ISO High-Level Data Link Control (HDLC)

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Note: The subject of this report is a mature standard. No significant developments are anticipated, but Datapro will provide a new report when the topic warrants it.

Datapro Summary

The International Organization for Standardization (ISO) Technical Committee 97 (TC 97, Computers and Information Processing) developed the High-Level Data Link Control (HDLC) protocol. HDLC addresses the physical connection standards for layer two of the International Organization for Standardization's (ISO's) Open Systems Interconnection (OSI) model. It permits synchronous, bit-oriented, independent data transmission. It provides simplex, half-duplex, or full-duplex communication. Network configurations may be point-to-point or multipoint over switched or nonswitched facilities. HDLC is approved as an international standard.

HDLC covers a wide array of applications. It permits simplex, half-duplex, or full-duplex transmission, configured point-to-point or multipoint, over switched or nonswitched facilities. It does not define a single system and should not be regarded as a specification for a data communications system. It is intended to provide a high degree of compatibility between data terminal equipment (DTE).

Several protocols, such as Unisys' Burroughs Data Link Control (BDLC), IBM's Synchronous Data Link Control (SDLC), and Unisys' Sperry (Univac) Universal Data Link Control (UDLC), are based on the HDLC concept. HDLC's capability of transmitting up to 127 frames before an acknowledgment is required makes it possible to transmit information via satellite, as well as via terrestrial facilities.

Stations

HDLC defines two types of stations on the data link. The station assuming the responsibility for the organization of data flow and for link-level error recovery functions is the **primary station**. All other stations on the link are **secondary stations**. The primary station transmits *command frames*, and the secondary stations transmit *response frames*.

For data transfer, HDLC considers two cases of data link control. The first case is when the primary station performs the primary data link control functions by controlling the secondary station through select commands. The second case is when the primary station controls the secondary station through poll commands.

Two terms are used to describe the data flow. The *data source* is the station currently transmitting information; the *data sink* is the station accepting the information. Information always flows from the data source to the data sink; acknowledgments flow in the opposite direction.

Classes of Procedures/ Configurations

A class of procedures is the basic repertoire of steps to which a station conforms in order to communicate. HDLC defines two classes of procedures and associated station configurations: balanced and unbalanced. Table 1 outlines the basic repertoire of commands and responses for each mode.

In the **unbalanced** class of procedures, the configuration consists of one primary station and one or more secondary stations. The primary station's responsibilities include setting up and disconnecting the link; sending information frames, supervisory, and unnumbered commands; and checking received frames. The secondary station checks received frames and sends supervisory information, as well as unnumbered responses. The communications link may be half or full duplex, switched or nonswitched. Control procedures operate in either normal or asynchronous

Table 1. Basic Repertoire of Commands and Responses*

Balanced Mode

Commands	Responses
I	I
RR	RR
RNR	RNR
SABM**	CMDR
DISC	UA
	DM

Unbalanced Normal Mode

Primary Station Commands	Secondary Station Responses
I	I
RR	RR
RNR	RNR
SNRM	DMDR
DISC	UA
	DM

Unbalanced Asynchronous Mode

Primary Station Commands	Secondary Station Responses
I	I
RR	RR
RNR	RNR
SARM	CMDR
DISC	UA
	DM

**See text for explanation of mnemonics.*
***Set Asynchronous Balanced Mode—used to set up the connection.*

response mode. Only one secondary station at a time can be placed in asynchronous response mode.

In the **balanced** class of procedure, the link consists of two combined stations and operates in the asynchronous balanced mode. A *combined* station acts as both a primary and a secondary station, sends and receives both commands and responses, and is responsible for error recovery. This type of operation provides for equal control by both stations on the link; both stations share link management. The HDLC balanced class of procedure applies to point-to-point configurations over switched or leased facilities. Commands are sent with the remote station address; responses are sent with the local station address. The combined station at either end may initiate link connection or disconnection.

Under either type of procedure, the data link exists in one of two channel states. The **active** condition occurs when the primary or the secondary station is actively transmitting a frame, abort sequence, or interframe time fill. In this state, the right to continue transmission is reserved. In the **idle** state, the station has terminated transmission. The idle state is characterized by the transmission of at least 15 consecutive one bits.

Modes of Operation

Two primary modes of operation are defined in HDLC. In the **normal response mode (NRM)**, the secondary station may initiate transmission only after receiving permission from the primary station; upon receiving permission, the secondary station issues a response transmission. The last frame of this transmission is indicated explicitly by the secondary station. After completing its transmission, the secondary station must wait until it again receives permission to transmit from the primary station.

In **asynchronous response mode (ARM)**, the secondary station may initiate transmission without permission from the primary station. The frames transmitted by the secondary station during ARM may be used to transfer information and/or to indicate status changes.

Three secondary modes of operation are also defined in HDLC. These include two disconnected modes, which are provided to prevent a secondary station from appearing operational during unusual situations or exception conditions. **Normal disconnected mode (NDM)** logically disconnects the station from the link; while in NDM, the secondary station remains ready to respond in normal response mode. The same situation exists during **asynchronous disconnected mode (ADM)**, except that the secondary station remains ready in asynchronous response mode.

The third secondary mode is the **initialization mode (IM)**. During IM, the link control of the secondary station is initialized or regenerated, or other parameters may be exchanged. IM is invoked when the primary station detects that the secondary station is not operating normally or that the link control program needs to be upgraded at the remote station. IM may also be requested by the secondary station for the same reasons.

Frame Structure

The HDLC frame structure consists of FLAG—ADDRESS—CONTROL—INFORMATION (Optional)—FRAME CHECK SEQUENCE—FLAG.

All frames must start and end with a **Flag** that consists of the bit sequence 01111110. All stations attached to the data link continuously search for this sequence. In this manner, the flag is used for frame synchronization. (A single flag may be used as the closing flag for one frame, as well as the opening flag for the next frame.)

Frames that do not begin and end with a flag, or frames that are too short (shorter than 32 bits between flags) are invalid and, therefore, ignored. Any frame that ends with an all "1" bit sequence that is equal to or greater than seven bits in length will also be ignored. Therefore, one method to abort a frame would be to transmit eight contiguous "1" bits.

Flag	Address	Control	Information	FCS	Flag
01111110	8 bits	8 bits	An unspecified length; usually a multiple of eight bits	16 bits	01111110

Table 2. Control Field Extensions

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.
NRM–NORMAL RESPONSE MODE.
ARM–Asynchronous response mode.
TWA–Two-way alternate.
TWS–Two-way simultaneous.

