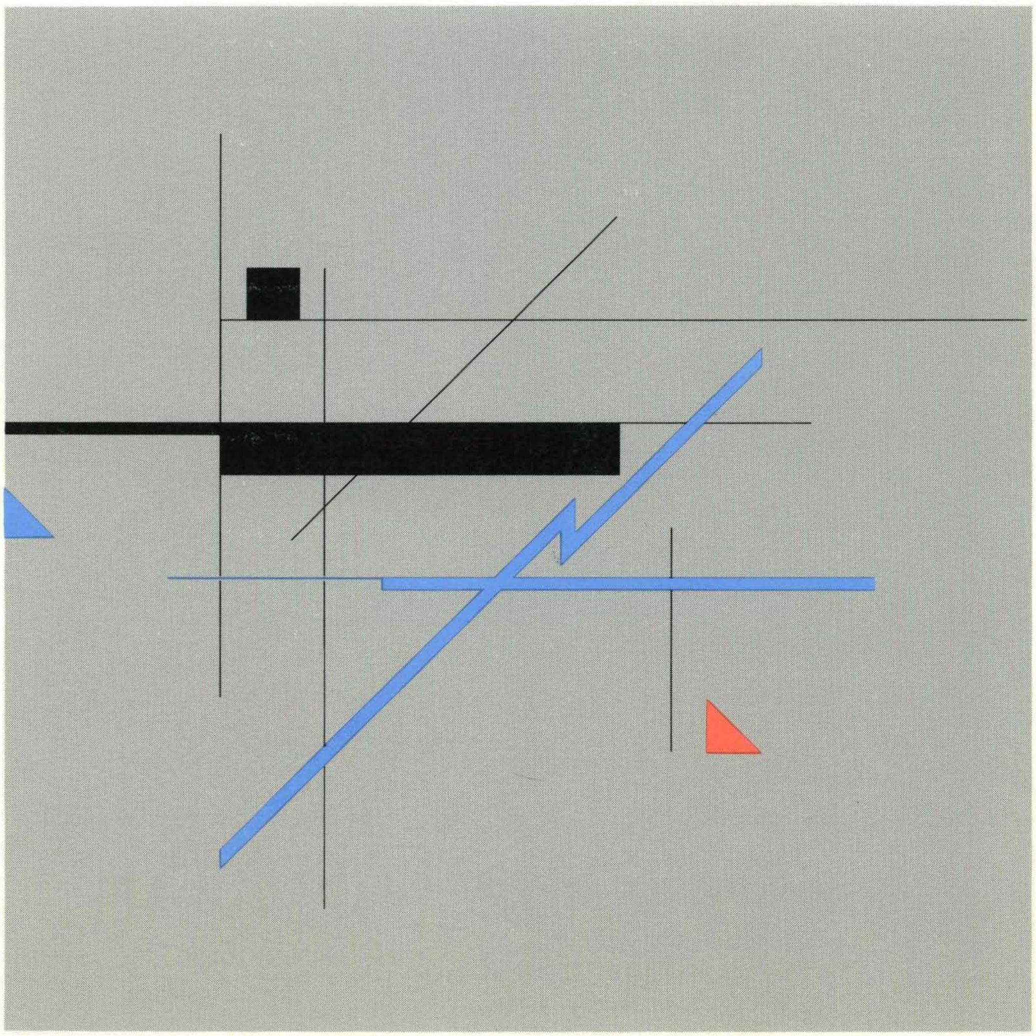
Synchronous Data Link Control

GA27-3093-04

Concepts



IBM

Synchronous Data Link Control

GA27-3093-04

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Note

Before using this document, read the general information under "Notices" on page vii.

Fifth Edition (May 1992)

This edition replaces and makes obsolete the previous edition, GA27-3093-03.

For a detailed list of changes, see "Summary of Changes" on page 85.

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Preface

This book describes IBM Synchronous Data Link Control (SDLC). It includes a brief communications overview, a basic description to familiarize the reader with the terminology and concepts of SDLC, and some representative examples of the uses of SDLC.

Readers who are not familiar with IBM's Systems Network Architecture (SNA) should first read *Systems Network Architecture Concepts and Products,* GC30-3072.

A reader who is familiar with other data link control procedures should not assume that familiar terms have the same definitions in SDLC procedures, or that familiar functions have the same names. The *IBM Dictionary of Computing*, GC20-1699, is a useful reference for the definitions of terms used in this book.

This book does not provide instructions for implementing SDLC, nor does it describe any specific equipment or programs that may be needed to implement SDLC. For specific information about an IBM SDLC implementation, refer to the appropriate IBM publication for that machine or system. For information on Systems Network Architecture (SNA), within which SDLC is a data link control, refer to *Systems Network Architecture Technical Overview,* GC30-3073 and *Systems Network Architecture Formats*, GA27-3136.

This book contains three chapters and four appendixes:

Chapter 1, "Introduction," contains general information on telecommunications and data link control.

Chapter 2, "Basic Concepts," presents the elementary information you need to understand SDLC.

Chapter 3, "Further Concepts, Applications, and Examples," presents additional concepts, defines the SDLC commands and responses, and shows some applications and examples of the use of SDLC for specific link configurations.

Appendix A, "SDLC Frame Summary," contains the binary codes for SDLC commands and responses.

Appendix B, "SDLC Computation of the FCS Field," describes the operation of cyclic redundancy checking and its use in the SDLC frame check sequence.

Appendix C, "IBM SDLC and Data Link Control Standards," shows the relationship between SDLC and data link control standards and explains IBM's conformance to these standards.

Appendix D, "Asynchronous SDLC," explains a form of SDLC that uses asynchronous rather than synchronous clocking.

A list of abbreviations, a glossary, and a summary of changes appear between Appendix D and the Index.

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Chapter 1. Introduction

This chapter introduces the various link configurations with which SDLC can be used and describes some of their operating characteristics.

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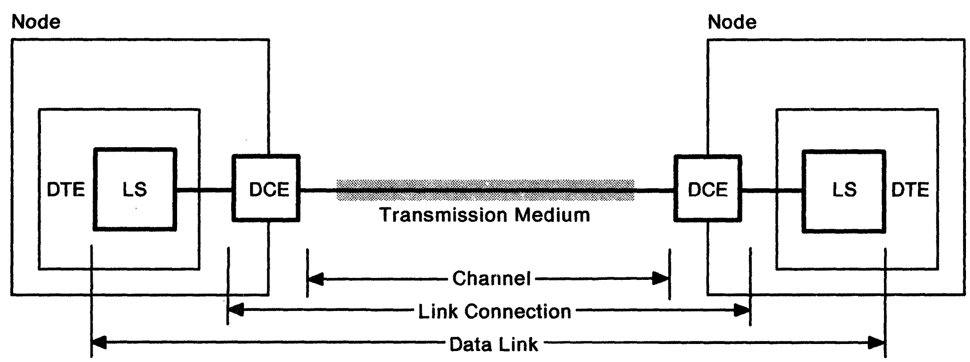
Synchronous Data Link Control (SDLC) is a discipline for managing synchronous, code-transparent, serial-by-bit information transfer between nodes that are joined by data links. Data may be sent simultaneously in both directions (referred to as *two-way simultaneous* transmission) or alternately, in one direction at a time (referred to as *two-way alternate* transmission).

The link connection may have a point-to-point, multipoint, or loop configuration; a point-to-point link may be nonswitched or switched. SDLC includes comprehensive detection and recovery procedures for transmission errors that may be introduced onto the link.

Readers who are familiar with the concepts of information transfer over the various link configurations may skip to Chapter 2, "Basic Concepts." Other readers should continue reading here or refer to the preface of this manual for reading references.

Data Links and Their Components

This book uses the term *data link* and a number of related terms whose relationship is described in the next paragraphs. (The terms are defined fully in the Glossary at the back of this book.) Figure 1 shows the relationship graphically.



DCE Data Circuit-terminating Equipment
DTE Data Terminal Equipment
LS Link Station

Figure 1. Components of a Data Link

Each SNA node that communicates with another SNA node over transmission media (such as telephone wires, microwave beams, fiber optic links, or satellite links, or combinations of these media) requires a link station and data circuit-terminating equipment (DCE).

A *link station* is the hardware and software that allows a node to attach to and provide control for a link. The link station is part of the *data terminal equipment (DTE)*—the general term for equipment, such as processors, controllers, and terminals, that communicate over data links.

Data circuit-terminating equipment (DCE) is the equipment used to establish, maintain, and terminate a connection, and to provide appropriate modulation of the business-machine signal for transmission on a telecommunication facility, and vice versa. The function of the DCE is separate from that of the DTE and is therefore shown separately in Figure 1, but it may be part of the same physical package as the DTE. The part of the data link that includes the DCEs and the channel between them, but not the link stations, is called the *link connection.* (Another term for link connection is *data circuit.*)

A data link consists of (1) the link stations at the SNA nodes it connects, (2) the DCEs associated with each link station, and (3) the channel that connects the DCEs together. In this book the term *channel* refers to the path provided by the transmission media that a link connection uses; the channel includes whatever signal conversion equipment is necessary to transfer data from one transmission medium to another within the channel. In this context, a channel is bidirectional—that is, it can transfer data in both directions.

Although Figure 1 and other figures in this book show a link connection and its channel extending over only one transmission medium, in practice they sometimes encompass more than one medium. Figure 2 shows an example in which the channel between a pair of DCEs uses both wires and optical fibers as transmission media. This figure also shows that the same transmission media may provide a number of separate channels.

Figure 1 shows a point-to-point configuration joining two SNA nodes; as described shortly, multipoint configurations can be used as well.

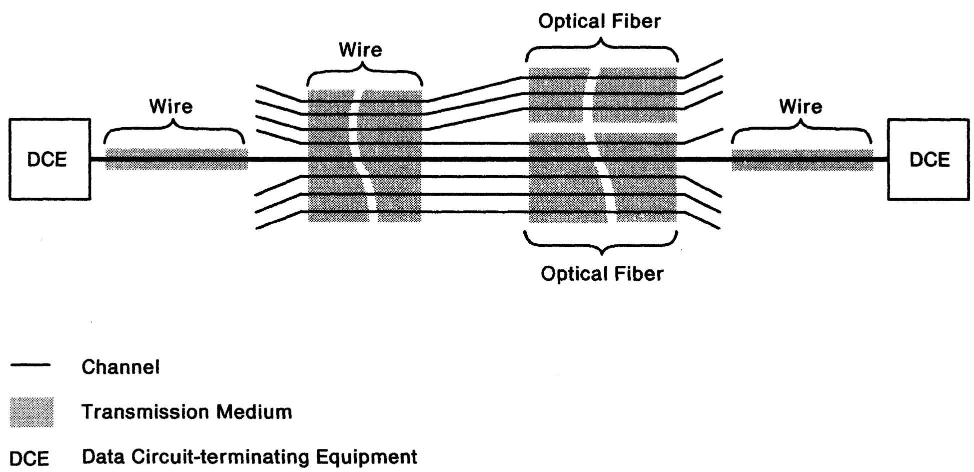


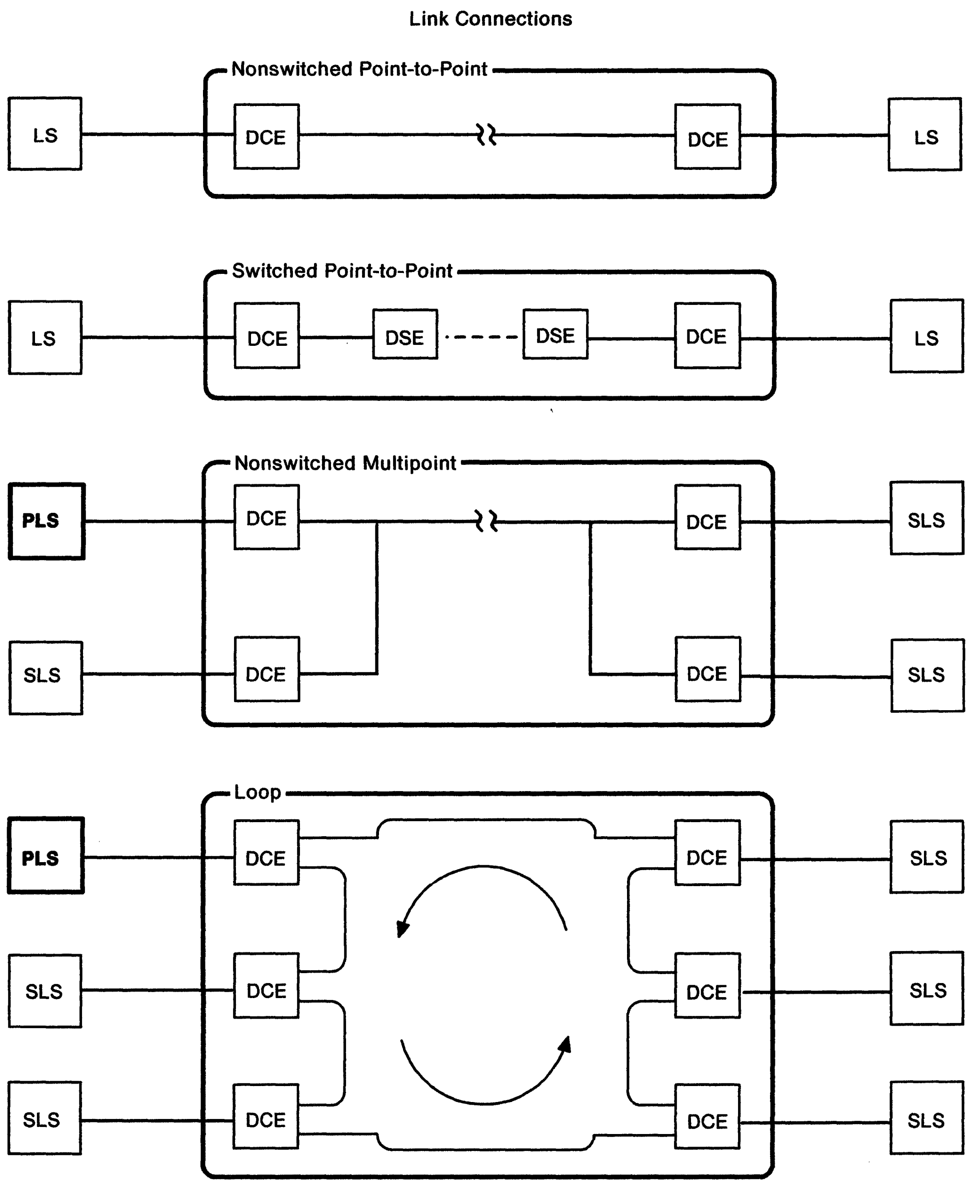
Figure 2. Channels and Transmission Media

Configurations and Operating Characteristics

The remainder of this chapter explains the various link connection and data link configurations for which SDLC can be used, and mentions some operating characteristics related to each.

A link connection can have one of the following basic configurations, as shown in Figure 3:

- Nonswitched point-to-point
- Switched point-to-point
- Nonswitched multipoint
- Loop.



DCE Data Circuit-terminating Equipment
DSE Data Switching Exchange
LS Link Station
PLS Primary Link Station
SLS Secondary Link Station

Figure 3. Link Connection Configurations

In a nonswitched configuration, the link connection exists for a period of time independent of whether it is being used to transmit data. This period of time may be continuous—that is, 24 hours a day, seven days a week—as when the user owns the facilities used or contracts with a public data network for the facilities. Alternatively, the duration may be shorter, as when the user contracts for the facilities to be available eight hours a day, five days a week.

In either case, if the facilities are contracted for rather than owned, the channels and transmission media used by the link connection may vary from time to time, even though nonswitched link connections are sometimes referred to as "permanent" to distinguish them from temporary, switched link connections.

In a switched configuration, a connection is established each time there is data to be transmitted, and the connection is broken after transmission is completed. Each time a switched connection is established it is likely to use a different combination of channels and transmission media.

A point-to-point configuration has two link stations; a multipoint configuration has three or more link stations. One link station on a multipoint link is called the *primary link station*; it controls use of the link by all the link stations attached to it. The rest of the link stations on the link are called *secondary link stations*. Chapter 2 describes the differences between primary and secondary link stations in more detail.

In a multipoint configuration, the secondary link stations communicate only with the primary link station—never with each other. The primary and each secondary form a pair logically distinct from each other pair; thus, each pair can be viewed as comprising a single point-to-point link sharing the same multipoint configuration with other point-to- point links. Only the primary link station, in its scheduling of the shared configuration, is aware of the multiple use of the common connection. The term *link* can then be applied to each pair of communicating link stations, independent of the underlying configuration.

Half-Duplex and Duplex

In all but the loop configuration, data and control signals can flow in either direction over the link connection. Whether they can flow simultaneously in both directions, or in only one direction at a time, depends on the equipment (such as amplifiers) in the channel, upon the data circuit-terminating equipment (DCE) in the link connection, and upon the link station that uses the link connection.

The term *duplex* refers to the capability of the channel and the link connection to transfer data in both directions at once. The term *half-duplex* refers to the capability of the channel and the link connection to transfer data in both directions, but *not* at the same time.

To the basic non-loop configurations listed above, the qualifiers *duplex* and *half-duplex* can be applied. The possible configurations are then:

- Half-duplex, nonswitched point-to-point
- Duplex, nonswitched point-to-point
- Half-duplex, switched point-to-point
- Duplex, switched point-to-point
- Half-duplex, nonswitched multipoint
- Duplex, nonswitched multipoint.

Two-Way Alternate and Two-Way Simultaneous Link Station Operation

If either the channel or the DCE is capable only of half-duplex operation, then the link stations on the link must send and receive data alternately—this is called *two-way alternate* transmission. If the channel and the DCE are both capable of duplex operation, then the link stations may send and receive data simultaneously—this is called *two-way simultaneous* transmission. Or they may send and receive data alternately, as for half-duplex operation.

Figure 4 shows the possible variations of link station operation for each of the link connection configurations shown in Figure 3. The configurations in this figure are labeled A through K.

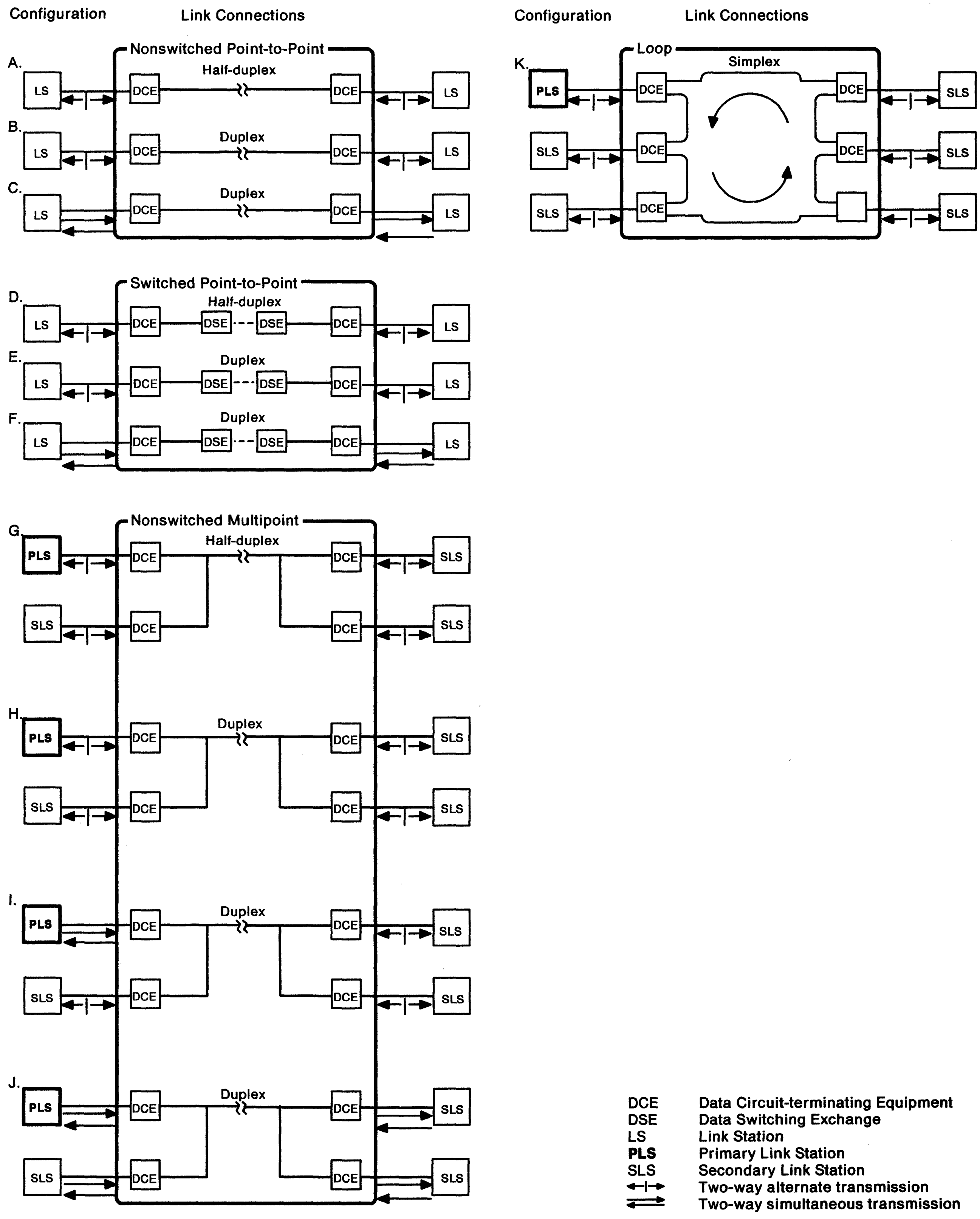


Figure 4. Link Connection Configurations and Link Station Operation

Configurations A, B, and C are nonswitched point to point. Configuration A is half duplex and therefore allows only two-way alternate transmission. A duplex configuration can accommodate either two-way alternate or two-way simultaneous transmission, as shown in configurations B and C, respectively.

