Data and Computer Communications

CH 07~08

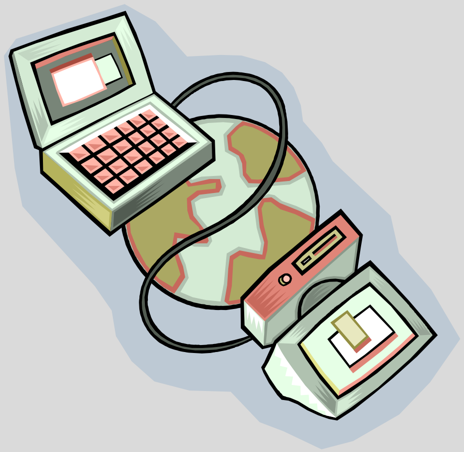
CHAPTER 7

Data Link Control Protocols

Data Link Control Protocols

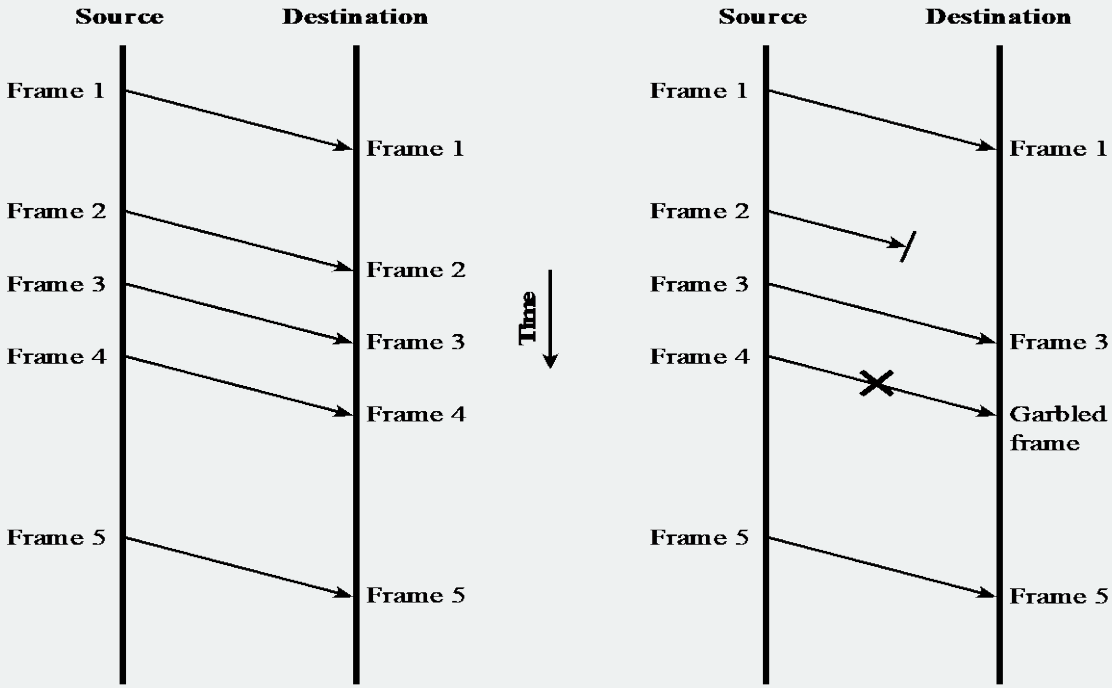
- Requirements and objectives for effective data communication between two directly connected transmitting-receiving stations:

- 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



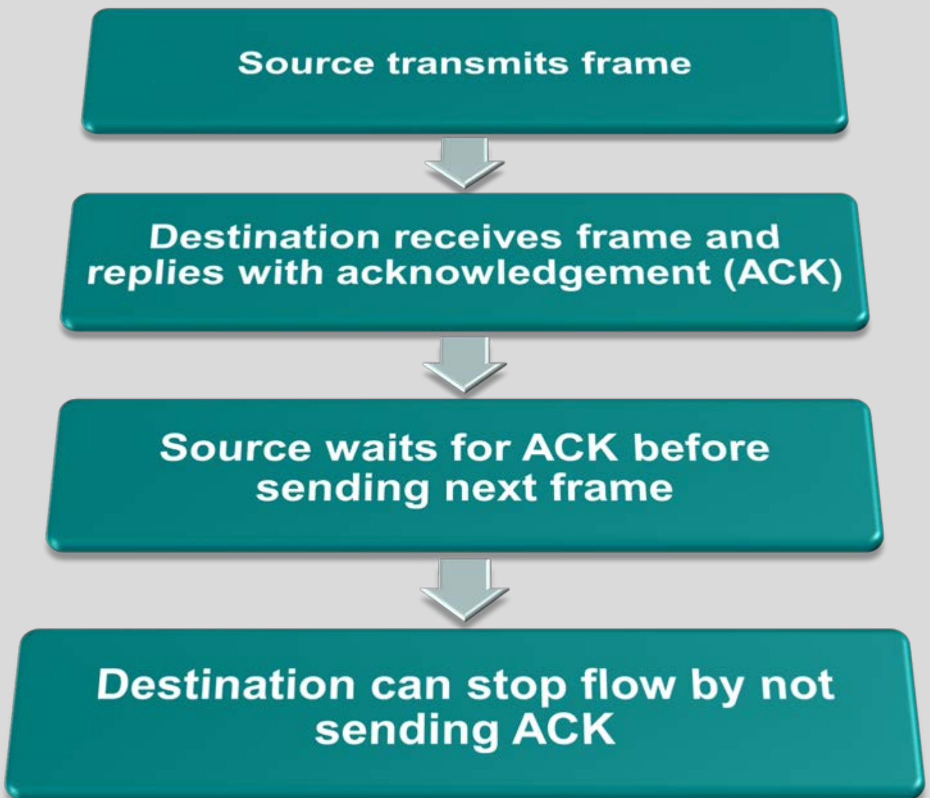
(a) Error-free transmission

(b) Transmission with losses and errors

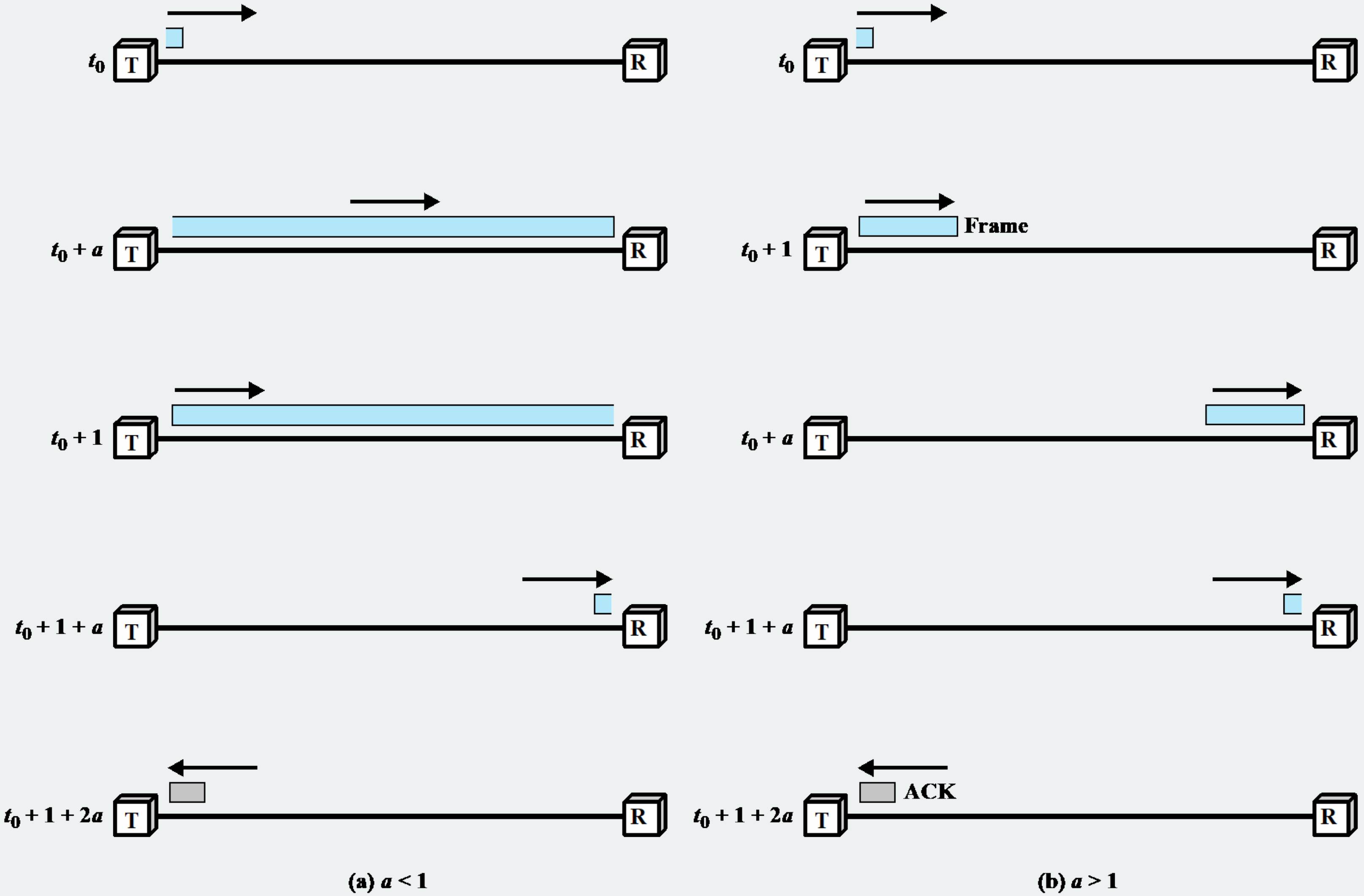
Figure 7.1 Model of Frame Transmission

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 the medium for an extended period, thus causing long delays at the other sending station