Interframe time fill is accomplished by transmitting either consecutive flags, a minimum of seven contiguous "1" bits, or a combination of both. Selection of interframe time fill methods depends on system requirements.

Since it is possible for six or more binary "1s" to be contiguous elsewhere in the frame, HDLC provides a mechanism that achieves transparency for these nonflag-related sequences using the process of *zero insertion.* The transmitter examines the frame content including the address, control, and FCS fields and inserts a zero after all sequences of five contiguous "1" bits. This ensures that a flag sequence is not simulated. At the receiving end, the incoming frames are examined and any "0" bit directly following five "1" bits is discarded.

The flag is followed by the **Address** field. In command frames, the address must identify the station(s) for which the command is intended. In response frames, the address must identify the station sending the response.

Normally, a single octet (eight-bit) address would be used, making a total of 256 combinations available. The address range can be extended, however, by reserving the first transmitted bit (low order) of each address octet, which is set to binary zero. This indicates that the following octet is an extension of the basic address. The format of the extended octet(s) must be the same as that of the basic octet, and, in this way, the address field may be recursively extended.

When extensions are used, the presence of a binary "1" in the first transmitted bit of the basic address octet indicates that only one address octet is used. Thus, the use of address extension restricts the range of single octet addresses to 128.

HDLC outlines three conventions for addressing frames, aside from assigning each station its own address.

The *global address* is a single address field combination that instructs all stations to accept and take action on the associated frame. When the command is intended for more than one station, the acknowledging stations must not respond simultaneously. The global address is also used for global polling. A response with the assigned station address may be given to a command with a global address when there is only one station for which the command is intended. This convention may be used to receive an unknown station's identification, as in switched or reconfigured situations. The combination 11111111 is reserved as the global address.

The address combination 00000000 in the first octet of the address field is never assigned to a station. This is the reserved *no station address* which in a command may be used for testing purposes, such as testing line loop fault.

One or more stations may be assigned a *group address*, as well as an individual address. This address may be used to broadcast to the assigned group of stations. Any address combination, except the global and the no-station address, may be assigned as a group address.

The **Information** field is an unspecified number of bits that need not follow any particular character structure. In most cases, however, a convenient structure, such as an octet, is used. Theoretically, there is no limit to the length of the information field; however, certain factors, like buffer size, may impose limitations.

The **Frame Check Sequence (FCS)** is a 16-bit field which appears prior to the closing flag. It detects errors in the frame and is the ones complement (modulo 2) of the sum of:

- The remainder of $x^k (x^{15} + x^{14} + x^{13} + \ldots + x + x + 1)$ divided (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency; and
- The remainder after multiplication by x^{16} and then the division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of 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 remainder of the division is preset to all ones and is then modified by division by the generator polynomial (as described above) on the Address, Control, and Information fields. The ones complement of the resulting remainder is transmitted as the 16-bit FCS sequence.

HDLC permits the FCS field to increase by multiples of eight bits (octets) if further protection against errors is needed. Such a suggestion also has been drafted into the revision of the ANSI Advanced Data Communications Control Procedures (ADCCP). It calls for a 32-bit FCS which, although it would increase overhead by 16 bits, would eliminate errors that may pass undetected using the 16-bit FCS. An example of such an error would be a scrambled single flag between frames when only a single flag between frames is used.

The **Control** field contains either commands or responses and sequence numbers. The control field functions to convey a command to the addressed station for the performance of a particular operation or to convey a response to such a command from the addressed station.

Three formats are defined for the control field, each performing a different function. In the *information transfer format,* or I format, the transfer of information is permitted. Only frames using the I control field format may contain an information field. Each I frame contains three elements: a send variable (S), a receive variable (R), and a poll/final bit set to either 1 or 0. A discussion of frame variables (numbering) and the poll/final bit appears later in this report.

In the *supervisory format,* or S format, link supervisory control functions are transmitted. Examples of supervisory functions include the acknowledgment of I frames and the request for retransmission of I frames.

The *unnumbered format,* or U format, provides additional link control functions. The control format's U format contains no sequence numbers; as a result, five modifier bits allow the definition of up to 32 additional command functions and 32 additional response functions. See Table 2 for an illustration of the extended control field.

Table 3. Summary of Poll/Final Bit Function

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.
NRM–NORMAL RESPONSE MODE.
ARM–Asynchronous response mode.
TWA–Two-way alternate.
TWS–Two-way simultaneous.

Control Field Procedures

Four **supervisory commands and responses** perform functions such as acknowledgment, polling, and temporary suspension of information transfer (see Figure 2 for bit encoding).

Receive Ready (RR), used by the primary and secondary stations, indicates readiness to receive an information frame or to acknowledge previously received information frames numbered up to N(R)–1. The primary station may also use RR with the poll bit set to "1" to solicit responses from a secondary station.

Reject (REJ) requests retransmission of information frames, beginning with the frame numbered N(R). Only one REJ condition from a given station may be established at one time. The REJ is cleared when the information frame that has an N(S) equal to the N(R) of the REJ command/response is received.

Receive Not Ready (RNR) indicates a busy condition or the inability to accept any additional information frames. A secondary station that receives an RNR while in the process of transmitting must stop transmitting information frames at the earliest possible time.

Selective Reject (SREJ) is used to request retransmission of an information frame numbered N(R). It is cleared when an information frame is received that has an N(S) count equal to the N(R) of the received SREJ command/response. Until the first SREJ error condition is cleared, no other sequence error commands can be transmitted.

Unnumbered commands and responses extend the number of link control functions. The transmission of frames in the unnumbered format, or U format, does not increment the sequence counts at either the primary or secondary station. Although this permits the addition of up to 32 additional functions, only 5 functions are defined; all others are reserved. The five unnumbered commands are briefly described below.

Set Normal Response Mode (SNRM) is a command that places the secondary station in NRM. No information field is permitted.

Set Asynchronous Response Mode (SARM) is a command that places the addressed secondary station in ARM. No information field is permitted.

The *Disconnect (DISC)* command terminates a previously set operational mode. It informs the secondary stations that the primary station is suspending its operation and that the secondary stations should place themselves in disconnected mode. No information field is permitted.

Set Normal Response Mode Extended (SNRME) is a command that places the secondary station in the extended normal response mode (NRME). In this mode, all control fields are two octets long.

Set Asynchronous Response Mode Extended (SARME) is a command placing the secondary station in the extended asynchronous response mode (ARME), where all control fields are two octets long.

In addition to the unnumbered commands, two unnumbered responses are defined:

The *Unnumbered Acknowledgement (UA)* response, used by the secondary station, acknowledges that it has received and accepted one of the unnumbered format commands. It is the response to SNRM, SARM, DISC, SNRME, and SARME. No information field is permitted with the UA response.