Configurations D, E, and F are switched point-to-point configurations. Configuration D is half duplex and therefore allows only two-way alternate transmission. A duplex configuration can accommodate either two-way alternate or two-way simultaneous transmission, as shown in configurations E and F, respectively.

Configurations D, E, and F are equivalent in data link operation to configurations A, B, and C, respectively; they differ only in that they use switched rather than nonswitched link connections. After a switched link connection is established, data link operation is the same as for nonswitched connections.

Configurations G through J are nonswitched multipoint. The link connection in configuration G is half duplex and therefore allows only two-way alternate transmission. The link connections in configurations H through J are duplex, but link station operation differs for these three configurations, as follows.

In configuration H, transmission is two-way alternate for the primary link station and for each secondary link station.

In configuration I, the primary link station can send to one of the secondary link stations while at the same time receiving from another secondary link station. Transmission is thus two-way simultaneous for the primary link station but two-way alternate for the secondary link stations.

In configuration J, the primary link station can send to and receive from the same secondary link station at the same time. Each secondary link station in this configuration can thus simultaneously send to and receive from the primary station, but only one of them at a time can do so.

The term *duplex-multipoint operation* is sometimes applied to configurations I and J.

In configuration K, the link connection is a loop. Although transmission on the loop is always in the same direction (referred to as *simplex* transmission), logically all the link stations use two-way alternate transmission.

In all of the configurations of Figure 4, the choice of two-way simultaneous or two-way alternate transmission is determined for each link station through control program parameters specified at the time the network is configured.

(Loop configurations are not further considered until Chapter 3, under "SDLC in a Loop Configuration" on page 40.)

Signal Conversion

When analog telecommunication facilities are used for data links, the binary digital information that is characteristic of information processing machines must be converted to a form similar to that used for transmitting speech signals. Two fundamental conversions are necessary, as shown in Figure 5:

- All data and control information are converted (*serialized*) to a serial stream of binary digits (0's and 1's). Data terminal equipment (DTE) makes this conversion.
- The binary signals are made compatible with analog transmission equipment by data circuit-terminating equipment (DCE).

Receiving equipment reverses both processes: binary information is recovered from received signals by DCE, and is then regrouped (*deserialized*) by DTE into the original data and control information.

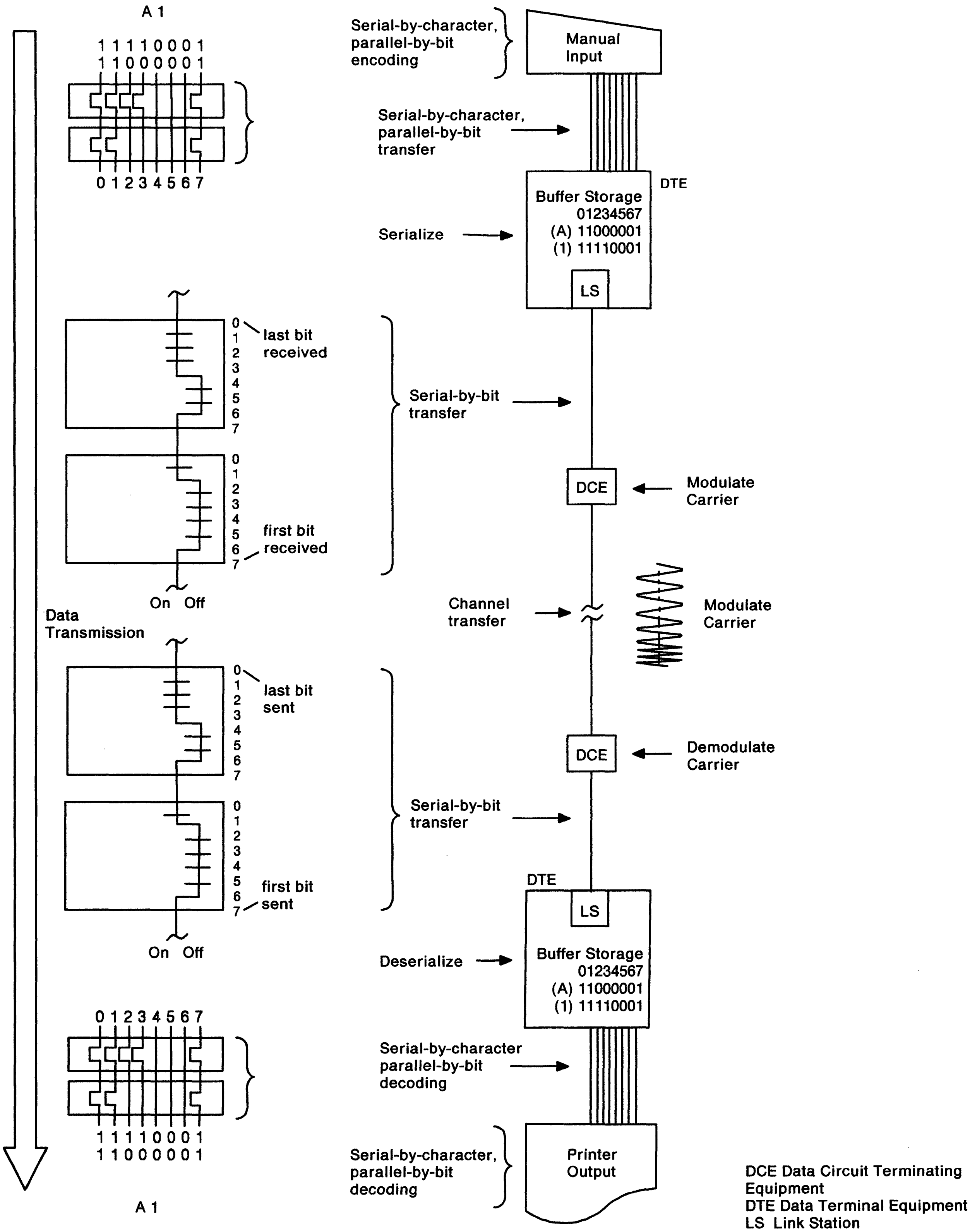


Figure 5. Data Conversion for Data Link Transfer

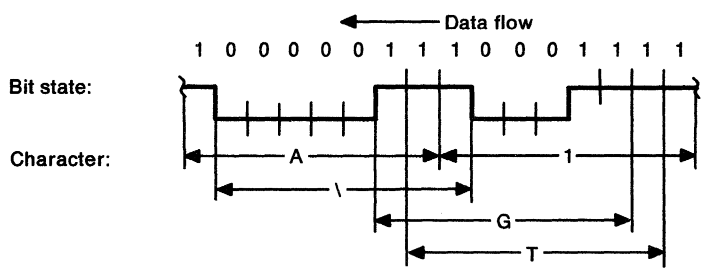
Data Link Control Activities

The actual transfer of data requires nondata transmissions for setting up, controlling, checking, and terminating the information exchange. Such transmissions are a part of data link control. (System control information, such as input/output device controls, is not considered data link control information.)

The following are data link control activities (see Figures 6) and 7).

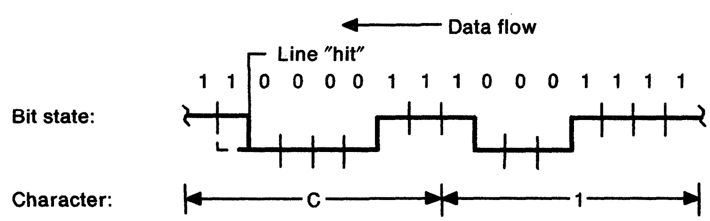
- Synchronizing—getting the receiver in bit synchronism and character synchronism with the transmitter
- Detecting and recovering from transmission errors
- Controlling send/receive—using a primary station to manage each data link (others are secondary stations)
- Reporting unacceptable conditions such as buffer overrun at the receiver.

Data link control keeps transmitter and receiver synchronized:



The receiver and the transmitter must be in bit and character synchronism (lack of synchronism results in inability of receiver to determine if incoming character is A, \, G, or T).

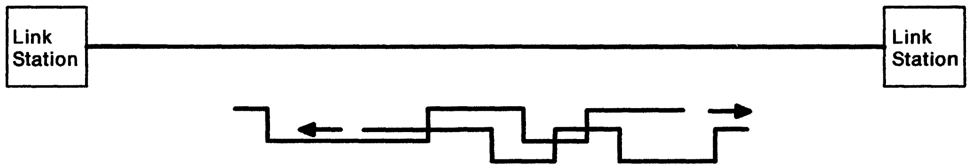
Data link control detects transmission errors:



A single binary digit is changed by a transmission error. The receiver must recognize that the error has occurred.

Figure 6. Some Data Link Control Activities—I

Data link control coordinates sending and receiving:



When one station transmits, the other station must receive; otherwise, no communication occurs.

Data link control handles exception conditions:

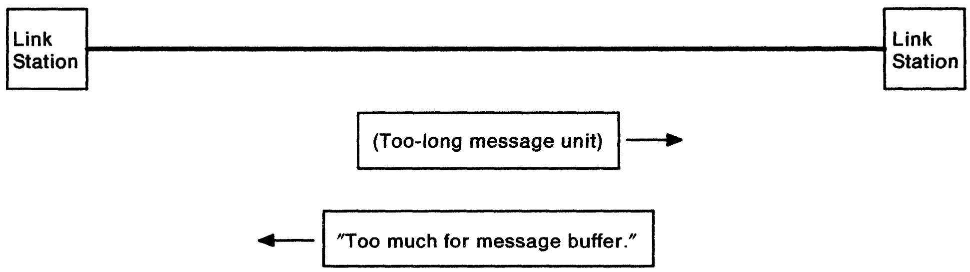


Figure 7. Some Data Link Control Activities—II

Bit Synchronization and Invert-on-Zero Coding

A synchronous transmission is time based to enable the DCE or DTE to identify the sequential binary digits (see Figure 8). SDLC procedures assume that bit synchronization is provided by either the DCE or the DTE.

A receiving DTE or DCE samples the value of the incoming signal at the same rate the transmitting DCE used to transmit the signal. There may be minor variations in timing between transmitter and receiver, however, that make it necessary for the receiver to dynamically adjust sample timing to keep sample times midway between bit transitions. DCEs that provide received-data timing to the DTE perform this function.

If the DCE does not provide received-data timing, the DTE must provide and adjust the sample timing. In this case, an *invert-on-zero* transmission coding method (also known as NRZI, *non-return to zero inverted*) is used, in which the DTE holds the signal condition in the same state to send a binary 1. To send a binary 0, the DTE changes the signal condition to the opposite state (see Figure 9). Thus, the long periods of binary 0 data that sometimes occur have successive transitions in the transmitted bit stream. (*Zero insertion*, a characteristic of SDLC procedures that is explained in Chapter 2, creates transitions when extended periods of binary 1 transmission occur.) Invert-on-zero transmission coding, if used on a link, must be used by all DTEs attached to the link.

SDLC is a bit-oriented procedure and any receiving error invalidates the segment of the transmission that contains the error; so it is important that bit synchronism be maintained. When DCEs do not provide received-data timing, the DTE must provide invert-on-zero transmission coding to reduce the probability of losing bit synchronism. Invert-on-zero coding may be required for certain DCEs that have specific bit-pattern sensitivities. Invert-on-zero coding may be prohibited for other DCEs that have different bit-pattern sensitivities.

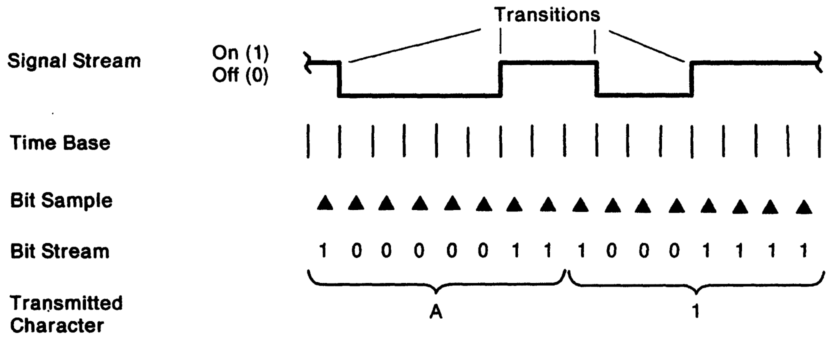


Figure 8. Discrete Transmission Coding

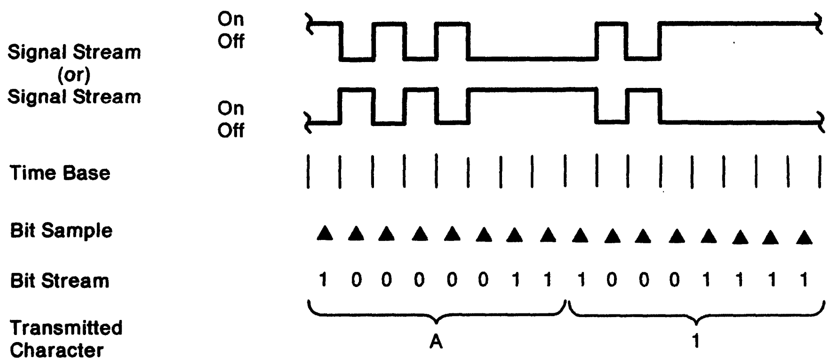


Figure 9. Invert-on-Zero Transmission Coding

Chapter 2. Basic Concepts

This chapter describes some basic concepts of SDLC and explains some SDLC procedures that help in recovery from transmission errors.

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Four concepts are fundamental to an understanding of SDLC:

- The definitions and responsibilities of primary and secondary link stations
- The definitions of the transmission states that affect information transfer
- How information is formatted into transmission frames
- How transmission frames are organized into larger sequences.

Primary and Secondary Link Stations

A *link station* comprises procedures and control information that coordinate the transfer of data between two nodes joined by a link connection.

A primary link station has the responsibility for controlling a data link; it issues commands. Secondary link stations receive commands from the primary link station and return responses to it. Each transmission on a link connection is from the primary station to one or more secondary stations, or from a secondary station to the primary station.

Transmission States

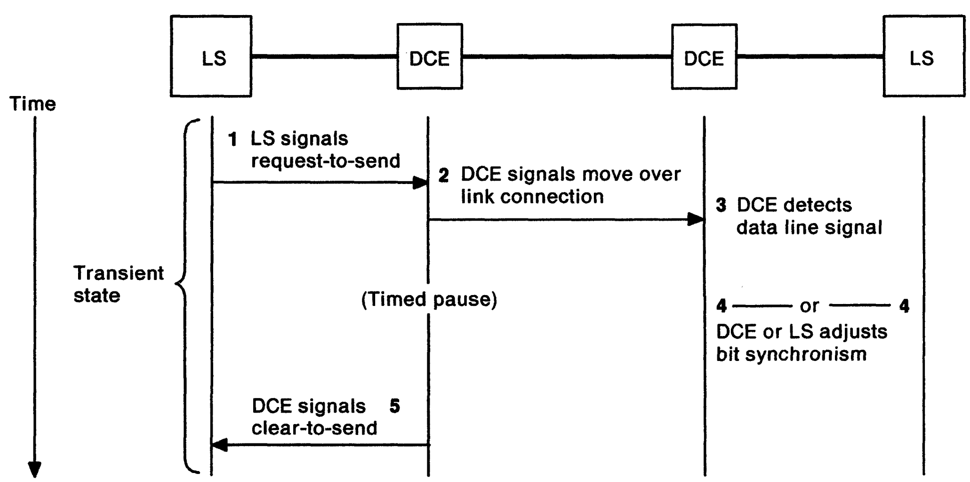
A link connection can be in one of three states:

- Transient state
- Idle state
- Active state.

A link connection can be in only one of these states at a time.

Transient State

The *transient state* exists when the link connection is being conditioned before initial transmission and after each transmit-receive reversal (or *turnaround*); see Figure 10.



DCE Data Circuit-terminating Equipment
LS Link Station

Figure 10. Period of the Transient State

Idle State

When a link connection is operational, but no SDLC control or information is currently being transmitted, it is in the *idle state.*

A link station detects the existence of the idle state when, after receiving an *idle pattern*—a succession of 15 consecutive binary 1's—it continues to receive binary 1's.

Note: A station that is not transmitting SDLC control or information data may, nevertheless, send signals onto the link connection.

The link connection configuration used determines the appropriate link station action in the idle state, as follows:

Link Connection	Primary Link Station	Secondary Link Station
Half-duplex point-to-point	Carrier off	Carrier off
Duplex point-to-point	All 1's	All 1's
Half-duplex multipoint	Carrier off	Carrier off
Duplex multipoint	All 1's	Carrier off

Active State

A link connection is in the *active state* when a link station is transmitting or receiving either information or data link control signals (via transmission frames described in the next section, "Transmission Frames" on page 19). The active transmission state is the nonidle, nontransient state. The link connection is also in the active state when a series of flags (also described in the next section) is being transmitted. In this case no information is exchanged, but the link connection is held in the active state (see Figure 11). A duplex link connection may be active in one direction and idle in the other.

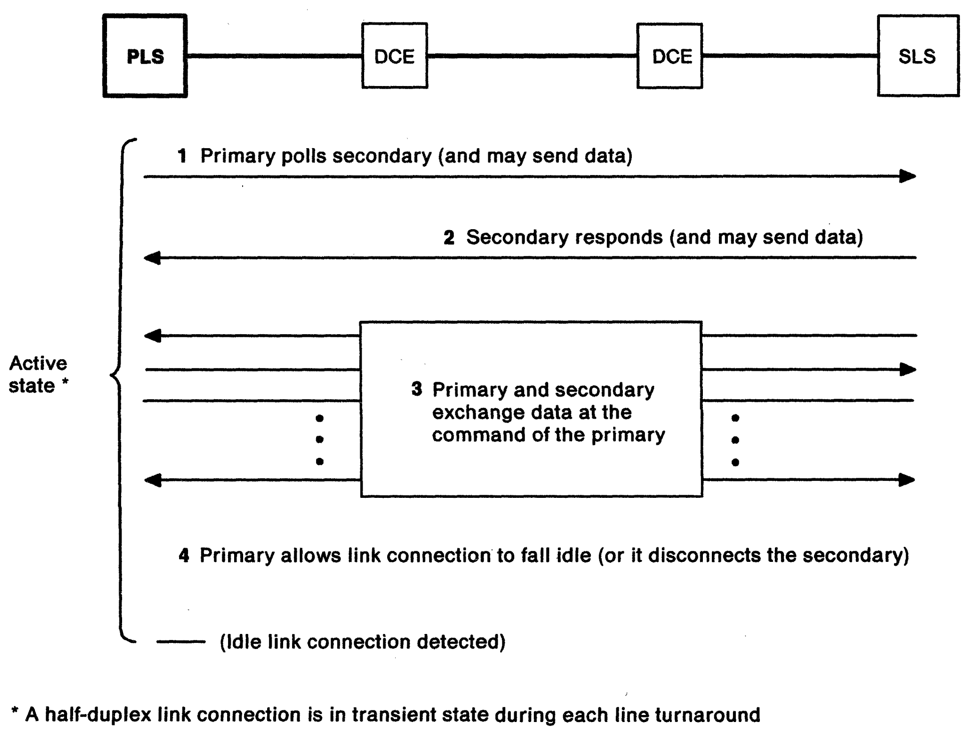


Figure 11. Period of the Active State

Transmission Frames

All data and control transmissions on an SDLC data link are organized in a specific format called a *transmission frame*—also called *SDLC frame*, or simply *frame* (see Figure 12). This format carries control information and user data between a transmitting station and a receiving station and allows a receiving station:

- To determine where the frame starts and ends.
- To determine whether the frame is intended for that station
- To determine what actions to perform with the information received
- To detect the occurrence of transmission errors in received frames
- To acknowledge its receipt of frames to the transmitting station.

