Data and Computer Communications

Tenth Edition

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CHAPTER 7

Data Link Control Protocols

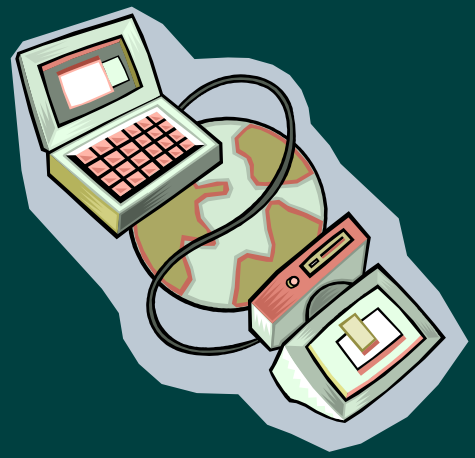
"A conversation forms a two-way communication link; there is a measure of symmetry between the two parties, and messages pass to and fro. There is a continual stimulus-response, cyclic action; remarks call up other remarks, and the behavior of the two individuals becomes concerted, co-operative, and directed toward some goal. This is true communication."

—*On Human Communication*,
Colin Cherry

Data Link Control Protocols

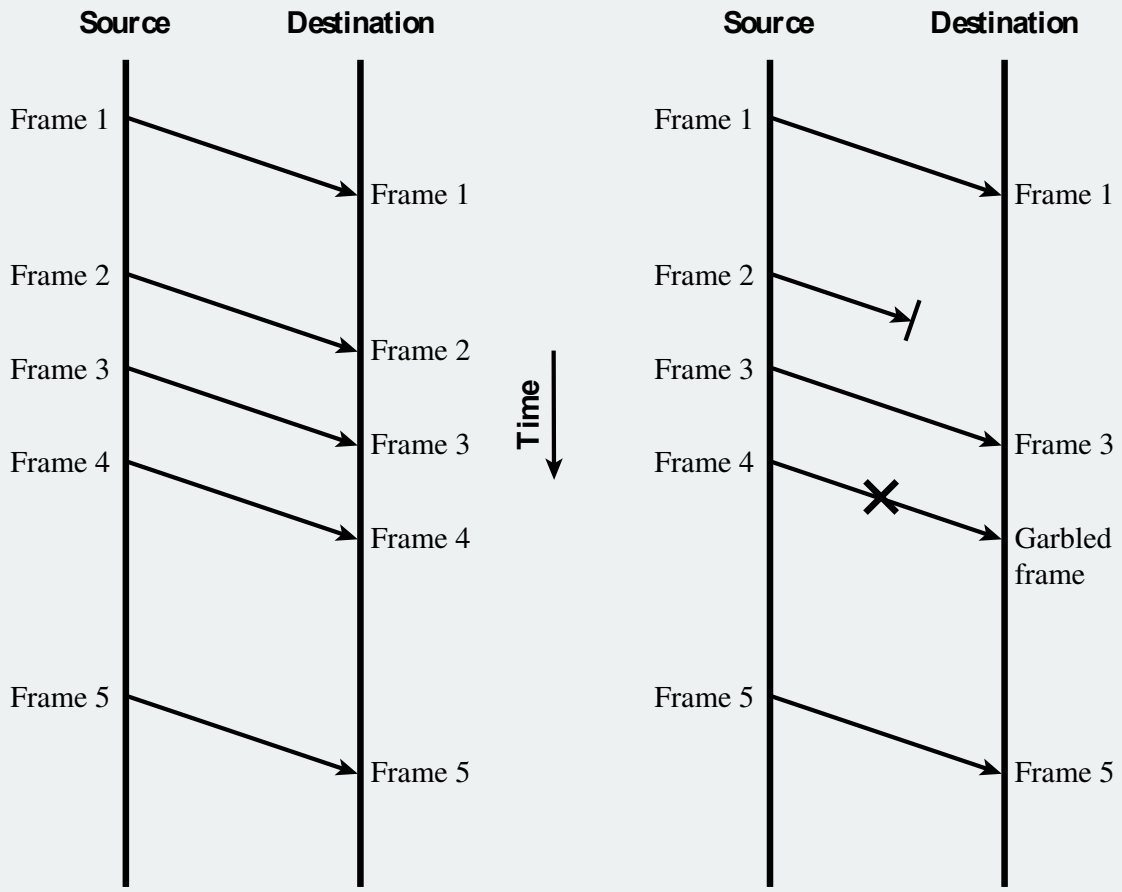
- Requirements and objectives for effective data communication between two directly connected transmitting-receiving stations:

- Frame synchronization
- Flow control
- Error control
- Addressing
- Control and data
- Link management



Flow Control

- Technique for assuring that a transmitting entity does not over-whelm a receiving entity with data
  - The receiving entity typically allocates a data buffer of some maximum length for a transfer
  - When data are received, the receiver must do a certain amount of processing before passing the data to the higher-level software
- In the absence of flow control, the receiver's buffer may fill up and overflow while it is processing old data



