OSI:

L2 - DLC ← chapter 2 (Data Link Control; for linking data)

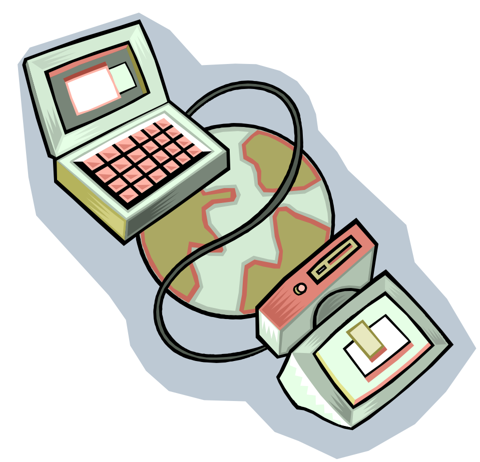
Guided
unguided

L1 Physical layer ← Chapter 1

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 (to avoid loss of data).

- 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

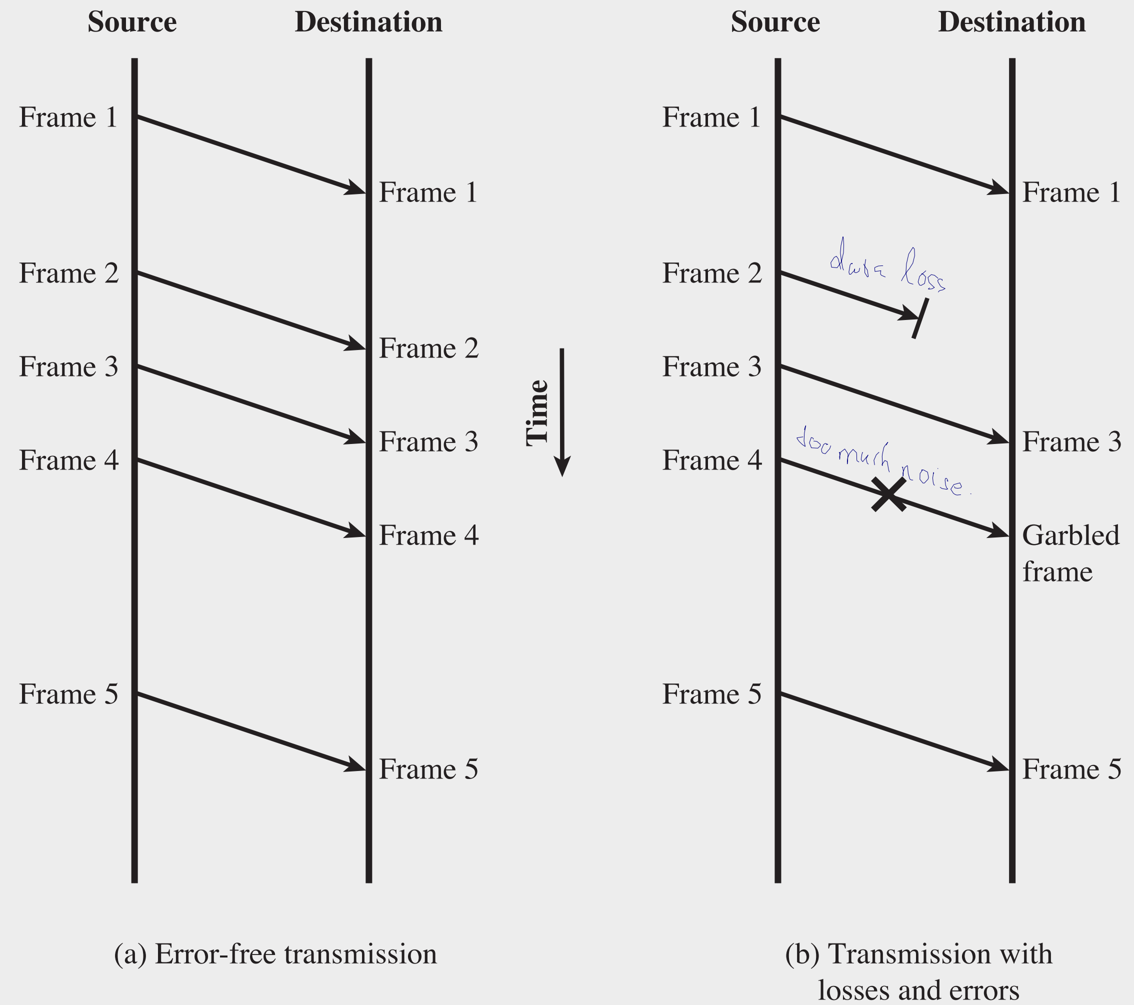
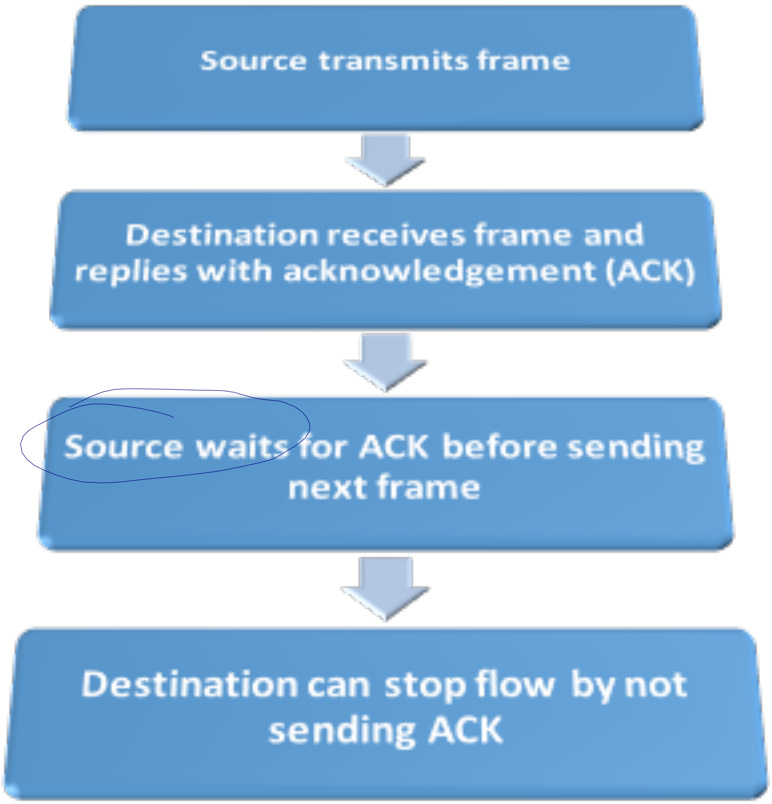