The *Command Reject (CMDR)* response, also used by the secondary station, reports one of the following conditions: an invalid or not implemented command has been received, an information frame has been received which exceeds the size of the buffer available, or a frame with an invalid N(R) has been received from the primary station. The response includes an information field to provide the reason for the CMDR.

Frame Numbering

Every information frame is numbered sequentially. In the unextended control field I format, the numbering modulo is eight; up to seven messages may be outstanding before an acknowledgment is required. The message numbers continually cycle through the entire seven-combination range of the three-bit field available for numbering.

In the extended control field format, seven bits are available for message numbering (see Table 2). This is an important characteristic of HDLC, since it increases the numbering modulo to 128. Modulo 128 permits up to 127 messages to be outstanding before an acknowledgment is required, and it is an effective counteraction against propagation delay. The modulo can be set to ensure a steady flow of information, even on facilities with long propagation delays, such as satellites.

Four terms are associated with the frame numbering function of the control field. Each data station maintains independent send and receive sequence numbers on the information frames it sends and receives. The *send state variable V(S)* denotes the *receive sequence number N(R)* of the next in-sequence information frame received. The value of V(R) and the corresponding N(R) is incremented by one when an error-free in-sequence equals the receive state variable. All information and supervisory frames contain the N(R), the expected sequence number of the incoming information frame.

Additional Commands/Responses

Four commands and five responses are defined for the secondary operational modes.

The *Set Initialization Mode (SIM)* command causes the addressed secondary station to initiate procedures that initialize its link-level control functions. No information field is permitted.

The *Unnumbered Poll (UP)* command solicits response frames from either a group of secondary stations (group poll) or an individual secondary station (individual poll). No information field is permitted. The response frame to the UP contains the station address, plus the N(S) and N(R) numbers as required. If the primary station detects an idle state (15 ones), or no response is given to the UP command within a given period of time, it is assumed that the secondary station has either completed or will not initiate transmission.

The *Unnumbered Information (UI)* command is used to transmit information to a secondary station or group of secondary stations without changing the V(S) or V(R) variables. No response is required.

The *Exchange Identification (XID)* command causes the addressed secondary station to identify itself. It may also be used to provide primary station identification and/or characteristics to the addressed secondary station. An information field is optional.

The *Disconnect Mode (DM)* response reports the status of a secondary station that is disconnected from the link. Such a station is in NDM or ADM. No information field is permitted. On a switched network where the call is initiated by the secondary station, the DM is sent as a request for a mode-setting command.

The *Request Disconnect (RD)* response indicates to the primary station that the secondary station wishes to be placed in one of the disconnected modes, ADM or NDM.

The *Request Initialization Mode (RIM)* response is used by the secondary station to report a need for initialization. After the RIM response, no further transmissions are accepted or transmitted until a SIM or DISC command is received. No information field is permitted.

The *Unnumbered Information (UI)* response is used by the secondary station to transmit information to the primary station without impacting the V(S) and V(R) variables at either end.

The *Exchange Identification (XID)* response is transmitted in reply to an XID command. An information field, which contains the secondary station's identification and/or characteristics, is optional.

Time-Outs

Time-out procedures are defined for both the unbalanced and balanced classes of procedure. For the unbalanced class, time-out is used to detect a no-reply or lost-reply condition. In ARM, each secondary station provides a command time-out function. The expiration of a specified time initiates error recovery procedures.

The duration of a time-out is system dependent and subject to agreement by communicating stations. To resolve possible contention situations, the secondary station's timer interval is longer than that of the primary station. In NRM, the secondary station waits for the primary station to initiate error recovery.

For the balanced class, each combined station provides a response time-out to detect a no-reply condition. The expiration of the time initiates error recovery procedures. The time-out duration is system dependent and subject to agreement by both stations. The interval of the timer in each station is unequal in order to resolve possible contention situations that might occur, especially in a two-way alternate operation. The timer starts when a station transmits a frame to which a reply is required. When the expected reply is received, the timer stops. ■

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Frame Structure 2

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Additional Commands/ Responses 4

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Synopsis

HDLC, a protocol that addresses the physical connection standards for layer two of the International Organization for Standardization's (ISO's) Open Systems Interconnection (OSI) model, permits synchronous, bit-oriented, independent data transmission. It provides simplex, half-duplex, or full-duplex communication. Network configurations may be point to point or multipoint over switched or nonswitched facilities.

Report Highlights

The International Organization for Standardization (ISO) Technical Committee 97 (TC 97, Computers and Information Processing) developed the High-Level Data Link Control (HDLC) protocol. Upon adoption by TC 97, the draft document was circulated to member bodies of the ISO for approval. HDLC has been approved as an international standard by member bodies from 23 countries; no member body expressed disapproval.

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Analysis

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Interframe time fill is accomplished by transmitting either consecutive flags, a minimum of seven contiguous "1" bits, or a combination of both. Selection of interframe time fill methods depends on system requirements.

Since it is possible for six or more binary "1s" to be contiguous elsewhere in the frame, HDLC provides a mechanism that achieves transparency for these nonflag-related sequences using the process of *zero insertion*. The transmitter examines the frame content including the address, control, and FCS fields and inserts a zero after all sequences of five contiguous "1" bits. This ensures that a flag sequence is not simulated. At the receiving end, the incoming frames are examined and any "0" bit directly following five "1" bits is discarded.

The flag is followed by the **Address** field. In command frames, the address must identify the station(s) for which the command is intended. In response frames, the address must identify the station sending the response.

Normally, a single octet (eight-bit) address would be used, making a total of 256 combinations available. The address range can be extended, however, by reserving the first transmitted bit (low order) of each address octet, which is set to binary zero. This indicates that the following octet is an extension of the basic address. The format of the extended octet(s) must be the same as that of the basic octet, and, in this way, the address field may be recursively extended.

When extensions are used, the presence of a binary "1" in the first transmitted bit of the basic address octet indicates that only one address octet is used. Thus, the use of address extension restricts the range of single octet addresses to 128.

HDLC outlines three conventions for addressing frames, aside from assigning each station its own address.

The *global address* is a single address field combination that instructs all stations to accept and take action on the associated frame. When the command is intended for more than one station, the acknowledging stations must not respond simultaneously. The global address is also used for global polling. A response with the assigned station address may be given to a command with a global address when there is only one station for which the command is intended. This convention may be used to receive an unknown station's identification, as in switched or reconfigured situations. The combination 11111111 is reserved as the global address.