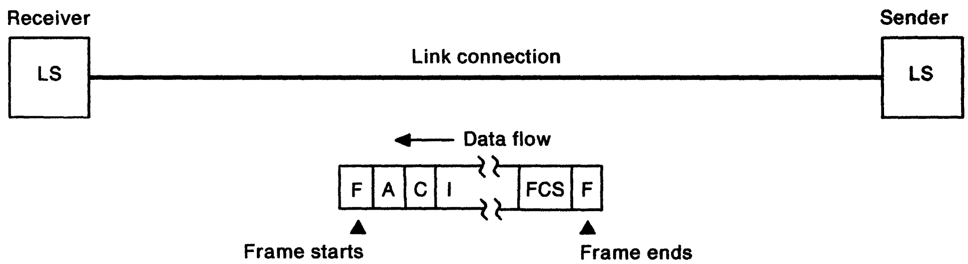


Figure 12. SDLC Transmission Frame

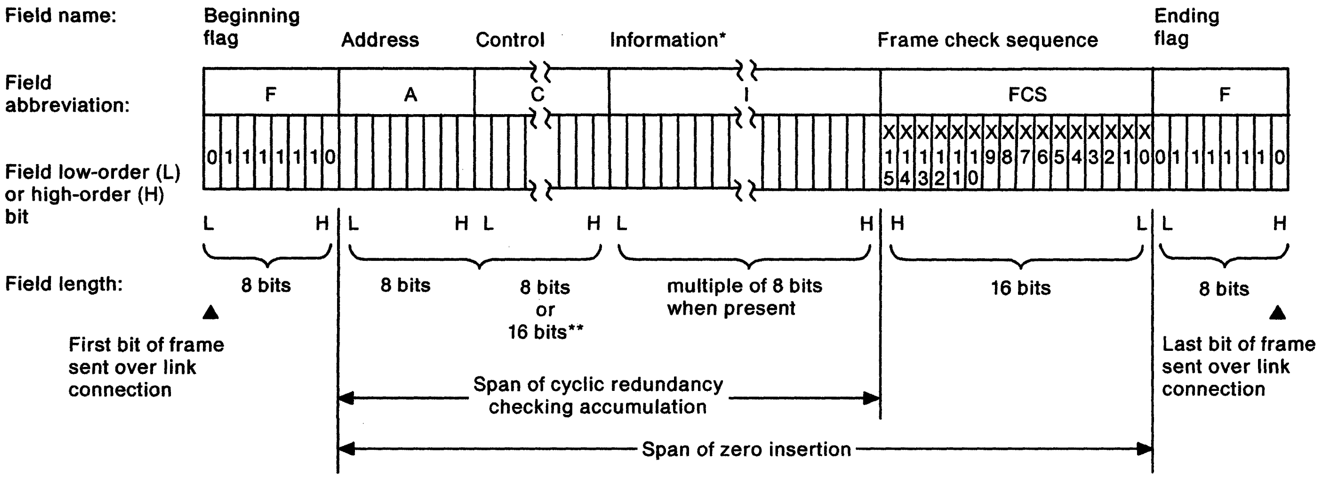
Frame Format

Each SDLC transmission frame has the same specific format. Each frame is made up of:

- A beginning flag (F) that marks the beginning of the frame
- An address (A) field that identifies the secondary station that is sending (or is to receive) the frame
- A control (C) field that specifies the function of the particular frame
- An optional information field that contains information data
- A frame check sequence (FCS) field that allows the receiving station to check the transmission accuracy of the frame
- An ending flag (F) that signals the end of the frame.

Each of these fields contains either 8 bits or a multiple of 8 bits (see Figure 13).

This figure shows the bit sequence in the frame as transmitted over the link connection. All fields except the frame check sequence are transmitted low-order bit first. The leftmost bit in each field shown in Figure 13, except the FCS field, is the *low-order* bit of that field. The leftmost bit of the FCS field is the ***high-order*** bit (most significant bit) of the FCS field.



* Optional, variable length
** 8 bits for modulo-8 operation, 16 bits for modulo-128 operation

Figure 13. Fields of the SDLC Transmission Frame, As Transmitted

Flags

The beginning flag and the ending flag enclose the SDLC frame. The beginning flag serves as a reference for the position of the A (address) and C (control) fields and initiates transmission error checking; the ending flag delimits the end of the FCS field and marks the end of the frame.

Both beginning and ending flags have the binary format 01111110. The ending flag for one frame may serve as the beginning flag for the next frame. Alternatively, the ending 0 of an ending flag may serve as the beginning 0 of a beginning flag, thus forming the pattern 011111101111110. Also, the transmitting link station inserts multiple flags between frames to maintain the active state if time fill is required. Zero insertion, described under “Zero Insertion” on page 24, prevents the flag pattern from occurring anywhere else in the frame.

Any ending flag may be followed by a frame, by another flag, or by an idle condition.

Address Field

The address field of an SDLC frame follows immediately after the beginning flag. It serves the same purpose as the address or return address on a letter mailed through the post office. The address that is sent is always the address of the secondary station on the link connection. If the primary station is transmitting the frame, the address is similar to the main address on a letter—it tells where the message is to go. If a secondary station is transmitting the frame, the address is similar to the return address on a letter—it tells where the message originated.

For application purposes, it may be useful to have special addresses specified that direct frames to a number of stations or to all the stations on the link connection. In this case, a secondary station may have three types of address:

- Its own individual address: a *station address*.
- An address that is common to a number of stations: a *group address*.

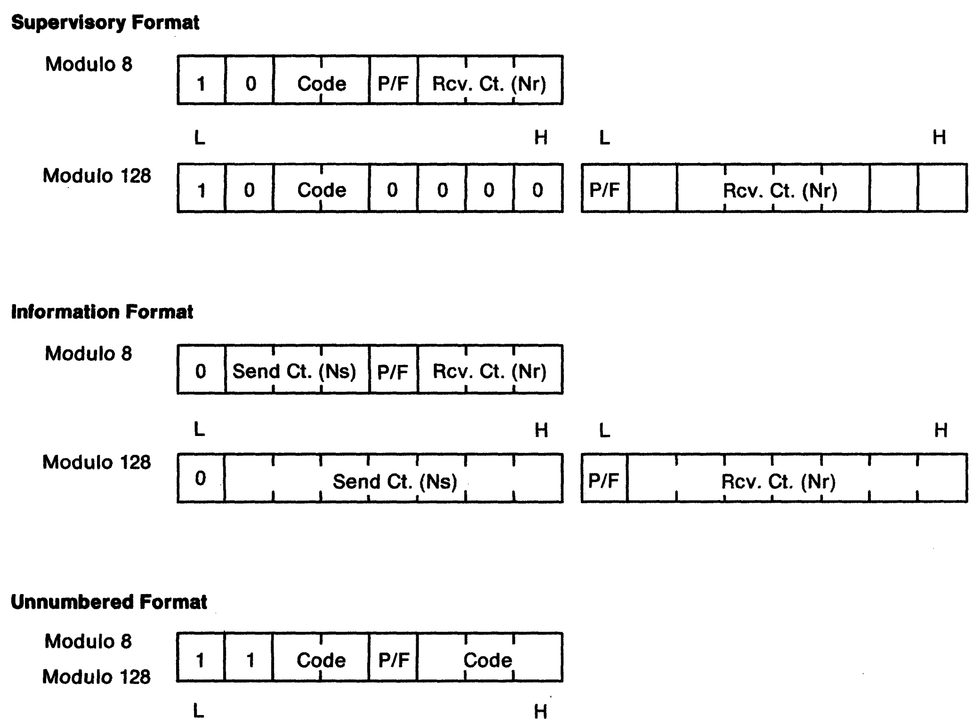
- An address that all stations on the link connection will accept: a *broadcast address* (sometimes called an *all-stations address*). An address field of all 1's is reserved for use solely as the broadcast address.

Note: An all-0's address field is reserved as a "no station's address"; therefore, no secondary station is assigned this as one of its addresses.

Control Field

The control field (C field) follows the address field. The control field defines the function of the frame and can be in one of the three formats shown in Figure 14: *unnumbered* (U) format, *supervisory* (S) format, or *information* (I) format. (The corresponding frame is similarly named.)

The control field bits shown as "Code" in the figure represent the SDLC command or response indicated by the frame. The commands and responses are explained in "Command and Response Definitions" on page 34, and are summarized in Appendix A.



L Low-order bit (first bit in each byte transmitted)
H High-order bit (last bit in each byte transmitted)

Figure 14. SDLC Frame: Control Field

Unnumbered (U) Format

Unnumbered frames are used for such functions as:

- Establishing and disconnecting the data link
- Reporting certain procedural errors
- Transferring data (when the location of the data in a sequence of frames is not to be checked).

Supervisory (S) Format

Supervisory frames assist in the transfer of information, though they do not carry information themselves. They are used to acknowledge received frames, to convey ready or busy conditions, and to report frame numbering errors (indicating that a numbered information frame was received out of its proper sequence).

Information (I) Format

Information frames transfer information. Besides indicating the format, the control field contains send and receive counts (*Ns* and *Nr*). SDLC procedures use the *Ns* count to ensure that these frames are received in their proper order; they use the *Nr* count to confirm that received information frames are accepted.

The *Ns* count indicates the number of the information frame within the sequence of information frames transmitted. The *Nr* count transmitted in a frame is the number (*Ns*) of the information frame that the station transmitting the *Nr* count expects to receive next. "Frame Numbering" on page 23 gives more details about this process.

Note: The *Ns* count is present only in a control (C) field of the information format. An *Nr* count appears in C fields of information and supervisory frames. Neither the *Nr* nor the *Ns* count is present in a C field of unnumbered frames.

The P/F Bit

All three C field formats contain a poll/final (P/F) bit. A P (poll) bit is sent to a secondary station to require that it initiate transmission; an F (final) bit is sent to a primary station by a secondary station in the last frame of a transmission. (Do not confuse the F (final) bit with the F (flag) frame delimiter pattern.) Only one P bit may be outstanding (unanswered by an F bit) at one time on any of the data links described thus far.

Information Field

Following the control field, there may or may not be an information field. The supervisory frame does not contain an information field.

Data to be transferred on the data link is contained in the information field of a frame. The information field does not have a set length, but must be a multiple of 8 bits. In each 8-bit grouping (octet), the low-order bit is sent first and the high-order bit is sent last.

Frame Check Sequence (FCS) Field

Following the information field (or control field if no information field is present) is the frame check sequence (FCS) field. The purpose of this field is to check the received frame for errors that may have been introduced by the link connection. This field contains a 16-bit check sequence that is the result of a computation on the contents of the A, C, and information fields at the transmitter. The computation method used is called *cyclic redundancy checking* (CRC).

The receiver makes a similar computation on the received frame. If the frame is received with an error, the receiver rejects the frame and discards it. Thus, the receiver accepts no frame that it finds to be in error.

The FCS field is followed by the ending flag, closing the frame.

See Appendix B, "SDLC Computation of the FCS Field," for more details on the FCS field and on CRC.

Frame Numbering

A station that is transmitting numbered information frames numbers each one by placing its number in the *Ns* count field of the frame. The receiving station checks this number to determine if any frames are missing or duplicated.

A station that is receiving numbered information frames accepts each one that is error free and in sequence and advances its receive count (*Nr*) for each such frame. If the received frame is error free, a receiving station's *Nr* count is the same as the *Ns* count that it will receive in the next numbered information frame—that is, a count of 1 greater than the *Ns* count of the last frame accepted. The receiver confirms its acceptance of numbered information frames by returning its *Nr* count to the transmitting station.

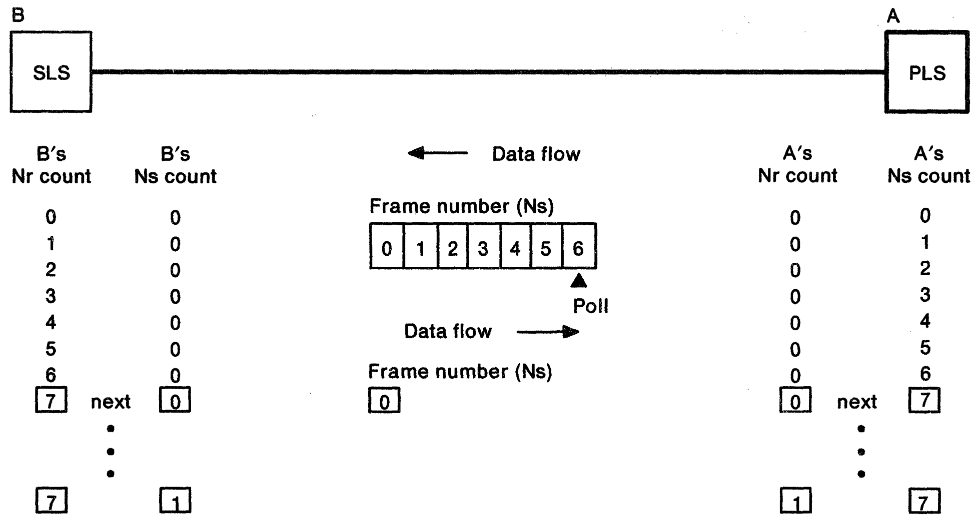
The *Nr* count at the receiving station advances when the station checks the frame and finds it to be error free and in sequence; *Nr* then becomes the count of the "next-expected" frame and should agree with the next incoming *Ns* count. If the incoming *Ns* count does not agree with the *Nr* count, the frame is out of sequence and *Nr* does not advance. The receiver does not accept out-of-sequence frames. It does, however, accept the incoming *Nr* count (for confirmation purposes) if the out-of-sequence frame is otherwise error free.

The counting capacity for *Nr* and *Ns* is 8, using the numbers 0 through 7 (for modulo-8 operation); or 128, using the numbers 0 through 127 (for modulo-128 operation). These counts "wrap around"; that is, 7 (or 127) is sequentially followed by 0. Up to seven (or 127) unconfirmed, numbered information frames may be outstanding (transmitted but not confirmed) at the transmitter.

The restriction that, at most, modulus-minus-1 frames (that is, 7 or 127 frames) may be outstanding at any time prevents ambiguity when error recovery results in retransmissions. For example, if eight I frames (numbered 0 through 7) were transmitted and a response were returned with an *Nr* count of 0, the transmitter could not determine whether the response confirmed the most recent I frames 0 through 7 or indicated that retransmission was required.

All unconfirmed frames must be retained by the transmitter, because some or all of them may have to be retransmitted if transmission errors or buffering constraints occur. The reported *Nr* count is the number of the next frame that the receiver expects to receive, so if, at a checkpoint, the *Nr* count is not the same as the transmitter's next frame (*Ns*) number, some of the frames already sent must be retransmitted. (See Figure 15 for an example of modulo-8 frame numbering.)

The *Nr* and *Ns* counts of both stations are initialized to 0 by control of the primary station. At other times, the counts advance as numbered frames are sent and received.



If B responds to the poll with Nr = :	A may send Ns frames:
7 (as above, all frames check OK)	7,0,1,2,3,4,5 (continue)
6 (frame 6 discarded because of error)	6,7,0,1,2,3,4 (retransmit and continue)
5 (error on frame 5, 5 and 6 discarded)	5,6,7,0,1,2,3 (retransmit and continue)
4 (error on frame 4, 4-6 discarded)	4,5,6,7,0,1,2 (retransmit and continue)
3 (error on frame 3, 3-6 discarded)	3,4,5,6,7,0,1 (retransmit and continue)
2 (error on frame 2, 2-6 discarded)	2,3,4,5,6,7,0 (retransmit and continue)
1 (error on frame 1, 1-6 discarded)	1,2,3,4,5,6,7 (retransmit and continue)
0 (error on frame 0, no frames accepted)	0,1,2,3,4,5,6 (retransmit)

Figure 15. Example of Modulo-8 Frame Numbering

Zero Insertion

A frame is identifiable because it begins and ends with a flag and contains only nonflag bit patterns between the flags. This characteristic does not restrict the contents of a frame because SDLC procedures require that the transmitter insert a binary 0 after any succession of five contiguous 1's within the frame. (This action is sometimes called "bit stuffing.") Thus, no pattern of 01111110 (a flag) is ever transmitted between the beginning and ending flags.

Zero-bit insertion is disabled when the flag is being transmitted. After testing for flag recognition, the receiver removes a 0 that follows five contiguous 1's (see Figure 16). A 1 that follows five contiguous 1's is not removed; it signifies a frame abort (if it is followed by one or more 1's) or the arrival of a flag (if it is followed by a 0). Inserted and removed 0's are not included in the frame check sequence computation.

Note: When invert-on-zero transmission coding is used, zero insertion eliminates the remaining possibility of prolonged transitionless periods (continuous 1 bits) in the active state (see "Bit Synchronization and Invert-on-Zero Coding" on page 11).

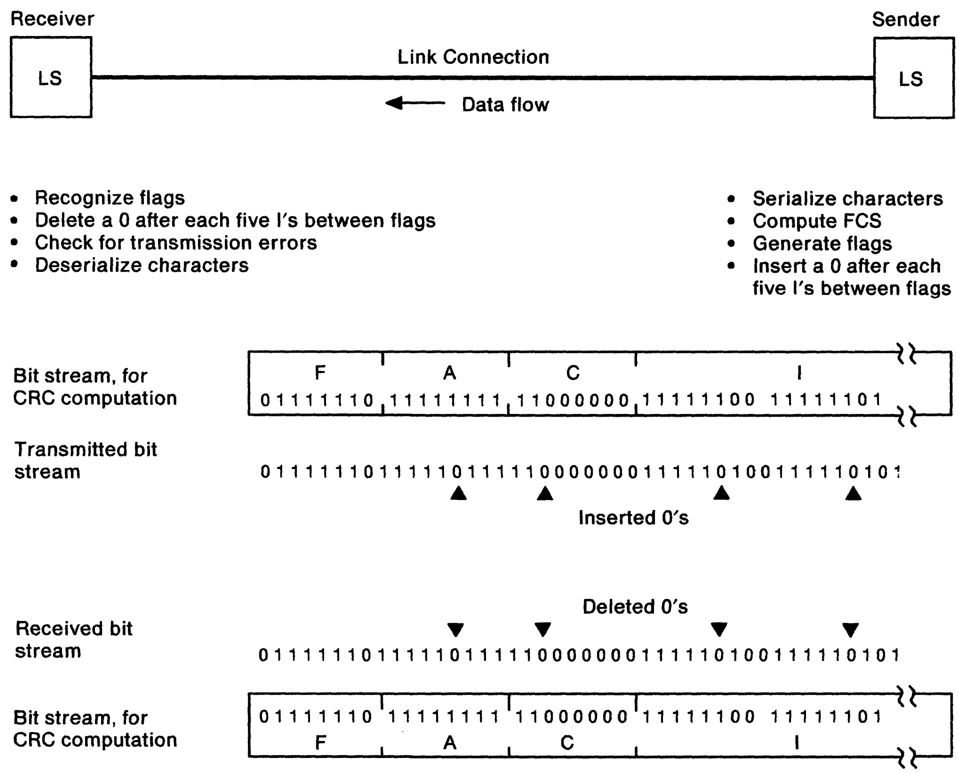


Figure 16. Zero Insertion and Deletion

Timeouts

The primary link station is responsible for the orderly, continuous operation of a data link, and it must check for responses to its commands. Two timeouts are operated by a primary link station for these purposes: (1) idle detect and (2) nonproductive receive.

Idle Detect

When the primary station transmits a frame with the P bit *on* in the C field, the station expects a response to be initiated within a certain period of time. In two-way alternate operation, the link connection is normally in the idle state when no transmission is taking place. If the idle state (or nonresponse condition) continues past the time when a response should have been received (for example, if the secondary station does not respond to a frame), the primary station will detect the protracted idle condition and should initiate recovery action.

The interval that should be allowed before recovery action includes:

1. Propagation time to the secondary station
2. Clear-to-send time at the secondary station DCE
3. Appropriate time for secondary station processing
4. Propagation time from the secondary station.

Factors (1), (2), and (4) vary as follows:

Link Connection *(see Figure 17)*	**Secondary Station DCE Clear-to-Send Delay**	**Approximate Two-Way Propagation Time** *(see Figure 17)*
Switched (through local exchange only) or very short (distance) nonswitched	0 ms to 25 ms	2 ms per 15 miles (23 km.) (*X*)
Long (distance) duplex (nonswitched)	0 ms to 25 ms	2 ms per 150 miles (230 km) + 24 ms (*Y*)
Long (distance) half-duplex (switched or nonswitched)	75 ms to 250 ms	2 ms per 150 miles (241 km) (*Y*)
Satellite duplex (switched or nonswitched)	0 ms to 250 ms	600 to 700 ms per hop[1] plus propagation time for connecting terrestrial links (*Z*)

With each type of link connection configuration, the minimum timeout includes an allowance for processing time at the secondary station. The sum of other times may be as great as 850-900 milliseconds (for a satellite link). If a response is received or is being received before the timeout expires, the timeout is reset.