Figure 7.1 Model of Frame Transmission

Stop-and-Wait Flow Control

- Simplest form of flow control

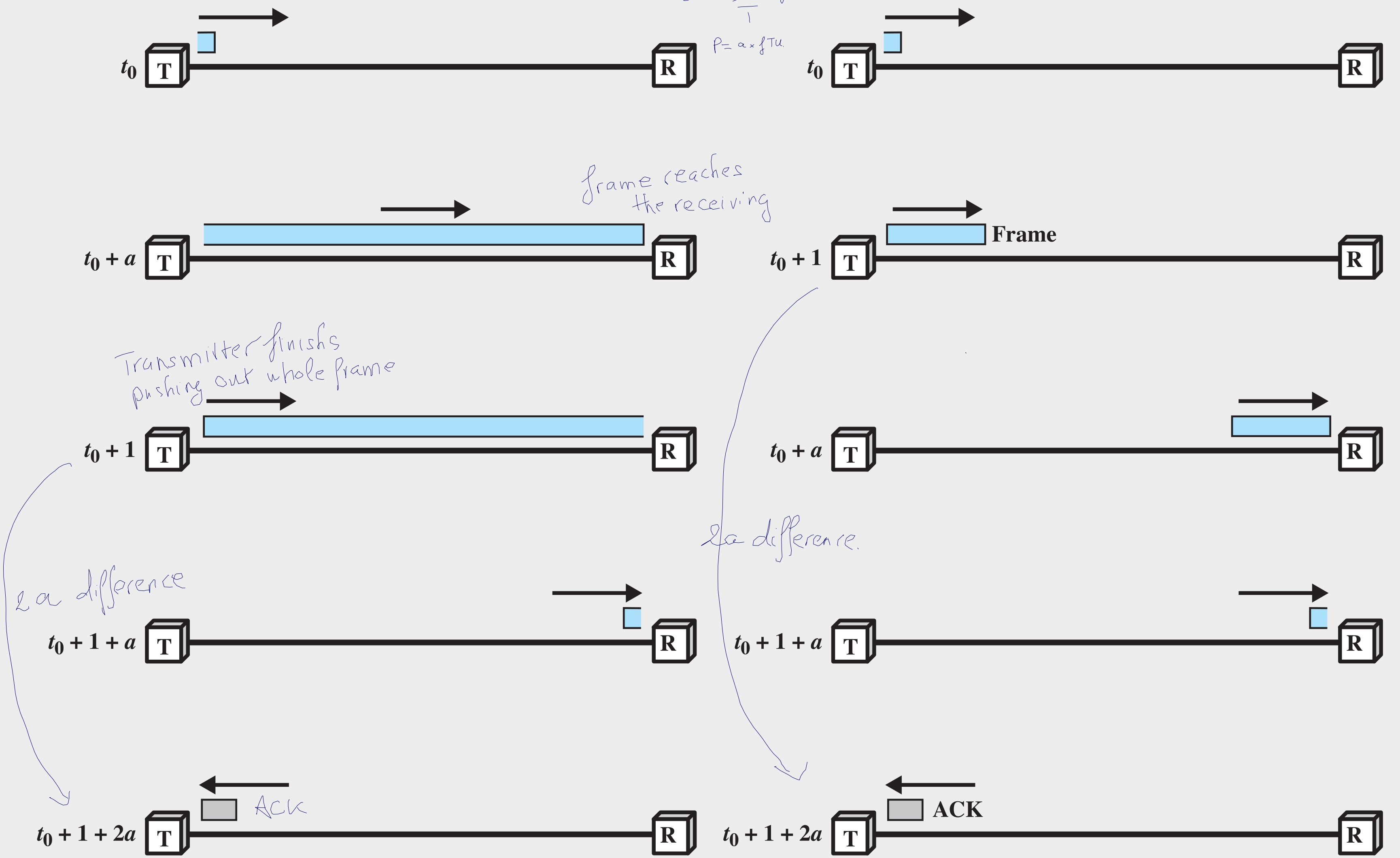


- It is often the case that a source will break up a large block of data into smaller blocks and transmit the data in many frames
  - The buffer size of the receiver may be limited
  - The longer the transmission, the more likely that there will be an error, necessitating retransmission of the entire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

propagation time = P, frame transmission time = T = 1,

$a = \frac{P}{T}$ fTU = Frame Transmission Unit.

$P = a \times fTU$.



The sender has to wait 2a time after last trx before sending new frame

(a) $a < 1$

The wait time is still 2a.

(b) $a > 1$

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

* Stop & wait protocol: – work well in LAN ($P \ll T$)
– worst in satellite comm ($P \ggg T$)

Sliding Windows Flow Control

- Allows multiple numbered frames to be in transit
  - Receiver has buffer W long (W: number of frames that Receiver can store i.e. buffer.)
  - Transmitter sends up to W frames without ACK
  - ACK includes (nth) number of next frame expected (if sent 4, receiver has received 3 frames & expecting 4th frame)
  - 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) received but too busy to process.
  - Must send a normal acknowledge to resume → send another ACK to resume
- If have full-duplex link, can piggyback ACKs

inject ACK into other frames in reply (in the case of full duplex) transmitter can send 7 frames w/o ack.

