ADM shall monitor received commands to detect a respond opportunity in order to (re)transmit DM (or RIM, XID, or RD as appropriate), i.e. no commands (other than XID) are accepted until the disconnected mode is terminated by the receipt of SNRM, SARM, SNRME, SARME or SIM.

3.2 Request disconnect (RD) response

The RD response is used to indicate to the primary that the secondary wishes to be placed in disconnected mode (NDM or ADM). In switched networks, a request for logical disconnect function at the data link level may also serve to initiate a request for a physical disconnect operation at the physical interface level; i.e., to have the requesting secondary go "on-hook". RD may be sent asynchronously if the secondary is in ARM, or, if in NRM, as a response to either a UP command or to any other command with the P-bit set to "1". No information field is permitted with the RD response.

A secondary which has sent an RD response and receives a command frame (or frames) other than DISC shall accept the command frame (or frames) if it is able to do so. If the secondary accepts the non-DISC command frame (or frames), it shall follow the normal HDLC elements of procedures to respond to the primary. Secondary acceptance of a frame other than DISC after sending an RD response shall cancel the RD response.

If the secondary still wishes to be placed in disconnected mode (NDM or ADM) it shall re-issue the RD response. If the secondary cannot accept the non-DISC frames due to internal problems it may respond with RD again.

3.3 Request initialization mode (RIM) response

The RIM is used to report a secondary need for initialization. Once a secondary station has established a RIM condition, additional commands subsequently received (other than SIM or DISC or if capable XID) shall be monitored only to detect a respond opportunity to retransmit RIM, i.e. no additional transmissions shall be accepted or actioned until the condition is reset by the receipt of SIM or DISC. No information field is permitted with this response.

3.4 Unnumbered information (UI) response

The UI response is used to send information (for example, status, operation interruption, or temporal data) to a primary without impacting the V(S) or V(R) state variables at either station. It should be noted that there may be some system-dependent restrictions on the use of the UI response, for example error control, flow control, etc.

3.5 Exchange identification (XID) response

The XID response is sent as a reply to an XID command. An information field containing the secondary station identification and/or characteristics is optionally present with the XID response. A secondary receiving an XID command shall, if capable, action the XID in any mode unless a UA response is pending or a CMDR condition exists.

On switched networks, the secondary may, at its respond opportunity, use the XID response which may optionally contain an information field, to request an XID exchange.

4 Implied changes to ISO 4335

4.1 The specification of the CMDR response not to be actioned in non-operational mode requires the following change in ISO 4335 :

Sub-clause 5.3.2.2 :

Add to the first line after secondary :

"in the operational mode"

4.2 The definition of the unnumbered poll (UP) command requires the following changes in ISO 4335 :

Sub-clause 4.1.1 :

Change the first sentence of the second paragraph to read :

"In this mode (NRM), the secondary cannot transmit until a command frame with the P-bit set to "1" or a UP command is received."

Add to the last sentence of the second paragraph :

"or a UP command with a P-bit set to "1" or "0"."

4.3 The definition of the unnumbered information (UI) and exchange identification (XID) commands require the following changes to the CMDR definition in ISO 4335 :

Sub-clause 5.3.2.2 :

Add to the second item following the first paragraph after I :

", UI or XID"

NOTE — Other additional changes to ISO 4335 may be required in addition to those above.

CONTENTS

Data communication — High level data link control procedures — Elements of procedures

0 INTRODUCTION

High level data link control (HDLC) procedures are designed to permit synchronous bit sequence independent data transmission.

This International Standard describes HDLC elements of procedures as outlined in clause 1. The reader should note that further study is in progress to define additional elements which enhance this document. This further study may result in a need for minor changes to the text of this International Standard.

In HDLC procedures, the normal cycle of the code transparent data communication between two data stations consists of the transfer of frames containing information from the data source to the data sink, acknowledged by a frame in the opposite direction. Until the data terminal equipment (DTE) comprising the data source receives the reply, it must hold the original information in memory in case the need should arise for retransmissions.

A data link involves two or more participating stations. For control purposes, one station on the link must assume responsibility for the organization of data flow and for link level error recovery operations. The station assuming these responsibilities is known as the primary and the frames it transmits are referred to as command frames. The other stations on the link are known as secondaries and frames they transmit are referred to as response frames.

For the transfer of data, the following two cases of data link control are considered :

In the first case, the DTE comprising the data source performs a primary data link control function and controls the DTE comprising the data sink that is associated with a secondary data link control function, by select type commands.

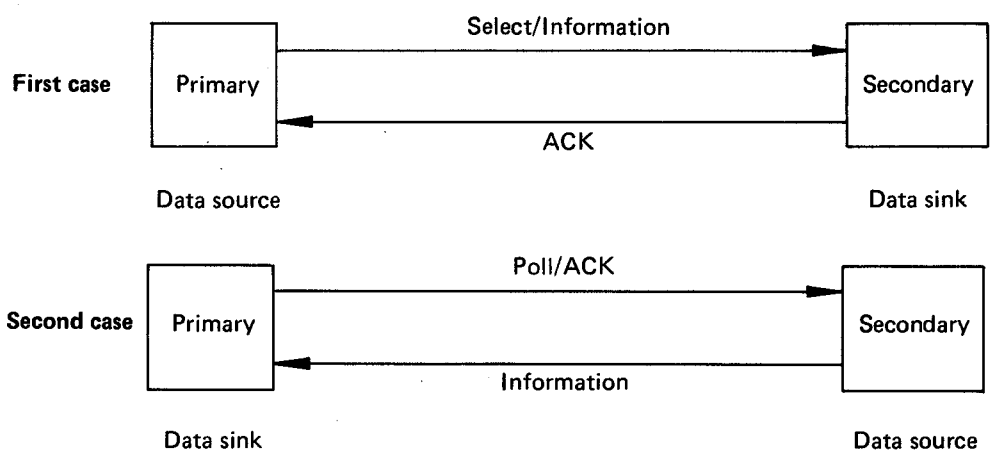
In the second case, the DTE comprising the data sink performs a primary data link control function and controls the DTE comprising the data source that is associated with a secondary data link control function, by poll-type commands.

The information flows from the data source to the data sink and the acknowledgements will always be transmitted in the opposite direction.

These two cases of control may be combined differently so that the data link becomes capable of two-way alternate communication, or two-way simultaneous communication.

The control of traffic between the data source and the data sink is effected by means of a numbering scheme, which is cyclic within a modulus specified in the standard and measured in terms of frames. An independent numbering scheme is used for each data source/data sink combination on the link.

The acknowledgement function is accomplished by the data sink informing the data source of the next expected sequence number. This can be done in a separate frame, not containing information, or within the control field of a frame containing information.



1 SCOPE AND FIELD OF APPLICATION

This International Standard describes elements of data link control procedures for synchronous bit sequence independent data transmission using the HDLC frame structure (see ISO 3309[1]) and independent frame numbering in both directions.

These HDLC elements of procedures are described specially in terms of the actions that occur on receipt of commands at a secondary.

This International Standard is intended to cover a wide range of applications, for instance, one-way, two-way alternate or two-way simultaneous data communication between DTE's which are usually buffered, including operations on different types of data circuits, for example, multipoint/point-to-point connections, duplex/half-duplex transmission, switched or non-switched, etc.

The defined HDLC elements of procedures are to be considered as a common basis for establishing different types of control procedures. This International Standard does not define any single system and should not be regarded as a specification for a data communication system. Not all the commands or responses, respectively, might be required for a particular system implementation.

A DTE intended to be operated within the constraints of this International Standard provides a high degree of compatibility, if it implements all features of the stipulated class of operation as specified in other HDLC standards.

2 OPERATIONAL MODES

In this International Standard two operational modes are defined for secondary stations; normal response mode (NRM) and asynchronous response mode (ARM).

2.1 Normal response mode (NRM)

NRM is an operational mode in which the secondary may initiate transmission only as the result of receiving explicit permission to do so from the primary. After receiving permission, the secondary shall initiate a response transmission. The response transmission may consist of one or more frames while maintaining an active channel state. The last frame of the response transmission will be explicitly indicated by the secondary. Following the indication of the last frame, the secondary will stop transmitting until explicit permission is again received from the primary.

2.2 Asynchronous response mode (ARM)

ARM is an operational mode in which the secondary may initiate transmission without receiving explicit permission from the primary. Such an asynchronous transmission may contain single or multiple frames and is used for information field transfer and/or to indicate status changes in the secondary (for example, the number of the next expected information frame, transition from a ready to a busy condition or vice versa, occurrence of an exception condition).

3 CONTROL FIELD AND PARAMETERS

3.1 Control field formats

The three formats defined for the control field are used to perform numbered information transfer, numbered supervisory functions and unnumbered control functions.

Control field format for	Control field bits							
	1	2	3	4	5	6	7	8
Information transfer command/response (I frame)	0	N(S)			P/F	N(R)		
Supervisory commands/responses (S frame)	1	0	S		P/F	N(R)		
Unnumbered commands/responses (U frame)	1	1	M		P/F	M		

where

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

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

S = Supervisory function bits

M = Modifier function bits

P/F = Poll bit – primary transmissions
Final bit – secondary transmissions
(1 = Poll/Final)

3.1.1 *Information transfer format – I*

The I format is used to perform an information transfer. Unless otherwise specified, it is the only format which may contain an information field. The functions of N(S), N(R), and P/F are independent, i.e. each I frame has an N(S) sequence number, an N(R) sequence number which may or may not acknowledge additional frames at the receiving station, and a P/F bit that may be set to "1" or "0".