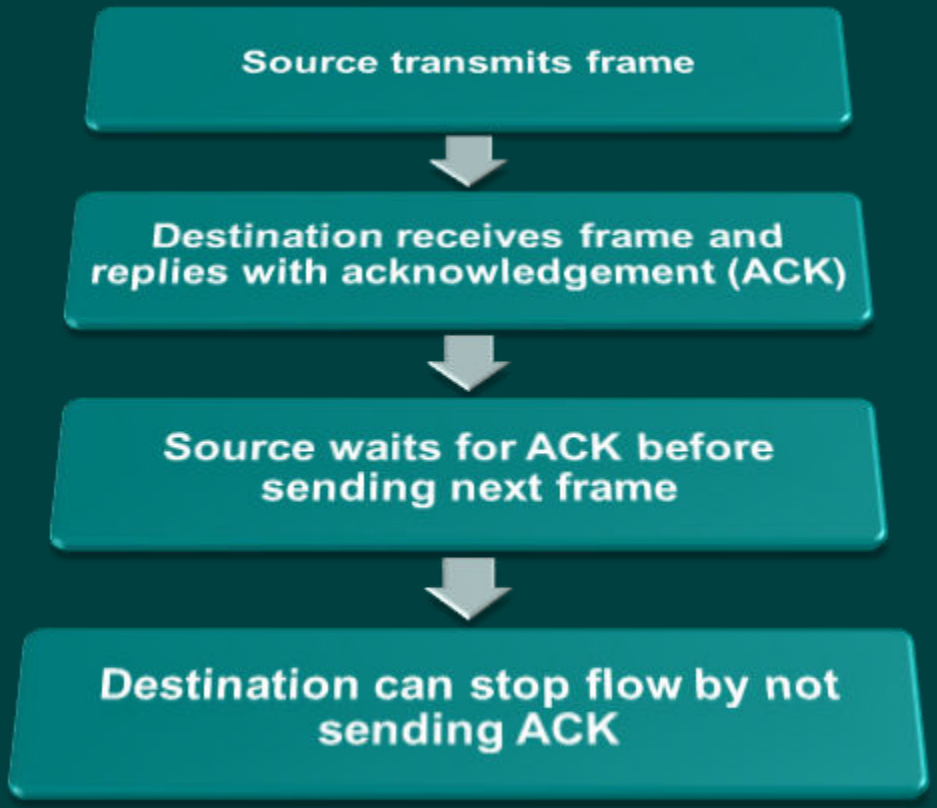
(a) Error-free transmission

(b) Transmission with losses and errors

Figure 7.1 Model of Frame Transmission

Stop-and-Wait Flow Control

- Simplest form of flow control



- It is often the case that a source will break up a large block of data into smaller blocks and transmit the data in many frames
  - The buffer size of the receiver may be limited
  - The longer the transmission, the more likely that there will be an error, necessitating retransmission of the entire frame
  - On a shared medium it is usually desirable not to permit one station to use the medium for an extended period, thus causing long delays at the other sending station

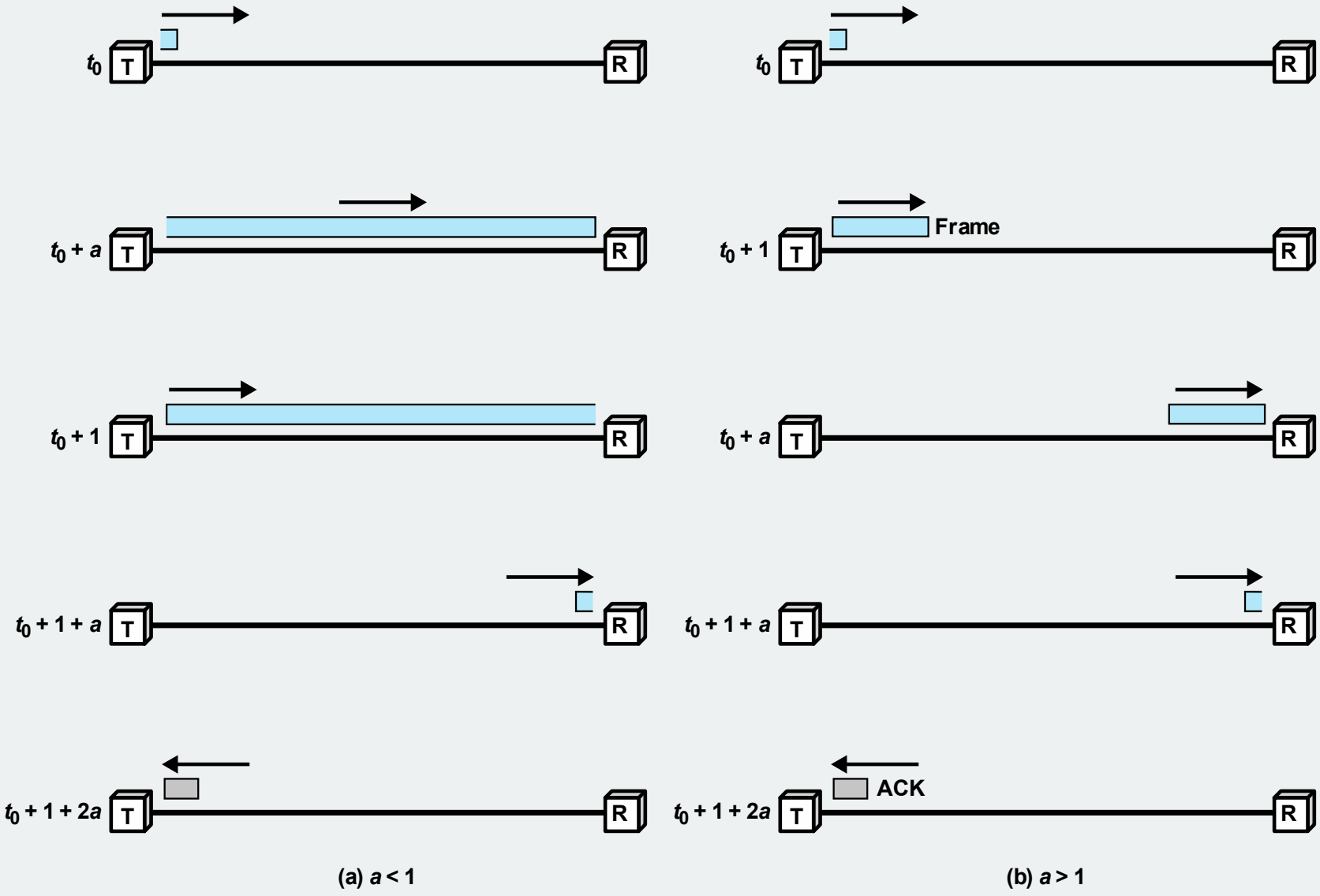


Figure 7.2 Stop-and-Wait Link Utilization (transmission time = 1; propagation time = *a*)

Sliding Windows Flow Control

- Allows multiple numbered frames to be in transit
  - Receiver has buffer W long
  - Transmitter sends up to W frames without ACK
  - ACK includes number of next frame expected
  - Sequence number is bounded by size of field (k)
    - Frames are numbered modulo 2^k
    - Giving max window size of up to $2^k - 1$
  - Receiver can ACK frames without permitting further transmission (Receive Not Ready)
  - Must send a normal acknowledge to resume
- If have full-duplex link, can piggyback ACKs