The address combination 00000000 in the first octet of the address field is never assigned to a station. This is the reserved *no station address* which in a command may be used for testing purposes, such as testing line loop fault.

One or more stations may be assigned a *group address*, as well as an individual address. This address may be used to broadcast to the assigned group of stations. Any address combination, except the global and the no station address, may be assigned as a group address.

The **Information** field is an unspecified number of bits that need not follow any particular character structure. In most cases, however, a convenient structure, such as an octet, is used. Theoretically, there is no limit to the length of the information field; however, certain factors, like buffer size, may impose limitations.

The **Frame Check Sequence (FCS)** is a 16-bit field which appears prior to the closing flag. It detects errors in the frame and is the ones complement (modulo 2) of the sum of:

- The remainder of $x^k (x^{15} + x^{14} + x^{13} + \ldots + x + x + 1)$ divided (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency; and
- The remainder after multiplication by x^{16} and then the division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of 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 remainder of the division is preset to all ones and is then modified by division by the generator polynomial (as described above) on the Address, Control, and Information fields. The ones complement of the resulting remainder is transmitted as the 16-bit FCS sequence.

HDLC permits the FCS field to increase by multiples of eight bits (octets) if further protection against errors is needed. Such a suggestion also has been drafted into the revision of the ANSI Advanced Data Communications Control Procedures (ADCCP). It calls for a 32-bit FCS which, although it would increase overhead by 16 bits, would eliminate errors that may pass undetected using the 16-bit FCS. An example of such an error would be a scrambled single flag between frames when only a single flag between frames is used.

The **Control** field contains either commands or responses and sequence numbers. The control field functions to convey a command to the addressed station for the performance of a particular operation or to convey a response to such a command from the addressed station.

Three formats are defined for the control field, each performing a different function. In the *information transfer format*, or I format, the transfer of information is permitted. Only frames using the I control field format may contain an information field. Each I frame contains three elements: a send variable (S), a receive variable (R), and a poll/final bit set to either 1 or 0. A discussion of frame variables (numbering) and the poll/final bit appears later in this report.

In the *supervisory format*, or S format, link supervisory control functions are transmitted. Examples of supervisory functions include the acknowledgment of I frames and the request for retransmission of I frames.

The *unnumbered format*, or U format, provides additional link control functions. The control format's U format contains no sequence numbers; as a result, five modifier bits allow the definition of up to 32 additional command functions and 32 additional response functions.

Control Field Procedures

Four **supervisory commands and responses** perform functions such as acknowledgment, polling, and temporary suspension of information transfer.

Receive Ready (RR), used by the primary and secondary stations, indicates readiness to receive an information frame or to acknowledge previously received information frames numbered up to N(R) – 1. The primary station may also use RR with the poll bit set to "1" to solicit responses from a secondary station.

Reject (REJ) requests retransmission of information frames, beginning with the frame numbered N(R). Only one REJ condition from a given station may be established at one time. The REJ is cleared when the information frame that has an N(S) equal to the N(R) of the REJ command/response is received.

Receive Not Ready (RNR) indicates a busy condition or the inability to accept any additional information frames. A secondary station that receives a RNR while in the process of transmitting must stop transmitting information frames at the earliest possible time.

Selective Reject (SREJ) is used to request retransmission of an information frame numbered N(R). It is cleared when an information frame is received that has an N(S) count equal to the N(R) of the received SREJ command/response. Until the first SREJ error condition is cleared, no other sequence error commands can be transmitted.

Unnumbered commands and responses extend the number of link control functions. The transmission of frames in the unnumbered format, or U format, does not increment the sequence counts at either the primary or secondary station. Five modifier bits are defined. Although this permits the addition of up to 32 additional functions, only 5 functions are defined; all others are reserved. The five unnumbered commands are briefly described below.

Set Normal Response Mode (SNRM) is a command that places the secondary station in NRM. No information field is permitted.

Set Asynchronous Response Mode (SARM) is a command that places the addressed secondary station in ARM. No information field is permitted.

The *Disconnect (DISC)* command terminates a previously set operational mode. It informs the secondary stations that the primary station is suspending its operation and that the secondary stations should place themselves in disconnected mode. No information field is permitted.

Set Normal Response Mode Extended (SNRME) is a command that places the secondary station in the extended normal response mode (NRME). In this mode, all control fields are two octets long.

Set Asynchronous Response Mode Extended (SARME) is a command placing the secondary station in the extended asynchronous response mode (ARME), where all control fields are two octets long.

In addition to the unnumbered commands, two unnumbered responses are defined:

The *Unnumbered Acknowledgement (UA)* response, used by the secondary station, acknowledges that it has received and accepted one of the unnumbered format commands. It is the response to SNRM, SARM, DISC, SNRME, and SARME. No information field is permitted with the UA response.

The *Command Reject (CMDR)* response, also used by the secondary station, reports one of the following conditions: an invalid or not implemented command has been received, an information frame has been received which exceeds the size of the buffer available, or a frame with an invalid N(R) has been received from the primary station. The response includes an information field to provide the reason for the CMDR.

Frame Numbering

Every information frame is numbered sequentially. In the unextended control field I format, the numbering modulo is eight; up to seven messages may be outstanding before an acknowledgment is required. The message numbers continually cycle through the entire seven-combination range of the three-bit field available for numbering.

In the extended control field format, seven bits are available for message numbering. This is an important characteristic of HDLC, since it increases the numbering modulo to 128. Modulo 128 permits up to 127 messages to be outstanding before an acknowledgment is required, and it is an effective counteraction against propagation delay. The modulo can be set to ensure a steady flow of information, even on facilities with long propagation delays, such as satellites.

Four terms are associated with the frame numbering function of the control field. Each data station maintains independent send and receive sequence numbers on the information frames it sends and receives. The *send state variable V(S)* denotes the *receive sequence number N(R)* of the next in-sequence information frame received. The value of V(R) and the corresponding N(R) is incremented by one when an error-free in-sequence equals the receive state variable. All information and supervisory frames contain the N(R), the expected sequence number of the incoming information frame.

Additional Commands/Responses

Four commands and five responses are defined for the secondary operational modes.

The *Set Initialization Mode (SIM)* command causes the addressed secondary station to initiate procedures that initialize its link level control functions. No information field is permitted.

The *Unnumbered Poll (UP)* command solicits response frames from either a group of secondary stations (group poll) or an individual secondary station (individual poll). No information field is permitted. The response frame to the UP contains the station address, plus the N(S) and N(R) numbers as required. If the primary station detects an idle state (15 ones), or no response is given to the UP command within a given period of time, it is assumed that the secondary station has either completed or will not initiate transmission.