3.1.2 *Supervisory format – S*

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

1) ISO 3309, *Data communication – High level data link control procedures – Frame structure.*

3.1.3 *Unnumbered format — U*

The U format is used to provide additional link control functions. This format contains no sequence numbers and consequently 5 "modifier" bit positions are available which allows definition of up to 32 additional command functions and 32 additional response functions.

3.2 Parameters

The various parameters associated with the control field formats are described in the following sub-clauses.

3.2.1 *Modulus*

Each I frame is sequentially numbered and may have the value 0 through MODULUS minus ONE (where MODULUS is the modulus of the sequence numbers). The modulus equals 8 for the unextended control field, and the sequence numbers cycle through the entire range. See 5.4 for description of the extended control field modulus.

The maximum number of sequentially numbered I frames that the primary or secondary may have outstanding (i.e. unacknowledged at any given time may never exceed one less than the modulus of the sequence numbers. This restriction is to prevent any ambiguity in the association of transmitted I frames with sequence numbers during normal operation and/or error recovery action.

NOTE — The number of outstanding I frames may be further restricted by the data station storage capability, i.e. the number of I frames that can be stored for transmission and/or retransmission in the event of a transmission error. Optimum link efficiency can only be obtained, however, if the minimum data station frame storage capacity is equal to or greater than the round trip transmission delay.

3.2.2 *Frame variables and sequence numbers*

In HDLC operation each data station maintains an independent send sequence number N(S) and receive sequence number N(R) on the I frames it sends and receives. Each secondary then maintains an N(S) count on the I frames it transmits to the primary, and an N(R) count on the I frames it has correctly received from the primary. In the same manner the primary maintains independent N(S) and N(R) counts for I frames sent to and recevied from each secondary on the link.

3.2.3 *Send state variable V(S)*

The send state variable denotes the sequence number of the next in sequence I frame to be transmitted. The send state variable can take on the value 0 through MODULUS minus ONE (where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of the send state variable is incremented by one with each successive I frame transmission, but cannot exceed N(R) of the last received frame by more than MODULUS minus ONE.

3.2.4 *Send sequence number N(S)*

Only I frames contain N(S), the send sequence number of transmitted frames. Prior to transmission of an in-sequence I frame, the value of N(S) is updated to equal the value of the send state variable.

3.2.5 *Receive state variable V(R)*

The receive state variable denotes the sequence number of the next in-sequence I frame to be received. This receive state variable can take on the values 0 through MODULUS minus ONE (where MODULUS is the modulus of the sequence numbering scheme and the numbers cycle through the entire range). The value of the receive state variable is incremented by the receipt of an error-free, in-sequence I frame whose send sequence number N(S) equals the receive state variable.

3.2.6 *Receive sequence number N(R)*

All I frames and S frames contain N(R), the expected sequence number of the next received I frame. Prior to transmission of a frame of the above types, the value of N(R) is updated to equal the current value of the receive state variable. N(R) indicates that the station transmitting the N(R) has correctly received all I frames numbered up to N(R) − 1.

See 5.3.2.2 for definitions of the range of values of N(R).

3.2.7 *Poll/Final (P/F) bit*

The poll (P/F) bit is used by the primary to solicit (poll) a response or sequence of responses from secondaries.

The final (P/F) bit is used by a secondary :

a) in NRM to indicate the final frame transmitted as the result of a previous soliciting (poll) command;

b) in ARM to indicate the response frame transmitted as the result of a soliciting (poll) command.

See clause 4 for further descriptions of the P/F bit functions.

3.3 Data link channel states

3.3.1 *Active channel state*

A channel is in an ACTIVE condition when the primary or a secondary is actively transmitting a frame, a single abort sequence or interframe time fill. In the ACTIVE state the right to continue transmission is reserved.

3.3.1.1 ABORT

Aborting a frame is accomplished by transmitting at least seven contiguous one bits (with non-inserted zeroes). Receipt of seven contiguous one bits is interpreted as an abort and the receiving station will ignore the frame.

NOTE — In sending more than seven one bits to abort, care must be taken that if 15 or more one bits are sent, including those already transmitted at the time of decision on abort, an IDLE channel state will result.

3.3.1.2 INTERFRAME TIME FILL

Interframe time fill is accomplished by transmitting continuous flags between frames. There is no provision for time fill within a frame.

3.3.2 *Idle channel state*

A channel is defined to be in an IDLE condition when a continuous ones state is detected that persists for at least 15 bit times; IDLE condition indicates that the remote station has terminated transmission.

4 FUNCTIONS OF THE POLL/FINAL (P/F) BIT

The poll/final (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.

4.1 Poll bit function

The P bit is used to solicit a response from the secondary.

On a link only one frame with a P bit set to "1" may be outstanding at a given time. Before a primary can issue another frame with P bit set to "1" it must receive a response frame from the secondary with the F bit set to "1". If no valid response frame is obtained within a system defined time-out, the retransmission of a command with the P bit set to "1" for error recovery purposes is permitted.

4.1.1 *Poll bit functions in NRM*

In NRM the P bit is set to "1" to solicit response frames from the secondary.

In this mode the secondary cannot transmit until a command frame with the P bit set to "1" is received. The primary can solicit I frames by sending an I frame with the P bit set to "1" or by sending certain S frames (RR, REJ or SREJ) with the P bit set to "1".

The primary can also restrict the secondary from transmitting I frames by sending an RNR S frame with the P bit set to "1".

4.1.2 *Poll bit functions in ARM*

In ARM, I frames can be transmitted by the secondary on an asynchronous basis. The P bit zero set to "1" is used, to solicit a response, at the earliest opportunity, with the F bit set to "1". For example, if the primary wants to get positive acknowledgement that a particular command has been received, it may set the P bit in the command to "1". This will force a response from the secondary as outlined in 4.2.

4.2 Final bit functions

4.2.1 *Final bit functions in NRM*

In NRM the secondary must set the F bit to "1" in the last frame of its response. Following transmission of the frame with the F bit set to "1" the secondary must stop transmitting until a subsequent command frame with a P bit set to "1" is received.

4.2.2 *Final bit function in ARM*

In ARM, the secondary will transmit a response frame with the F bit set to "1" only in response to a received command frame with the P bit set to "1". Following the receipt of a command frame with the P bit set to "1", the secondary must initiate transmission of a response with the F bit set to "1".

In the case of a two-way simultaneous communication where the secondary is transmitting when the command frame with the P bit set to "1" is received, the F bit will be set to "1" in the earliest possible subsequent response frame to be transmitted.

In ARM, the transmission of a response frame with the F bit set to "1" does not require the secondary to stop transmitting. Additional responses frames may be transmitted following the response frame which had the F bit set to "1". Thus, in ARM the F bit is not to be interpreted as the end of transmission by the secondary. It is only to be interpreted as indicating the response of the secondary to the previous command frame with the P bit set to "1".

4.3 Use of the P/F bit to assist in error recovery (see also clause 6)

As the P and F bits are always exchanged as a pair (for every P there is one F, and the P cannot be issued until the previous P has been matched with an F) the N(R) contained in a frame with a P or F bit set to "1" can be used to detect I frame sequence errors. This capability can provide early detection of I frame sequence errors and indicate the frame sequence number to begin retransmission. This capability is referred to as check pointing.

4.3.1 *Check pointing in NRM*

In NRM the N(R) of a received frame which has the P (command) or F (response) bit set to "1" shall initiate error recovery if N(R) does not acknowledge at least all I frames transmitted previous to and concurrent with the last frame which was transmitted with the P or F bit set to "1". In all cases the N(R) of a correctly received I or S frame shall confirm previously transmitted I frames through N(R) − 1.

4.3.2 *Check pointing in ARM*

In ARM the N(R) of a received frame which has the P (command) or F (response) bit set to "1" will cause the receiver to initiate error recovery if the N(R) does not acknowledge at least all I frames transmitted previous to and concurrent with the last frame which was transmitted with the P or F bit set to "1".

In ARM a secondary transmission (one or more response frames) will be retransmitted if the transmission is not acknowledged by the primary within a system specified time-out period. Since contention may occur, in the case of two-way alternate communications the interval employed by the secondary must be greater than that employed by the primary so as to permit contention situations to be resolved in favour of the primary.

4.4 Summary of P/F bit function

The applicability of the P/F bit functions in the two operational modes (NRM and ARM) and on links employing two-way alternate and two-way simultaneous communication is summarized in the table below.

	Operational mode	NRM				ARM			
	Communication mode	TWA		TWS		TWA		TWS	
	P/F bit in command/response	P	F	P	F	P	F	P	F
Functions	Solicit information	x		x					
	Last frame indication	x	x		x				
	Solicit supervisory or unnumbered response	x		x		x		x	
	Check pointing	x	x	x	x	x	x	x	x

x : Indicates that the function is applicable

TWA : Two-way alternate
TWS : Two-way simultaneous

5 COMMANDS AND RESPONSES

This clause defines the commands and associated responses. Sub-clauses 5.1, 5.2 and 5.3 contain the definition of the set of commands and responses (listed below) for each of the control field formats.