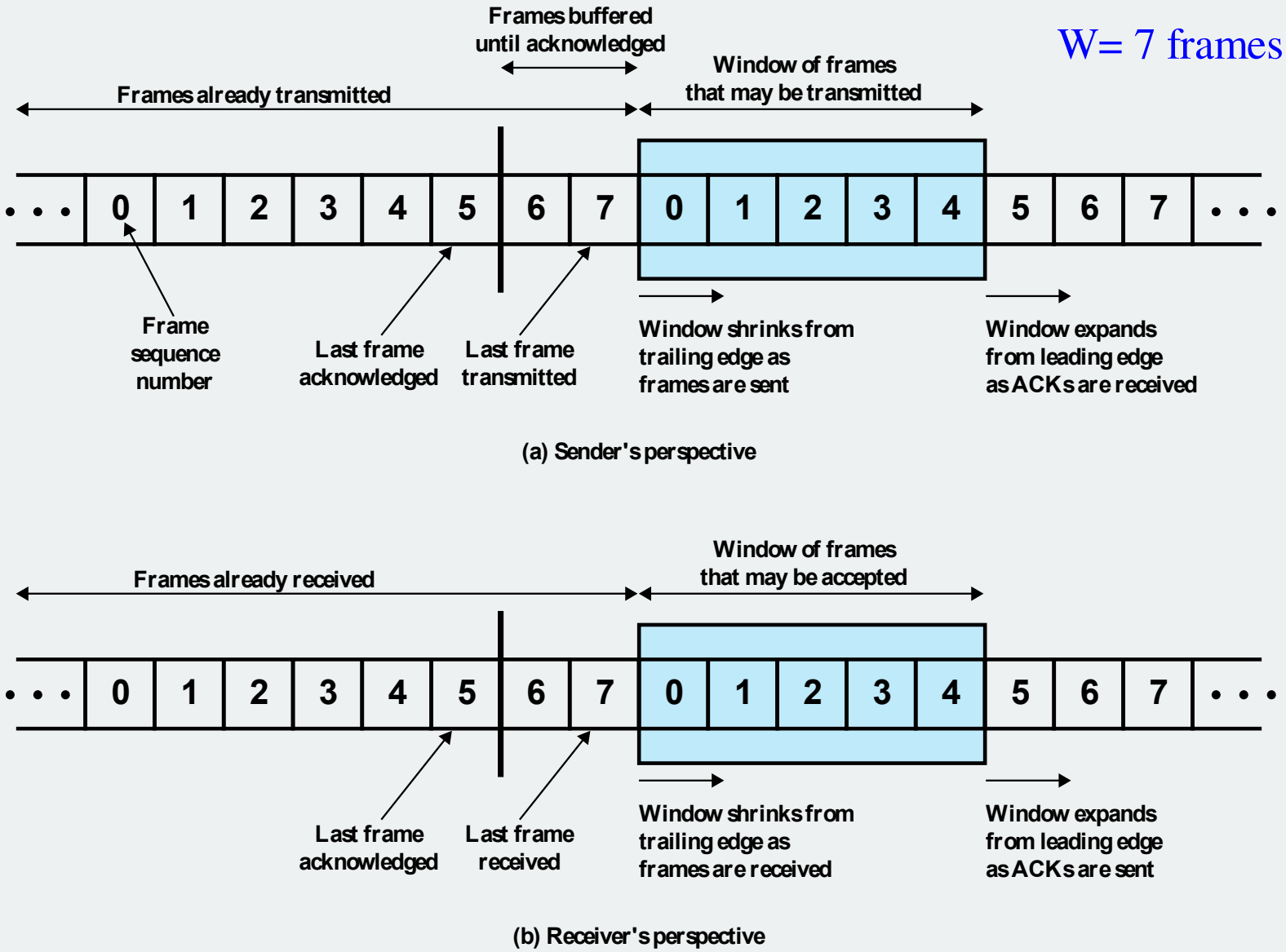


Figure 7.3 Sliding-Window Depiction

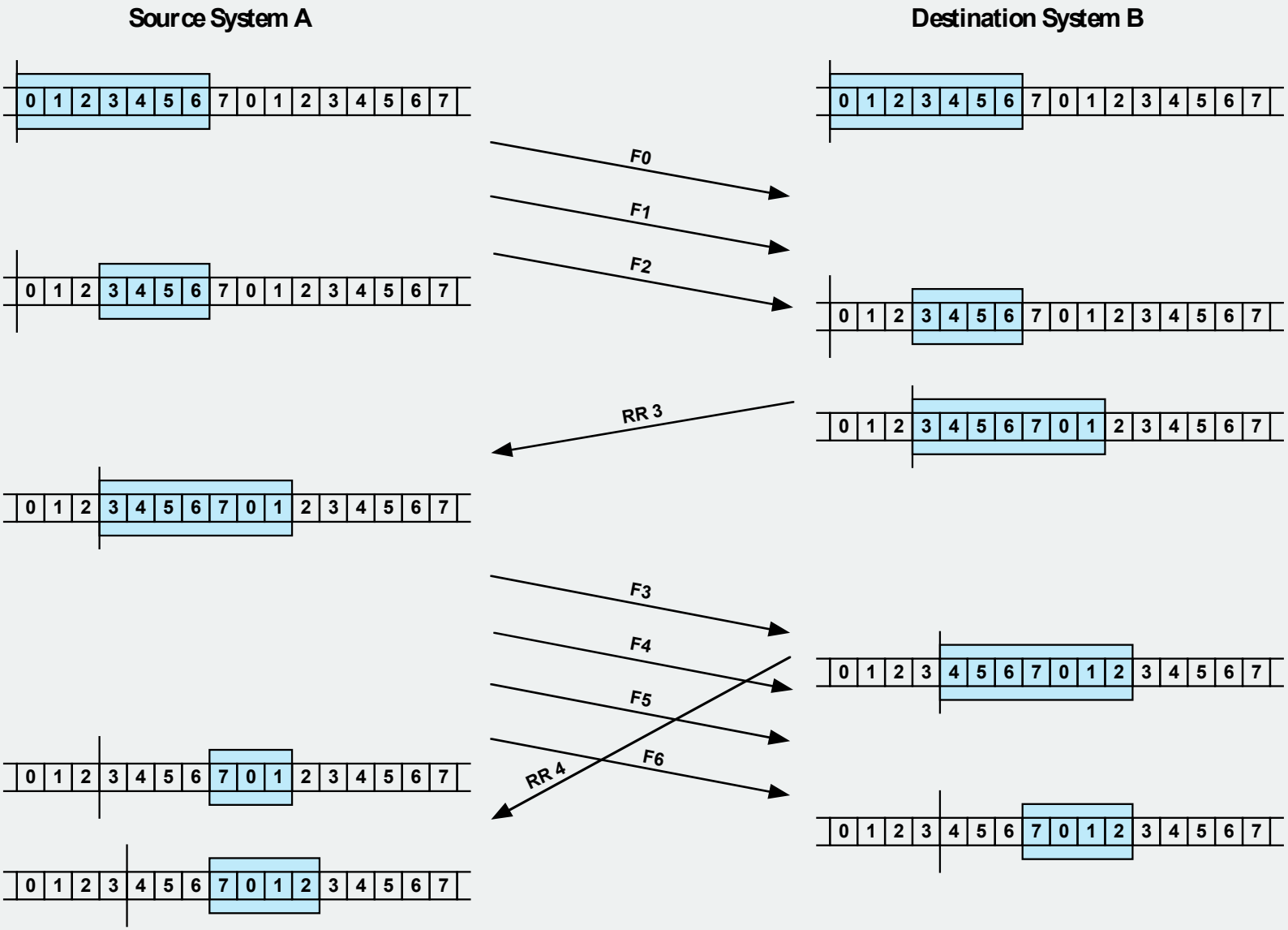
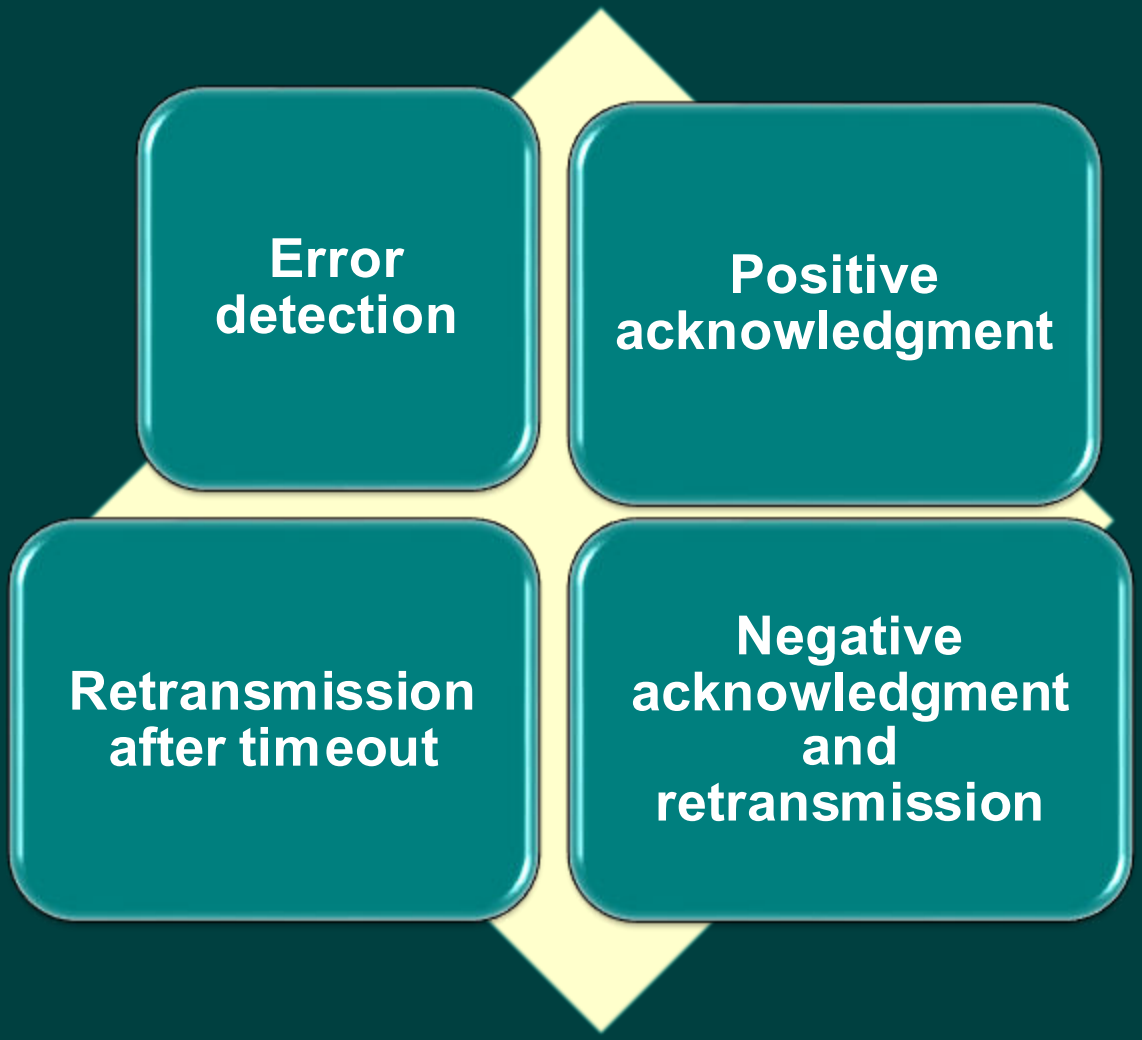