The *Unnumbered Information (UI)* command is used to transmit information to a secondary station or group of secondary stations without changing the V(S) or V(R) variables. No response is required.

The *Exchange Identification (XID)* command causes the addressed secondary station to identify itself. It may also be used to provide primary station identification and/or characteristics to the addressed secondary station. An information field is optional.

The *Disconnect Mode (DM)* response reports the status of a secondary station that is disconnected from the link. Such a station is in NDM or ADM. No information field is permitted. On a switched network where the call is initiated by the secondary station, the DM is sent as a request for a mode-setting command.

The *Request Disconnect (RD)* response indicates to the primary station that the secondary station wishes to be placed in one of the disconnected modes, ADM or NDM.

The *Request Initialization Mode (RIM)* response is used by the secondary station to report a need for initialization. After the RIM response, no further transmissions are accepted or transmitted until a SIM or DISC command is received. No information field is permitted.

The *Unnumbered Information (UI)* response is used by the secondary station to transmit information to the primary station without impacting the V(S) and V(R) variables at either end.

The *Exchange Identification (XID)* response is transmitted in reply to an XID command. An information field, which contains the secondary station's identification and/or characteristics, is optional.

Time-Outs

Time-out procedures are defined for both the unbalanced and balanced classes of procedure. For the unbalanced class, time-out is used to detect a no-reply or lost-reply condition. In ARM, each secondary station provides a command time-out function. The expiration of a specified time initiates error recovery procedures.

The duration of a time-out is system dependent and subject to agreement by communicating stations. To resolve possible contention situations, the secondary station's timer interval is longer than that of the primary station. In NRM, the secondary station waits for the primary station to initiate error recovery.

For the balanced class, each combined station provides a response time-out to detect a no-reply condition. The expiration of the time initiates error recovery procedures. The time-out duration is system dependent and subject to agreement by both stations. The interval of the timer in each station is unequal in order to resolve possible contention situations that might occur, especially in a two-way alternate operation. The timer starts when a station transmits a frame to which a reply is required. When the expected reply is received, the timer stops. ■

ISO High-Level Data Link Control (HDLC)

In this report:

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Synopsis

Editor's Note

HDLC, a protocol that addresses the physical connection standards for layer two of the International Organization for Standardization's (ISO's) Open Systems Interconnection (OSI) model, permits synchronous, bit-oriented, independent data transmission. It provides simplex, half-duplex, or full-duplex communication. Network configurations may be point-to-point or multipoint over switched or nonswitched facilities.

Report Highlights

The International Organization for Standardization (ISO) Technical Committee 97 (TC 97, Computers and Information Processing) developed the High-Level Data Link Control (HDLC) protocol. Upon adoption by TC 97, the draft document was circulated to member bodies of the ISO for approval. HDLC has been approved as an international standard by member bodies from 23 countries; no member body expressed disapproval.

HDLC covers a wide array of applications. It permits simplex, half-duplex, or full-duplex transmission, configured point-to-point or multipoint, over switched or nonswitched facilities. It does not define a single system, and should not be regarded as a specification for a data communications system. It is intended to provide a high degree of compatibility between data terminal equipment (DTE).

Several protocols, such as Unisys' Burroughs Data Link Control (BDLC), IBM's Synchronous Data Link Control (SDLC), and Unisys' Sperry (Univac) Universal Data Link Control (UDLC) are based on the HDLC concept. HDLC's capability of transmitting up to 127 frames before an acknowledgment is required makes it possible to transmit information via satellite, as well as via terrestrial facilities.

Analysis

Stations

HDLC defines two types of stations on the data link. The station assuming the responsibility for the organization of data flow and for link level error recovery functions is the **primary station.** All other stations on the link are **secondary stations.** The primary station transmits *command frames*, and the secondary stations transmit *response frames.*

For data transfer, HDLC considers two cases of data link control. The first case is when the primary station performs the primary data link control functions by controlling the secondary station through select commands. The second case is when the primary station controls the secondary station through poll commands.

Two terms are used to describe the data flow. The *data source* is the station currently transmitting information; the *data sink* is the station accepting the information. Information always flows from the data source to the data sink; acknowledgments flow in the opposite direction.

Classes of Procedures/Configurations

A class of procedures is the basic repertoire of steps to which a station conforms in order to communicate. HDLC defines two classes of procedures and associated station configurations: balanced and unbalanced. Table 1 outlines the basic repertoire of commands and responses for each mode; Table 3 depicts the optional commands and responses to supplement the basic repertoire.

In the **unbalanced** class of procedures, the configuration consists of one primary station and one or more secondary stations. The primary station's responsibilities include setting up and disconnecting the link; sending information frames, supervisory, and unnumbered commands; and checking received frames. The secondary station checks received frames and sends supervisory information, as well as unnumbered responses. The communications link may be half- or full-duplex, switched or nonswitched. Control procedures operate in either normal or asynchronous response mode. Only one secondary station at a time can be placed in asynchronous response mode.

In the **balanced** class of procedure, the link consists of two combined stations and operates in the asynchronous balanced mode. A *combined* station acts as both a primary and a secondary station, sends and receives both commands and responses, and is responsible for error recovery. This type of operation provides for equal control by both stations on the link; both stations share link management. The HDLC balanced class of procedure applies to point-to-point configurations over switched or leased facilities. Commands are sent with the remote station address; responses are sent with the local station address. The combined station at either end may initiate link connection or disconnection.

Under either type of procedure, the data link exists in one of two channel states. The **active** condition occurs when the primary or the secondary station is actively transmitting a frame, abort sequence, or interframe time fill. In this state, the right to continue transmission is reserved. In the **idle** state, the station has terminated transmission. The idle state is characterized by the transmission of at least 15 consecutive one bits.

Figure 1.
The HDLC Frame Structure

Flag	Address	Control	Information	FCS	Flag
01111110	8 bits	8 bits	An unspecified length; usually a multiple of eight bits	16 bits	01111110

Modes of Operation

Two primary modes of operation are defined in HDLC. In the **normal response mode (NRM)**, the secondary station may initiate transmission only after receiving permission from the primary station; upon receiving permission, the secondary station issues a response transmission. The last frame of this transmission is indicated explicitly by the secondary station. After completing its transmission, the secondary station must wait until it again receives permission to transmit from the primary station.

In **asynchronous response mode (ARM)**, the secondary station may initiate transmission without permission from the primary station. The frames transmitted by the secondary station during ARM may be used to transfer information and/or to indicate status changes.