Information transfer format commands

I – Information

Supervisory format commands

RR – Receive ready

RNR – Receive not ready

REJ – Reject

SREJ – Selective reject

Unnumbered format commands

SNRM – Set normal response mode

SARM – Set asynchronous response mode

DISC – Disconnect

SNRME – Set normal response mode extended

SARME – Set asynchronous response mode extended

Information transfer format responses

I – Information

Supervisory format responses

RR – Receive ready

RNR – Receive not ready

REJ – Reject

SREJ – Selective reject

Unnumbered format responses

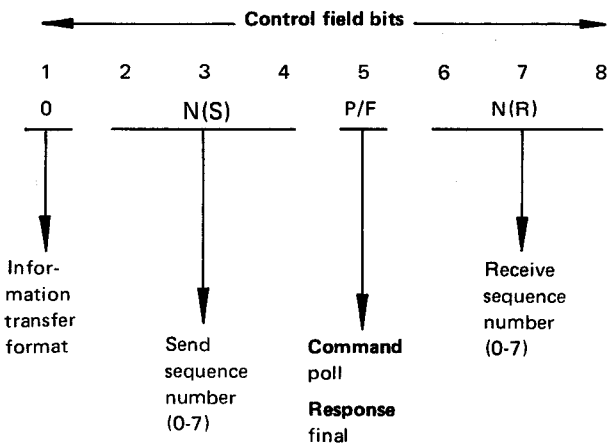
UA – Unnumbered acknowledge

CMDR – Command reject

5.1 Information transfer format command and response

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

The encoding of the I command/response control field is :



The I frame control field contains two sequence numbers : N(S), send sequence number, which indicates the sequence number associated with the I frame : N(R), receive number, which indicates the sequence number (as of the time of transmission) of the next expected I frame to be received and consequently indicates that the I frames numbered up to N(R) – 1 have been correctly received.

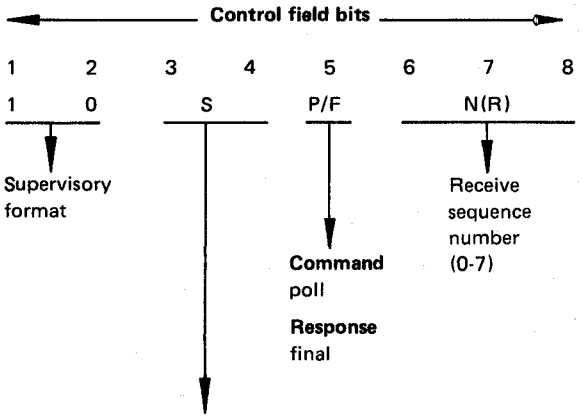
See clause 4 for description of P/F bit functions.

5.2 Supervisory format commands and responses

Supervisory S, commands and responses are used to perform numbered supervisory functions such as acknowledgement, polling, temporary suspension of information transfer, or error recovery.

Frames with the S format shall not contain an information field and therefore do not increment the sequence numbers at either the transmitter or receiver.

The encoding of the S command/response control field :



Commands			Responses		
RR	– Receive ready	00	RR	– Receive ready	
REJ	– Reject	01	REJ	– Reject	
RNR	– Receive not ready	10	RNR	– Receive not ready	
SREJ	– Selective reject	11	SREJ	– Selective reject	

An S frame contains an N(R), receive sequence number, which indicates the sequence number of the next expected I frame to be received at the time of transmission and consequently indicates that all received I frames numbered up to N(R) – 1 have been correctly received.

See clause 4 for description of the P/F bit functions.

5.2.1 *Receive ready, RR, (S bits = 00) command and response*

The receive ready, RR, frame is used by the primary or secondary to :

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

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

RR may be used to clear a busy condition that was initiated by the transmission of RNR. See 6.1.

The primary may use the RR command with the poll bit set to "1" to solicit responses from (poll) a secondary.

5.2.2 *Reject, REJ, (S bits = 01) command and response*

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

Only one REJ exception condition, from a given station to another station, may be established at any given time : another REJ or SREJ may not be actioned until the first REJ exception condition has been cleared unless other conditions have been detected as indicated in 6.2.1 to 6.2.4.

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 command/response.

5.2.3 *Receive not ready, RNR, (S bits = 10) command and response*

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

Indication that the busy condition has cleared and I frames will now be accepted is communicated by the transmission of an RR, REJ, SREJ, SARM, SNRM, SARME, SNRME, and UA with or without the P/F bit set to "1", or an I frame with the P/F bit set to "1".

A secondary receiving an RNR frame when in the process of transmitting (i.e. two-way simultaneous) shall stop transmitting I frames at the earliest possible time. It is suggested that a secondary in NRM return a frame with the F bit set to "1" before suspending transmission.

The primary may use the RNR command with the poll bit set to "1" to obtain an S frame from the secondary. The S frame from the secondary shall have final bit set to "1".

5.2.4 *Selective reject, SREJ, (S bits = 11) command and response*

The selective reject, SREJ, frame is used by the primary or secondary to request retransmission of the single I frame numbered N(R). I frames numbered up to N(R) – 1 are acknowledged; I frame N(R) is not accepted. (Once a SREJ has been transmitted, the only I frames accepted are those numbered in sequence following the I frame requested, and the specific retransmitted I frame indicated by the N(R) in the SREJ command/response.)

The SREJ exception condition is cleared (reset) upon receipt of an I frame with an N(S) count equal to the N(R) of the SREJ command/response.

After a station transmits a SREJ, it may not transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared. (To do so would acknowledge as correctly received all I frames up to N(R) – 1, where N(R) is the sequence number in the second SREJ or REJ).

I frames that may have been transmitted following the I frame indicated by the SREJ command/response are not retransmitted as the result of receiving a SREJ. Additional

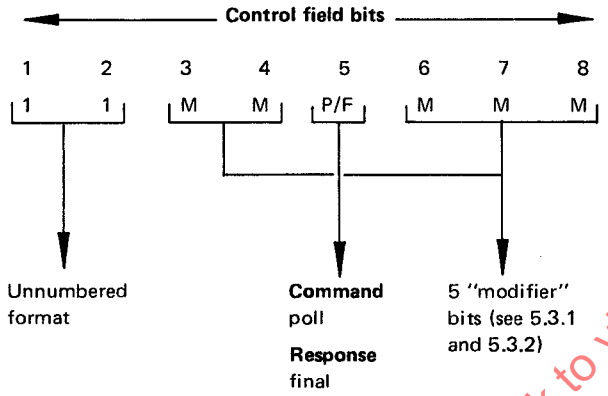
I frames pending initial transmission may be transmitted following the retransmission of the specific I frame requested by the SREJ.

See 6.2 for sequence error recovery procedures.

5.3 Unnumbered format commands and responses

Unnumbered, U, commands and responses are used by the primary and secondary to extend the number of link control functions. Frames transmitted with the U format do not increment the sequence counts at either the transmitting or receiving station. Five "modifier" bits are defined which allow up to 32 additional fucntions. Five combinations are defined below, all others are reserved.

The encoding of the U command/response control field is :



See clause 4 for description of the P/F bit functions.

5.3.1 *Unnumbered commands*

The following unnumbered commands are defined :

Control field bits								
1	2	3	4	5	6	7	8	
1	1	1	1	P	0	0	0	SARM command
1	1	0	0	P	0	0	1	SNRM command
1	1	0	0	P	0	1	0	DISC command
1	1	1	1	P	0	1	0	SARME command
1	1	1	1	P	0	1	1	SNRME command

See clause 4 for description of the P/F bit functions.

The SNRM, SARM, DISC, SNRME and SARME unnumbered mode setting commands require the secondary to acknowledge acceptance by responding with an unnumbered acknowledgement, UA, frame. The secondary station transmission of a UA response following the receipt of one of theses commands takes precedence over any I or S format response which may be pending at the secondary. The secondary may ignore all frames received following receipt of a mode setting command until it has sent a UA response acknowledging receipt of that command.

In two-way alternate communications, a secondary, following the receipt of a mode setting command, is restricted to transmitting a single UA response frame. In two-way simultaneous communication a secondary which is transmitting concurrent to the receipt of one of these mode setting commands shall initiate transmission of a single UA response frame at the first "respond opportunity".

The secondary may continue transmission following return of the UA response, if appropriate.

5.3.1.1 Set normal response mode (SNRM) command

The SNRM command is used to place the addressed secondary in the response mode (NRM). No information field is permitted with the SNRM command. The secondary confirms acceptance of SNRM by transmission at the first respond opportunity of a single UA response with the F bit set to "1". Upon acceptance of this command, the secondary send and receive variables are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Whether the station retransmits unacknowledged outstanding I frames or not may be decided at the higher level.

5.3.1.2 Set asynchronous response mode (SARM) command

The SARM command is used to place the addressed secondary in the asynchronous response mode (ARM). No information field is permitted with the SARM command. The secondary confirms acceptance of SARM by the transmission at the first respond opportunity of a UA response. Upon acceptance of this command the secondary send and receive variables are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Whether the station retransmits unacknowledged outstanding I frames or not may be decided at the higher level.