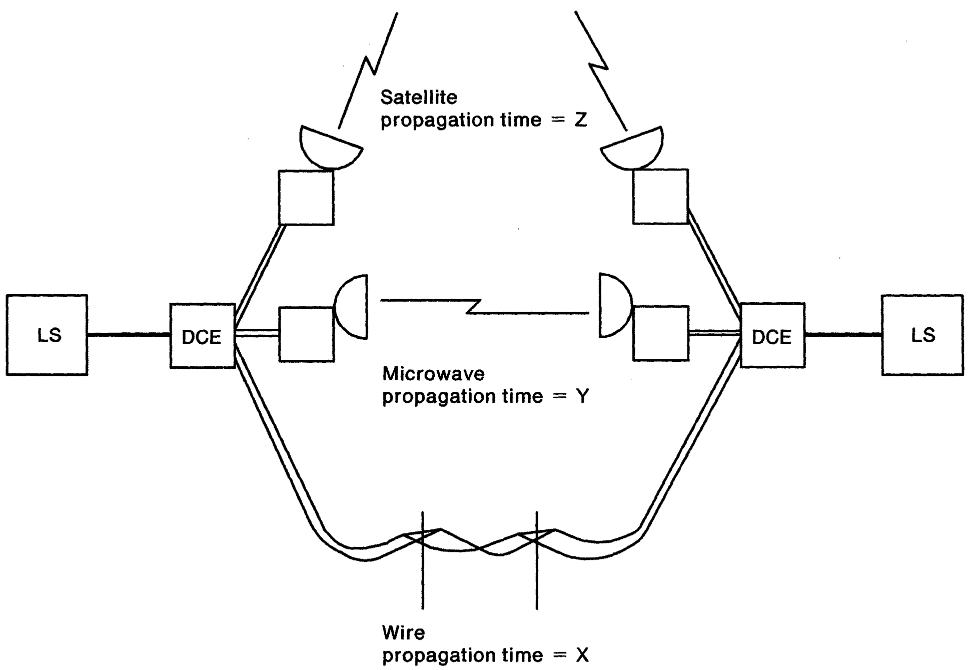


Figure 17. Examples of Telecommunication Facilities

1 A satellite hop is one uplink and one downlink.

Nonproductive Receive

When bits are being received that do not result in frames, a *nonproductive receive* condition exists. This condition could be caused by secondary station malfunctions that cause continuous transmission. The primary station must provide a time-out period when a nonproductive receive condition occurs. The usual timeout period ranges from 3 to 30 seconds. If the nonproductive receive condition continues after the the problem is normally not recoverable at the data link control level and must be handled by some method above the data link control level.

Abort Conditions

The act of prematurely terminating the transmission of a frame is called *aborting* the transmission.

The transmitting station aborts a transmission by sending a minimum of seven consecutive binary 1′s with no zero insertion (see Figure 18). This sequence is called an *abort pattern.* (Unintentional aborting is prevented by zero insertion.) The abort pattern terminates the frame without an FCS field or an ending flag.

Following transmission of the abort pattern, the link connection may be permitted to go to the idle state or it may remain in the active state.

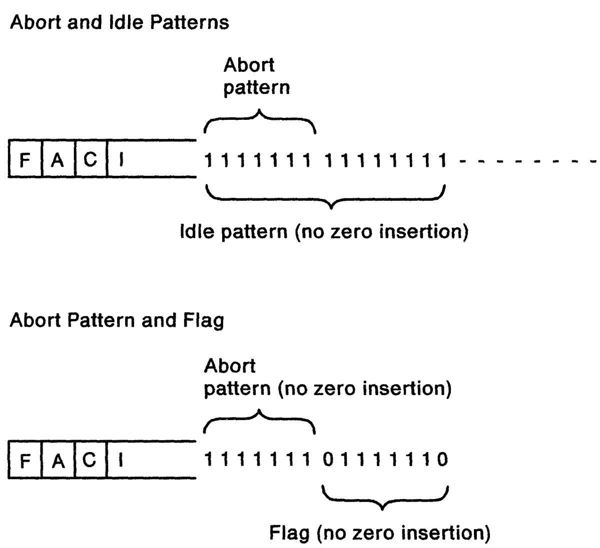


Figure 18. Transmitting Station Aborts Transmission

Either a primary or a secondary station may abort a transmission. An abort pattern of seven 1′s may be followed by eight (minimum) additional 1′s (a total of at least 15 contiguous 1′s), which idles the data link as long as the 1′s continue, or it may be followed by a frame. Seven to fourteen 1′s constitute an abort pattern; fifteen or more 1′s constitute an idle pattern.

Recovery from Errors and Special Conditions

SDLC detects various kinds of errors (such as CRC errors and frames out of order) and special conditions (such as a "busy" station). SDLC can provide recovery from some of these errors and conditions; the term *link-level recovery* is applied to these recovery actions. When unable to provide recovery from errors or special conditions, SDLC reports them to higher levels of SNA for resolution. The term *higher-level recovery* is applied to recovery actions outside SDLC.

Link-Level Recovery

At the link level, SDLC procedures detect discrepancies that may be recovered from by retransmitting the frame. For example:

- A busy station is temporarily unable to continue to receive. It reports this condition to the transmitting station.
- A received *Nr* count does not confirm the appropriate numbered information frames previously transmitted. Retransmission is initiated.
- A receiving station discards a frame because:
  - it contains a CRC error
  - it is out of numerical order
  - the station cannot accept it because of a busy condition (I frames only)
  - the ending flag is not displaced from the beginning flag by a multiple of 8 bits.
  - it is less than 32 bits long.
- A response to a poll is not received; the poll is normally repeated.
- An attempt to bring a secondary station online does not succeed; the command is repeated.

Retransmissions may be counted to detect that the situation is not considered to be recoverable at the link level. The counting of retransmission attempts is not specified by SDLC procedures. Usually, they are counted within the transmitting DTE and, at some planned number *n*, correct link station action is reported as unrecoverable at the link level. Among those actions that should be retried are attempts to:

- Obtain acknowledgment of a command
- Resume communication with a busy station
- Achieve initial, online status of a secondary station.

Higher-Level Recovery

Link-level error detection applies to the address, control, information, and FCS fields of the frame. Some detected errors cannot be recovered from at the link level; for example:

- If a secondary station responds by rejecting a command with which the station is not compatible, only an acceptable alternative command can relieve its error condition. Intervention from a higher level is required to analyze and act upon the status report in the secondary station's response.[2] .
- If the transmitting station has aborted transmission because of an internal malfunction or an expended retransmission count, intervention from a higher level is required to analyze and act upon the situation.
- If a secondary station response to the exchange of station identification (described under "SDLC on a Switched Link" on page 39) contains the wrong

2 Rejecting a command is described under "FRMR (Frame Reject)" on page 37

identification, intervention from a higher level is required to analyze and act upon the situation.

The type of intervention required depends upon the station's decision-making power at a level higher than the link level. At a terminal, for example, operator intervention may be needed.

Chapter 3. Further Concepts, Applications, and Examples

This chapter describes additional concepts, defines the SDLC commands and responses, and shows applications and examples of SDLC command and response flows for specific configurations.

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Secondary-Station Mode Definitions

A secondary link station may be in one of three modes: *initialization mode, normal response mode,* or *normal disconnected mode.* The meanings of these modes are as follows.

Initialization Mode

Initialization mode is the mode for initializing or reinitializing a link station with the appropriate link protocols.

Normal Response Mode (NRM) and Normal Response Mode Extended (NRME)

A secondary station in either normal response mode (NRM) or normal response mode extended (NRME) does not initiate unsolicited transmissions. It transmits only in response to a poll, which is a frame received from the primary station, with the P bit *on* in the C field.

The secondary station may respond with one or more frames. The F bit is *on* in the last (or only) frame of the response. A primary station will not poll any other secondary station until (1) it receives the F bit response to an outstanding P bit or (2) a timeout has completed.

Normal Response Mode: A secondary link station assumes normal response mode when it receives a SNRM (Set Normal Response Mode) command from the primary link station. The SNRM command causes modulo-8 operation of the link. In modulo-8 operation, each S frame and each I frame contains a 1-byte control field that includes 3 bits for the *Nr* count (and, for I frames only, 3 bits for the *Ns* count). The use of 1-byte control fields allows up to seven SDLC frames to be outstanding (that is, unacknowledged) on a link.

When in normal response mode, the secondary (1) expects every control field it receives in a command to be 1 byte long, and (2) sends only 1-byte control fields in its responses.

Normal Response Mode Extended (NRME): A secondary link station assumes normal response mode extended when it receives a SNRME (Set Normal Response Mode Extended) command from the primary link station. The SNRME command causes modulo-128 operation of the link. In modulo-128 operation, each S frame and each I frame contains a 2-byte control field that includes 7 bits for the *Nr* count, (and, for I frames only, 7 bits for the *Ns* count). The use of 2-byte control fields allows up to 127 SDLC frames to be outstanding (that is, unacknowledged) on a link.

When in normal response mode extended, the secondary (1) expects every control field it receives in a supervisory (S) or information (I) command to be 2 bytes long, and (2) sends only 2-byte control fields in its supervisory and information responses. Unnumbered (U) commands and responses contain 1-byte control fields.

Normal Disconnected Mode (NDM)

A secondary station that receives and accepts a DISC (Disconnect) command assumes normal disconnected mode; it also assumes this mode:

- When power is turned on, or when the station is enabled for data link operation
- Following a transient disabling condition (such as a power failure)
- When a switched connection is made.

In NDM, a secondary station will respond only as the result of receiving a command with the P bit *on* and may accept only a TEST, XID, CFGR, SNRM, SNRME, or SIM command from the primary station. One of these commands that is not accepted, or any other command in which the P bit is *on*, causes a disconnected secondary station to respond with a disconnected mode status or an initialization request.

Command and Response Definitions

This section describes the commands and responses contained in the C field of an SDLC frame. When received by a secondary station, a frame is a command; when received by a primary station, a frame is a response.

Commands and responses in the unnumbered (U) format have a 1-byte control field for both modulo-8 and modulo-128 operation of the link over which they pass. Commands and responses in the supervisory (S) and numbered information (I) formats have a 1-byte control field for modulo-8 operation of the link and a 2-byte control field for modulo-128 operation of the link.

Figure 19 summarizes all SDLC commands and responses.

Binary formats*	Acronym	Command	Response	Info. Field Prohibited	Resets Nr and Ns	Confirms frames through Nr-1	Defining Characteristics
Unnumbered (U) Format (Modulo 8 and 128)							
000P 0011	UI	X					Unnumbered command that carries information.
000F 0011	UI		X				Unnumbered response that carries information.
000F 0111	RIM		X	X			Initialization needed; expect SIM.
000P 0111	SIM	X		X	X		Set initialization mode; the using system prescribes the procedures.
000F 1111	DM		X	X			This station is in disconnected mode.
001P 0011	UP	X		X			Response is optional if P bit is not on.
010P 0011	DISC	X		X			Do not transmit or receive information.
010F 0011	RD		X	X			This station wants to disconnect.
011F 0011	UA		X	X			Acknowledgment for unnumbered commands (SNRM, SNRME, DISC, or SIM).
100P 0011	SNRM	X		X	X		Set normal response mode; transmit on request by secondary only.
100F 0111	FRMR		X				Invalid frame received; must receive SNRM, SNRME, DISC, or SIM.
101P 1111	XID	X					Information field contains identification.
101F 1111	XID		X				Information field contains identification.
110P 0111	CFGR	X					Information field contains function descriptor.
110F 0111	CFGR		X				Information field contains function descriptor.
110P 1111	SNRME	X		X	X		Set normal response mode extended; transmit on request by secondary only.
111P 0011	TEST	X					Information field contains test pattern.
111F 0011	TEST		X				Information field contains test pattern.
111F 1111	BCN		X	X			Signals loss of input.
Supervisory (S) Format (Modulo 8)							
rrrP 0001	RR	X		X		X	Ready to receive.
rrrF 0001	RR		X	X		X	Ready to receive.
rrrP 0101	RNR	X		X		X	Not ready to receive.
rrrF 0101	RNR		X	X		X	Not ready to receive.
rrrP 1001	REJ	X		X		X	Transmit or retransmit starting with frame Nr.
rrrF 1001	REJ		X	X		X	Transmit or retransmit starting with frame Nr.
Supervisory (S) Format (Modulo 128)							
0000 0001 rrrr rrrP	RR	X		X		X	Ready to receive.
0000 0001 rrrr rrrF	RR		X	X		X	Ready to receive.
0000 0101 rrrr rrrP	RNR	X		X		X	Not ready to receive.
0000 0101 rrrr rrrF	RNR		X	X		X	Not ready to receive.
0000 1001 rrrr rrrP	REJ	X		X		X	Transmit or retransmit starting with frame Nr.
0000 1001rrrr rrrF	REJ		X	X		X	Transmit or retransmit starting with frame Nr.

Each byte is transmitted low-order bit first, high-order bit last.
* The rightmost bit shown is transmitted first; leftmost bit is transmitted last.

F - Final bit (1 or 0)　　P - Poll bit (1 or 0)
r - Nr (receive count 1 or 0)　　s - Ns (send count 1 or 0)

Figure 19 (Part 1 of 2). Summary of Command and Response C Fields as Present in Storage

Binary formats*	Acronym	Command	Response	Info. Field Prohibited	Resets Nr and Ns	Confirms frames through Nr-1	Defining Characteristics
Information (I) Format (Modulo 8)							
rrrP sss0	I	X				X	Sequenced I frame.
rrrF sss0	I		X			X	Sequenced I frame.
Information (I) Format (Modulo 128)							
ssss sss0 rrrr rrrP	I	X				X	Sequenced I frame.
ssss sss0 rrrr rrrF	I		X			X	Sequenced I frame.

Each byte is transmitted low-order bit first, high-order bit last.
* The rightmost bit shown is transmitted first; leftmost bit is transmitted last.

F - Final bit (1 or 0) P - Poll bit (1 or 0)
r - Nr (receive count 1 or 0) s - Ns (send count 1 or 0)

Figure 19 (Part 2 of 2). Summary of Command and Response C Fields as Present in Storage

Unnumbered (U) Format

A C field in the unnumbered (U) format (see Figure 14) has the two low-order (first-sent) bits *on* (binary 11). Unnumbered frames are not sequence checked and do not use *Nr* or *Ns* counts. Excluding the P/F bit, the other five C field bits are available for encoding the commands and responses of U frames. These commands and responses are:

BCN Beacon *(response)*
CFGR Configure *(command or response)*
DISC Disconnect *(command)*
DM Disconnected Mode *(response)*[3]
FRMR Frame Reject *(response)*[4]
RD Request Disconnect *(response)*[5]
RIM Request Initialization Mode *(response)*[6]
SIM Set Initialization Mode *(mode-setting command)*
SNRM Set Normal Response Mode *(mode-setting command)*
SNRME Set Normal Response Mode Extended *(mode-setting command)*
TEST Test *(command or response)*
UA Unnumbered Acknowledgment *(response)*[7]
UI Unnumbered Information frame *(command or response)*[8].
UP Unnumbered Poll *(command)*[9]
XID Exchange Station Identification *(command or response)*

3 Formerly ROL—Request Online.
4 Formerly CMDR—Command Reject.
5 Formerly RQD—Request Disconnect.
6 Formerly RQI—Request for Initialization.
7 Formerly NSA—Nonsequenced Acknowledgment.
8 Formerly NSI—Nonsequenced Information frame
9 Formerly NSP—Nonsequenced Poll.

Note: For descriptions of UP, BCN, and CFGR, see "SDLC in a Loop Configuration" on page 40.

As a command or a response, a UI frame is the format for transmitting information without sequence numbers.

Note: UI frames are not used in IBM products.

SNRM (Set Normal Response Mode) or SNRME (Set Normal Response Mode Extended): This command places the secondary station in normal response mode (NRM) or normal response mode extended (NRME) for information transfer. SNRM indicates that the transmissions on the link will be modulo 8 (that is, the *Nr* and *Ns* counts range in value from 0 to 7) and that each C field in a frame is 1 byte long. SNRME indicates that the transmissions on the link will be modulo 128 (that is, the *Nr* and *Ns* counts range in value from 0 to 127) and that each C field is 2 bytes long.

In either case, the maximum number of I frames that can be sent before an acknowledgment is required is the modulus minus 1—that is, 7 or 127. This means that consecutive *Nr* counts can be the same only if they confirm the same block of frames. See "Frame Numbering" on page 23 for additional information on *Nr* and *Ns* counts.

UA is the expected response. The primary and secondary station *Nr* and *Ns* counts are reset to 0. No unsolicited transmissions are allowed from a secondary station that is in NRM or NRME. The secondary station remains in NRM or NRME until it receives a DISC or SIM command.

DISC (Disconnect): This command terminates other modes and places the receiving (secondary) station in disconnected mode. The expected response is UA. (A link station on a switched link then disconnects, which is similar to hanging up a telephone.) A secondary station that is in disconnected mode cannot receive or send supervisory or information frames.

RD (Request Disconnect): This request is sent by a secondary station desiring to be disconnected (by a DISC command).

UA (Unnumbered Acknowledgment): This is the affirmative response to an SNRM, SNRME, DISC, or SIM command.

RIM (Request Initialization Mode): An RIM frame is transmitted by a secondary station to notify the primary station of the need for an SIM command.

SIM (Set Initialization Mode): This command initiates system-specified procedures that initialize link-level functions. UA is the expected response. The primary and secondary station *Nr* and *Ns* counts are reset to 0.

DM (Disconnected Mode): A secondary station sends this response to indicate that it is in disconnected mode.

FRMR (Frame Reject): A secondary station that is in NRM or NRME sends this response only when it receives an invalid frame. A received frame may be invalid for any of several reasons:

- The function specified by its C field is not implemented at the secondary station. This category includes unassigned commands.
- The information field is too long to fit into the receiving station buffers. This use of FRMR is optional.

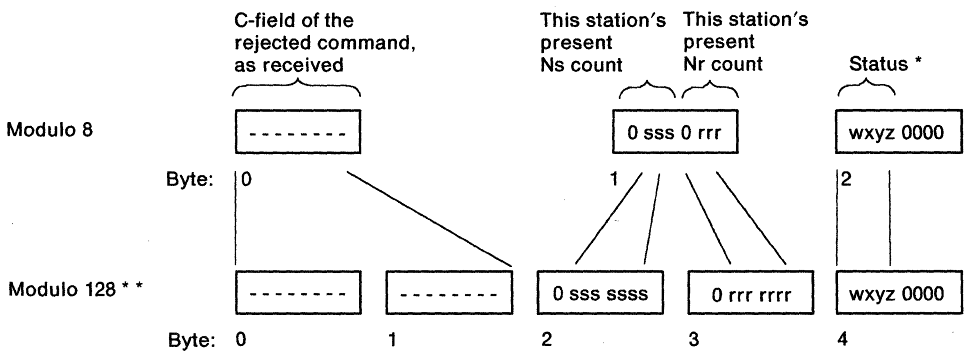
- The C field in the received frame does not allow an information field to be included with the frame, but an information field is present.
- The *Nr* count that was received from the primary station is invalid.

The secondary station cannot release itself from the FRMR condition, nor does it act upon the frame that caused the condition. It sends FRMR in response to any further commands it receives other than an acceptable mode-setting command (SNRM, SNRME, DISC, or SIM), which resets the frame-reject condition.

The secondary station sends an information field containing status as part of the FRMR response frame (see Figure 20).

TEST (Test): As a command, a TEST frame may be sent to a secondary station in any mode to solicit a TEST response. If an information field is included with the command, it is returned in the response. If the secondary station has insufficient buffering available for the information field, a TEST response with no information field is returned.

XID (Exchange Station Identification): As a command, XID solicits the identification of the receiving (secondary) station. An information field may be included in the frame to convey identification of the transmitting (primary) station. An XID response is required from the secondary station. An information field in the response may be used for identification of the responding secondary station.



* Status: w - Invalid or nonimplemented command
x - Prohibited information field received
y - Buffer overrun (information field is too long)
z - received Nr count is invalid

* * When the FRMR response rejects an unnumbered (U) format command the rejected C field is placed in byte 0 and byte 1 is set to all 0's.

Figure 20. Information Field of the FRMR Response, as Transmitted

Supervisory (S) Format

Supervisory (S) frames may be used to acknowledge receipt of I frames and to control information interchange. No information field is permitted in the S frame itself. The 2 low-order bits of the C field in this format (the first 2 bits sent) are 1 and 0 (binary 10) (see Figure 14). Excluding the 4 bits for P/F and the *Nr* count, 2 bits remain for encoding the commands and responses of S frames. These commands and responses are:

RR Receive Ready *(command or response)*
RNR Receive Not Ready *(command or response)*

REJ Reject *(command or response)*

RR (Receive Ready): Sent by either a primary or a secondary station, RR confirms numbered frames through *Nr*-1 and indicates that the originating station is ready to receive additional I frames.

RNR (Receive Not Ready): Sent by either a primary or a secondary station, RNR indicates a temporarily busy condition caused by unavailability of buffers or other internal constraints.

As a command or response, RNR confirms numbered information frames through *Nr*-1 and indicates that frame *Nr* is expected next.

A secondary station reports the clearing of a Receive Not Ready condition by transmitting an I frame with the F bit *on* or an RR or REJ frame with the F bit *on* or *off*.

A primary station indicates that a Receive Not Ready condition has been cleared by transmitting an I frame with the P bit *on* or an RR or REJ frame with the P bit *on* or *off*.

REJ (Reject): This command or response may be transmitted to request transmission or retransmission of numbered information (I) frames. REJ confirms frames through *Nr*-1 and requests the retransmission of numbered information frames starting at the *Nr* count contained in the REJ frame. An REJ command or response may be interspersed in the sequence of transmitted frames. The Reject condition is cleared when the requested frame or a mode-setting command has been correctly received.

Information (I) Format

Information (I) frames are sequentially numbered by the transmitting station. The *Ns* count provides for numbering the frame being sent and the *Nr* count provides acknowledgment for the I frames received. When information is being sent in both directions simultaneously, each station reports its current *Ns* or *Nr* counts, or both, in each I or S frame exchanged.

The expected acknowledgment is an S or I frame whose *Nr* count confirms correctly received frames. (S frames may be interspersed with I frames, as needed.)

SDLC on a Switched Link

One of the participating stations on a switched link must act as a primary station. The other station must assume the role of the secondary station. The primary station manages the link; it initiates and controls the information exchange.

The SDLC procedures allow the stations to identify themselves to each other using an XID command/response exchange. The use of XID is *not* restricted to a switched link.