Figure 7.4 Example of a Sliding-Window Protocol

Error Control Techniques



Lost frames

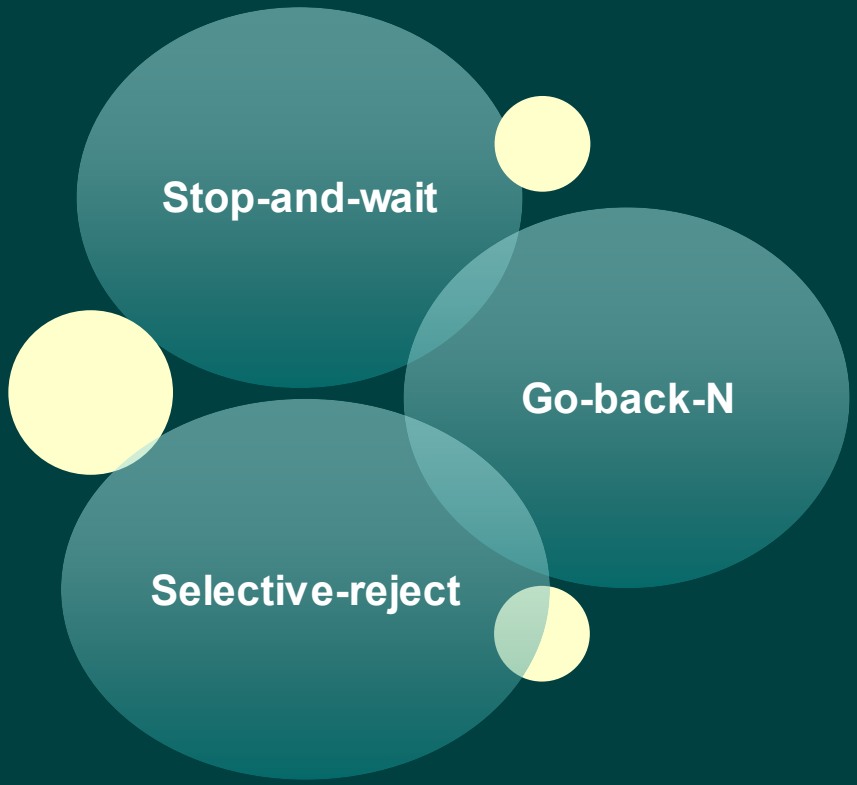
- a frame fails to arrive at the other side