5.3.1.3 Disconnect (DISC) command

The DISC command is used to terminate an operational mode previously set by a command. In both switched and non-switched networks it is used to inform addressed secondaries that the primary is suspending operation and that the secondaries should assume a logically disconnected mode. In switched networks, a logical disconnect function at the data link level may also serve to initiate a physical disconnect operation at the physical interface level; i.e., to have the addressed secondary go "on-hook". No information field is permitted with the DISC command. Prior to actioning the command the secondary confirms the acceptance of DISC by the transmission of a UA response.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Whether the station retransmits unacknowledged outstanding I frames or not may be decided at the higher level.

5.3.1.4 SET NORMAL RESPONSE MODE EXTENDED (SNRME) COMMAND

The SNRME command is used to place the addressed secondary in the normal response mode extended (NRME) where all control fields will be two octets in length as defined in 5.4. The secondary confirms acceptance of SNRME by transmission at the first respond opportunity of a UA response, with the F bit set to "1", in the extended control field format. Upon acceptance of this command the secondary send and receive variables are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Whether the station retransmits unacknowledged outstanding I frames or not may be decided at the higher level.

5.3.1.5 SET ASYNCHRONOUS RESPONSE MODE EXTENDED (SARME) COMMAND

The SARME command is used to place the addressed secondary in the asynchronous response mode extended (ARME) where all control fields will be two octets in length as defined in 5.4. The secondary confirms acceptance of SARME by transmission at the first respond opportunity of a UA response in the extended control field format. Upon acceptance of this command the secondary send and receive variables are set to zero.

Previously transmitted I frames that are unacknowledged when this command is actioned remain unacknowledged. Whether the station retransmits unacknowledged outstanding I frames or not may decided at the higher level.

5.3.2 *Unnumbered responses*

The following unnumbered responses are defined :

Control field bits								
1	2	3	4	5	6	7	8	
1	1	0	0	F	1	1	0	UA response
1	1	1	0	F	0	0	1	CMDR response

5.3.2.1 UNNUMBERED ACKNOWLEDGE (UA) RESPONSE

The UA response is used by the secondary to acknowledge the receipt and acceptance of the U format commands defined in 5.3.1. Received U format commands are not actioned until the UA response is transmitted. The UA response is transmitted in the normal or extended control field format as directed by the received U format command.

No information field is permitted with the UA response.

5.3.2.2 COMMAND REJECT (CMDR) RESPONSE

The CMDR response is used by the secondary to report that one of the following conditions resulted from the receipt of a frame without FCS error from the primary :

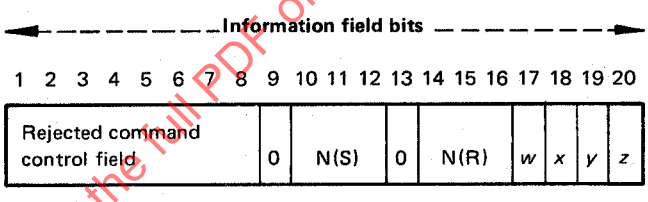
— the receipt of a command that is invalid or not implemented;

— the receipt of an I frame with an information field which exceeded the size of the buffer available;

— the receipt of an invalid N(R) from the primary.

An invalid N(R) is defined as one which points to an I frame which has previously been transmitted and acknowledged or to an I frame which has not been transmitted and is not the next sequential I frame pending transmission.

The secondary transmits the CMDR at the first respond opportunity. An information field will be returned with this response to provide the reason for the command rejct response. The information field contains the following field and information.



where

Rejected command control field is the control field of the received frame which caused the command reject;

N(S) is the current send sequence variable value at the secondary (bit 10 = low-order bit);

N(R) is the current receive sequence variable value at the secondary (bit 14 = low-order bit);

w set to "1" indicates the control field received and returned in bits 1 through 8 was invalid or not implemented;

x set to "1" indicates the control field received and returned in bits 1 through 8 was considred invalid because the frame contained an information field which is not permitted with this command. Bit w must be set to "1" in conjunction with this bit;

y set to "1" indicates the information field received exceeded the maximum information field length which can be accommodated by the secondary;

z set to "1" indicates the control field received and returned in bits 1 through 8 contained an invalid N(R) number.

The w, x, y and z bits in the information field of the CMDR may all be equal to zero, indicating an unspecified rejection of the command for one or more of the conditions cited above.

If required, the information field contained with the CMDR may be padded with zero bits so as to end on any convenient, mutually agreed-character, byte, word or machine-dependent boundary.

See also 6.4.

The format for the information field returned with the CMDR response is as follows when control field extension (see 5.4) is used :

Information field bits →

1 16	17	18 24	25	26 32	33			36
Rejected extended command control field	0	N(S)	0	N(R)	*w*	*x*	*y*	*z*

Bit 18 and bit 26 are the low-order bits of the sequence numbers.

5.4 Control field extension

The control field may be extended by the addition of a second contiguous octet immediately following the standard control field. This capability provides for N(S) and N(R) numbering of modulo 128.

When the secondary operational environment regarding control field format is not known by the primary, a set mode command sent by the primary should not be expressed in extended format.

Control field extension for the three formats is as follows :

Control field format for	Control field bits															
	1st Octet								2nd Octet							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Information transfer command/ response (I frame)	0	N(S)							P/F	N(R)						
Supervisory commands/ responses (S frame)	1	0	S	S	X	X	X	X	P/F	N(R)						
Unnumbered commands/ responses (U frame)	1	1	M	M	U	M	M	M	P/F	X	X	X	X	X	X	X

where X bits are reserved and set to zero and the value of U is unspecified. Bit 2 and bit 10 are the low-order bits of the sequence numbers.

6 EXCEPTION CONDITION REPORTING AND RECOVERY

This clause describes the error recovery procedures which are available to effect recovery following the detection/occurrence of an exception condition of the link level. Exception conditions described are those situations which may occur as the result of transmission errors, station malfunction or operational situations.

6.1 Busy

The busy condition results when a station is temporarily unable to receive or continue to receive I frames due to internal constrain for example receive buffering limitations. In this case an RNR frame is transmitted. Traffic pending transmission may be transmitted from the busy station prior to or following the RNR. Details of how a busy condition is cleared are given in 5.2.3.

6.2 N(S) sequence error

An N(S) sequence exception condition occurs in the receiver when an I frame received error free (no FCS error) contains an N(S) that is not equal to the receive state variable at the receiver. The receiver does not acknowledge (increment its receive state variable) the frame causing the sequence error or any I frames which may follow until an I frame with the correct N(S) is received. Unless SREJ is to be used to recover from a given sequence error, the information field of all I frames received whose N(S) does not equal the receive state variable R will be discarded. (See 6.2.3 for SREJ recovery.)

A primary or secondary which receives one or more I frames having sequence errors but FCS error free shall accept the control information contained in the N(R) field and the P/F bit to perform link control functions, for example to receive acknowledgement of previously transmitted I frames, and to cause a secondary to respond (P bit set to "1"). Therefore, the retransmitted I frame may contain an N(R) field and/or P/F bit information that are updated and therefore different from that contained in the originally transmitted I frame.

Following the occurrence of a sequence error, the following means are available for initiating the retransmission of lost or errored I frames.

6.2.1 *Poll/Final (P/F) bit recovery* (see also 4.3)

When a station receives a frame with the P/F bit set to "1", it initiates retransmission of unacknowledged I frames previously transmitted with sequence numbers less than or equal to the N(S) sequence number of the last P/F frame transmitted. Retransmission starts with the lowest numbered unacknowledged I frame. I frames are retransmitted sequentially. New I frames may be transmitted if they become available. Such retransmission of I frames is known as checkpoint retransmission.

Checkpoint retransmission is not initiated under the following conditions :

a) If an REJ with the P/F bit equal to "0" has been received and actioned, checkpoint retransmission is inhibited on the next P/F frame received.

b) If an SREJ with the P/F bit equal to "0" has been received and actioned, retransmission is inhibited on the next frame with the P/F bit equal to "1" when this frame is an SREJ and contains the same N(R) as the first SREJ.

c) If an unnumbered format frame with the P/F bit equal to "1" is received, P/F bit recovery is inhibited.

d) If an SREJ with the P/F bit equal to "1" is received, SREJ retransmission takes precedence over checkpoint retransmission.

6.2.2 *REJ recovery*

The REJ command/response is primarily used to initiate an earlier exception recovery (retransmission) following the detection of a sequence error than is possible by P/F bit recovery; for example in two-way simultaneous information transfer if REJ is immediately transmitted upon detection of a sequence error there is no requirement to wait for a frame with P/F bit set to "1".

Only one "sent REJ" exception condition, from a given station to another given station is established at a time. A "sent REJ" exception is cleared when the requested I frame is received, when the response/command time-out function expires, or when a P/F checkpoint cycle that was initiated concurrent with or following the transmission of REJ is completed. When the station perceives by time-out or by the check pointing mechanism that the requested I frame will not be received, because either the requested I frame or the REJ was in error/lost the REJ may be repeated. The REJ command/response shall be transmitted only one time within a P/F checkpoint cycle.

A primary or secondary receiving REJ initiates sequential (re-)transmission of I frames starting with the I frame indicated by the N(R) contained in the REJ frame.