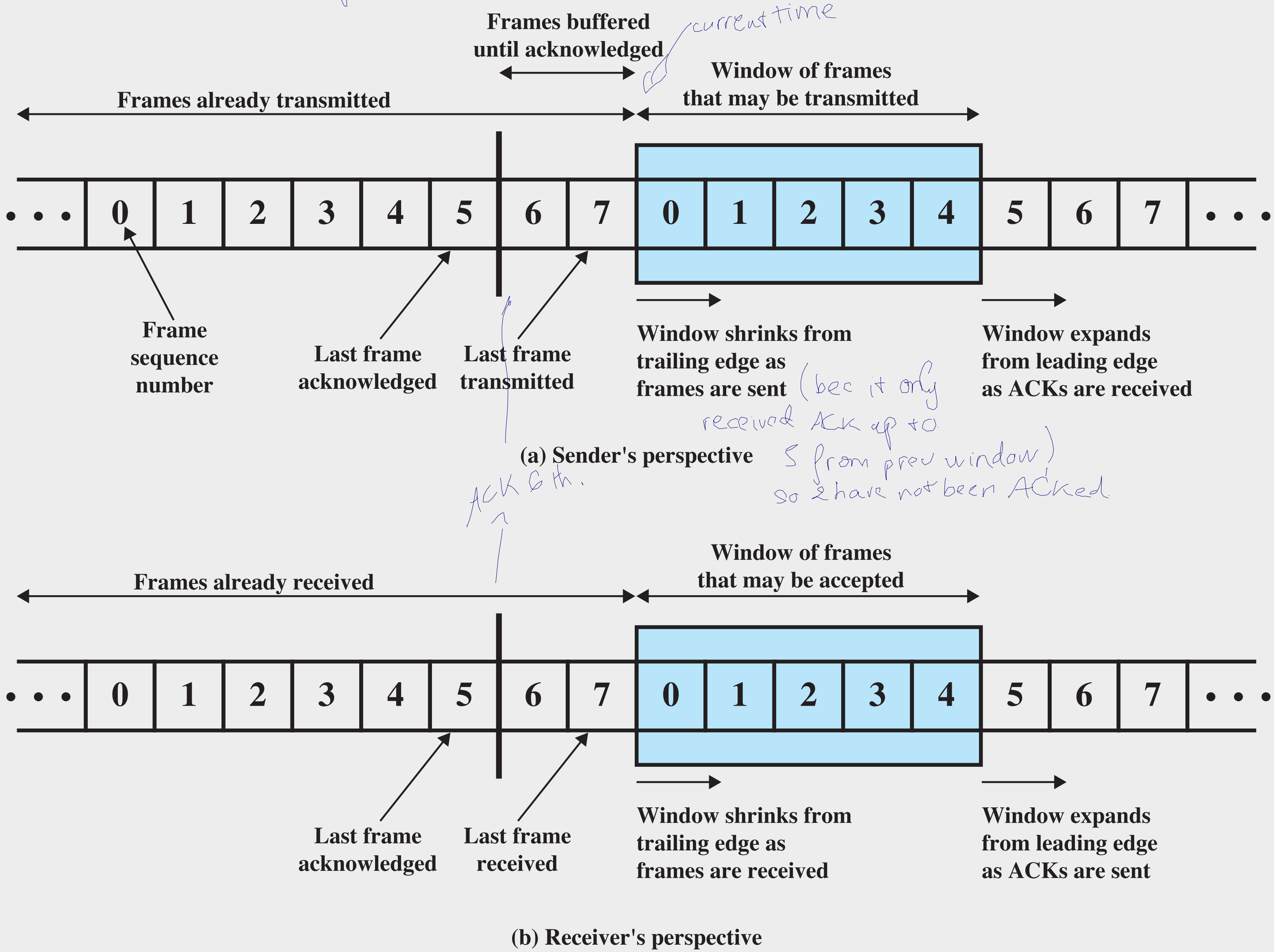


Figure 7.3 Sliding-Window Depiction