Three secondary modes of operation are also defined in HDLC. These include two disconnected modes, which are provided to prevent a secondary station from appearing operational during unusual situations or exception conditions. **Normal disconnected mode (NDM)** logically disconnects the station from the link; while in NDM, the secondary station remains ready to respond in normal response mode. The same situation exists during **asynchronous disconnected mode (ADM)**, except that the secondary station remains ready in asynchronous response mode.

The third secondary mode is the **initialization mode (IM)**. During IM, the link control of the secondary station is initialized or regenerated, or other parameters may be exchanged. IM is invoked when the primary station detects that the secondary station is not operating normally or that the link control program needs to be upgraded at the remote station. IM may also be requested by the secondary station for the same reasons.

Frame Structure

The HDLC frame structure consists of FLAG—ADDRESS—CONTROL—INFORMATION (Optional)—FRAME CHECK SEQUENCE—FLAG (see Figure 1).

All frames must start and end with a **Flag** that consists of the bit sequence 01111110. All stations attached to the data link continuously search for this sequence. In this manner, the flag is used for frame synchronization. (A single flag may be used as the closing flag for one frame, as well as the opening flag for the next frame.)

Frames that do not begin and end with a flag or frames that are too short (shorter than 32 bits between flags) are invalid and, therefore, ignored. Any frame that ends with an all "1" bit sequence that is equal to or greater than seven bits in length will also be ignored. Therefore, one method to abort a frame would be to transmit eight contiguous "1" bits.

Interframe time fill is accomplished by transmitting either consecutive flags, a minimum of seven contiguous "1" bits, or a combination of both. Selection of interframe time fill methods depends on system requirements.

Since it is possible for six or more binary "1s" to be contiguous elsewhere in the frame, HDLC provides a mechanism that achieves transparency for these nonflag-related sequences using the process of *zero insertion*. The transmitter examines the frame content including the address, control, and FCS fields and inserts a zero after all sequences of five contiguous "1" bits. This insures that a flag sequence is not simulated. At the receiving end, the incoming frames are examined and any "0" bit directly following five "1" bits is discarded.

The flag is followed by the **Address** field. In command frames, the address must identify the station(s) for which the command is intended. In response frames, the address must identify the station sending the response.

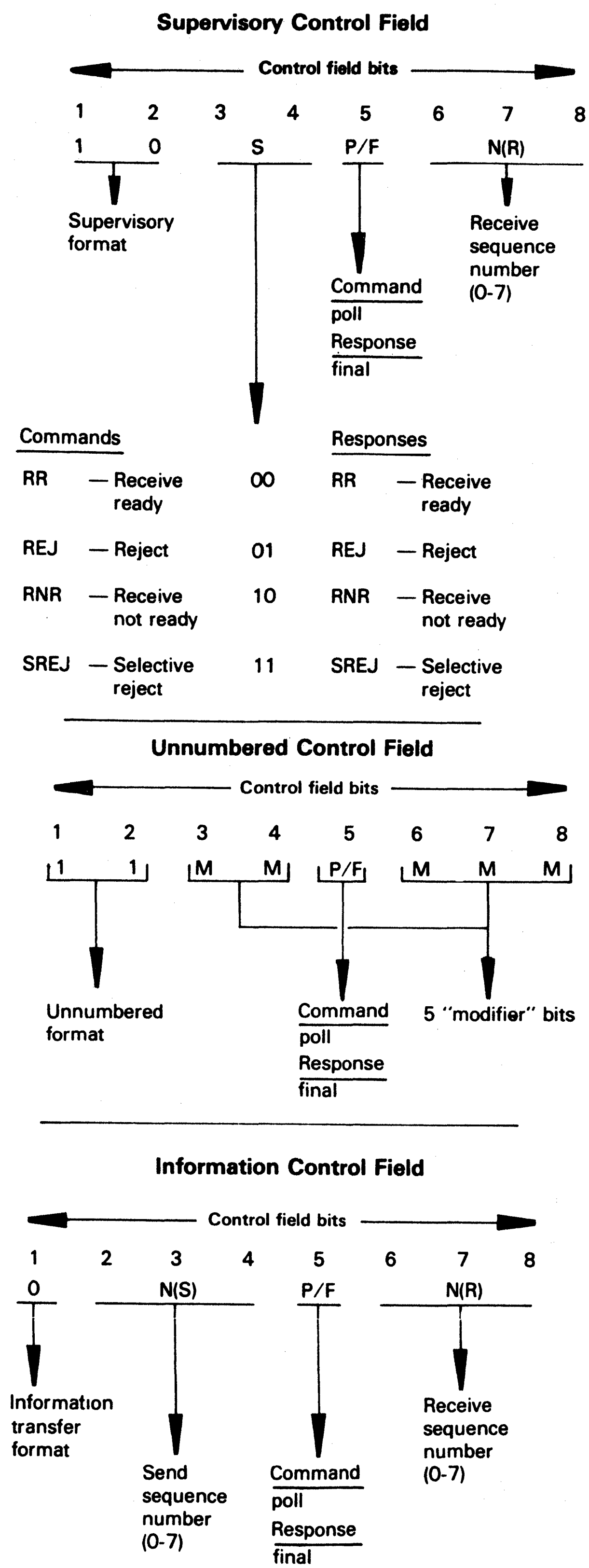
Normally, a single octet (eight-bit) address would be used, making a total of 256 combinations available. The address range can be extended, however, by reserving the first transmitted bit (low order) of each address octet, which is set to binary zero. This indicates that the following octet is an extension of the basic address. The format of the extended octet(s) must be the same as that of the basic octet, and, in this way, the address field may be recursively extended.

When extensions are used, the presence of a binary "1" in the first transmitted bit of the basic address octet indicates that only one address octet is used. Thus, the use of address extension restricts the range of single octet addresses to 128.

HDLC outlines three conventions for addressing frames, aside from assigning each station its own address.

The *global address* is a single address field combination that instructs all stations to accept

Figure 2.
Encoding of HDLC Control Field Commands/ Responses



and take action on the associated frame. When the command is intended for more than one station, the acknowledging stations must not respond simultaneously. The global address is also used for global polling. A response with the assigned station address may be given to a command with a global address when there is only one station for which the command is intended. This convention may be used to receive an unknown station's identification, as in switched or reconfigured situations. The combination 11111111 is reserved as the global address.

The address combination 00000000 in the first octet of the address field is never assigned to a station. This is the reserved *no station address* which in a command may be used for testing purposes, such as testing line loop fault.

One or more stations may be assigned a *group address*, as well as an individual address. This address may be used to broadcast to the assigned group of stations. Any address combination, except the global and the no station address, may be assigned as a group address.