If (1) retransmission beginning with a particular frame occurs due to checkpointing (sections 4.3.1, 4.3.2, and 6.2.1), and (2) an REJ is received which would also start retransmission with the same particular frame (as identified by the N(R) in the REJ), the retransmission resulting from the REJ shall be inhibited.

6.2.3 *SREJ recovery*

The SREJ command/response is primarily used to initiate more efficient error recovery by requesting the retransmission of a single I frame following the detection of a sequence error rather than the retransmission of the I frame requested plus all additional I frames which may have been subsequently transmitted. To improve transmission efficiency it is recommended that the SREJ command/response be transmitted as the result of the detection of a sequence error where only a single I frame is missing (as determined by receipt of the out-of-sequence N(S)).

When an I frame sequence error is detected, the SREJ is transmitted at the earliest possible time. When a station sends an SREJ with the P/F bit equal to "0" and the "sent SREJ" condition is not cleared when the station is ready to issue the next frame with the P/F bit equal to "1", the station sends an SREJ with the P/F bit equal to "1" with the same N(R) as the original SREJ.

Since a frame sent with P/F equal to "1" has the potential of causing a checkpoint retransmission, a station will not send an SREJ with the same N(R) [same value and same numbering cycle] as that of the previously sent frame with P/F bit equal to "1".

Only one "sent SREJ" exception condition from a given station to another given station is established at a time. A "sent SREJ" exception condition is cleared when the requested I frame is received, when the response/command time-out function expires, or when a P/F checkpoint cycle that was initiated concurrent with or following the transmission of SREJ is completed. When the station perceives by time-out or by the checkpointing mechanism that the requested I frame will not be received, because either the requested I frame or the SREJ was in error/lost, the SREJ may be repeated.

When a station receives and actions an SREJ with the P/F bit equal to "0", it will disable actioning of the next SREJ if the SREJ has the P/F bit equal to "1" and has the same N(R) [i.e., has the same value and same numbering cycle] as the original SREJ.

6.2.4 *Time-out recovery*

In the event the remote station, due to a transmission error, does not receive (or receives and discards) a single I frame or the last I frame(s) in a sequence of I frames, it will not detect an out-of-sequence exception and therefore will not transmit SREJ/REJ. The station which transmitted the unacknowledged I frame(s) shall, following the completion of a system specified time-out period, take appropriate recovery action to determine the point at which retransmission must begin.

It is recommended that a station which has timed out waiting for a response should not retransmit all unacknowledged frames immediately. A secondary station in ARM will, in this time-out case, either retransmit its last single frame or transmit new frames if they are available. A primary station may enquire status with a supervisory frame.

NOTE – To account for possible retransmissions after time-out, a receiving station should not set an SREJ condition when it receives an I frame with an N(S) one less than its receive state variable.

If a station does retransmit all unacknowledged I frames after a time-out, it must be prepared to receive a following REJ frame with an N(R) greater than the send state variable of the station which retransmits.

6.3 FCS error

Any frame received with an FCS error is not accepted by the receiver. The frame is discarded, and no action is taken as the result of that frame. If the frame experiencing an FCS error was a response frame with the F bit set to "1", a resulting time-out will occur in the primary prior to initiating recovery action.

6.4 Command rejection

A command rejection condition is established upon the receipt of an error-free frame which contains an invalid command/response in the control field, an invalid frame format, an invalid N(R) or an information field which exceed the maximum information field length which can be accommodated by the secondary.

At the primary this exception condition is subject to recovery/resolution at a higher level.

At the secondary this exception condition is reported by a CMDR response for appropriate primary action. Once a secondary has established a CMDR exception, no additional I frames are accepted, except for examination of the state of the P bit and the N(R) field until the condition is reset by the primary. The CMDR response is repeated at each respond opportunity until recovery is effected by the primary. The CMDR condition may be reset by reception of a mode set command or a DISC command.

ANNEX A

VOCABULARY

For the purpose of this International Standard the following definitions apply :

abort : A function invoked by a sending primary or secondary causing the recipient to discard (and ignore) all bit sequences transmitted by the sender since the preceding flag sequence.

accept : The condition assumed by a (primary or secondary) station upon accepting a correctly received frame for processing.

address field (A) : The sequence of eight (or any multiple of eight, if extended) bits immediately following the opening flag sequence of a frame identifying the secondary sending (or designated to receive) the frame.

address field extension : Enlarging the address field to include more addressing information.

basic status : A secondary's capability to send or receive a frame containing an information field.

centralized control : A control in which all the primary functions of the data link are centralized in one station.

command : In data communications, an instruction represented in the control field or a frame and transmitted by the primary. It causes the addressed secondary to execute a specific data link control function.

command frame : All frames transmitted by a primary.

contention mode : A mode of transmission in which a transmitter can send on its own initiative.

control field (C) : The sequence of eight (or sixteen, if extended) bits immediately following the address field of a frame. The content of the control field is interpreted by :

a) the receiving secondary, designated by the address field, as a command instructing the performance of some specific function;

b) the receiving primary, as a response from the secondary, designated by the address field, to one or more commands.

control field extension : Enlarging the control field to include additional control information.

data link : An assembly of two or more terminal installations and the interconnecting line operating according to a particular method that permits information to be exchanged; in this context the term "terminal installation" does not include the data source and the data sink.

exception condition : The condition assumed by a secondary upon receipt of a command which it cannot execute due to either a transmission error or an internal processing malfunction.

flag sequence (F) : The unique sequence of eight bits (01111110) employed to delimit the beginning and ending of a frame.

frame : The sequence of contiguous bits, bracketed by beginning and ending flag sequences. A valid frame is at least 32 bits in length and contains an address field, a control field and a frame check sequence. A frame may or may not include an information field.

frame check sequence (FCS) : The field immediately preceding the ending flag sequence of a frame, containing the bit sequence that provides for the detection of transmission errors by the receiver.

higher level : The conceptual level of control or processing logic existing in the hierarchical structure of a station (primary or secondary) that is above the link level and upon which the performance of link level functions are dependent, for example device control, buffer allocation, station management, etc.

information field (INFO) : The sequence of bits, occurring between the last bit of the control field and the first bit of the frame check sequence. The information field contents are not interpreted at the link level.

inter-frame time fill : The sequence of flag sequences transmitted between frames. This standard does not provide for time fill within a frame.

invalid frame : A sequence of bits, following the receipt of an apparent beginning flag sequence that either :

a) is terminated by an abort sequence, or

b) contains less than 32 bits before an apparent ending flag sequence is detected.

link level : The conceptual level of control or processing logic existing in the hierarchical structure of a station (primary or secondary) that is responsible for maintaining control of the data link. The link level functions provide an interface between the station high level logic and the data link : these functions include (transmit) bit injection and (receive) bit extraction, address/control field interpretation, command/response generation, transmission and interpretation, and frame check sequence computation and interpretation.

primary : That part of the data station that supports the primary control functions of the data link. The primary generates commands for transmission and interprets received responses. Specific responsibilities assigned to the primary include :

a) initialization of control signal interchange;

b) organization of data flow;

c) actions regarding error control and error recovery functions at the link level.

primary/secondary : The general case where the link contains a single primary and one or more secondary stations.

response : In data communications, a reply represented in the control field of a response frame. It advises the primary with respect to the action taken by the secondary to one or more commands.

response frame : All frames transmitted by a secondary.

secondary : That part of the data station that executes data link control functions as instructed by the primary. A secondary interprets received commands and generates responses for transmission.

secondary status : The current condition of a secondary with respect to processing the series of commands received from the primary.

unnumbered commands : The commands that do not contain sequence numbers in the control field.

unnumbered responses : The responses that do not contain sequence numbers in the control field.

ANNEX B

TIMER CONSIDERATIONS

(Not an integral part of the body of this International Standard)

In order to detect a no-reply or lost reply condition, each primary shall provide a response time-out function. Also, in ARM, in order to detect a no-reply or lost-reply condition, each secondary shall provide a command time-out function. In any case, the expiration of a timer shall initiate appropriate error recovery procedures.

The duration of a time-out is system dependent and subject to bilateral agreement.

B.1 NORMAL RESPONSE

B.1.1 Primary reply timer

Start condition

Transmission of a command frame with P bit set to "1".

NOTE – No more than one poll may be outstanding at one time.

Restart condition

Receipt of an error-free frame with F bit set to "0".

Stop condition

Receipt of an error-free frame with F bit set to "1".

B.1.2 Secondary reply timer

There is no need for secondary reply timer.

B.2 ASYNCHRONOUS RESPONSE MODE

B.2.1 Primary reply timer

Start condition

Transmission of a command frame with P bit set to "1".

Restart condition

In two-way simultaneous communication, the timer is not restarted. In two-way alternate communication, however, the timer shall be restarted upon transmission of each frame until the link is relinquished (by reverting to idle state) by the primary.

Stop condition

Receipt of an error-free frame with F bit set to "1".

B.2.2 Secondary reply timer

Start condition

Transmission of an I frame.

Restart condition

In two-way simultaneous communication, the timer is not restarted. In two-way alternated communication, however, the timer shall be restarted upon transmission of each frame until the link is relinquished (by reverting to idle state) by the secondary.