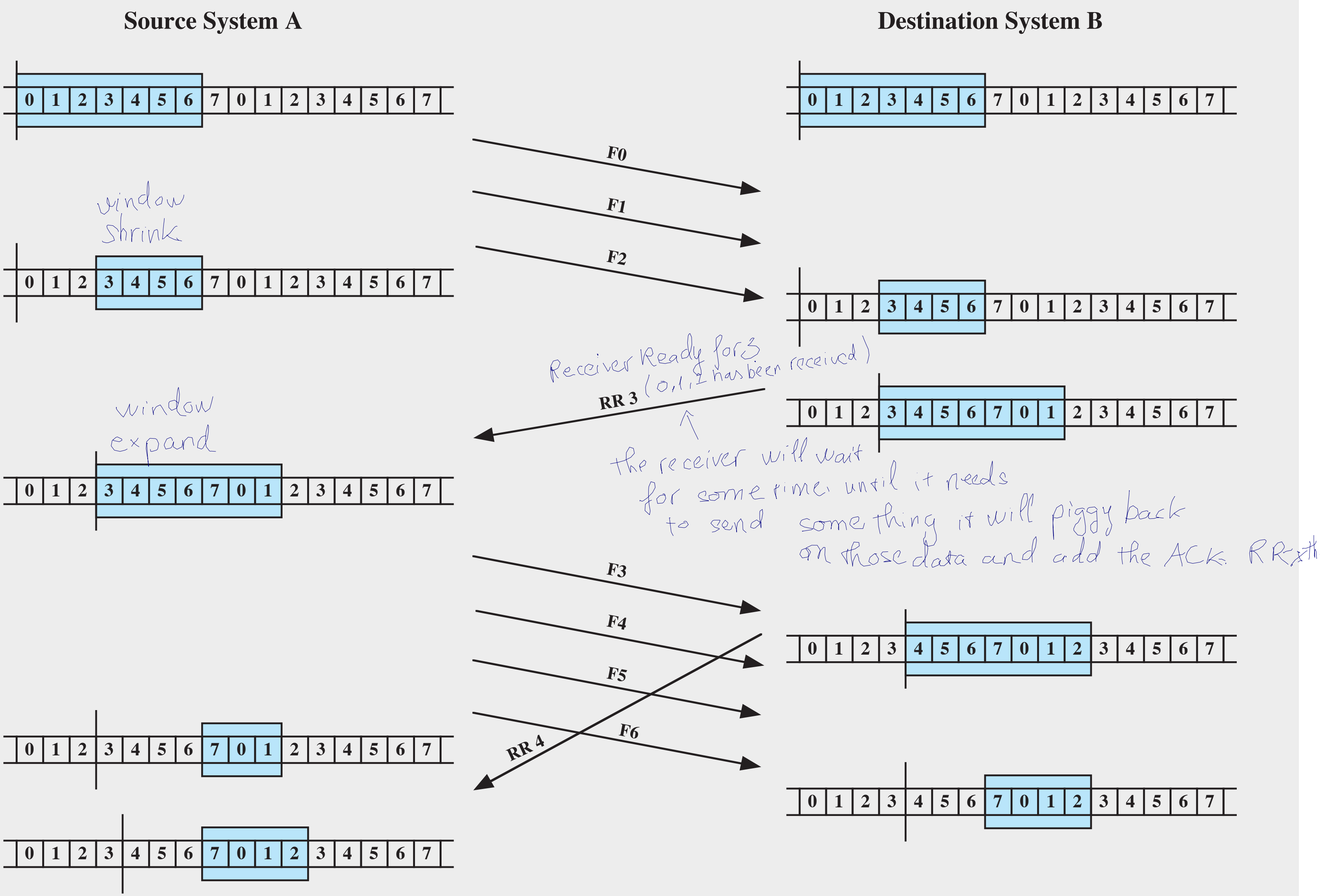
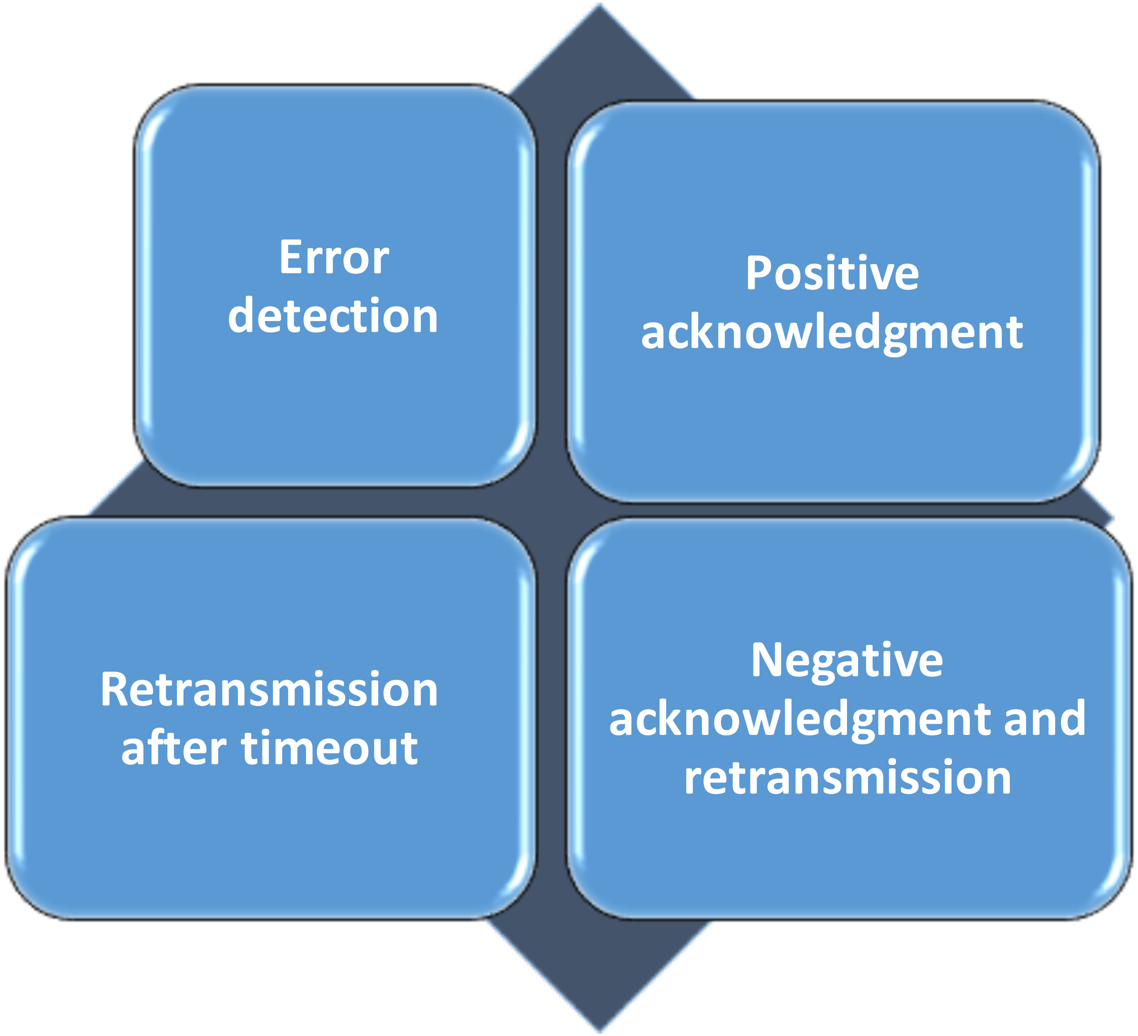