The SDLC procedures for a switched link are essentially the same as for a nonswitched point-to-point link. An "inactivity" timeout (on conditions similar to nonproductive receive[10]) is required to alert switched stations of link inactivity. If

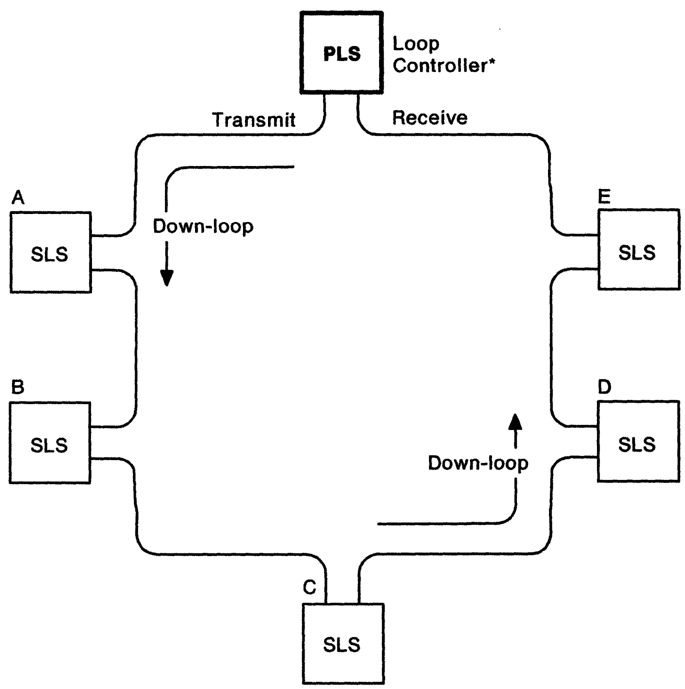
[10] Described under "Timeouts" on page 25

the timeout expires at either station, that station may attempt to alert the other. After a user-specified number of unsuccessful attempts, the station with the expired timeout disconnects the switched link connection by "going on hook." This is equivalent to "hanging up" a telephone.

SDLC in a Loop Configuration

For some applications, a loop configuration may be preferable to a multipoint configuration for the interconnection of multiple secondary stations to the primary station.

A loop consists of a simplex (one-way only) link connection. The link connection originates at the transmit port of the primary station, connects one or more secondary stations in a serial fashion, and then terminates back at the receive port of the primary station. Figure 21 shows a loop having five secondary stations.



* May be stand-alone or connected to a larger system by direct wiring or a data link

PLS Primary link station
SLS Secondary link station

Figure 21. Loop Configuration

Loop Operation

The link stations on a loop use two-way alternate operation, even though transmissions flow between the DCEs on the loop in one direction only. Only one station, the primary or a secondary, transmits at any moment. The secondary stations transmit sequentially in the order in which they are attached to the link connection.

Primary Station Transmitting

The primary station sends command frames that are addressed to any or all of the secondary stations on the loop. Each frame it sends carries the individual, group, or broadcast address of the station or stations to which the frame is directed.

Every secondary station on the loop decodes the address field of each frame the primary station sends and serves as a repeater for all primary transmissions to the down-loop stations (see Figure 22). Upon detecting a frame containing its station address, a group address for a group to which it belongs, or the broadcast address, the secondary station accepts the frame from the loop for processing. The secondary also passes the frame to down-loop stations.

When the primary has finished sending frames, it follows the last flag with a minimum of eight consecutive 0's (a flag followed by eight 0's is a turnaround sequence). It then transmits continuous 1's, which create a go-ahead sequence (01111111). In this way, the primary totally controls all loop communication. The primary, while continuing to transmit 1's, goes into receive mode.

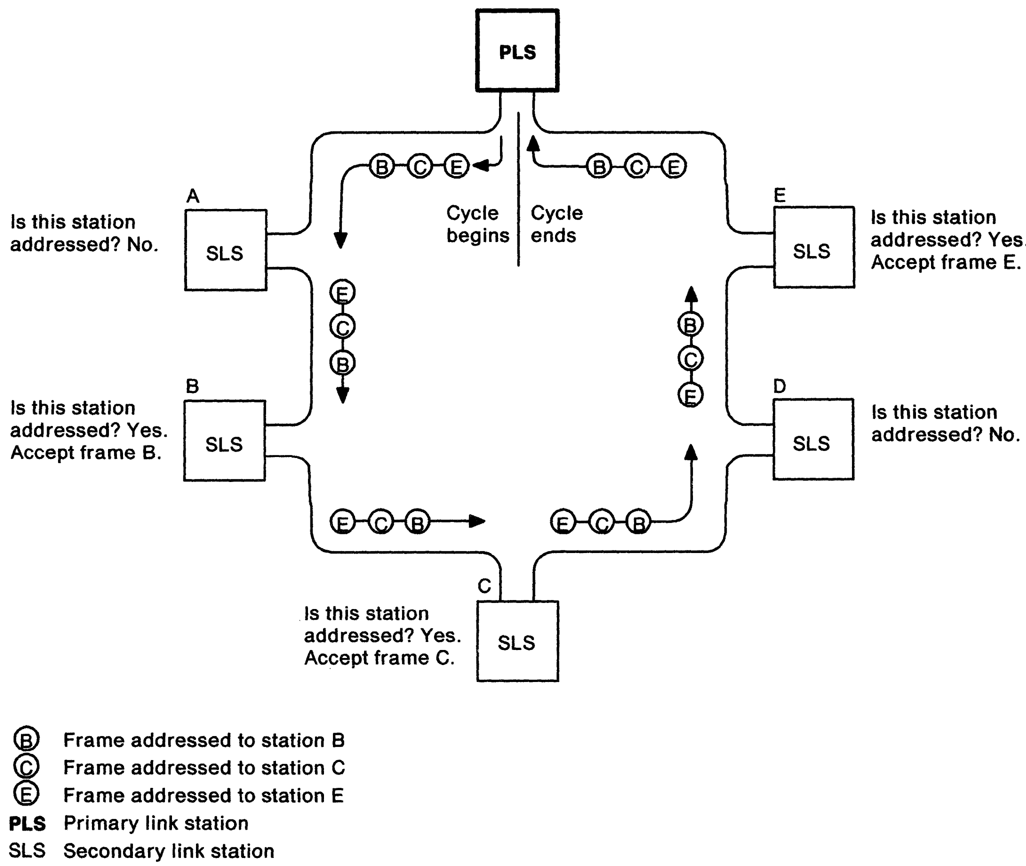


Figure 22. SDLC Loop Exchanges: Primary Station Transmitting

Secondary Station Transmitting

In this description, the primary station has completed transmission, has placed itself in receive mode, and is transmitting continuous 1's—the go-ahead sequence (see Figure 23).

Before transmitting on the loop, a secondary station must have received a frame addressed to it with the P bit *on*, or received a UP-command frame with the P bit *off*.

In the case of a UP frame with the P bit *off*, a secondary station transmission is optional if a response is not required for acknowledgment or status purposes.

The first down-loop secondary detects the go-ahead sequence. If it has a response to send, the secondary changes the seventh 1-bit to a 0-bit, thereby creating a flag. It follows the flag with one or more response frames that contain its individual address. After sending its last frame, the secondary again becomes a repeater, forwarding the continuous 1-bits it receives from the primary station.

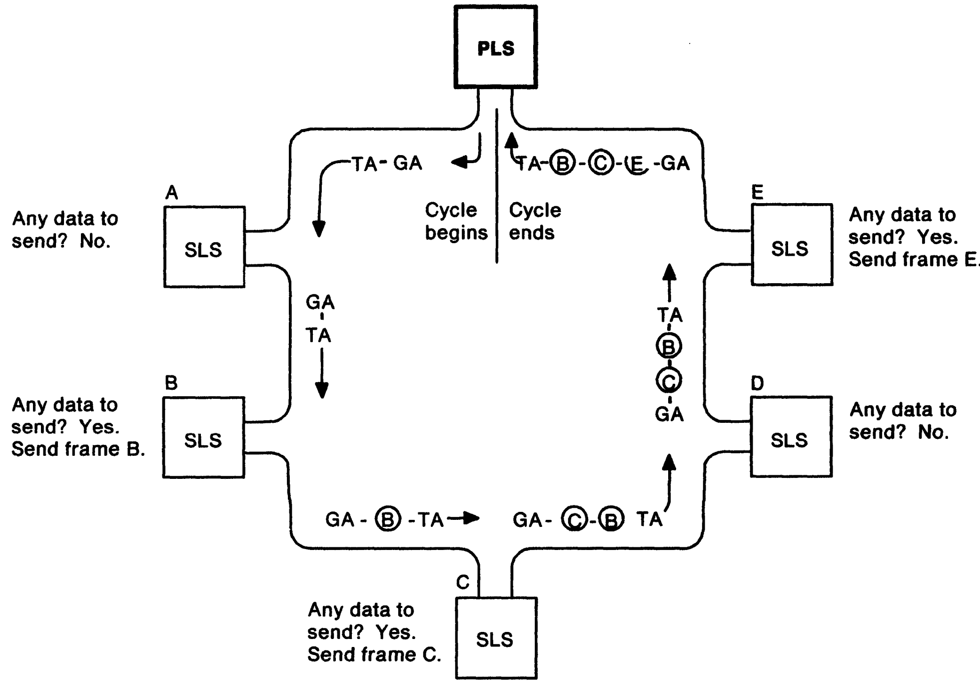
The next down-loop secondary operates similarly when it detects the go-ahead sequence that results from the continuous 1-bits.

This procedure continues until the last down-loop secondary to transmit completes its transmission. The cycle completes when the primary receives its own turnaround sequence and a series of response frames from all the secondary stations that responded, if any.

If a secondary does not convert the go-ahead sequence received after the turnaround sequence into a flag, it forfeits that opportunity to transmit.

To abort a transmission, a secondary needs only to stop sending the transmission and to pass on the incoming 1-bits. It need not generate its own abort sequence.

If, when transmitting, a secondary receives eight contiguous 0-bits, it must terminate its transmission. This is called the *shut-off sequence* and is originated by the primary station.



Ⓑ	Frame sent by station B
Ⓒ	Frame sent by station C
Ⓔ	Frame sent by station E
GA	Go-ahead sequence
TA	Turnaround sequence
PLS	Primary link station
SLS	Secondary link station

Figure 23. SDLC Loop Exchanges: Secondary Stations Transmitting

Loop Commands

UP (Unnumbered Poll)

The Unnumbered Poll command with the P bit set to 0 provides a function that is particularly useful in loop configurations. While a poll of all addressed (station, group, or broadcast) secondary stations is being performed, a response transmission is optional and depends on the actual need for each secondary station to transmit.

UP With P Bit Set To 0: The primary station sends an optional response poll (UP with P bit set to 0) to poll one station, a group of stations, or all the stations on the loop. A response is not necessarily required. Individual secondary stations will respond if one of the following conditions exists:

- The secondary has received one or more numbered I frames since the last time it responded. The secondary must send a confirming *Nr* to the primary signifying its acceptance of the frames.
- The secondary has received an unnumbered command that requires a response since the last time it responded.
- An exception condition has occurred since a previous response opportunity and an appropriate response frame is pending transmission or retransmission.

  Exception conditions are problems that occur because of transmission errors, station malfunctions, or operational constraints. Examples include busy conditions; frame numbering errors; and frames rejected because of invalid control fields, invalid *Nr* counts, or overlong information fields.
- The secondary has changed from the Receive Ready to the Receive Not Ready condition since the last time it responded.
- The secondary has changed from the Receive Not Ready to the Receive Ready condition since the last time it responded.
- The primary has not acknowledged one or more I frames transmitted by the secondary and the secondary retransmits the unacknowledged I frames.
- The secondary is in disconnected mode and sends a DM response to request a mode-setting command (SNRM) to become operational.

If none of the preceding conditions exists, the response is optional and may be sent if information frames are pending initial transmission.

UP with P Bit Set to 1: A mandatory response poll (UP with P bit set to 1) is addressed to an individual station, a group of stations, or all the secondary stations on a loop. It serves to perform an unnumbered poll of the addressed secondary stations. The stations that are addressed by a mandatory response poll *must* respond.

A polled station will respond either with frames it has waiting to transmit or retransmit, or, if no such frames exist, with another appropriate response (RR, RNR, or DM).

CFGR (Configure)

A primary station uses the CFGR command to cause various diagnostic operations to be performed by a secondary station. Upon receiving a CFGR command, a secondary station transmits a CFGR response to acknowledge it.

The CFGR command contains a function descriptor subcommand in a single-byte information field. These subcommands are listed below. Following the name of each subcommand is its bit configuration in the information field; an X in the low-order bit position means that the bit can be set to either 0 or 1. If it is set to 1, the specified function is to be started. If it is set to 0, the function is to be stopped.

- **Clear** (00000000)
  Clear causes the secondary station to stop all functions that it previously started when it received the CFGR command.

- **Beacon Test** (0000001X)
  Beacon Test causes the secondary station receiving it to suppress the transmission of the carrier, or to begin transmitting the carrier again after suppressing it. If X is a 1-bit, the secondary is to suppress transmission. If X is a 0-bit, the secondary is to resume transmission.

  Note: If the carrier is ordered suppressed at a secondary station, the next down-loop secondary will transmit BCN responses indicating loss of the carrier.

- **Monitor Mode** (0000010X)
  This subcommand causes the addressed secondary to place itself in a monitor mode, that is, a receive-only mode. Once a secondary is in the monitor mode, it cannot transmit until it receives a Monitor Mode Clear (00000100) or Clear (00000000) subcommand.

- **Wrap** (0000100X)
  The Wrap subcommand causes the secondary station to wrap its transmission output directly into its receiving input. This effectively places the secondary station offline for the duration of the wrap test.

- **Self-Test** (0000101X)
  The Self-Test subcommand causes the addressed secondary to begin a series of internal diagnostic tests. The secondary will not respond until the tests are complete. If the poll bit in the CFGR command was set to 1, the secondary will respond following completion of the internal tests at its earliest opportunity to respond. However, if the poll bit in the CFGR command was set to 0, the secondary will, following completion of the test, respond to the next poll-type frame it receives. The secondary ignores all other transmissions it receives while it is testing after receiving a Self-Test subcommand.

  The secondary indicates the results of the tests by setting the low-order bit (X) in the information field of its response to either 1 or 0. A 1 indicates that the tests were unsuccessful. A 0 indicates that they were successful. Regardless of the results of the tests, the test function is ended.

- **Modified Link Test** (0000110X)
  This subcommand (if incorporated) provides an alternative form of link test to that previously described for the TEST command and response (see "TEST" under "Unnumbered (U) Format" on page 36).

  If the modified-link-test function is started (X bit is set to 1), the secondary station will respond to a TEST command with a TEST response that has an information field. This field contains the first byte of the TEST command information field, if any, repeated *n* times; the number *n* is implementation dependent. If the TEST command has no information field, the TEST response contains *n* bytes; the configuration of these bytes is implementation dependent.

If the modified-link-test function has not been set (X bit is set to 0), the secondary station will respond to a TEST command (with or without an information field) with a TEST response having a zero-length information field.

Loop Responses

BCN (Beacon)

Upon detecting the loss of communication at its input, a secondary station begins to transmit a BCN response. This allows the primary station to locate the problem in the loop and to take appropriate action. In the BCN response, the F bit can be either a 1 or a 0. As soon as the input resumes normal status (the problem that caused the secondary to send the BCN response is solved), the secondary stops transmitting the BCN response.

CFGR (Configure)

The CFGR response is transmitted by secondary stations only in response to a CFGR command. The structure of the CFGR responses is identical to that of the CFGR commands. If the low-order bit in the information field of the response is set to 1, the configure function specified by the function-descriptor subcommand in the information field has been started. If the low-order bit in the information field is set to 0, the configure function specified by the function-descriptor subcommand has been stopped. The configure function that the secondary station is responding to is the same one specified in the first 7 bits of the function-descriptor subcommand in the CFGR command.

Note: When performing *some* CFGR subcommands (for example, Self-Test), the secondary may not respond to CFGR commands until the function is completed.

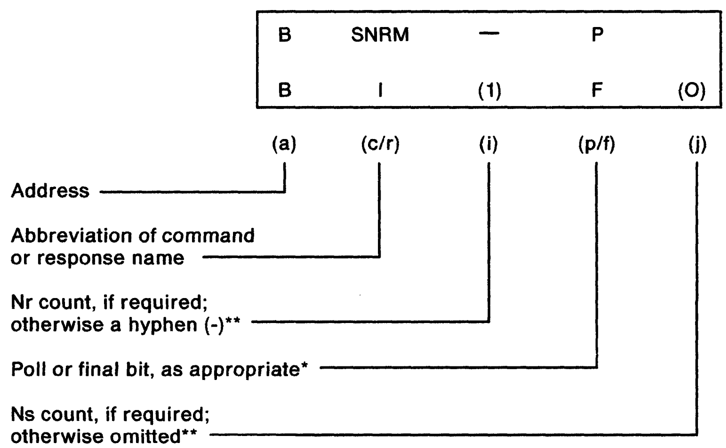
Examples of SDLC Exchanges

Figure 25 through Figure 29, which conclude this chapter, show examples of SDLC exchanges of data and control information for:

- Two-way alternate exchanges on nonswitched point-to-point links
- Two-way simultaneous exchanges on nonswitched point-to-point links
- Two-way simultaneous exchanges on nonswitched multipoint links
- Two-way alternate exchanges on switched point-to-point links
- Two-way alternate exchanges on SDLC loops.

Figure 24 shows the symbolic format for the commands and responses that appear in these example.

In the examples, time progresses downward; trailing vertical lines indicate a duration of information-field transmission. The order of transmission of the A (address) and C (control) fields as shown is left to right, regardless of the direction of the arrow.



*P = poll bit *on* (command)
$\overline{P}$ = poll bit *off* (command)
F = final bit *on* (response)
$\overline{F}$ = final bit *off* (response)

**i = 0, 1,..., 7 or 127
j = 0, 1,..., 7 or 127

Figure 24. Format of Examples of SDLC Exchanges

Two-way Alternate Exchanges on Nonswitched Point-to-Point Links

A (PLS) ——— B (SLS)

	A (PLS) → B	B → A (SLS)	
Negative response to poll	B,SNRM-P →		A sets B's response mode. Nr counts and Ns counts are reset to 0.
		← B,UA-F	B acknowledges.
	B,RR-P(0) →		A polls B for transmission.
		← B,RR-F(0)	B has nothing to transmit. (B remains in NRM.)
Affirmative response to poll: secondary station sends numbered frames	B,RR-P(0) →		A polls B for transmission.
		← B,I(0)F(0)	B sends final I-frame.
	B,RR-P(1) →		A confirms frame 0 and polls B for transmission.
		← B,I(1)$\overline{F}$(0)	B sends numbered I-frames.
		← B,I(2)$\overline{F}$(0)	
		← B,I(3)F(0)	B sends final I-frame.
	B,I(0)$\overline{P}$(4) →		A confirms frames 1-3 sent by B and starts sending numbered I-frames.
	B,I(1)$\overline{P}$(4) →		
	B,I(2)P(4) →		A sends poll I-frame. B must respond.
		← B,RR-F(3)	B confirms frames 0-2 sent by A.
Online and offline status changes	B,DISC-P →		A sets B offline.
		← B,UA-F	B acknowledges. (B assumes NDM.)
		← B,DM-F	B reports disconnected status.
	B,SNRM-P →		A sets B online. Nr and Ns counts are reset to 0.
		← B,UA-F	B acknowledges. (B assumes NRM.)

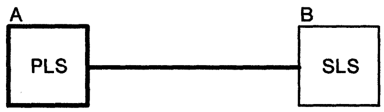
Figure 25 (Part 1 of 2). Two-way Alternate Exchanges on Nonswitched Point-to-Point Links

Primary and secondary stations exchange numbered frames

Primary and secondary stations exchange numbered frames	B,I(0)$\overline{P}$(0) →		A sends frame 0.
	B,I(1)P(0) →		A sends poll I-frame. B must respond.
		← B,I(0)F(2)	B confirms frames 0-1 sent by A and sends frame 0.
	B,RR-P(1) →		A confirms frame 0 sent by B and polls B for transmission.
		← B,I(1)$\overline{F}$(2)	B sends numbered I-frames.
		← B,I(2)$\overline{F}$(2)	
	(CRC error)		A discards frame 2 because of a CRC error.
		← B,I(3)$\overline{F}$(2)	
		← B,I(4)F(2)	B sends final I-frame.
	B,RR-P(2) →		A confirms frame 1 sent by B.
		← B,I(2)$\overline{F}$(2)	B sends frames 2-4 again.
		← B,I(3)$\overline{F}$(2)	
		← B,I(4)F(2)	B sends final I-frame.
	B,RR-$\overline{P}$(5) →		A confirms frames 2-4 sent by B. (B remains in NRM.)