Stop condition

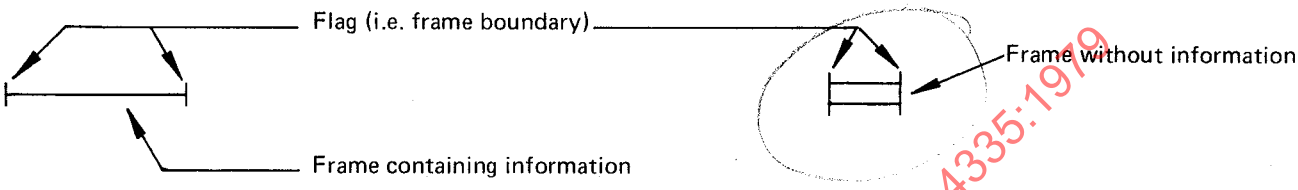
Receipt of an error-free frame containing the expected N(R).

ANNEX C

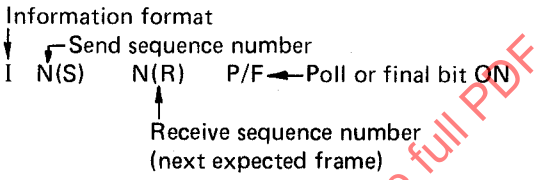
EXAMPLES OF THE USE OF COMMANDS AND RESPONSES

(Not an integral part of the body of this International Standard)

The notation used in the annex C diagrams is illustrated below.

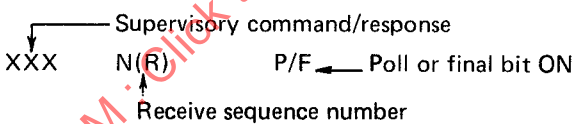


Information frame :



Example : Pri xmits : I2,6 P. This denotes a primary information frame with send sequence number 2, the next expected I frame from the secondary is receive sequence number 6 (frames numbered 5 and below are therefore acknowledged) and the poll bit is set to "1" (i.e. the secondary is to initiate transmission with I frames if available).

Supervisory frame :

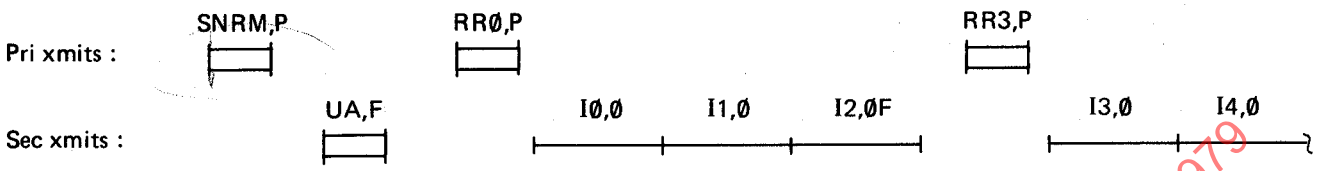


Example : Pri xmits : RR2 P. This denotes a receive ready (RR) command, N(R) = 2 (i.e. the next expected I frame from the secondary is receive sequence number 2), and the poll bit is set to "1".

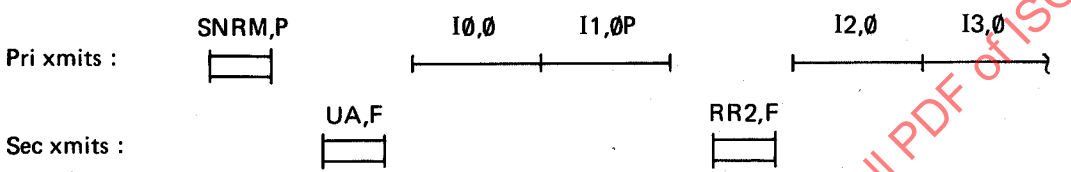
C.1 EXAMPLES OF NORMAL RESPONSE MODE (NRM) 2 WAY ALTERNATE (HDX) TRANSMISSION

C.1.1 Normal response mode (NRM) HDX without transmission errors

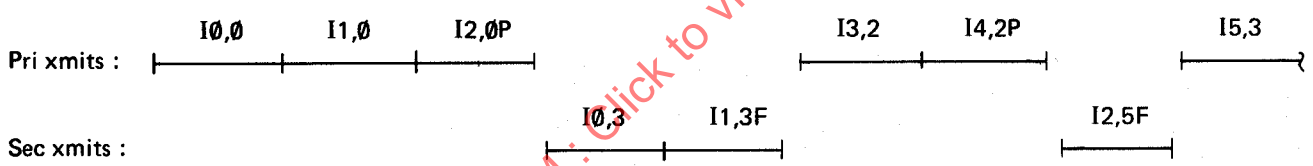
C.1.1.1 *NRM start-up procedure and secondary only information transfer*



C.1.1.2 *NRM start-up procedure and primary only information transfer*

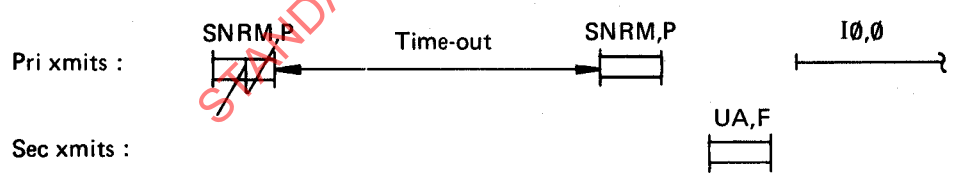


C.1.1.3 *NRM information transfer by primary and secondary*

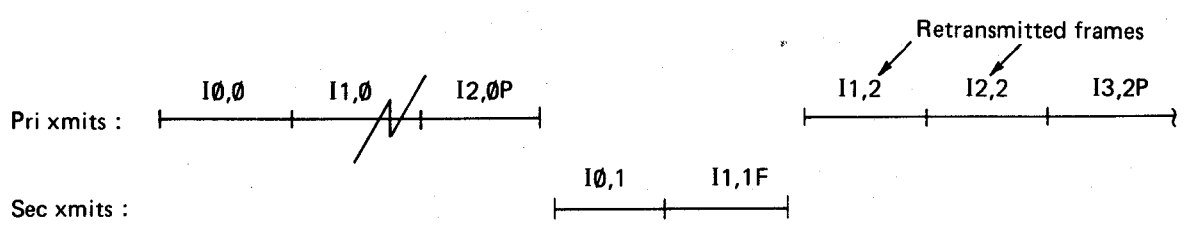


C.1.2 Normal response mode (NRM) HDX with transmission errors in command frames

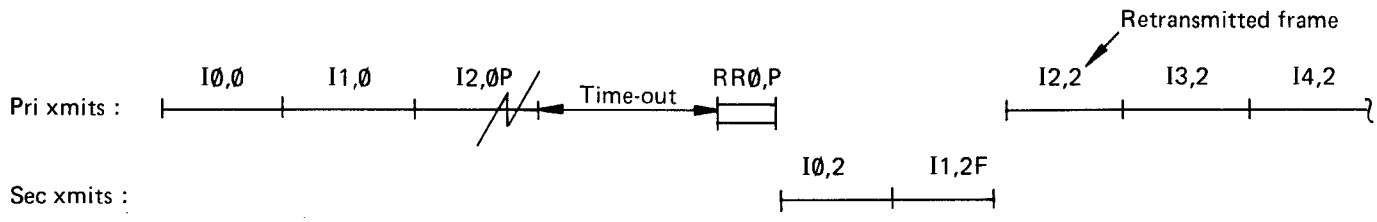
C.1.2.1 *NRM start-up command error*



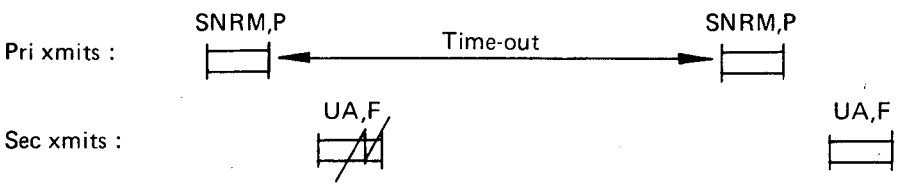
C.1.2.2 *NRM primary information frame error*