Damaged frames

- frame arrives but some of the bits are in error

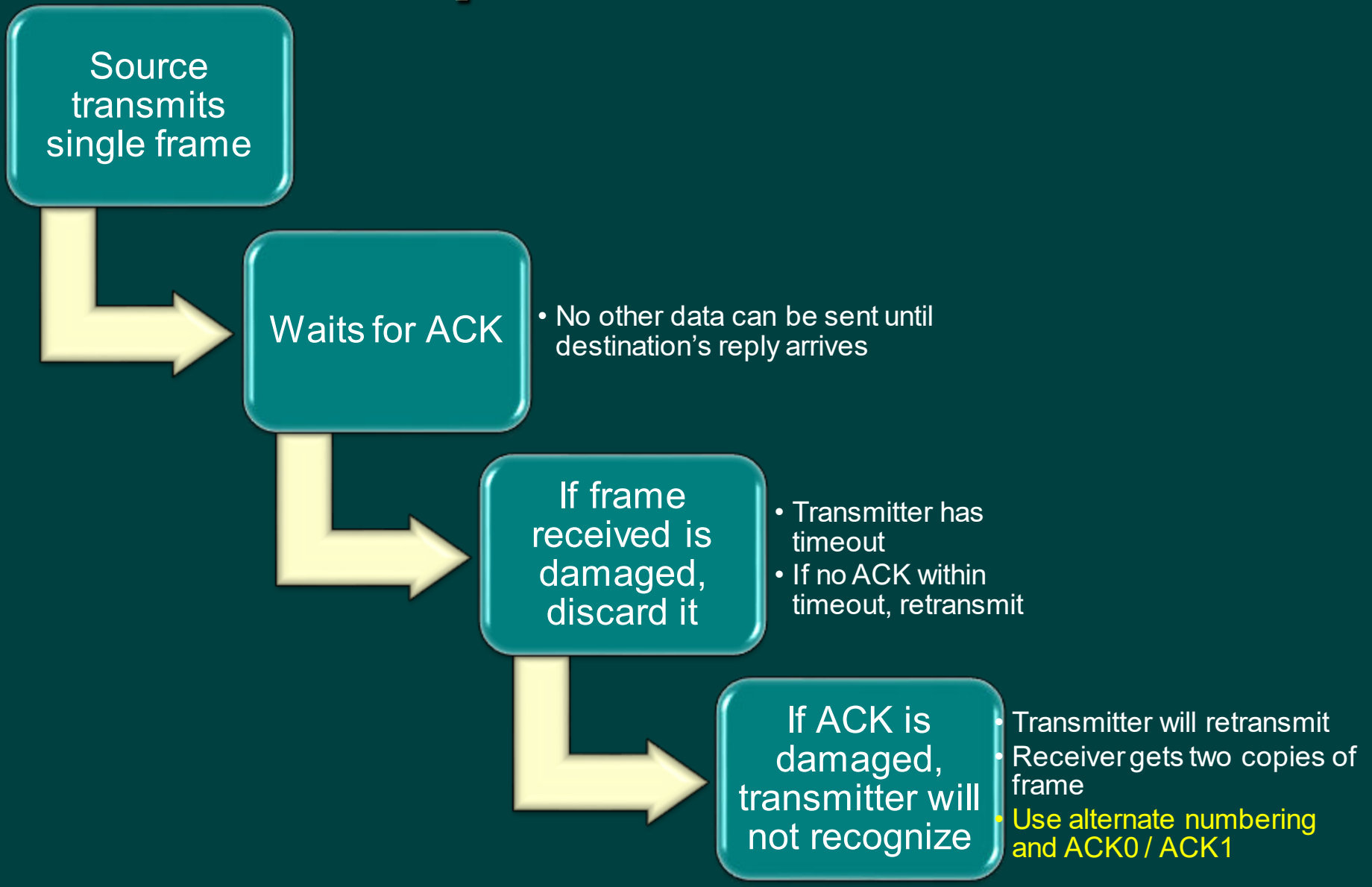
Automatic Repeat Request (ARQ)

- Collective name for error control mechanisms
- Effect of ARQ is to turn an unreliable data link into a reliable one



Versions of ARQ

Stop and Wait ARQ



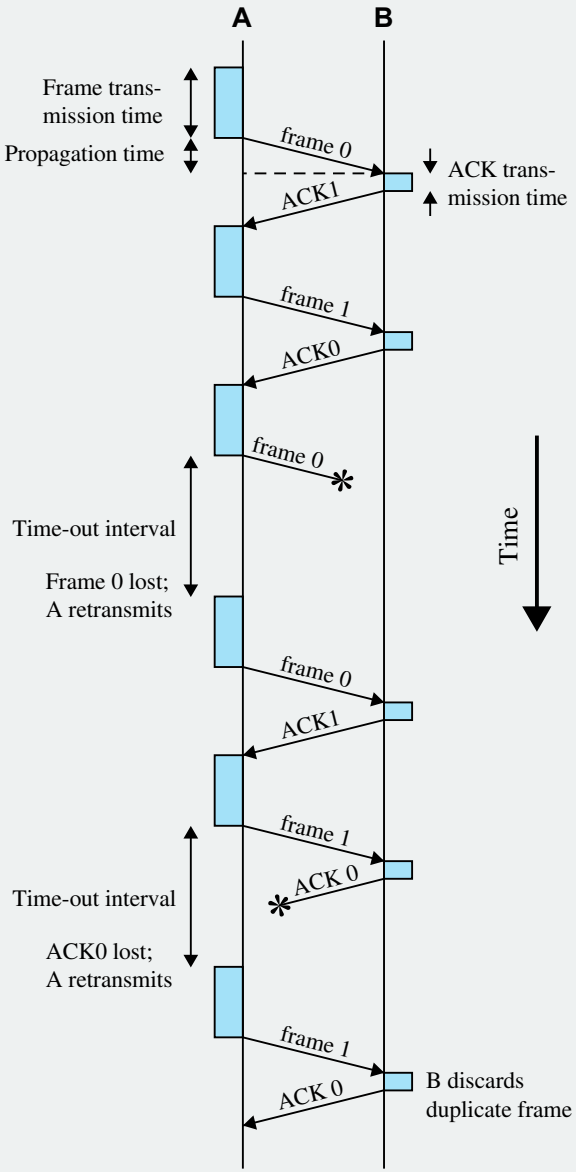


Figure 7.5 Stop-and-Wait ARQ

Go-Back-N ARQ

- Most commonly used error control
- Based on sliding-window
- Use window size to control number of outstanding frames
- While no errors occur, the destination will acknowledge incoming frames as usual
  - RR=receive ready, or piggybacked acknowledgment
- If the destination station detects an error in a frame, it may send a negative acknowledgment
  - REJ=reject
  - Destination will discard that frame and all future frames until the frame in error is received correctly
  - Transmitter must go back and retransmit that frame and all subsequent frames