Figure 7.4 Example of a Sliding-Window Protocol

Error Control Techniques



Lost frames

- a frame fails to arrive at the other side

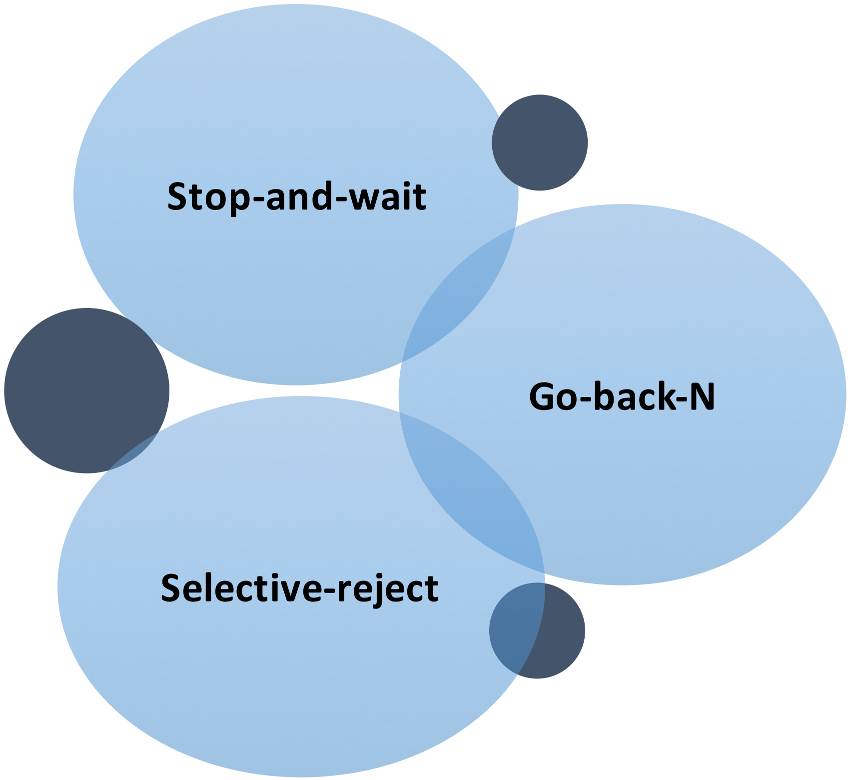
Damaged frames

- frame arrives but some of the bits are in error

Automatic Repeat Request (ARQ)

Stop & wait.
Selective reject
Go back N

- 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

- sender uses timeout to detect frame loss, damage, or ACK loss, damage & resend.
- receiver just uses ACK0/ACK1 for positive response, no reaction on frame loss or damage.
- sender must wait for ACK from receiver before sending a new frame.

Source transmits single frame

Waits for ACK

No other data can be sent until destination's reply arrives

If frame received is damaged, discard it

- Transmitter has time out.
- if no ACK within timeout, retransmit.

similar as frame lost, just wait for sender to time out & resend the last frame.

If ACK is damaged, transmitter will not recognize

similar as frame lost, wait for transmitter to time out & resend the frame.

- Transmitter will retransmit.
- Receivers gets 2 copies of frame
- Use alternate numbering and ACK0/ACK1

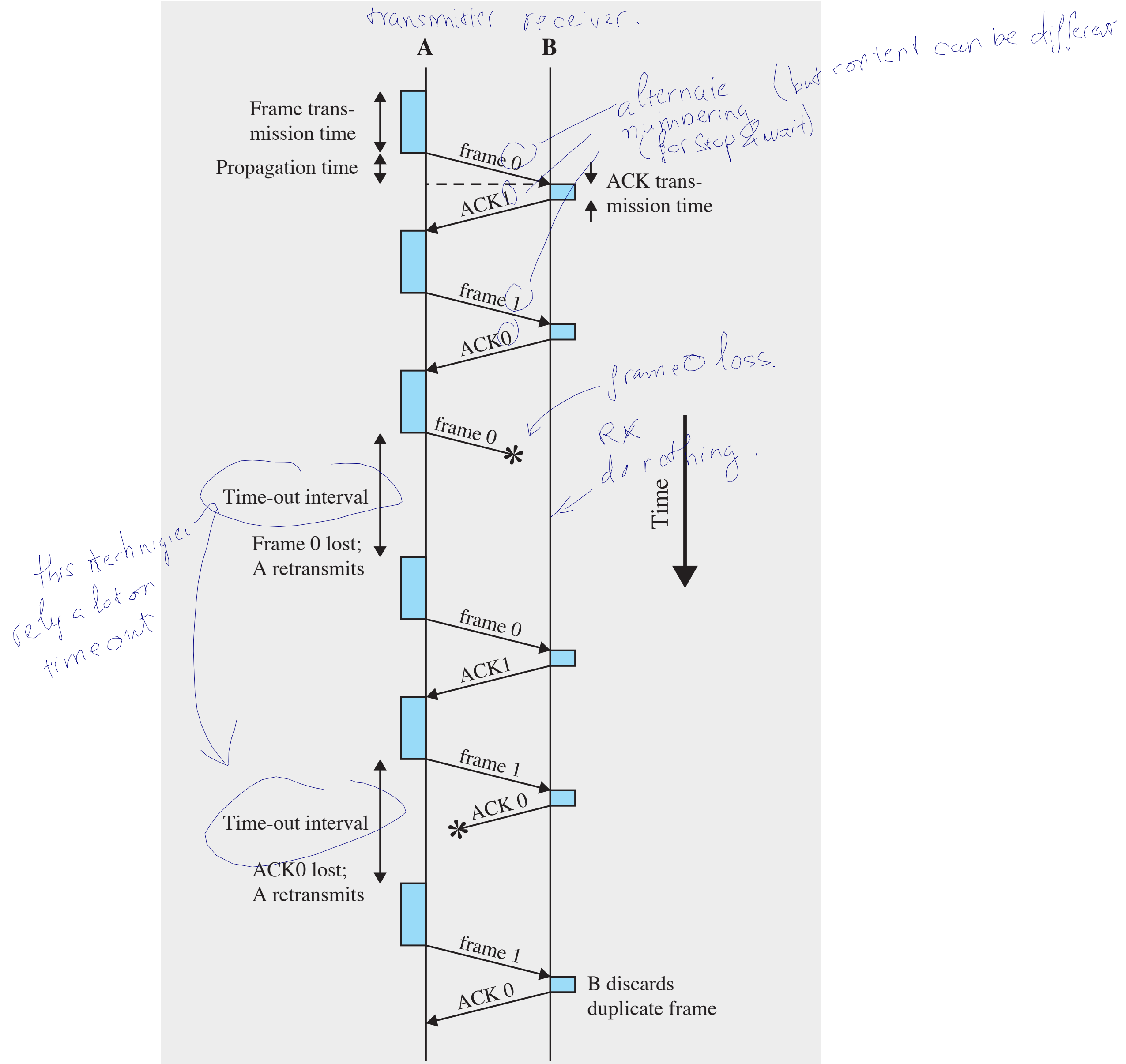


Figure 7.5 Stop-and-Wait ARQ

Go-Back-N ARQ

- Most commonly used error control
- Based on sliding-window → ACK-n → shrink & expansion
- 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 REJ-n : resend n^{th} frame please
  - 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
- Transmitter maintains the timeout window, if it does not receive any RR from Receiver by the time out it will send an ACK : RR (P bit = 1) to ask for status from Receiver. Receiver will send an RR-nth telling the sender which frame it needs retransmission.