The **Information** field is an unspecified number of bits that need not follow any particular character structure. In most cases, however, a convenient structure, such as an octet, is used. Theoretically, there is no limit to the length of the information field; however, certain factors, like buffer size, may impose limitations.

The **Frame Check Sequence (FCS)** is a 16-bit field which appears prior to the closing flag. It detects errors in the frame and is the ones complement (modulo 2) of the sum of:

- The remainder of $x^k (x^{15} + x^{14} + x^{13} + \ldots + x + x + 1)$ divided (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency; and
- The remainder after multiplication by x^{16} and then the division (modulo 2) by the generator polynomial $x^{16} + x^{12} + x^5 + 1$ of 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 remainder of the division is preset to all

Table 1. Basic Repertoire of Commands and Responses*

Commands	Responses
Balanced Mode	
Commands	**Responses**
I	I
RR	RR
RNR	RNR
SABM**	CMDR
DISC	UA
	DM
Unbalanced Normal Mode	
Primary Station Commands	**Secondary Station Responses**
I	I
RR	RR
RNR	RNR
SNRM	DMDR
DISC	UA
	DM
Unbalanced Asynchronous Mode	
Primary Station Commands	**Secondary Station Responses**
I	I
RR	RR
RNR	RNR
SARM	CMDR
DISC	UA
	DM

**See text for explanation of mnemonics.*
***Set Asynchronous Balanced Mode—used to set up the connection.*

ones and is then modified by division by the generator polynomial (as described above) on the Address, Control, and Information fields. The ones complement of the resulting remainder is transmitted as the 16-bit FCS sequence.

HDLC permits the FCS field to increase by multiples of eight bits (octets) if further protection against errors is needed. Such a suggestion also has been drafted into the revision of the ANSI Advanced Data Communications Control Procedures (ADCCP). It calls for a 32-bit FCS which, although it would increase overhead by 16 bits, would eliminate errors that may pass undetected using the 16-bit FCS. An example of such an error would be a scrambled single flag between frames when only a single flag between frames is used.

The **Control** field contains either commands or responses and sequence numbers. The control field functions to convey a command to the addressed station for the performance of a particular operation or to convey a response to such a command from the addressed station.

Three formats are defined for the control field, each performing a different function (see Figure 2). In the *information transfer format*, or I format, the transfer of information is permitted. Only frames using the I control field format may contain an information field. Each I frame contains three elements: a send variable (S), a receive variable (R), and a poll/final bit set to either 1 or 0. A discussion of frame variables (numbering) and the poll/final bit appears later in this report.

In the *supervisory format*, or S format, link supervisory control functions are transmitted. Examples of supervisory functions include the acknowledgment of I frames and the request for retransmission of I frames.

The *unnumbered format*, or U format, provides additional link control functions. The control format's U format contains no sequence numbers; as a result, five modifier bits allow the definition of up to 32 additional command functions and 32 additional response functions. See Table 2 for an illustration of the extended control field.

Table 2. Control Field Extensions

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

Note: 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.

Table 3. Optional Functions for the Unbalanced/Balanced Classes of Procedures

Operation Mode*	Option Number	Functional Description	Required Change**
U/B	1A	Provides the ability to:	
		—exchange identification and/or characteristics of stations	Add command: XID, Add response: XID
		—request logical disconnection	Add response: RD
U/B	2	Provides the ability for more timely reporting of I frame sequence errors	Add command: REJ, Add response: REJ
U/B	3	Provides the ability for more efficient recovery from I frame sequence errors by requesting retransmission of a single frame	Add command: SREJ, Add response: SREJ
U/B	4	Provides the ability to exchange information fields without impacting the I frame sequence numbers	Add command: UI, Add response: UI
B	5	Provides primary ability to initialize remote stations and secondary ability to request initialization	Add command: SIM, Add response: RIM
U	5	Provides primary ability to initialize remote stations and secondary ability to request initialization	Add command: SIM, Add response: RIM
B	6	Provides the ability to perform unnumbered group polling as well as individual polling	Add command: UP
U	6	Provides primary ability to perform unnumbered group polling as well as individual polling	Add command: UP
U/B	7	Provides addressing for greater than single octet addressing	Use extended addressing format in lieu of basic addressing format
B	8	Limits the procedure to allow I frame to be commands only	Delete response: I
U	8	Limits the procedure to one-way I frame transfer using commands	Delete response: I
B	9	Limits the procedure to allow I frame to be responses only	Delete command: I
U	9	Limits the procedure to one-way I frame transfer using responses	Delete command: I
B	10	Provides the ability to use extended sequence numbering (Modulo 128)	Use extended control field format in lieu of basic control field format. Use SABME (set Asynchronous Balanced Mode Extended) in lieu of SABM
U	10	Provides the ability to use extended sequence numbering (Modulo 128)	Use extended control field format in lieu of basic control field format. Use SXRME in lieu of SXRM.***
U	11	Provides the ability to reset the state variable associated with only one direction of information flow	Add command: RSET

U—Unbalanced.
B—Balanced.
***Changes to the basic repertoire of commands/responses (see Table 1) to modify the fundamental classes of procedures.*
****SXRM equals SARM in unbalanced asynchronous mode, SNRM in unbalanced normal mode.*

Control Field Procedures

Four **supervisory commands and responses** perform functions such as acknowledgment, polling, and temporary suspension of information transfer (see Figure 2 for bit encoding).

Receive Ready (RR), used by the primary and secondary stations, indicates readiness to receive an information frame or to acknowledge previously received information frames numbered up to N(R)-1. The primary station may also use RR with the poll bit set to "1" to solicit responses from a secondary station.

Reject (REJ) requests retransmission of information frames, beginning with the frame numbered N(R). Only one REJ condition from a given station may be established at one time. The REJ is cleared when the information frame that has an N(S) equal to the N(R) of the REJ command/response is received.

Receive Not Ready (RNR) indicates a busy condition or the inability to accept any additional information frames. A secondary station that receives a RNR while in the process of transmitting must stop transmitting information frames at the earliest possible time.

Selective Reject (SREJ) is used to request retransmission of an information frame numbered N(R). It is cleared when an information frame is received that has an N(S) count equal to the N(R) of the received SREJ command/response. Until the first SREJ error condition is cleared, no other sequence error commands can be transmitted.

Unnumbered commands and responses extend the number of link control functions. The transmission of frames in the unnumbered format, or U format, does not increment the sequence counts at either the primary or secondary station. Five modifier bits are defined (see Figure 2). Although this permits the addition of up to 32 additional functions, only 5 functions are defined; all others are reserved. The five unnumbered commands are briefly described below.