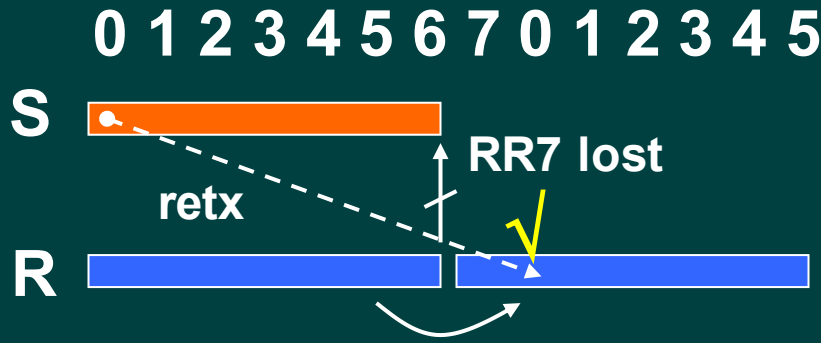
Selective-Reject (ARQ)

- Also called selective retransmission
- Only rejected frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered
- Minimizes retransmission
- Receiver must maintain large enough buffer
- More complex logic in transmitter
  - Less widely used
- Useful for satellite links with long propagation delays

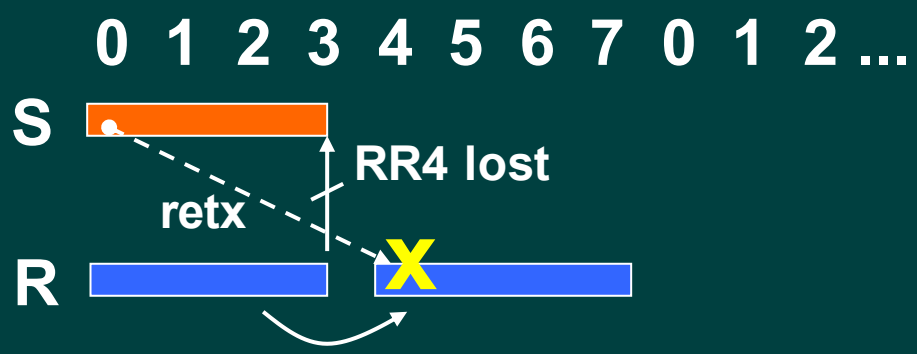
Selective-Reject (ARQ)

- Window Size Limitation
  - **For a k-bit sequence number, the maximum window size is limited to 2^{k-1}.**

k=3, W=7



k=3, W=4



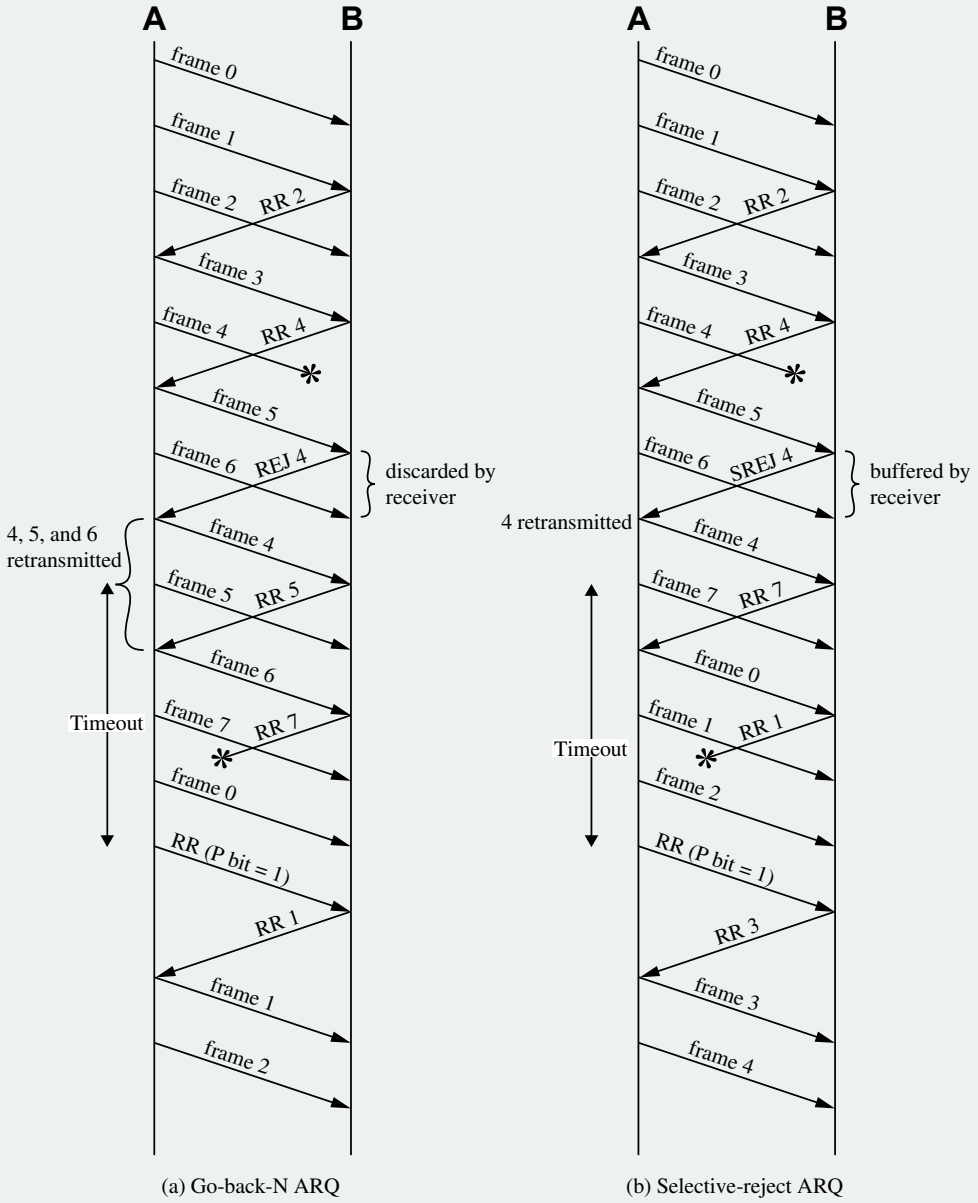


Figure 7.6 Sliding-Window ARQ Protocols

High Level Data Link Control (HDLC)

Most important data link control protocol

Specified as ISO 3009, ISO 4335

Basis for other data link control protocols

Station types

Primary - controls operation of link

Secondary - under control of primary station

Combined - issues commands and responses

Link configurations

Unbalanced - 1 primary, multiple secondary

Balanced - 2 combined stations

HDLC Data Transfer Modes

Normal Response Mode (NRM)