Figure 25 (Part 2 of 2). Two-way Alternate Exchanges on Nonswitched Point-to-Point Links

Two-way Simultaneous Exchanges on Nonswitched Point-to-Point Links



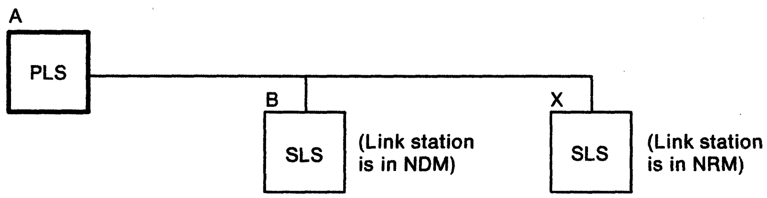
	A (PLS)	B (SLS)	
Secondary station comes online; primary and secondary stations exchange numbered frames	B,RR-P(0) →		A polls B.
		← B,RIM-F	B requests initialization.
	B,SIM-P →		A sets B to initialization mode.
		← B,UA-F	B acknowledges.
			B is brought online through system procedures when initialization is complete.
	B,SNRM-P →		A sets B's response mode. Nr counts and Ns counts are reset to 0.
		← B,UA-F	B acknowledges.
	B,RR-P(0) →		A polls B for transmission.
	B,I(0)$\bar{P}$(0) →	← B,I(0)$\bar{F}$(0)	Simultaneous exchange of numbered I-frames. (B uses longer frames than A.)
	B,I(1)$\bar{P}$(0) →		A sends frame 1.
	B,I(2)$\bar{P}$(0) →	← B,I(1)$\bar{F}$(2)	A sends frame 2. B confirms frames 0-1 sent by A and sends frame 1.
	B,I(3)$\bar{P}$(1) →		A confirms frame 0 sent by B and sends frame 3.
		← B,I(2)F(3)	B confirms frame 2 sent by A and sends frame 2.
	B,RR-P(3) →		A confirms frames 1-2 sent by B.
		← B,RR-F(4)	B confirms frame 3 sent by A. (B remains in NRM.)
Busy secondary station	B,I(4)$\bar{P}$(3) →		A sends numbered I-frames.
	B,I(5)$\bar{P}$(3) →		
	B,I(6)$\bar{P}$(3) →		
	B,I(7)$\bar{P}$(3) →		(This link uses modulo-8 frame numbering)
	B,I(0)P(3) →		A polls B.
		← B,RNR-F(0)	B becomes busy, but confirms frames 4-7 sent by A.
	B,RR-P(3) →		A asks if B is still busy.
		← B,RR-F(0)	B can receive again and expects frame 0.
	B,I(0)$\bar{P}$(3) →		A sends frame 0 again.
	B,I(1)$\bar{P}$(3) →		A continues with frame 1.
	B,I(2)P(3) →		A sends poll I-frame.
		← B,RR-F(3)	B confirms frames 0-2 sent by A. (B remains in NRM.)

Figure 26 (Part 1 of 2). Two-way Simultaneous Exchanges on Nonswitched Point-to-Point Links

	B,SNRM-P		A sets B's response mode to reset the Nr counts and Ns counts to 0.
		B,UA-F	B acknowledges.
	B,RR-P(0)		A polls B.
		B,I(0)$\bar{\text{F}}$(0)	B sends numbered I-frames.
		B,I(1)$\bar{\text{F}}$(0)	
		B,I(2)$\bar{\text{F}}$(0)	
	B,RNR-$\bar{\text{P}}$(3)	B,I(3)$\bar{\text{F}}$(0)	A becomes busy, but confirms frames 0-2 sent by B.
Busy primary station		B,RR-F(0)	B stops sending.
	B,RR-P(3)		A polls B.
		B,I(3)$\bar{\text{F}}$(0)	B retransmits frame 3.
		B,I(4)F(0)	B sends frame 4.
	(CRC error)		A has a CRC error on frame 4 and experiences an idle-detect time out.
	B,RR-P(4)		A polls B, confirms frame 3 sent by B.
		B,I(4)F(0)	B sends frame 4 again.
	B,RR-$\bar{\text{P}}$(5)		A confirms frame 4 sent by B. (B remains in NRM.)
	B,XXX-P		A sends frame with an undefined C field.
		B,FRMR-F	B rejects the frame.
Invalid command			Higher level at A processes the status reported by B in the FRMR response.
	B,SNRM-P		A resets B's error condition. Nr counts and Ns counts are reset to 0.
		B,UA-F	B acknowledges. (B remains in NRM.)
	B,RR-P(0)		A polls B for transmission.
		B,I(0)$\bar{\text{F}}$(0)	B sends numbered I-frames.
	B,I(0)$\bar{\text{P}}$(0)	B,I(1)$\bar{\text{F}}$(0)	Simultaneous exchange of numbered I-frames. (A uses longer frames than B.)
		B,I(2)$\bar{\text{F}}$(0)	
	B,I(1)$\bar{\text{P}}$(2)	(CRC error)	B receives frame 0 with a CRC error.
		B,I(3)$\bar{\text{F}}$(0)	
Numbering error in simultaneous exchange		B,I(4)$\bar{\text{F}}$(0)	A's frame 1 is out of numerical order at B. B sends REJ because it expects frame 0. A sends frame 0 again and confirms frames 0-4 sent by B.
	B,I(0)$\bar{\text{P}}$(5)	B,REJ-$\bar{\text{F}}$(0)	
		B,I(5)F(0)	
			B sends final I-frame.
	B,I(1)$\bar{\text{P}}$(6)		A retransmits frame 1 and confirms frame 5.
	B,RR-P(6)		A confirms frame 5 sent by B and polls B.
		B,RR-F(2)	B confirms frame 1 sent by A. (B remains in NRM.)

Figure 26 (Part 2 of 2). Two-way Simultaneous Exchanges on Nonswitched Point-to-Point Links

Two-way Simultaneous Exchanges on Nonswitched Multipoint Links



Secondary stations come online; primary station sends to one and receives from the other.	B,RR-P →			A polls B for status.
		← B,RIM-F		B asks for initialization mode.
	B,SIM-P →			A sets B to initialization mode.
		← B,UA-F		B acknowledges.
				B is brought online through system procedures when initialization is complete.
	B,SNRM-P →			A sets B online. Nr counts and Ns counts are reset.
		← B,UA-F		B acknowledges.
	X,RR-P(0) →			A polls X for transmission.
	B,I(0)-$\overline{P}$(0) →		← X,I(0)$\overline{F}$(0)	X sends numbered frames to A while A sends to B.
	B,I(1)$\overline{P}$(0) →		← X,I(1)$\overline{F}$(0)	
			← X,I(2)$\overline{F}$(0)	
			← X,I(3)F(0)	X completes its transmission of numbered frames.
	B,RR-P(0) →			A polls B for confirmation.
		← B,RR-F(2)*		B confirms frames 0-1 sent by A.
	X,RR-$\overline{P}$(4) →			A confirms frames 0-3 sent by B. (B and X remain in NRM.)
Interleaved primary station transmission	X,I(0)$\overline{P}$(4) →			A sends numbered frames to X.
	B,I(2)$\overline{P}$(0) →			A sends numbered frames to B.
	X,I(1)P(4) →			A concludes sending to X and requests confirmation.
	B,I(3)$\overline{P}$(0) →		← X,RR-F(2)*	A continues sending to B; X confirms frames 0-1 sent by A.
	B,I(4)P(0) →			A concludes sending to B and requests confirmation.
		← B,RR-F(5)*		B confirms frames 0-4 sent by A (B and X remain in NRM).

* If a secondary station has information to send, this confirmation may be in the I format.

Figure 27. Two-way Simultaneous Exchanges on Nonswitched Multipoint Links

Two-way Alternate Exchanges on Switched Point-to-Point Links

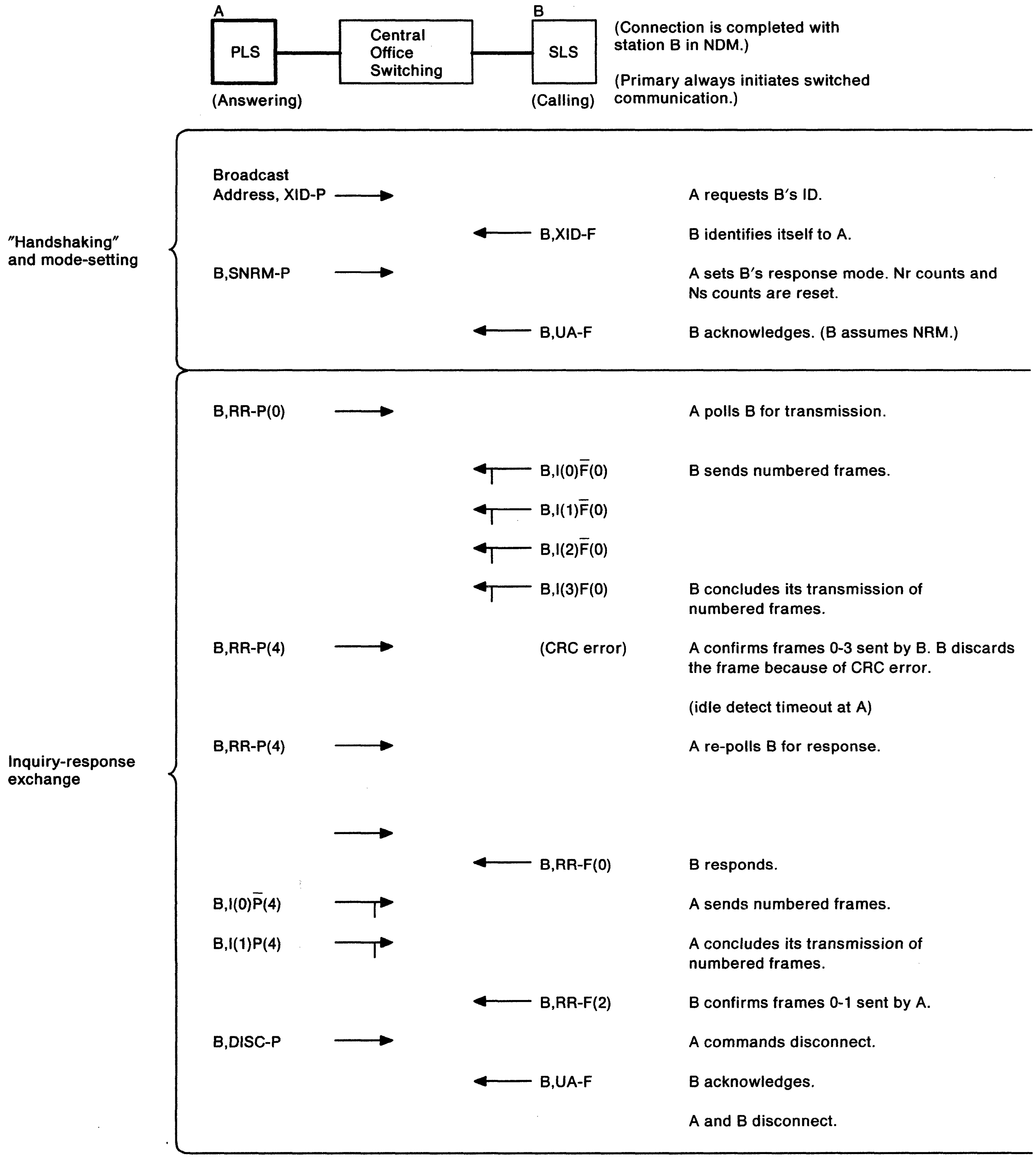
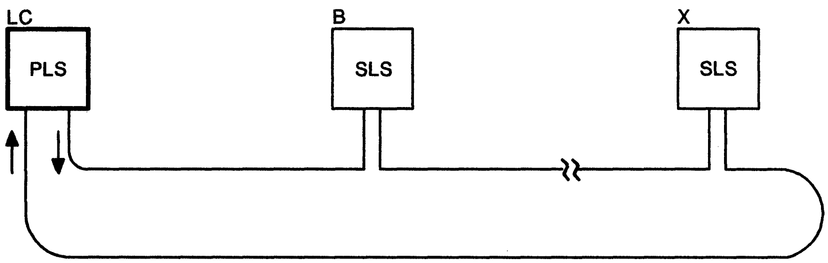


Figure 28. Two-way Alternate Exchanges on Switched Point-to-Point Links

Two-Way Alternate Exchanges on SDLC Loops



Secondary stations come on in NDM

ba = broadcast address (established by the using system)
flag = SDLC F (01111110)
GA = Go-ahead sequence
LC = Loop Controller

1's	1's	1's	LC receives 1's; loop is complete.
ba,UP-P	ba,UP-P	ba,UP-P	LC polls for status.
GA, 1's	B,DM-F	B,DM-F	B requests online status.
1's	GA	X,DM-F	X requests online status.
1's	1's	GA	LC receives 1's.
B,SNRM-$\bar{P}$	B,SNRM-$\bar{P}$	B,SNRM-$\bar{P}$	Set B's online response mode.
X,SNRM-$\bar{P}$	X,SNRM-$\bar{P}$	X,SNRM-$\bar{P}$	Set X's online response mode.
ba,UP-$\bar{P}$	ba,UP-$\bar{P}$	ba,UP-$\bar{P}$	
GA, 1's	B,UA-$\bar{F}$	B,UA-$\bar{F}$	B acknowledges.
1's	GA	X,UA-$\bar{F}$	X acknowledges.
1's	1's	GA	LC receives 1's.
ba,UP-$\bar{P}$	ba,UP-$\bar{P}$	ba,UP-$\bar{P}$	LC starts a poll cycle.
GA, 1's	B,I(0)$\bar{F}$(0)	B,I(0)$\bar{F}$(0)	B responds to the poll.
1's	B,I(1)$\bar{F}$(0)	B,I(1)$\bar{F}$(0)	
1's	B,I(2)$\bar{F}$(0)	B,I(2)$\bar{F}$(0)	B concludes its transmission of numbered frames.
1's	GA	X,I(0)F(0)	X responds to the poll.
1's	1's	GA	LC receives 1's.
B,RR-$\bar{P}$(3)	B,RR-$\bar{P}$(3)	B,RR-$\bar{P}$(3)	LC confirms B's frames.
X,RR-$\bar{P}$(1)	X,RR-$\bar{P}$(1)	X,RR-$\bar{P}$(1)	LC confirms X's frame.
B,I(0)$\bar{P}$(3)	B,I(0)$\bar{P}$(3)	B,I(0)$\bar{P}$(3)	LC sends numberd frames to B.
B,I(1)P(3)	B,I(1)P(3)	B,I(1)P(3)	LC concludes its transmission of numbered frames.
GA, 1's	B,RR-F(2)	B,RR-F(2)	B confirms X's frames 0-1.
1's	GA	GA	LC receives 1's.

Figure 29 (Part 1 of 2). Two-Way Alternate Exchanges on SDLC Loops

ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	LC starts a poll cycle.
GA, 1's	GA, 1's	X,I(1)$\overline{F}$(0)	X responds to the poll, but LC receives the frame with a CRC error.
(CRC error)			
1's	1's	GA	LC receives 1's.
ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	LC starts a poll cycle.
GA, 1's	GA, 1's	X,I(1)$\overline{F}$(0)	X retransmits the unconfirmed frame on a poll cycle.
1's	1's	GA	LC receives 1's.
X,RR-$\overline{P}$(2)	X,RR-$\overline{P}$(2)	X,RR-$\overline{P}$(2)	LC confirms X's frame.
ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	ba,UP-$\overline{P}$	LC starts a poll cycle.
GA, 1's			Loop operation continues.

Figure 29 (Part 2 of 2). Two-Way Alternate Exchanges on SDLC Loops

Appendix A. SDLC Frame Summary

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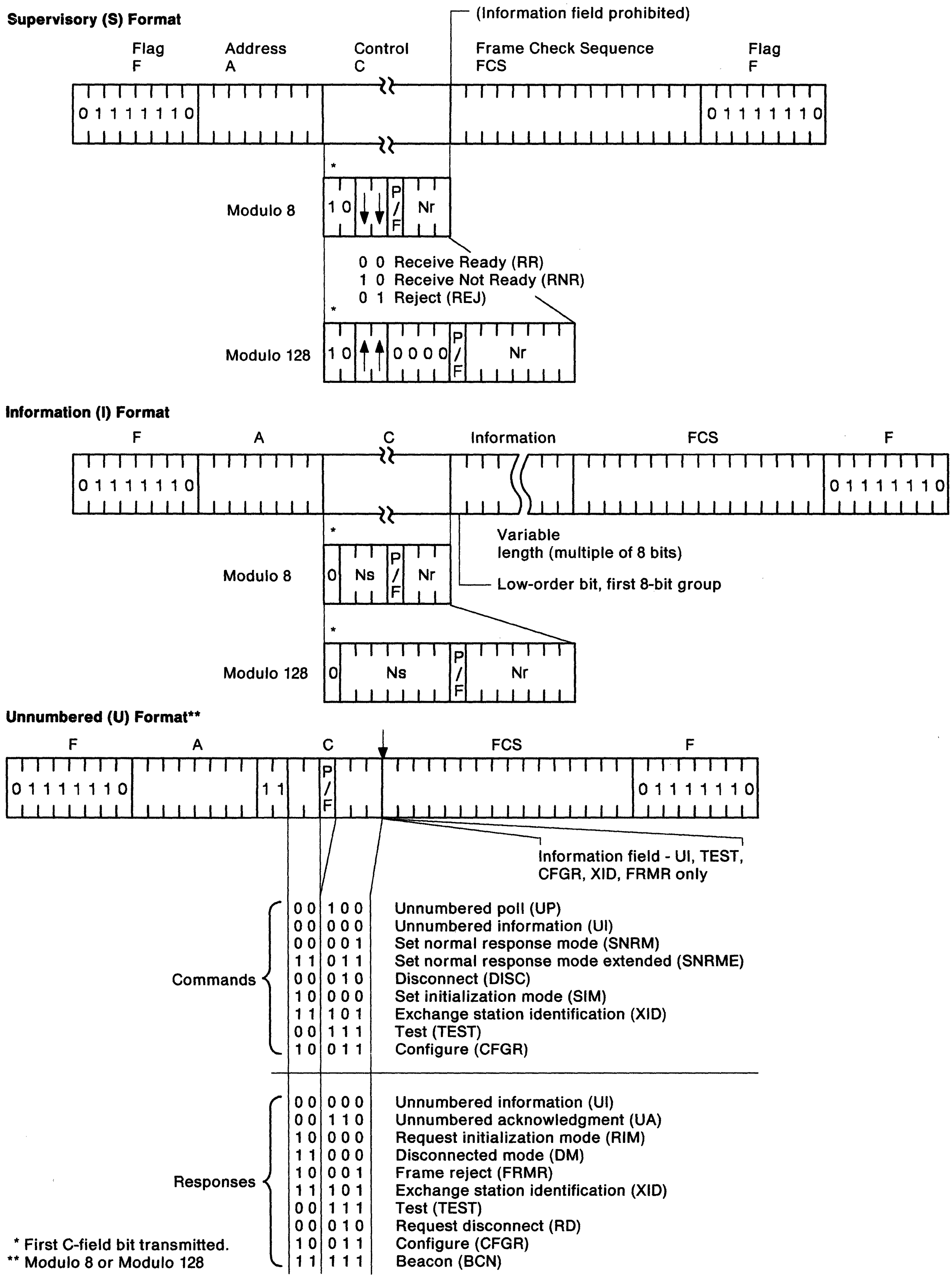

Figure 30. SDLC Frames, As Transmitted

Appendix B. SDLC Computation of the FCS Field

This appendix shows how SDLC computes the value of the FCS (frame check sequence) field of transmission frames. For an overview of the FCS field, see (1) "Frame Check Sequence (FCS) Field" on page 22 and (2) Figure 16.

Note: This appendix is not intended as a text on the use and computation of the FCS field.

In the SDLC implementation of cyclic redundancy checking (CRC) for the FCS field, the CRC computation at the transmitter starts with the first bit following the opening flag (A field) and stops at the end of the data (information field or control field). (The FCS field is an inversion, or ones-complement, of the transmitter's remainder at that point.) The result of a transmission correctly received is a constant: 1111000010111000 (x_0 through x_{15}—see Figure 31).

In the SDLC application of CRC, a modified polynomial expression (modulo 2) of the transmission to be checked is divided by the generating polynomial, $X^{16} + X^{12} + X^5 + 1$. Integer quotient digits are ignored, and the transmitter sends the complement of the resulting remainder value as the FCS field (see Figure 32).

In addition to the division of the binary value of the data by the generating polynomial to generate a remainder for checking, the following manipulations occur:

1. The dividend is initially preset to all-1's (see Figure 31). This adds the binary value of the preset bits to that of the data bits.
2. The transmitter's remainder is inverted bit by bit (FCS field) as it is sent to the receiver. The high-order bit of the FCS field is transmitted first.
3. The receiver treats the FCS field as part of its dividend. Continued computation raises the value of the dividend polynomial by the factor X^{16}. Since the dividend/remainder at the receiver is equal to that at the transmitter at the beginning of the FCS field, the remainder at the receiver at the end of the FCS field is a constant that is characteristic of the divisor.

If a receiver computation does not yield the constant, 1111000010111000, it is assumed that the frame was received in error. Its entire content is suspect and is discarded; no action is taken. The transmitter is responsible for determining that the receiver has not accepted that frame.