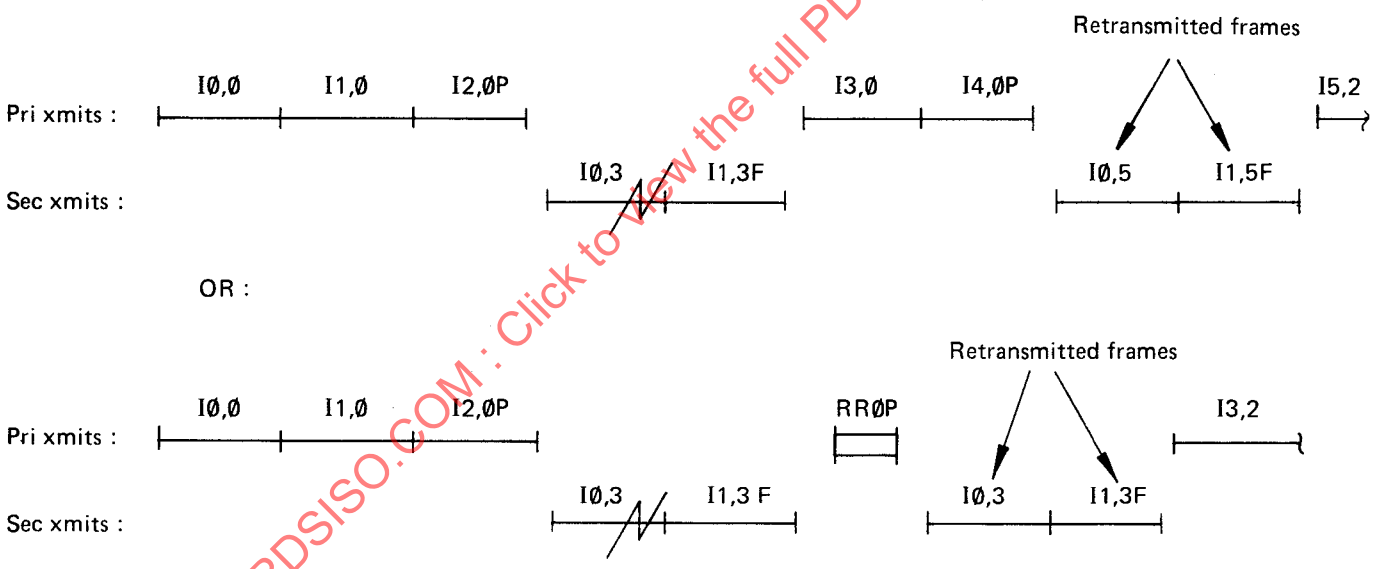
C.1.2.3 *NRM primary poll frame error*



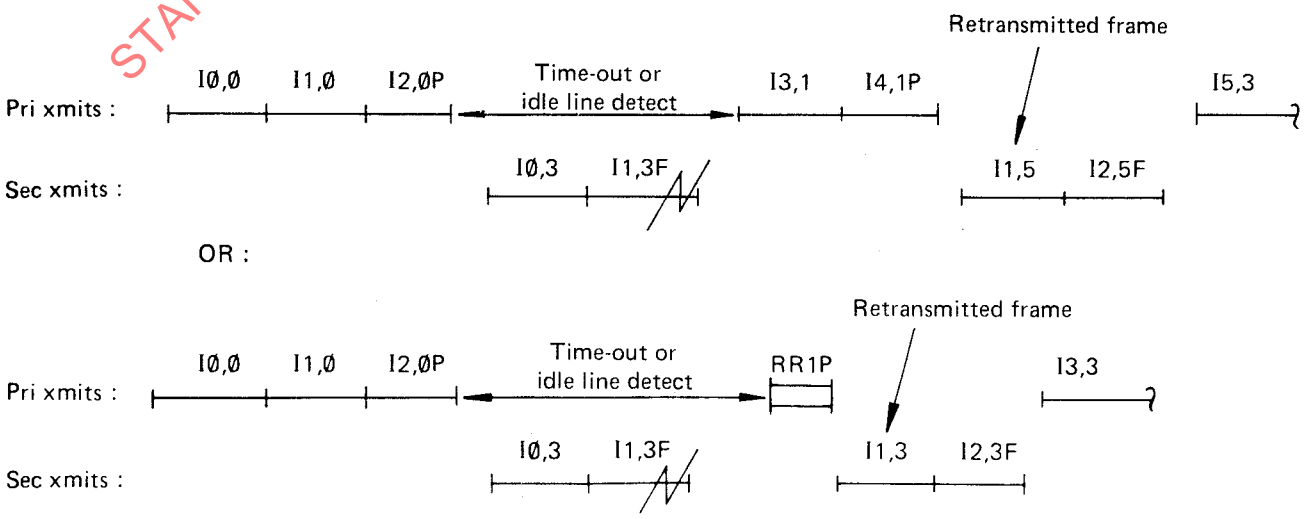
C.1.3.1 *NRM start-up response error*



C.1.3.2 *NRM secondary information frame error*



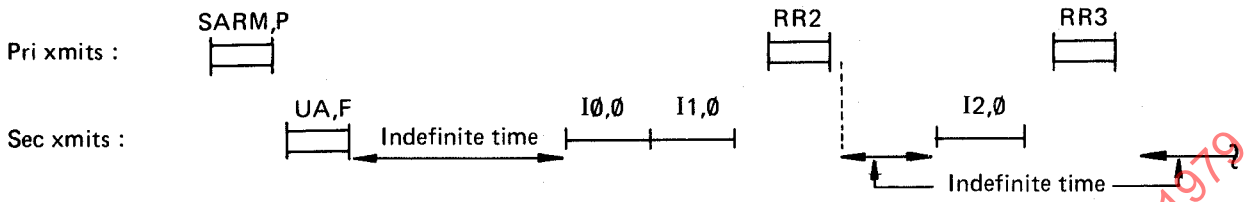
C.1.3.3 *NRM secondary "final" frame error*



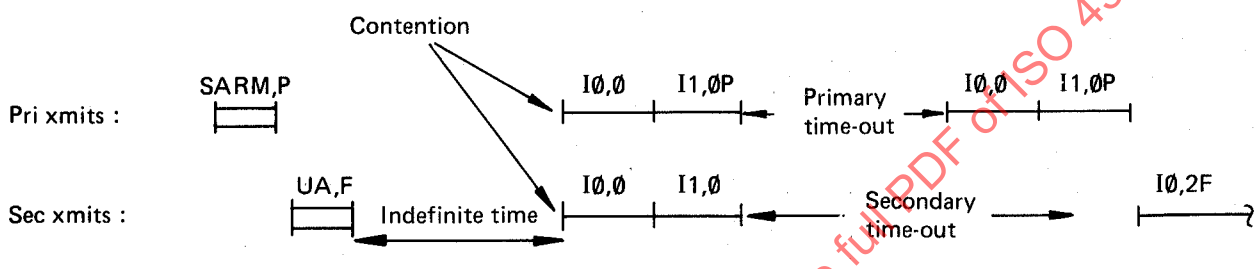
C.2 EXAMPLES OF ASYNCHRONOUS RESPONSE MODE (ARM) 2-WAY ALTERNATE (HDX) TRANSMISSION

C.2.1 Asynchronous response mode (ARM) HDX without transmission error

C.2.1.1 *ARM start-up procedure and secondary only information transfer*

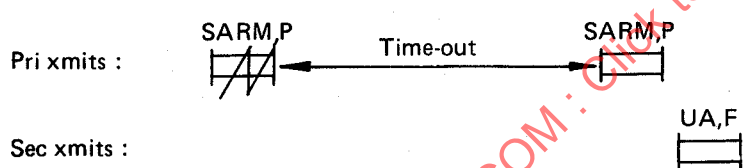


C.2.1.2 *ARM primary and secondary information transfer with contention situation*



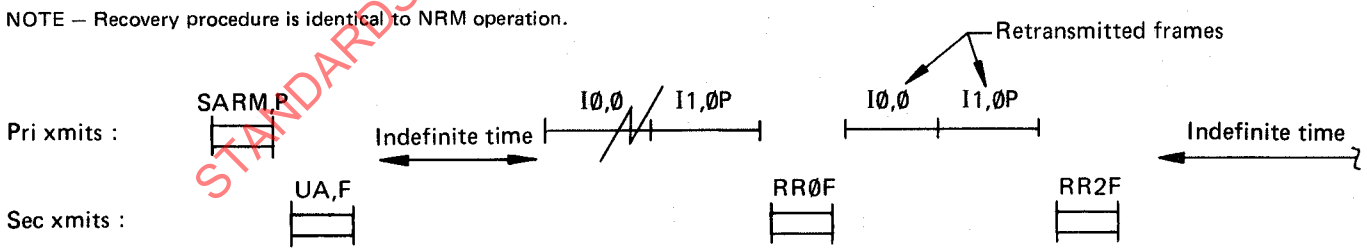
C.2.2 Asynchronous response mode (ARM) HDX with transmission errors in command frames

C.2.2.1 *ARM start-up command error*



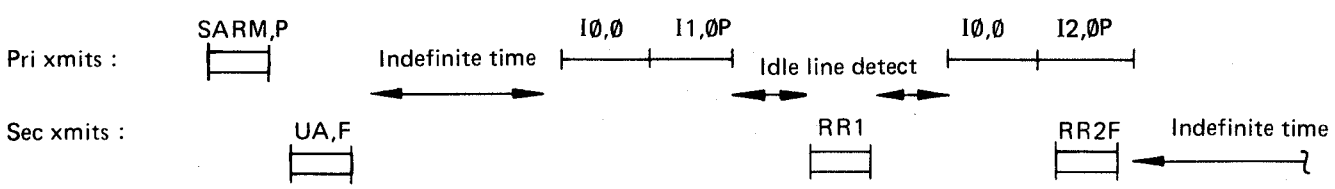
C.2.2.2 *ARM primary information frame error*

NOTE – Recovery procedure is identical to NRM operation.



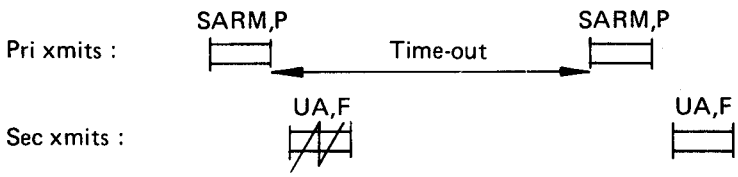
C.2.2.3 *ARM primary "poll" information frame error*

NOTE – Recovery procedure is identical to NRM operation.