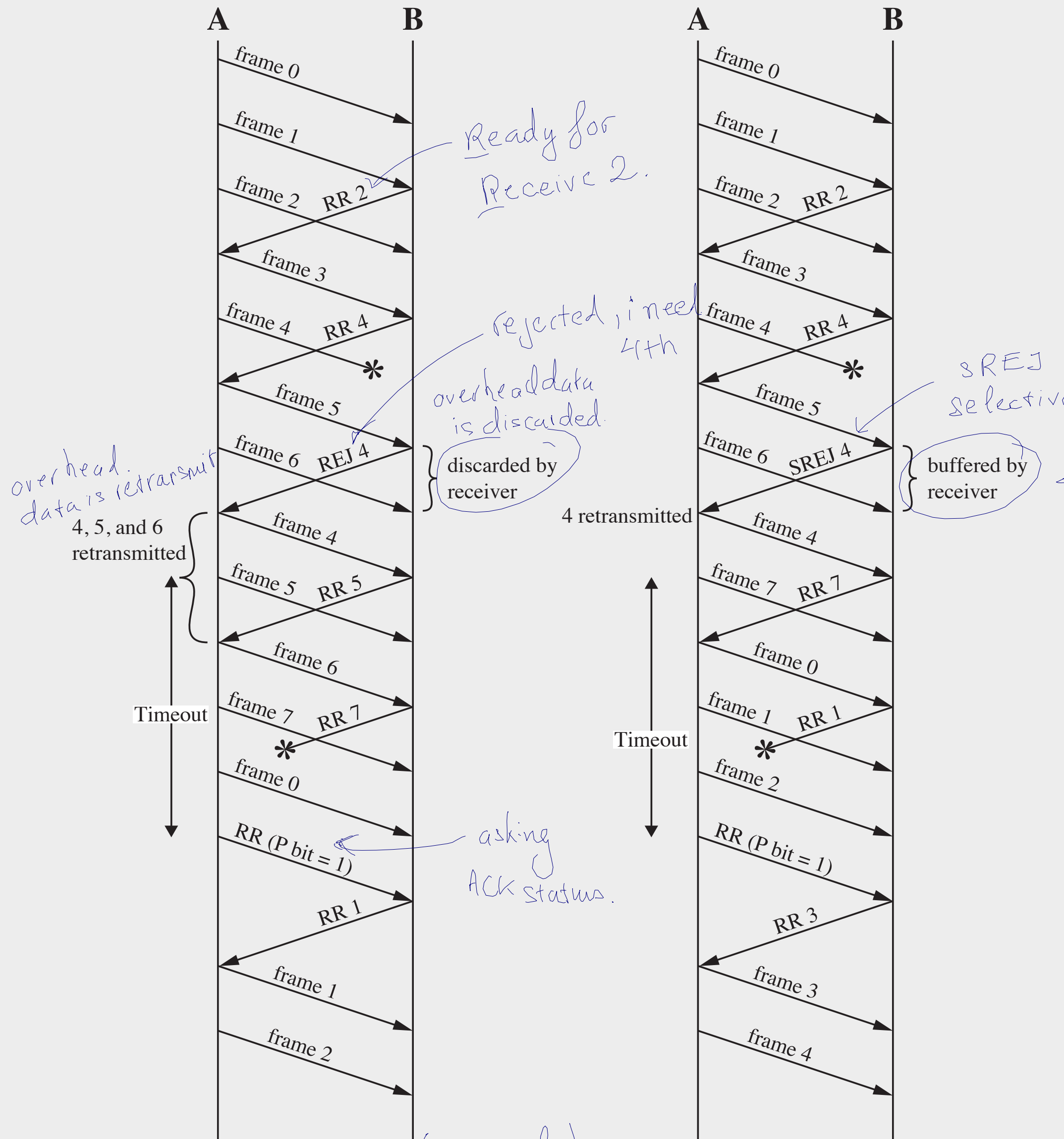
Selective-Reject (ARQ)

If receive detects frame n^{th} damage or loss, it sends SREJ-n to ask sender to retransmit that n^{th} frame ONLY rejecting

- Also called selective retransmission
- Only rejected frames are retransmitted (instead of whole batch start from the 1st rejected)
- 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

End lecture on June 04th

some assignment on Google Classroom



(a) Go-back-N ARQ (commonly used)

(b) Selective-reject ARQ

not widely used.
- complex.
- today transmission has very low error

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 → for vendors who produce the HW device to follow

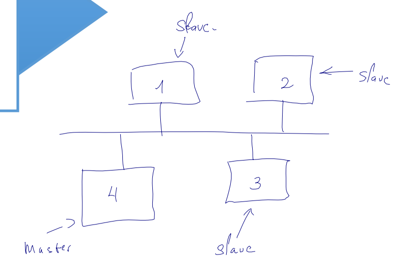
Basis for other data link control protocols

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

  1 master
  others are slave.
- 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