Set Normal Response Mode (SNRM) is a command that places the secondary station in NRM. No information field is permitted.

Set Asynchronous Response Mode (SARM) is a command that places the addressed secondary station in ARM. No information field is permitted.

The *Disconnect (DISC)* command terminates a previously set operational mode. It informs the secondary stations that the primary station is suspending its operation and that the secondary stations should place themselves in disconnected mode. No information field is permitted.

Set Normal Response Mode Extended (SNRME) is a command that places the secondary station in the extended normal response mode (NRME). In this mode, all control fields are two octets long.

Set Asynchronous Response Mode Extended (SARME) is a command placing the secondary station in the extended asynchronous response mode (ARME), where all control fields are two octets long.

In addition to the unnumbered commands, two unnumbered responses are defined:

The *Unnumbered Acknowledgement (UA)* response, used by the secondary station, acknowledges that it has received and accepted one of the unnumbered format commands. It is the response to SNRM, SARM, DISC, SNRME, and SARME. No information field is permitted with the UA response.

The *Command Reject (CMDR)* response, also used by the secondary station, reports one of the following conditions: an invalid or not implemented command has been received, an information frame has been received which exceeds the size of the buffer available, or a frame with an invalid N(R) has been received from the primary station. The response includes an information field to provide the reason for the CMDR.

Table 4. Summary of Poll/Final Bit Function

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.
NRM—Normal response mode.
ARM—Asynchronous response mode.
TWA—Two-way alternate.
TWS—Two-way simultaneous.

Frame Numbering

Every information frame is numbered sequentially. In the unextended control field I format, the numbering modulo is eight; up to seven messages may be outstanding before an acknowledgment is required. The message numbers continually cycle through the entire seven-combination range of the three-bit field available for numbering.

In the extended control field format, seven bits are available for message numbering (see Table 2). This is an important characteristic of HDLC, since it increases the numbering modulo to 128. Modulo 128 permits up to 127 messages to be outstanding before an acknowledgment is required, and it is an effective counteraction against propagation delay. The modulo can be set to ensure a steady flow of information, even on facilities with long propagation delays, such as satellites.

Four terms are associated with the frame numbering function of the control field. Each data station maintains independent send and receive sequence numbers on the information frames it sends and receives. The *send state variable V(S)* denotes the *receive sequence number N(R)* of the next in-sequence information frame received. The value of V(R) and the corresponding N(R) is incremented by one when an error-free in-sequence equals the receive state variable. All information and supervisory frames contain the N(R), the expected sequence number of the incoming information frame.

Poll/Final Bit

The poll/final (P/F) bit is located in the fifth bit position of the unextended control field and in the ninth bit position of the extended control field. It serves a function in both command and response frames (see Table 4). In command frames, the P/F bit is called the P bit; in response frames, the F bit.

The P bit solicits a response from a secondary station. Since only one frame with the P bit set to "1" may be outstanding at one time, the primary station must receive a response from a secondary station with the F bit set to "1" before transmitting another poll frame.

In normal response mode, the P bit is set to "1" to solicit a response from a secondary station. In this mode, the secondary station cannot transmit until it receives a poll command.

In asynchronous response mode, the secondary station can transmit information frames on an asynchronous basis. The secondary station transmits an F response only in response to a command frame with the P bit set to "1". Unlike in NRM, transmission of an F frame in ARM does not require the secondary station to stop transmitting. Additional response frames may be transmitted. Thus, in ARM, the F frame bit should not be interpreted as the end of transmission, but only as a response to the previous command frame.

The P/F bit can also assist in error recovery. It is possible to detect sequence errors in information frames by matching each P bit with an F bit, since these bits are always exchanged as a pair. This method, called *checkpointing*, prescribes that a P bit cannot be issued until the previous P bit has been matched with an F bit. While checkpointing in ARM, a contention situation may occur. In this case, contention during two-way alternate transmission is solved by creating a longer interval for the secondary station than for the primary station, so that contention is resolved in favor of the primary station.

Additional Commands/Responses

Four commands and five responses are defined for the secondary operational modes.

The *Set Initialization Mode (SIM)* command causes the addressed secondary station to initiate procedures that initialize its link level control functions. No information field is permitted.

The *Unnumbered Poll (UP)* command solicits response frames from either a group of secondary stations (group poll) or an individual secondary station (individual poll). No information field is permitted. The response frame to the UP contains the station address, plus the N(S) and N(R) numbers as required. If the primary station detects an idle state (15 ones), or no response is given to the UP command within a given period of time, it is assumed that the secondary station has either completed or will not initiate transmission.

The *Unnumbered Information (UI)* command is used to transmit information to a secondary station or group of secondary stations without changing the V(S) or V(R) variables. No response is required.

The *Exchange Identification (XID)* command causes the addressed secondary station to identify itself. It may also be used to provide primary station identification and/or characteristics to the addressed secondary station. An information field is optional.

The *Disconnect Mode (DM)* response reports the status of a secondary station that is disconnected from the link. Such a station is in NDM or ADM. No information field is permitted. On a switched network where the call is initiated by the secondary station, the DM is sent as a request for a mode-setting command.

The *Request Disconnect (RD)* response indicates to the primary station that the secondary station wishes to be placed in one of the disconnected modes, ADM or NDM.

The *Request Initialization Mode (RIM)* response is used by the secondary station to report a need for initialization. After the RIM response, no further transmissions are accepted or transmitted until a SIM or DISC command is received. No information field is permitted.

The *Unnumbered Information (UI)* response is used by the secondary station to transmit information to the primary station without impacting the V(S) and V(R) variables at either end.

The *Exchange Identification (XID)* response is transmitted in reply to an XID command. An information field, which contains the secondary station's identification and/or characteristics, is optional.

Timeouts

Timeout procedures are defined for both the unbalanced and balanced classes of procedure. For the unbalanced class, timeout is used to detect a no-reply or lost-reply condition. In ARM, each secondary station provides a command timeout function. The expiration of a specified time initiates error recovery procedures.

The duration of a timeout is system dependent and subject to agreement by communicating stations. To resolve possible contention situations, the secondary station's timer interval is longer than that of the primary station. In NRM, the secondary station waits for the primary station to initiate error recovery.

For the balanced class, each combined station provides a response timeout to detect a no-reply condition. The expiration of the time initiates error recovery procedures. The timeout duration is system dependent and subject to agreement by both stations. The interval of the timer in each station is unequal in order to resolve possible contention situations that might occur, especially in a two-way alternate operation. The timer starts when a station transmits a frame to which a reply is required. When the expected reply is received, the timer stops. ■