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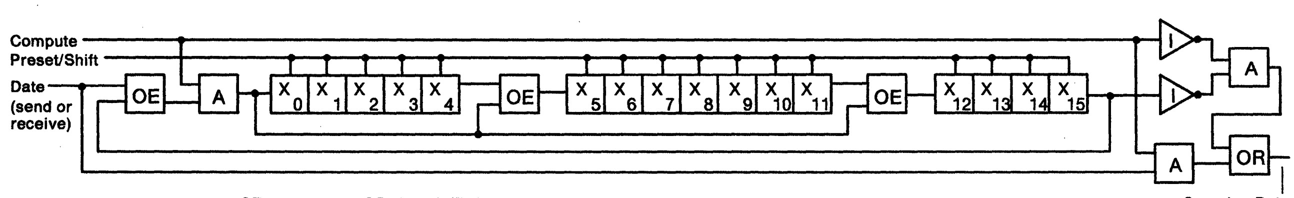
	Input to Transmitter (Sent and computed)		Transmitter Computation- Dividend/Remainder (preset to 1's)* X_0	X_5	X_{12} X_{15}	Input to Receiver (Received and computed)	Receiver Computation- Dividend/Remainder (preset to 1's)* X_0	X_5	X_{12} X_{15}
Preset			11111	1111111	1111		11111	1111111	1111
Hypothetical 19-bit Frame	0	A	11111	0111111	0111	0	11111	0111111	0111
	1	A	01111	1011111	1011	1	01111	1011111	1011
	1	A	00111	1101111	1101	1	00111	1101111	1101
	1	A	00011	1110111	1110	1	00011	1110111	1110
	1	A	10001	0111011	0111	1	10001	0111011	0111
	0	A	11000	0011101	0011	0	11000	0011101	0011
	0	A	11100	1001110	0001	0	11100	1001110	0001
	1	A	01110	0100111	0000	1	01110	0100111	0000
	1	C	10111	1010011	0000	1	10111	1010011	0000
	0	C	01011	1101001	1000	0	01011	1101001	1000
	0	C	00101	1110100	1100	0	00101	1110100	1100
	1	C	10010	0111010	1110	1	10010	0111010	1110
	1	C	11001	1011101	1111	1	11001	1011101	1111
	0	C	11100	0101110	0111	0	11100	0101110	0111
	0	C	11110	1010111	1011	0	11110	1010111	1011
	0	C	11111	1101001	0101	0	11111	1101001	0101
	1	I	01111	1110101	1010	1	01111	1110101	1010
	1	I	10111	0111010	0101	1	10111	0111010	0101
	1	I	01011	1011101	0010	1	01011	1011101	0010
Invert and shift out FCS			00101	1101110	1001	1	10101	0101110	0001
			00010	1110111	0100	0	11010	0010111	1000
			00001	0111011	1010	1	11101	1001011	0100
			00000	1011101	1101	1	11110	0100101	0010
			00000	0101110	1110	0	01111	0010010	1001
			00000	0010111	0111	1	00111	1001001	0100
			00000	0001011	1011	0	00011	1100100	1010
			00000	0000101	1101	0	00001	1110010	0101
			00000	0000010	1110	0	10000	0111001	1010
			00000	0000001	0111	1	11000	1011100	0101
			00000	0000000	1011	0	11100	1101110	1010
			00000	0000000	0101	0	01110	0110111	0101
			00000	0000000	0010	0	10111	1011011	0010
			00000	0000000	0001	1	11011	0101101	0001
			00000	0000000	0000	0	11101	0010110	0000
			00000	0000000	0000	1	11110	0001011	1000

* Generator polynomial (divisor) = $X^{16} + X^{12} + X^5 + 1$, exemplified in shift register form:



OE = exclusive OR; A = AND; I = invert

Outgoing Data

Figure 31. An Example of Cyclic Redundancy Checking

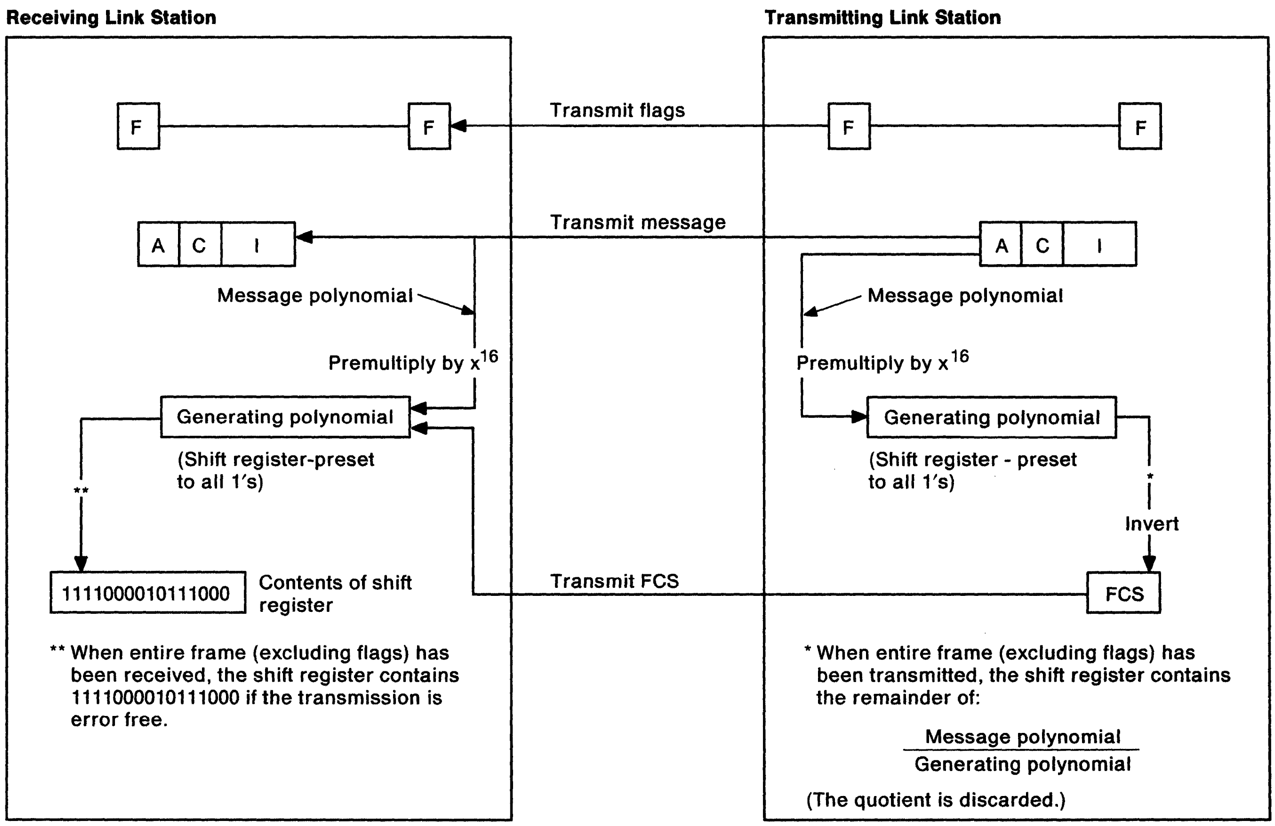


Figure 32. CRC Operation with SDLC

Appendix C. IBM SDLC and Data Link Control Standards

It is IBM's technical judgment that SDLC, as implemented in IBM telecommunication products, conforms with a defined operational subset of ISO HDLC: the Unbalanced Normal Class of Procedure. SDLC, as implemented in IBM telecommunication products, is more precise in certain aspects than the HDLC standards.

International standards are generally written to provide a wide freedom of choice for both function and configuration selection depending on application needs and objectives.

The ISO HDLC approved and proposed standards comprise several interrelated standards, which are designated as follows:

- **ISO International Standard (IS) 3309, Data Communication—High-Level Data Link Control Procedures—Frame Structure (1984)**

  This standard specifies the format of the HDLC transmission unit (frame). It identifies the functional fields of the frame (address, control, information, and frame check sequence) and the location of each. In addition, it specifies:

  - The unique 8-bit framing pattern (flag) used to begin and end the frame
  - The bit insertion and deletion process used to provide code independence and data transparency
  - The frame-check-sequence polynomial and algorithm
  - The order of bit transmission.

- **ISO International Standard (IS) 4335, Data Communication—High-Level Data Link Control Elements of Procedures (1987)**

  This standard specifies the overall functional capabilities defined for HDLC within the frame structure standard. It defines possible operational modes and specifies the definition and encoding of the link level commands and responses that may be used in the control field of the frame. Protocols to be observed in the use of the commands and responses are described and illustrated by sequence diagrams of typical operational examples. This standard represents the superset or "menu" of HDLC functions that are available. It does not discuss how this superset may be limited in specific modes of operation, applications, or configurations.

- **ISO International Standard (IS) 7809, High-Level Data Link Control Consolidation of Classes of Procedures (1984)**

  This standard specifies and describes the class of procedure applicable for centralized data link control of point-to-point and multipoint configurations for both (1) Normal and Asynchronous Response Modes of operation and (2) Asynchronous Balanced Mode class of procedure applicable for peer-to-peer interchange in a point-to-point configuration. It provides the subset of HDLC functions (commands and responses) that are mandatory and those that are optional.

As noted earlier, standards give implementers considerable latitude in the choice of functional options and alternative configurations. This freedom may result in incompatibilities between different products that individually conform to HDLC. The following two examples illustrate how incompatibilities might occur.

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Example 1: HDLC permits any number of bits in the information field of an Information command or response frame; SDLC permits any number of 8-bit bytes. Thus SDLC is a subset of HDLC. However, the XYZ Corporation could choose 13-bit characters, which is also an allowable subset of HDLC. Yet one set of products expects the messages to consist of 8*n* bits; the other, 13*n* bits. Usually, when information received does not conform to an expected bit length, a "transmission error" or an "improper information field" status would be indicated by the receiver. So, in this case, while both products are in conformance with HDLC, they would be incompatible.

Example 2: HDLC also provides a number of optional functional extensions for special application considerations or performance improvement. IBM SDLC products, in general, incorporate one or more of these functional extensions. However, if two products do not have the same functional subset, effective and productive communications between the two may not be possible. When an IBM SDLC product receives a transmission that is undefined for that product, an exception condition results.

The judgment that SDLC is in conformance with ISO HDLC is also based on the following:

- SDLC complies with **IS 3309, Frame Structure**, for information fields with an integral number of 8-bit bytes.
- SDLC commands and responses (that is, elements of procedure) that have corresponding HDLC counterparts comply with the ISO HDLC definitions and protocols as specified in **IS 4335**.
- Announced IBM SDLC products conform to the Unbalanced Normal (UN) Class of Procedure as specified in **IS 7809** and the Normal Disconnected Mode (NDM) as specified in **IS 4335**. These IBM SDLC products provide the required basic (minimum) command and response repertoire, and particular products provide one or more of the available optional functions. Unbalanced Normal operation with Normal Disconnected Mode is the only class of procedure currently used in IBM SDLC products.

Figure 33 lists the basic command and response requirements for the ISO Unbalanced Normal Class of Procedures (**IS 7809**) as well as the commands and responses available for optional functional extensions.

Figure 34 contains the names of the commands and responses corresponding to the HDLC acronyms appearing in Figure 33. (The SDLC acronyms are the same.) This figure also shows the former HDLC/SDLC acronyms and command/response names that may appear in earlier documentation on HDLC and SDLC.

All IBM SDLC products implement the basic repertoire of commands and responses of the Unbalanced Normal (UN) class. In addition, specific IBM SDLC products may support one or more of the available optional functions. For instance, particular IBM SDLC products support one or more of the following optional functions:

1	(XID-XID/RD)
2	(REJ-REJ)
5	(SIM-RIM)

IBM SDLC does contain additional commands and responses not in the ISO Elements of Procedure (or addenda).

Note: SDLC includes the Configure (CFGR) command and CFGR and Beacon (BCN) responses for application in loop configurations only. ISO HDLC does not include loop operation.

Some IBM SDLC products do not allow the use of the Request Disconnect (RD) response (this response is a recent addition to the ISO Elements of Procedure). The REJ command and response are used only in those IBM SDLC products that provide two-way simultaneous information interchange. To determine the SDLC capabilities and characteristics of a specific IBM product, refer to the appropriate publications for that product.

Note: National and international standards, approved and proposed, are subject to continual review, modification, and enhancement. Although not likely, the changes may alter IBM's judgment on SDLC conformance as stated in the preceding, which is based on the level of ISO HDLC documentation existing as of 1990.

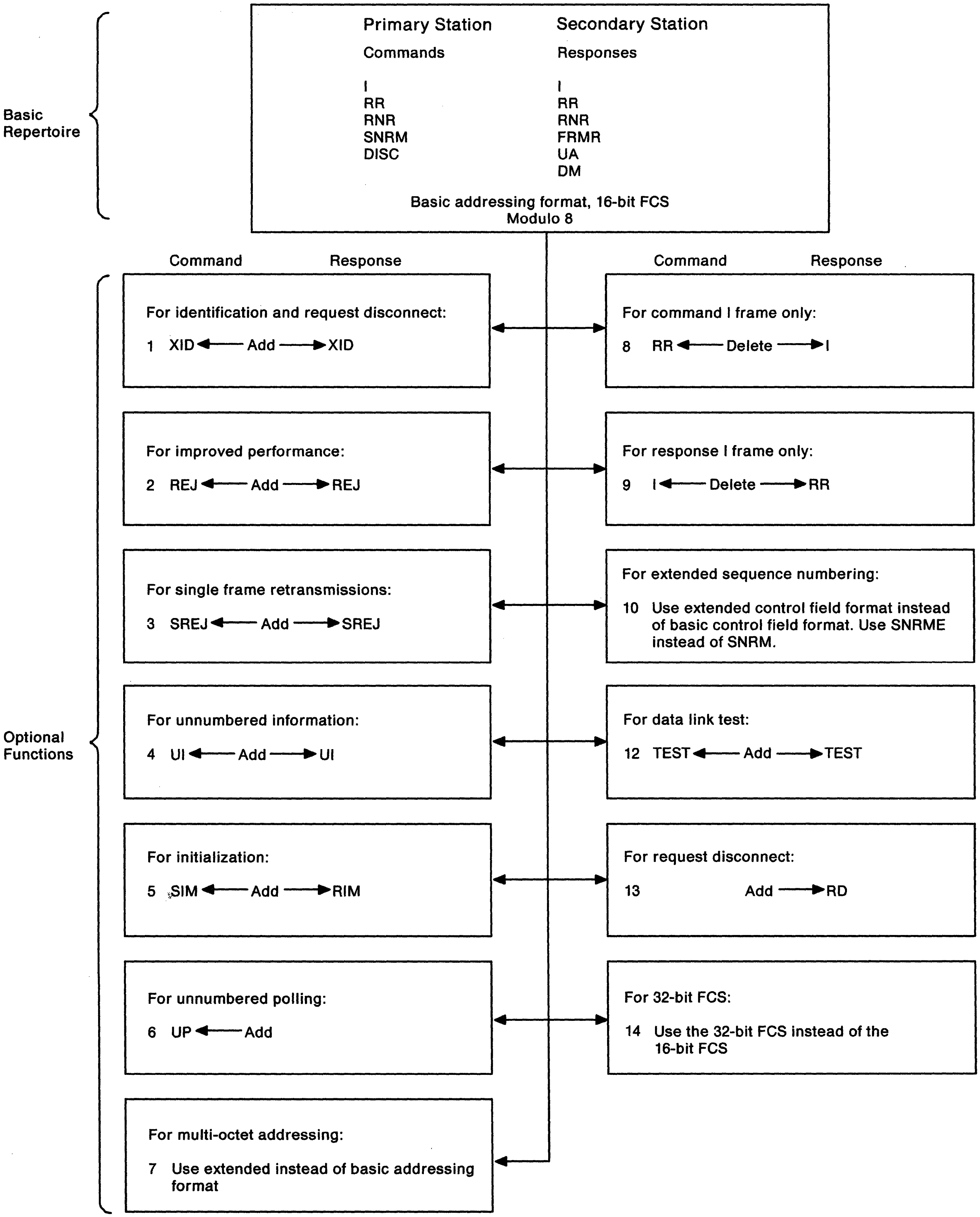


Figure 33. HDLC Unbalanced Normal Class of Procedures

Present Acronym	Present Name	Former Acronym	Former Name	Command	Response
I	Information			X	X
RR	Receive Ready			X	X
RNR	Receive Not Ready			X	X
REJ	Reject			X	X
SNRM	Set Normal Response Mode			X	
SIM	Set Initialization Mode			X	
DISC	Disconnect			X	
XID	Exchange Identification			X	X
UI	Unnumbered Information	NSI	Nonsequenced Information	X	X
UP	Unnumbered Poll	NSP	Nonsequenced Poll	X	
UA	Unnumbered Acknowledgment	NSA	Nonsequenced Acknowlegment		X
DM	Disconnected Mode	ROL	Request Online		X
FRMR	Frame Reject	CMDR	Command Reject		X
RIM	Request Initialization Mode	RQI	Request Initialization Mode		X
RD	Request Disconnect	RQD	Request Disconnect		X

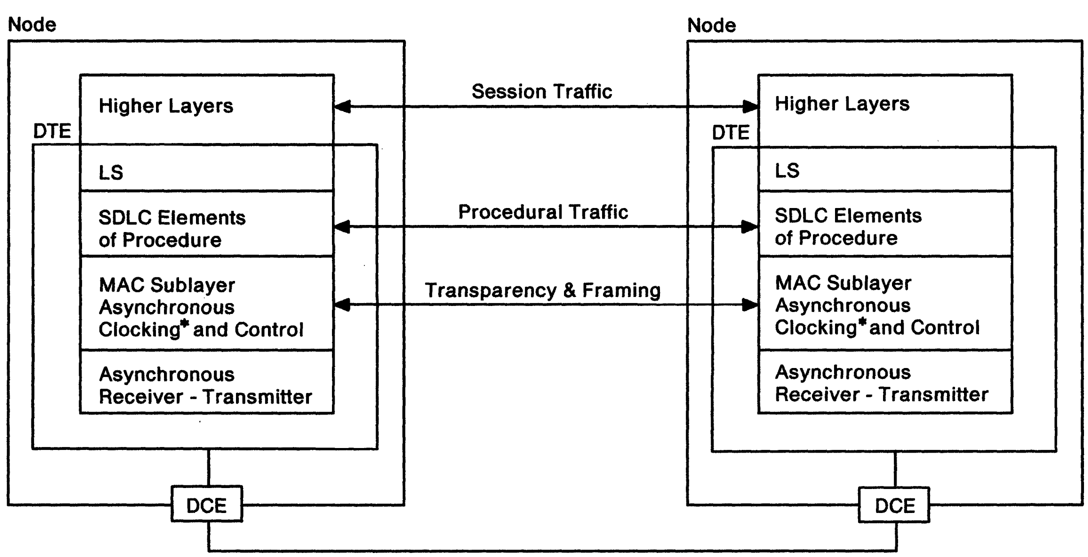
Figure 34. HDLC Commands and Responses

Appendix D. Asynchronous SDLC

Asynchronous SDLC is a form of SDLC in which the synchronous clocking component of SDLC is replaced by an asynchronous clocking component, thus allowing standard SDLC frames to be transported over asynchronous link connections.[11] Asynchronous SDLC functions might typically be implemented, for example, in programmable work stations. The function of the asynchronous SDLC component of a station is to provide the code and data transparency and the framing needed to transfer data between the SDLC elements of procedure component and the asynchronous support component of the station. The asynchronous support component can be implemented in hardware, software, microcode, or a mix of these. The SDLC elements of procedure remain unchanged.

Asynchronous SDLC combines the benefits of SDLC, including its widespread use within multiple-layer "stacks" (such as SNA), with the benefits of low-cost, asynchronous hardware and line adapters.

The full benefits of SDLC can be realized using asynchronous adapter cards and asynchronous modems by inserting an asynchronous media access control (MAC) sublayer beneath full SDLC elements of procedure, as shown in Figure 35.



DCE Data Circuit-terminating Equipment
DTE Data Terminal Equipment
LS Link Station
MAC Media Access Control
* Clocking may be provided by the DCE instead

Figure 35. Asynchronous SDLC Layering

[11] Asynchronous SDLC is defined by International Standards ISO/IEC 8885, ISO/IEC DIS 7809.2, ISO/IEC DIS 3309.2, and ISO/IEC DIS 4335.

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Format of an Asynchronous SDLC Frame

The format of an asynchronous SDLC frame is the same as that of the synchronous SDLC frame except for the bytes inserted to achieve transparency and the start and stop bits that delimit each 8-bit byte. Time fill between bytes, if required, is a continuous mark-hold (all 1's) condition for the duration required.

Figure 36 shows the bits that make up each character transmitted as an asynchronous bit stream.

As transmitted, each byte is preceded by one start bit; contains five, six, or seven data bits, plus an optional parity bit (transmitted low-order bit first) or eight data bits without a parity bit; and is followed by one stop bit (see Figure 36). This asynchronous bit stream format is used by all asynchronous receiver-transmitters and many existing scanners. The byte size is established when the station is configured.