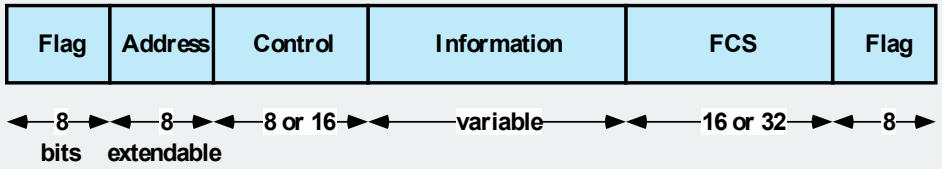
- Used with an unbalanced configuration
- Primary initiates transfer

Asynchronous Balanced Mode (ABM)

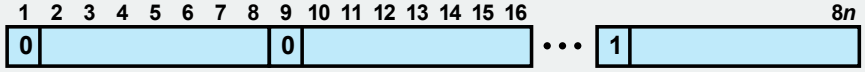
- Used with a balanced configuration
- Either station initiates transmission
- Has no polling overhead
- Most widely used

Asynchronous Response Mode (ARM)

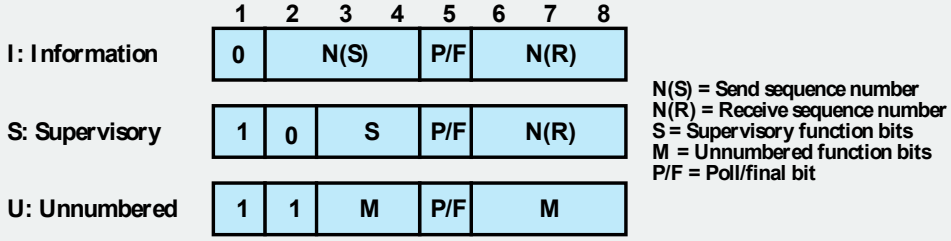
- Used with unbalanced configuration
- Secondary may transmit without permission from primary
- Rarely used



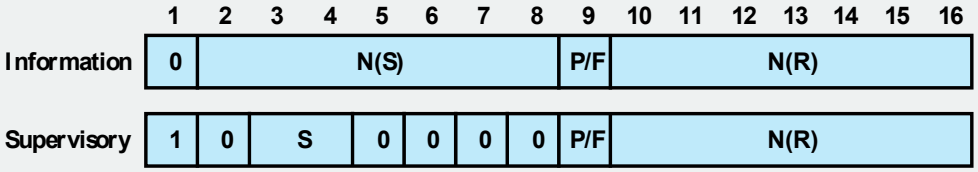
(a) Frame format



(b) Extended Address Field



(c) 8-bit control field format



(d) 16-bit control field format

Figure 7.7 HDLC Frame Structure

Original Pattern:

```
11111111111101111111011111110
```

After bit-stuffing

```
111110111111011011111101011111010
```

Figure 7.8 Bit Stuffing

Address Field

- Identifies secondary station that transmitted or will receive frame
- Usually 8 bits long
- May be extended to multiples of 7 bits
  - Leftmost bit indicates if is the last octet (1) or not (0)
- Address 11111111 allows a primary to broadcast a frame for reception by all secondaries
- This field is not needed for point-to-point links

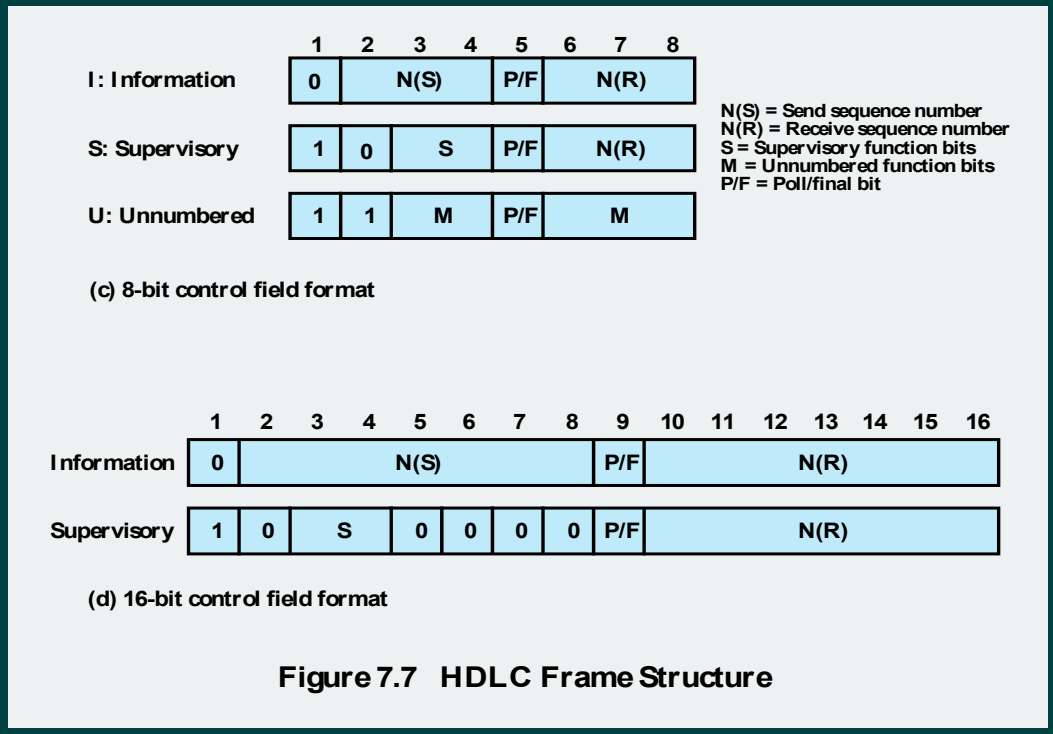


Figure 7.7 HDLC Frame Structure

- HDLC defines three types of frames, each with a different control field format
  - Information frames (I-frames)
    - Carry the data to be transmitted for the user
    - Flow and error control data, using the ARQ mechanism, are piggybacked on an information frame
  - Supervisory frames (S-frames)
    - Provide the ARQ mechanism when piggybacking is not used
  - Unnumbered frames (U-frames)
    - Provide supplemental link control functions

Control Field

- Use of poll/final (P/F) bit depends on context
- In command frames P bit is set to 1 to solicit (poll) a response from the peer HDLC entity
- In response frames F bit is set to 1 to indicate the response frame transmitted as a result of a soliciting command
- The basic control field for S- and I-frames uses 3 bit sequence numbers
  - An extended control field can be used that employs 7-bit sequence numbers
- U-frames always contain an 8-bit control field

Information and Frame Check Sequence (FCS) Fields

Information Field

- Present only in I-frames and some U-frames
- Must contain an integral number of octets
- Variable length

Frame Check Sequence Field (FCS)