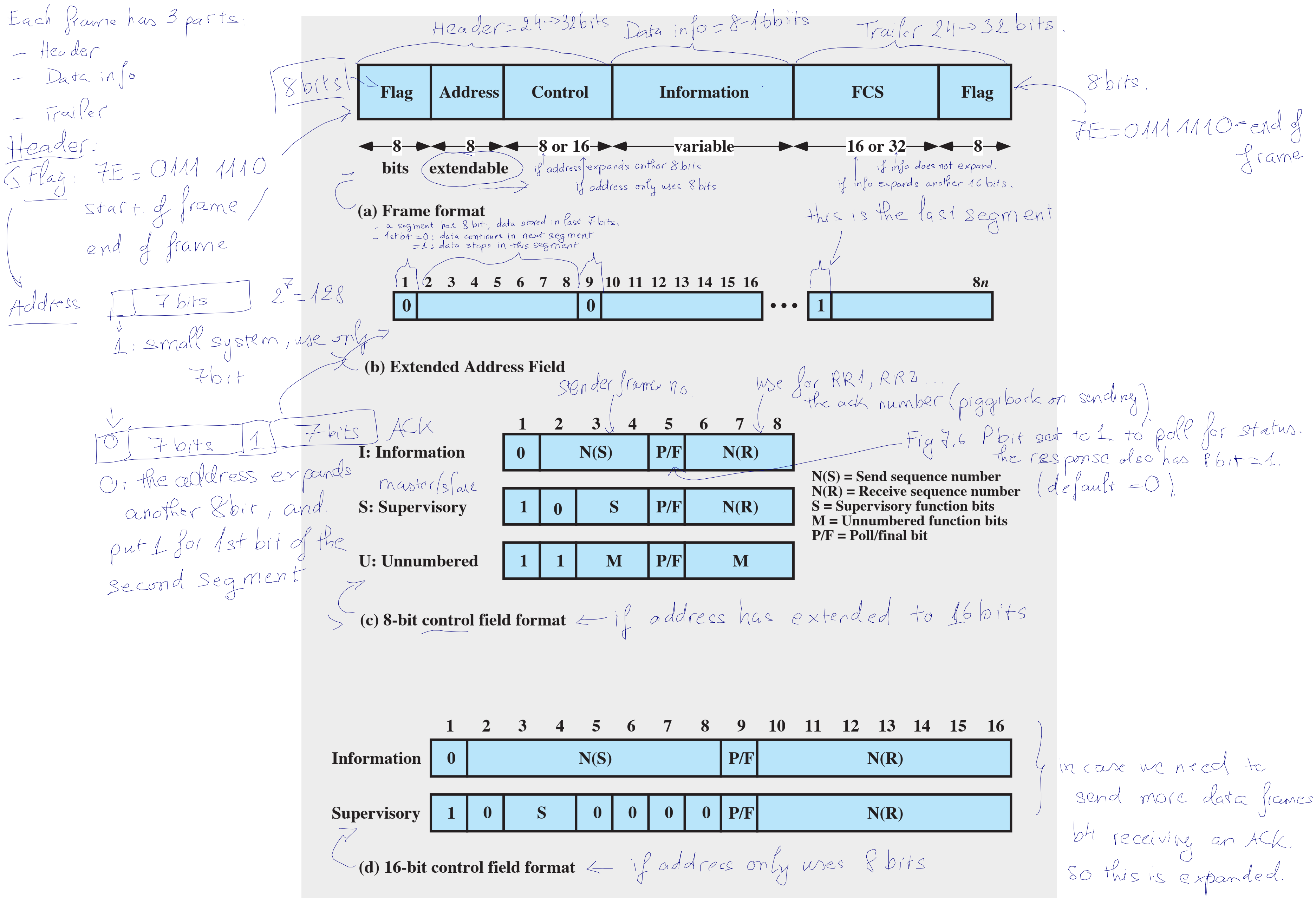


Figure 7.7 HDLC Frame Structure

real data but might be mistaked as end of frame.

Original Pattern:

7E: end of frame.

that's why we need bit stuffing.

1111111111110111111 01111110

transmitter inject 0 to avoid frame cut.

After bit-stuffing

1111101111101101111101011111010

6-1s

receiver removes this 0 bit before process the data

If receiver sees 5 1s, check next bit:
- if 0, remove it (bit stuffing)
- if 10, end of frame marker.
- if 11, error (can't have 7 1s in a row)

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

2 segments, each has 1st bit = 0 or 1

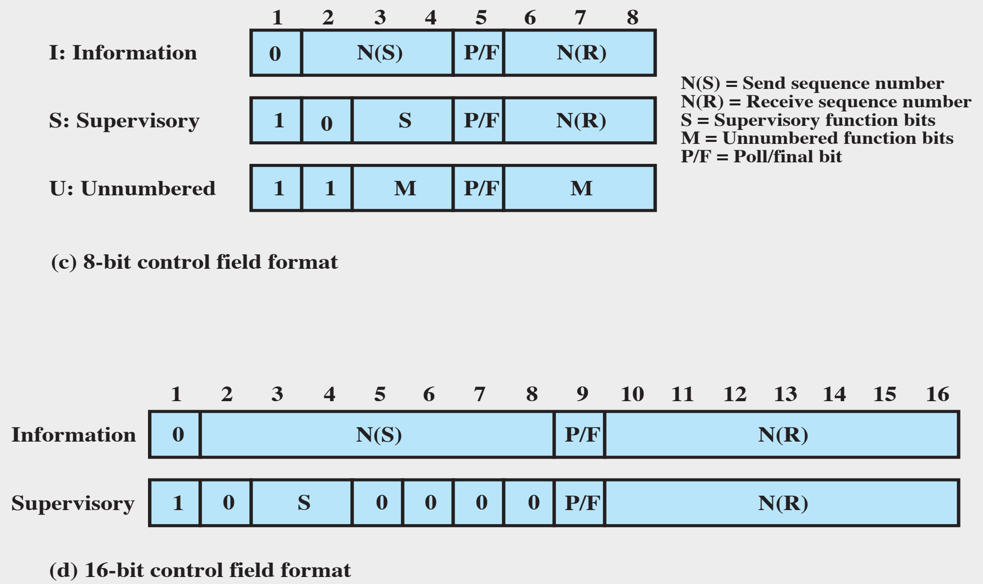


Figure 7.7 HDLC Frame Structure

- 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

} only needs 8 bits for control field.

Control Field → 8 bit → 16 bit

- 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 → ask for status (I can't receive your ACK so far)
- 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

for detecting error in the frame it receives

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

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) buffer of receiver is full	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