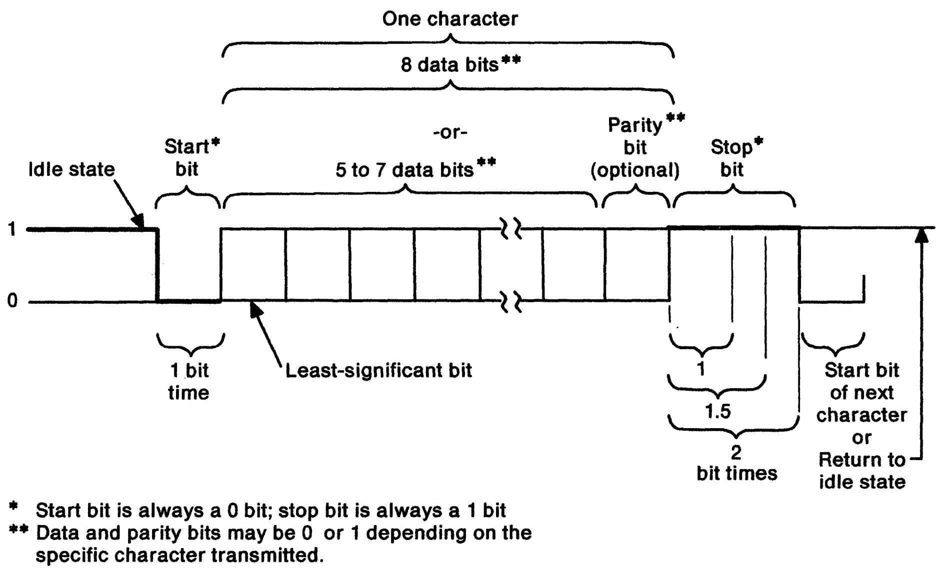

Figure 36. Asynchronous Bit Stream: Start, Data, Parity, and Stop Bits

Asynchronous SDLC Elements of Procedure

The elements of procedure, control-field format, and command-response definitions are the same for asynchronous SDLC as for SDLC.

Idle Link Condition

An idle link condition is an all-1's (mark-hold) condition. Since the idle condition exists during an interbyte time fill and interframe time fill, a timer is required to define an interval after which, if no link activity has occurred, an error condition is assumed—for example, an error in an ending flag or a malfunction in a remote station. This is the existing SDLC idle-detect timer.

Frame Abort Signal

An otherwise invalid sequence, Control Escape (to be described) and flag (stored as X'7D7E'), defines the frame abort signal.

Asynchronous SDLC Transparency Modes and Levels

Asynchronous SDLC defines two *transparency modes* and, for one of these modes, three *transparency levels*. These modes allow certain application data bytes that would otherwise be altered or interpreted as controls in certain network environments to pass unaffected through the network. The transparency modes also allow 8-bit data to be transmitted over a 7-bit link connection.

The modes and levels are:

- Eight-bit data transparency mode
- Character transparency mode
  - Basic level
  - Flow-control level
  - Control-character level.

The transparency mode and level are established when the station is configured.

Eight-Bit Data Transparency Mode

A technique called *eight-bit data transparency* allows 8-bit data to be transmitted over a link connection that does not allow transmission of eight data bits within a single byte. In this mode, eight-bit data is encoded into 7-bit characters and may thus be transmitted over 7-bit link connections.

Using this technique, the contents of an SDLC frame, including the frame check sequence (FCS),[12] are divided into 7-byte sequences, with each byte carrying the same low-order bits of its corresponding 8-bit storage byte. Each sequence is followed by a suffix character that contains the most-significant bits for the preceding seven characters. The last sequence may have fewer than seven characters. If so, no pad characters are inserted; this short sequence is followed by the suffix character.

Eight-bit data transparency, when used, is the first manipulation performed after calculation of the FCS, prior to any other transparency manipulations.

Figure 37 on page 72 shows an example of the technique by which the transmitter part of an asynchronous receiver-transmitter obtains each 8-bit character of the SDLC frame (including the FCS) from storage, transforms it to a 7-bit character with a parity bit, and then sends it over the link connection. In doing so, the receiver-transmitter collects the most-significant bit from each 8-bit character into the suffix character, computes the parity bit for each converted character, and sends the character, including the parity bit, over the link connection. The least-significant bit is sent first; the parity bit is sent last. After sending the sequence of up to seven converted characters, the receiver-transmitter sends the suffix character.

In Figure 37, the technique is shown for two characters. For sequences of fewer than seven characters, the suffix character contains a 0-bit in each unused bit position.

[12] The FCS is computed the same as if the frame were to be transmitted over an SDLC link

At the other end of the link connection, the receiving receiver-transmitter reassembles the SDLC frame, applies a complementary 8-bit data transparency manipulation to restore the most-significant bits to each character, computes the FCS, and places the original 8-bit bytes of the SDLC frame in storage.

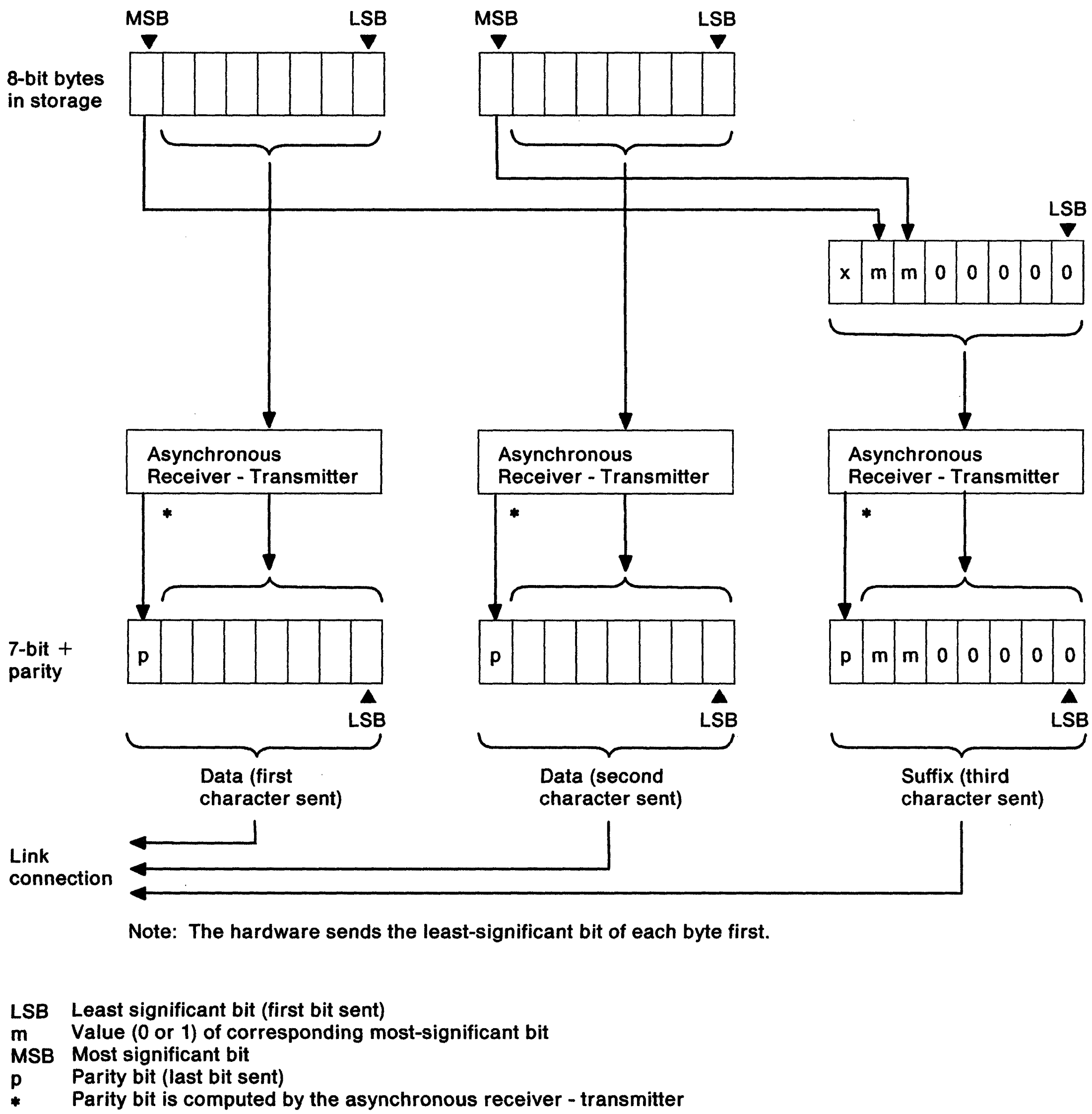

Figure 37. Eight-bit Data Transparency Manipulation: 8-bit to 7-bit Mapping

Character Transparency Mode

To provide character transparency, a transmitting station inserts a Control Escape (CE) byte preceding:

- A flag byte
- A data byte that has the same bit pattern as a Control Escape byte
- Other possibly control-sensitive bytes appearing as "data" within the frame—that is, the address, control, information, and FCS fields.

Asynchronous SDLC does not use zero-insertion techniques to provide character transparency.

The CE byte (in storage) is the byte value X'7D'. The flag byte is the byte value X'7E', the existing SDLC flag sequence.

Complementing and recomplementing the sixth from the low-order bit provides several significant benefits:

- The flag and CE bytes do not occur within the frame content. The occurrence of a flag byte uniquely defines the start or end of a frame.
- The transparency algorithm may be applied to any additional byte values that may have "control" significance[13] so as to preclude their appearance as "data" within the frame.

Any CE byte within a frame received from a link connection is discarded (that is, not included in the FCS calculation or delivered to higher layers). Any byte that follows a CE byte is complemented as above, included in the FCS calculation, and delivered to higher layers.

As an illustration, the following two paragraphs describe how "data" CE and flag transparency is achieved. This description reflects the basic level of character transparency mode.

At the transmitter side: Following accumulation of the FCS, a flag or CE sequence occurring as "data" within these fields is modified in storage (before transmission) by complementing the sixth bit from the low-order bit—that is, the sixth bit following the start bit. This action converts a "data" flag from X'7E' to X'5E' and a "data" CE from X'7D' to X'5D'. (The CE bytes inserted to achieve transparency are not modified.)

At the receiver side: Before calculating the FCS, the stored received bit sequence is transformed by complementing the same (sixth) bit, restoring it to its original value.

Character Transparency Levels

The three transparency levels—basic, flow-control, and control-character—differ in the data-stream characters to which transparency is applied.

Basic Transparency Level

The basic transparency level ensures that X'7E' characters occurring in the frame or FCS are not interpreted as flag characters and that X'7D' characters are not interpreted incorrectly.

- Each X'7E' character is stored as X'7D5E' before sending.
- Each X'7D' character is stored as X'7D5D' before sending.

Flow-Control Transparency Level

The flow-control transparency level[14] allows the ASCII X-On and X-Off characters (X'11' and X'13') to be passed transparently over the link connection. The data is sent as 8-bit characters.

- Each X'11' character is stored as X'7D31' before sending.
- Each X'13' character is stored as X'7D33' before sending.

[13] Networks may differ in the set of control characters they recognize and act upon. Examples are X-On, X-Off, and DLE.

[14] This use of the term *flow control* is unrelated to the SNA meaning of the term.

- Each X'7E' character is stored as X'7D5E' before sending.
- Each X'7D' character is stored as X'7D5D' before sending.

Control-Character Transparency Level

The transmitter applies character transparency to all characters in the range from X'00' to X'1F', as well as X'7F' and the basic-level transparency characters, X'7E' and X'7D'.

Full-Transparency Mode

The term *full-transparency mode* refers to the combination of the 8-bit data transparency mode and the control-character transparency level of character transparency mode. Full-transparency mode allows all ASCII control characters to be passed transparently over the link connection. In addition, 8-bit data is sent as 7-bit characters.

Transparency Default Modes

The transparency default modes, if not overridden by the implementation or installation decisions, are:

- Eight-bit transparency, with seven data bits and even, odd, or mark parity
- Control-character transparency—using this level allows characters to flow over most link connections; however, throughput is less than it would be if minimal transparency were used.

Transmitting and Receiving Algorithms

The algorithms given in this section are general and based upon a block orientation—that is, data is processed in blocks of *n* bytes rather than as a stream of bits. Specific product implementations may use somewhat different algorithms.

Transmitting Algorithm

When transmitting to the link connection:

1. The transmitter obtains the data byte by byte from storage and optionally computes parity on each byte
2. The transmitter computes and appends the FCS to the data bytes.
3. The transmitter applies 8-bit data transparency to each byte (only if the connection was established over a 7-bit link connection).
4. The transmitter applies the specified character transparency to each byte.
5. The transmitter adds the opening and closing flags to form a complete frame.

   Note: A flag is either an opening flag or a closing flag; a single flag is not both the closing flag of one frame and the opening flag of the next frame.
6. The transmitter sends the frame, byte by byte via the asynchronous receiver-transmitter.

Receiving Algorithm

When receiving from the link connection:

1. The receiver receives the frame, byte by byte via the asynchronous receiver-transmitter.
2. The receiver hunts for an opening flag in the byte stream.
3. The receiver skips any additional flags in the byte stream until it detects the first non-flag byte.

4. The receiver receives and buffers all characters until it detects the closing flag. If the receiver detects an error, it deletes the frame and returns to step 1. If the receiver detects any invalid characters, it deletes the frame and returns to step 1.
5. The receiver discards the opening and closing flags.
6. The receiver makes, in reverse, the character tranparency manipulation applied by the transmitter.
7. If the link connection uses 8-bit data transparency, the received 7-bit bytes, including suffix bytes, are accumulated in storage. If the link connection does not use 8-bit data transparency, the received 8-bit bytes are accumulated in storage.
8. The receiver computes the FCS of the received frame and compares it with the received FCS.
9. The received and calculated FCS values are compared and, if equal, the data has been received error-free. If the FCS values are not equal, the receiver discards the data as invalid and signals the condition to the upper layer.

Abbreviations, Glossary, Summary of Changes, and Index

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List of Abbreviations

A	address (field)
BC	block check (field)
BCN	Beacon
C	control (field)
CE	Control Escape (byte)
CFGR	Configure
CRC	cyclic redundancy check
DCE	data circuit-terminating equipment
DISC	Disconnect (command)
DLE	Data link escape
DM	Disconnected Mode
DTE	data terminal equipment
F	flag (pattern or field) or final (bit)
FCS	frame check sequence
FRMR	Frame Reject
HDLC	High-level Data Link Control
I	information (field, frame, or C-field format)
ISO	International Organization for Standardization
LS	link station
MAC	media access control
MRP	mandatory response poll
ms	millisecond
NDM	normal disconnected mode
Nr	receive count (next sequence number expected to receive)
NRM	normal response mode
NRME	normal response mode extended
NRZI	nonreturn-to-zero inverted (zero-complementing differential coding)
Ns	send count (transmitter's sequence number)
ORP	optional response poll
P/F	poll/final bit
PWS	programmable work station
RD	Request Disconnect
REJ	Reject
RIM	Request Initialization Mode
RNR	Receive Not Ready (busy)
RR	Receive Ready
S	Supervisory (field, frame, or C-field format)
SDLC	Synchronous Data Link Control
SIM	Set Initialization Mode
SNRM	Set Normal Response Mode
SNRME	Set Normal Response Mode Extended
TEST	Test
UA	Unnumbered Acknowledgment
UI	Unnumbered Information
UP	Unnumbered Poll
XID	Exchange Station Identification

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Glossary

This glossary contains terms and definitions related to Synchronous Data Link Control (SDLC), and includes terms and definitions from these sources:

- The *IBM Dictionary of Computing*
- The *ISO Vocabulary—Information Processing* and the *ISO Vocabulary—Office Machines*, developed by the International Organization for Standardization, Technical Committee 97, Subcommittee 1. Definitions of published segments of the vocabularies are identified by the symbol (I) after the definition; definitions from draft international standards, draft proposals, and working papers in development by the ISO/TC97/SC1 vocabulary subcommittee are identified by the symbol (T) after the definition.

A

asynchronous. With respect to transmission protocols, pertaining to operation of a link in which there is no timing signal with which the receiving station and the transmitting station remain locked; the receiver's bit clock is reset with each character received.

asynchronous SDLC. A data-link level communications protocol that allows data to be transmitted over an asynchronous line using a control protocol similar to SDLC.

B

buffer. A storage area reserved for use in performing input/output operations

C

carrier. A continuous frequency capable of being modulated or impressed with an information-carrying signal.

channel. A communication path between stations.

character transparency. A transform applied by a data sender to a data stream that effectively hides control characters from the network to prevent the network from interpreting and acting on them.

command. A control signal; loosely, an instruction in machine language.

communication channel. An electrical path that facilitates transmission of information from one location to another.

communication common carrier. In the U.S.A. and Canada, a public data transmission service that provides the general public with transmission service facilities; for example, a telephone or telegraph company.

confirmation. A type of response by a receiver that allows a sender to continue.

D

data. Any representation to which meaning is, or might be, assigned.

data circuit. (1) A pair of associated transmit and receive channels that provide a means of two-way data communication (I). (2) In SNA, synonym for link connection.

data circuit-terminating equipment (DCE). In a data station, the equipment that provides the signal conversion and coding between the data terminal equipment (DTE) and the line. (I)

Note: The DCE may be separate equipment or an integral part of the DTE or of the intermediate equipment.

data link. The communication channel and communication controls of all stations connected to the communication channel, used in the transmission of information between two or more stations.

data station. The data terminal equipment (DTE), the data circuit-terminating equipment (DCE), and any intermediate equipment. (I)

data switching exchange (DSE). The equipment installed at a single location to provide switching functions, such as circuit switching, message switching, and packet switching. (I)

data terminal equipment (DTE). That part of a data station that serves as a data source, data sink, or both. (I)

F

frame. See transmission frame.

I

invert-on-zero coding. A transmission coding method in which the DTE changes the signal to the opposite state to send a binary 0 and leaves it in the same state to send a binary 1.

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L

link. Synonym for data link.

link connection. In SNA, the physical equipment providing two-way communication between one link station and one or more other link stations; for example, a telecommunication line and data circuit-terminating equipment (DCE). A link connection, such as a multipoint, loop, or token-ring configuration, can be shared among multiple, logically distinct links.

link station. The combination of hardware and software that allows a node to attach to and provide control for a link.

N

node. An endpoint of a link or a junction common to two or more links in a network. Nodes can be distributed to host processors, communication controllers, cluster controllers, or terminals. Nodes can vary in routing and other functional capacities.

numbered frames. Information segments arranged in numbered order for accountability.

P

polling. On a multipoint connection or a point-to-point connection, the process by which data stations are invited one at a time to transmit. (I)

primary link station. The link station on a link that is responsible for control of that link.

propagation delay. The time needed for a signal to travel through a conductive medium from one point to another.

propagation time. The time needed for a signal to travel from one point on a conductive medium to another.

R

receiver-transmitter. See universal receiver-transmitter.

response. In SDLC, the control information in the C-field of the link header, sent from the secondary station to the primary station.

retransmit. To repeat the transmission of a message or segment of a message.

retry. To resend data a prescribed number of times or until the data are received correctly.

S

solicited. Stimulated, sought, or requested.

station. See link station.

status. The condition or state of hardware or software, usually represented by a status code.

synchronous. Occurring with a regular or predictable time relationship. With respect to transmission protocols, pertaining to operation of a link in which the receiving station and the transmitting station remain in synchronism through a timing signal with which both stations are in phase ("phase-locked"); the receiver's bit clock is not reset each time a character is received.

Synchronous Data Link Control (SDLC). A discipline conforming to subsets of the Advanced Data Communication Control Procedures (ADCCP) of the American National Standards Institute (ANSI) and High-level Data Link Control (HDLC) of the International Organization for Standardization, for managing synchronous, code-transparent, serial-by-bit information transfer over a link connection. Transmission exchanges may be duplex or half-duplex over switched or nonswitched links. The configuration of the link connection may be point-to-point, multipoint, or loop.

T

telecommunication facility. Transmission capabilities, or the means for providing such capabilities, made available by a communication common carrier or by a telecommunication administration.

timeout. Measurement of time interval allotted for certain events to occur (such as a response to polling or other controls) before corrective (recovery) action is taken.

transmission frame. In SDLC, the vehicle for every command, every response, and all information that is transmitted using SDLC procedures.

transmission medium. The physical medium that conveys signals between data stations; for example, twisted-pair wire, optical fiber, coaxial cable. (T)

transparent. In data transmission, pertaining to information not recognized by the receiving program or device as transmission control characters.

turnaround. The reversal of the direction of transmission from send to receive (or from receive to send); usually used in reference to a half-duplex communication channel.

U

universal receiver-transmitter. A circuit used in asynchronous, synchronous, or combined asynchronous and synchronous data communication applications to provide all the necessary logic to receive data serial-in parallel-out and to transmit parallel-in serial-out; usually it transmits by means of duplex transmission, and can accommodate various word lengths.

X

X-Off. Transmitter off.

X-On. Transmitter on.

Summary of Changes

A new appendix, Appendix D, "Asynchronous SDLC" on page 69, is added in this edition.

Minor errors in Figures 9 and 20 (Figures 8 and 19 in the prior edition) have been corrected.

Several minor formatting and editorial changes are also included.

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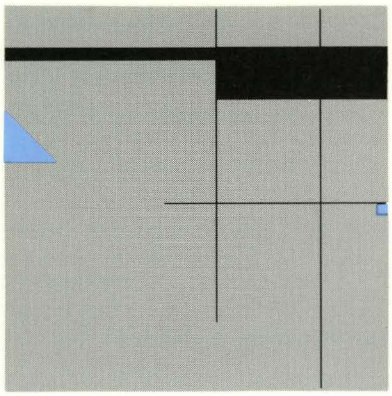

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