- Error detecting code calculated from the remaining bits of the frame, exclusive of flags
- The normal code is the 16 bit CRC-CCITT
- Optional 32-bit FCS, using CRC-32, may be employed if the frame length or the line reliability dictates this choice

Table 7.1

HDLC Commands and Responses

Name	Command/ Response	Description
Information (I)	C/R	Exchange user data
Supervisory (S)		
Receive ready (RR)	C/R	Positive acknowledgment; ready to receive I-frame
Receive not ready (RNR)	C/R	Positive acknowledgment; not ready to receive
Reject (REJ)	C/R	Negative acknowledgment; go back N
Selective reject (SREJ)	C/R	Negative acknowledgment; selective reject
Unnumbered (U)		
Set normal response/extended mode (SNRM/SNRME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous response/extended mode (SARM/SARME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous balanced/extended mode (SABM, SABME)	C	Set mode; extended = 7-bit sequence numbers
Set initialization mode (SIM)	C	Initialize link control functions in addressed station
Disconnect (DISC)	C	Terminate logical link connection
Unnumbered Acknowledgment (UA)	R	Acknowledge acceptance of one of the set-mode commands
Disconnected mode (DM)	R	Responder is in disconnected mode
Request disconnect (RD)	R	Request for DISC command
Request initialization mode (RIM)	R	Initialization needed; request for SIM command
Unnumbered information (UI)	C/R	Used to exchange control information
Unnumbered poll (UP)	C	Used to solicit control information
Reset (RSET)	C	Used for recovery; resets N(R), N(S)
Exchange identification (XID)	C/R	Used to request/report status
Test (TEST)	C/R	Exchange identical information fields for testing
Frame reject (FRMR)	R	Report receipt of unacceptable frame

(Table can be found on page 254 in the textbook)

HDLC Operation

- Consists of the exchange of I-frames, S-frames and U-frames
- Involves three phases:

Initialization

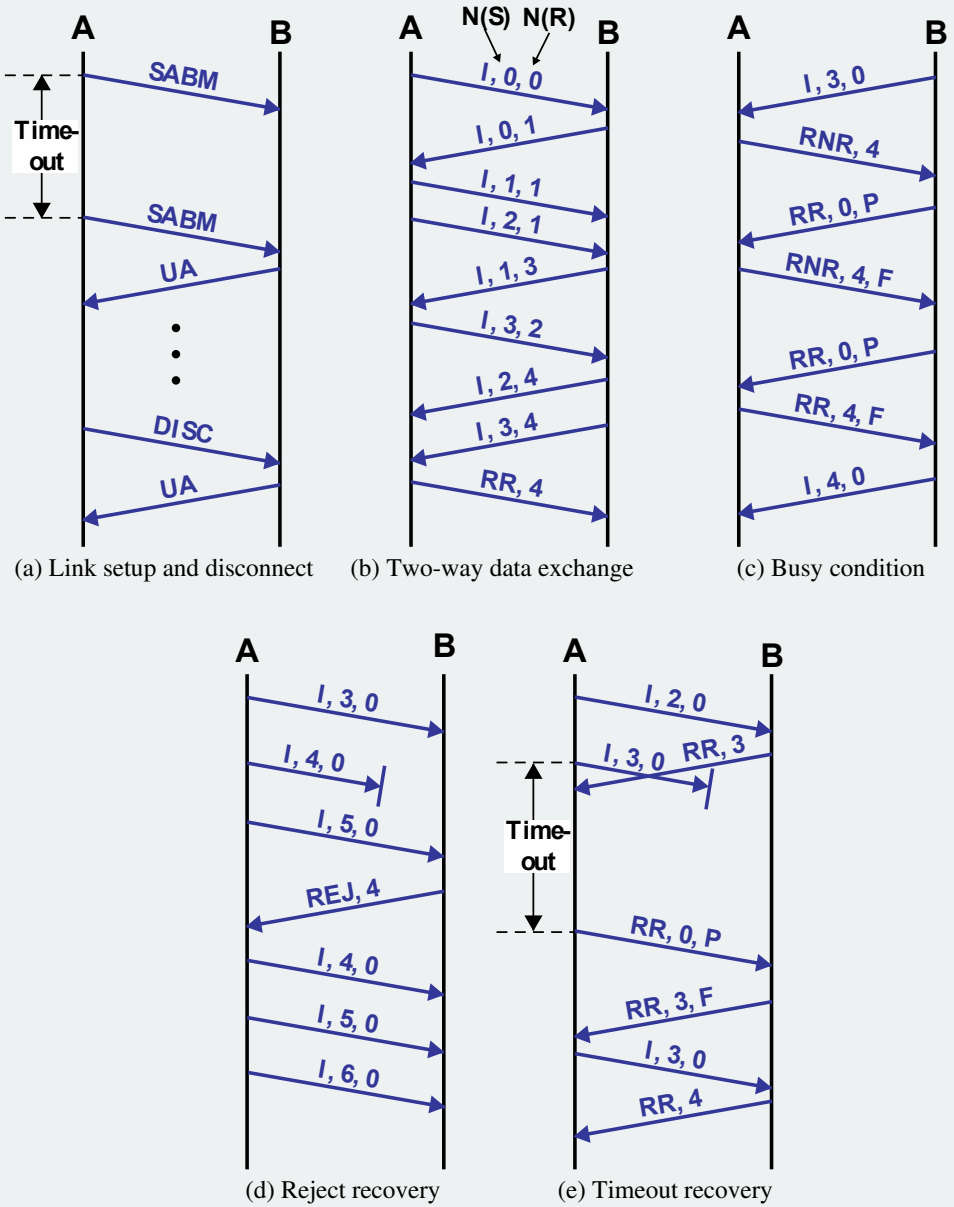
- Signals the other side that initialization is requested
- Specifies which of the three modes (NRM, ABM, ARM) is requested
- Specifies whether 3- or 7-bit sequence numbers are to be used

Data Transfer

- The N(S) and N(R) fields of the I-frame are sequence numbers that support flow control and error control
- An HDLC module will number them sequentially
- Receive Ready (RR) is used when there is no reverse user data traffic

Disconnect

- Either module can initiate
  - Either on its own initiative if there is some sort of fault, or at the request of its higher-layer user
- Sends disconnect (DISC) frame
- Remote entity replies with a UA
- Any outstanding unacknowledged
- I-frames may be lost
  - Recovery is the responsibility of higher layers



(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

(d) Reject recovery (e) Timeout recovery

Figure 7.9 Examples of HDLC Operation

Summary

- Flow control
  - Stop-and-wait flow control
  - Sliding-window flow control
- Error control
  - Stop-and-wait ARQ
  - Go-back-N ARQ
  - Selective-reject ARQ
- High-level data link control (HDLC)
  - Basic characteristics
  - Frame structure
  - Operation