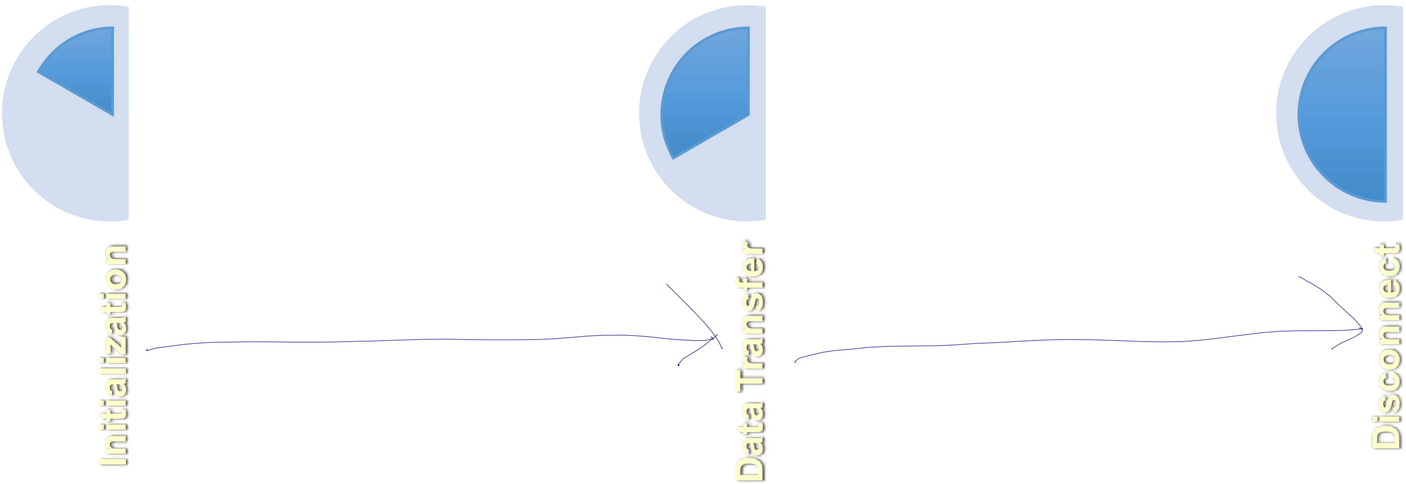
Table 7.1

HDLC Commands and Responses

(Table can be found on page 230 in the textbook)

HDLC Operation

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



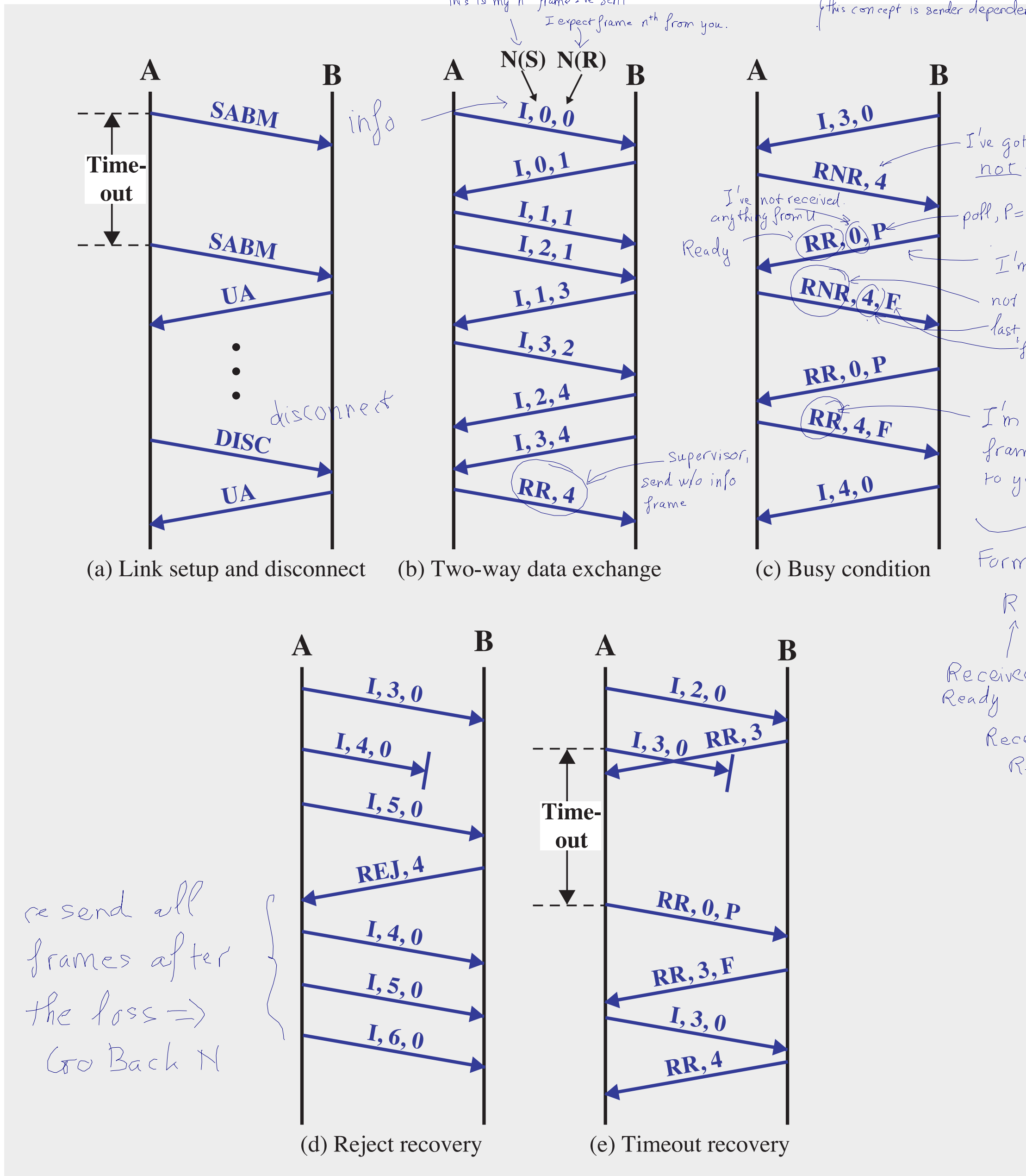


Figure 7.9 Examples of HDLC Operation

I've got your 3rd frame but I'm not ready!

poll, P = 1

I'm ready, are you (Poll)?

not ready.

last receive frame 3

"final", response to the Poll.

I'm ready & I expect 4th frame, also I'm replying to your poll (F = 1)

Format of supervisor frame:

RR/RNR, expected frame, P/F

Received Ready

Receive NOT Ready

optional:

P: for polling status.

F: reply to poll

Summary

- Flow control
  - Stop-and-wait flow control → stop & wait for ACK → uses timeout to control error
  - Sliding-window flow control → expand → shrink
- Error control
  - Stop-and-wait ARQ ← slow & ineffecient
  - Go-back-N ARQ ← popular & widely used.
  - Selective-reject ARQ ← complex, not widely used.
- High-level data link control (HDLC)
  - Basic characteristics
  - Frame structure
  - Operation