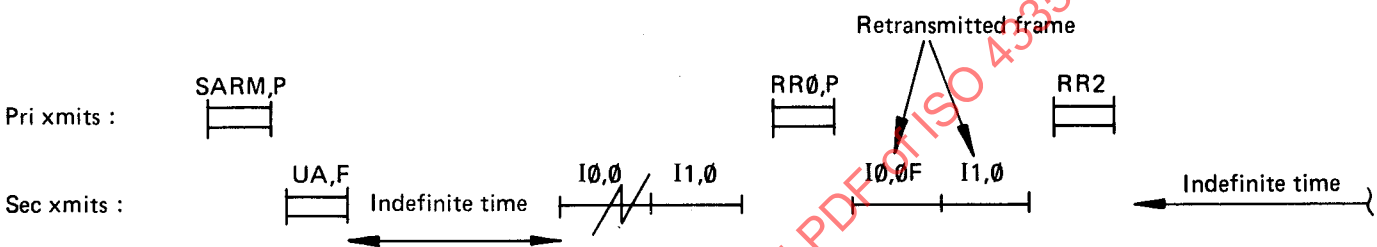


C.2.3 Asynchronous response mode (ARM) HDX with transmission errors in response frames

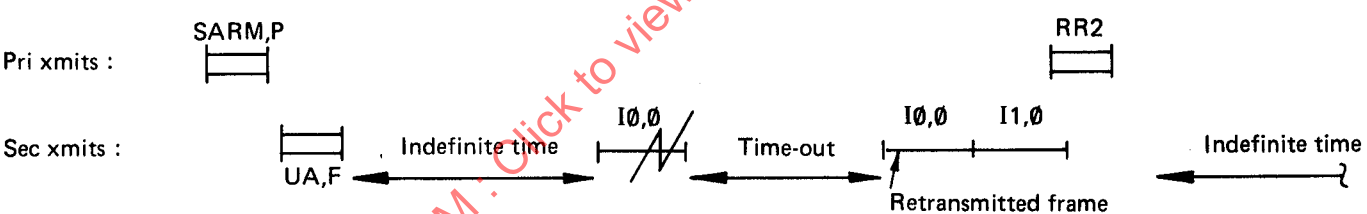
C.2.3.1 *ARM start-up*



C.2.3.2 *ARM secondary information frame error*



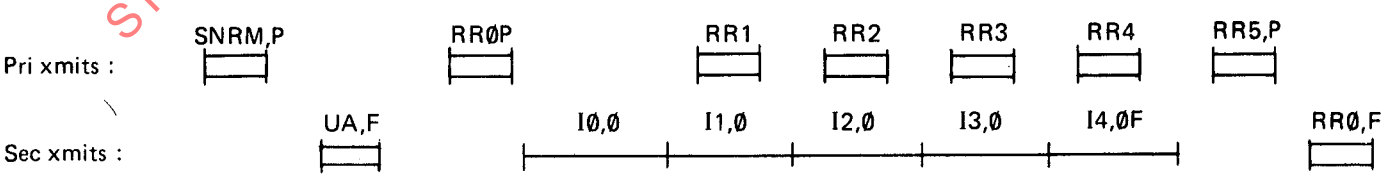
C.2.3.3 *ARM secondary "final" information frame error*



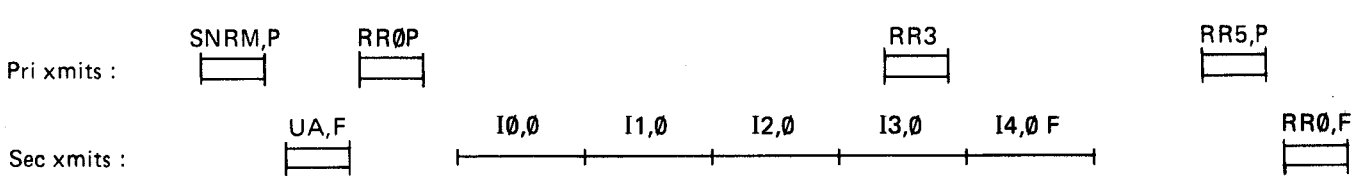
C.3 EXAMPLES OF NORMAL RESPONSE MODE (NRM) 2-WAY SIMULTANEOUS (FDX) TRANSMISSION

C.3.1 Normal response mode (NRM) FDX without transmission errors

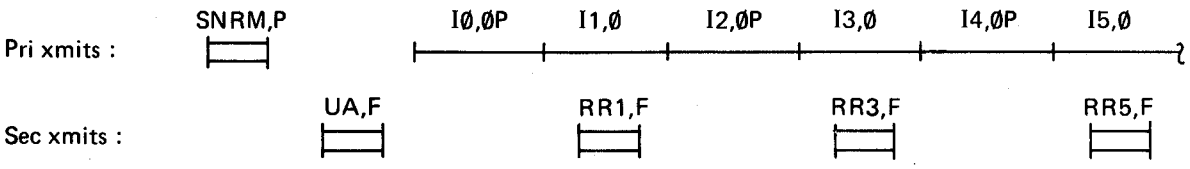
C.3.1.1 *NRM start-up procedure and secondary only information transfer*



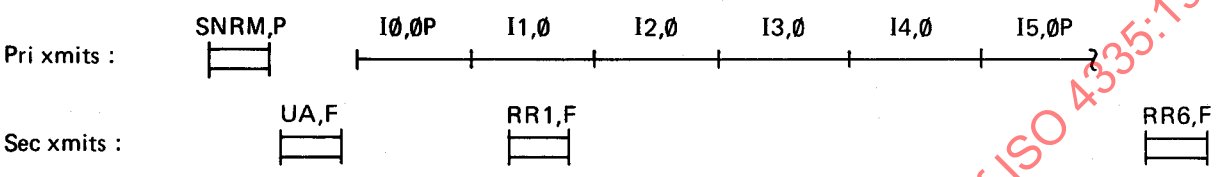
OR (where primary acknowledgements are returned for several response frames)



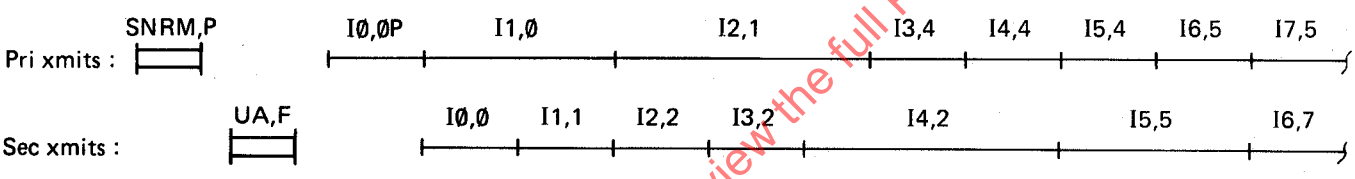
C.3.1.2 *NRM start-up procedure and primary only information transfer*



OR (where primary sets poll bit to "1" to solicit acknowledgement for several frames)

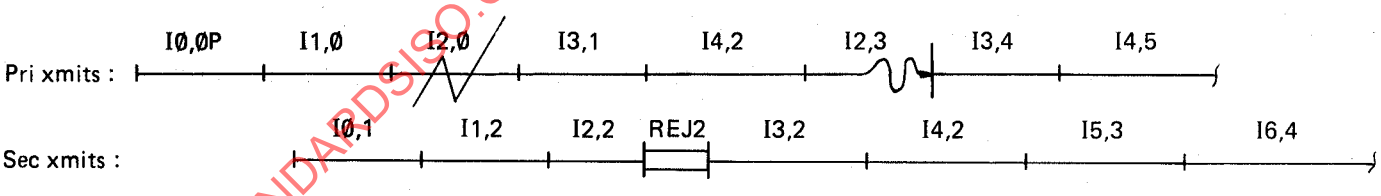


C.3.1.3 *NRM start-up procedure and primary/secondary information transfer*

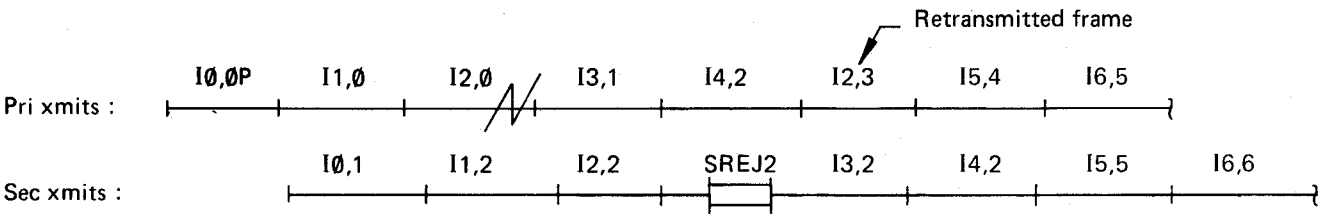


C.3.2 Normal response mode (NRM) FDX with transmission errors in command frames

C.3.2.1 *NRM REJ capability*



C.3.2.2 *NRM SREJ capability*



* Optional : Frame may be completed or aborted.