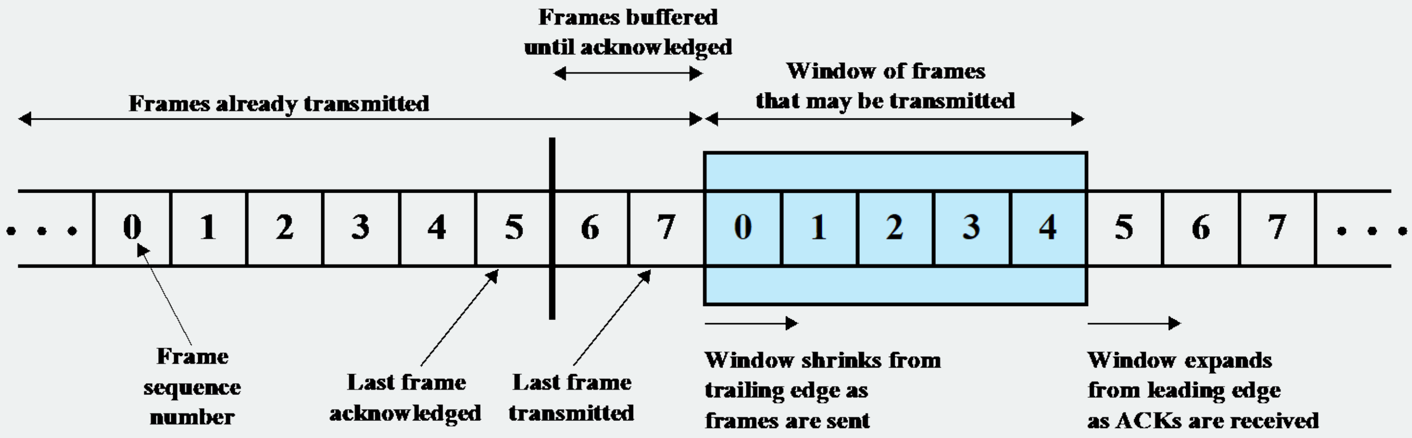


이게 길만 길수록 안좋음

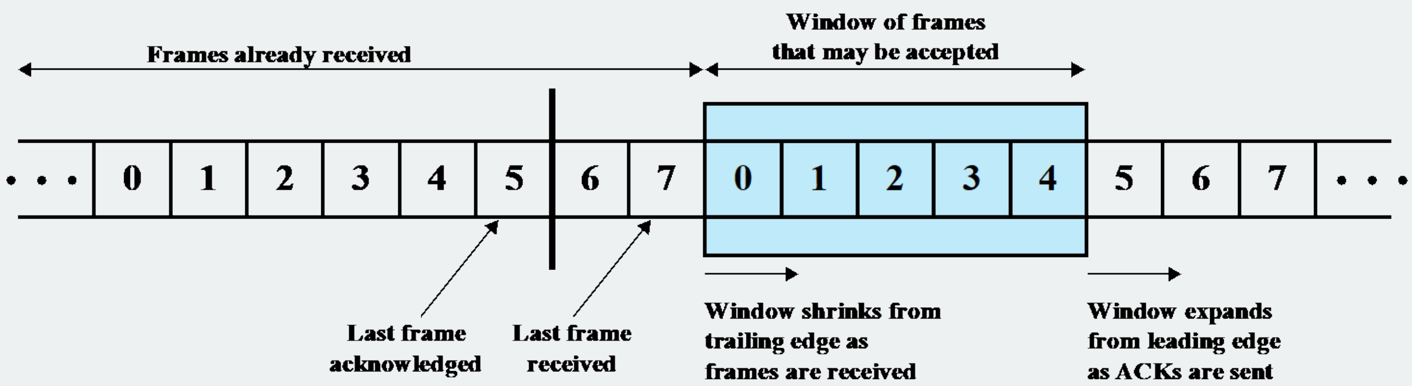
Figure 7.2 Stop-and-Wait Link Utilization (transmission time = 1; propagation time = a)

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



(a) Sender's perspective



(b) Receiver's perspective

Figure 7.3 Sliding-Window Depiction

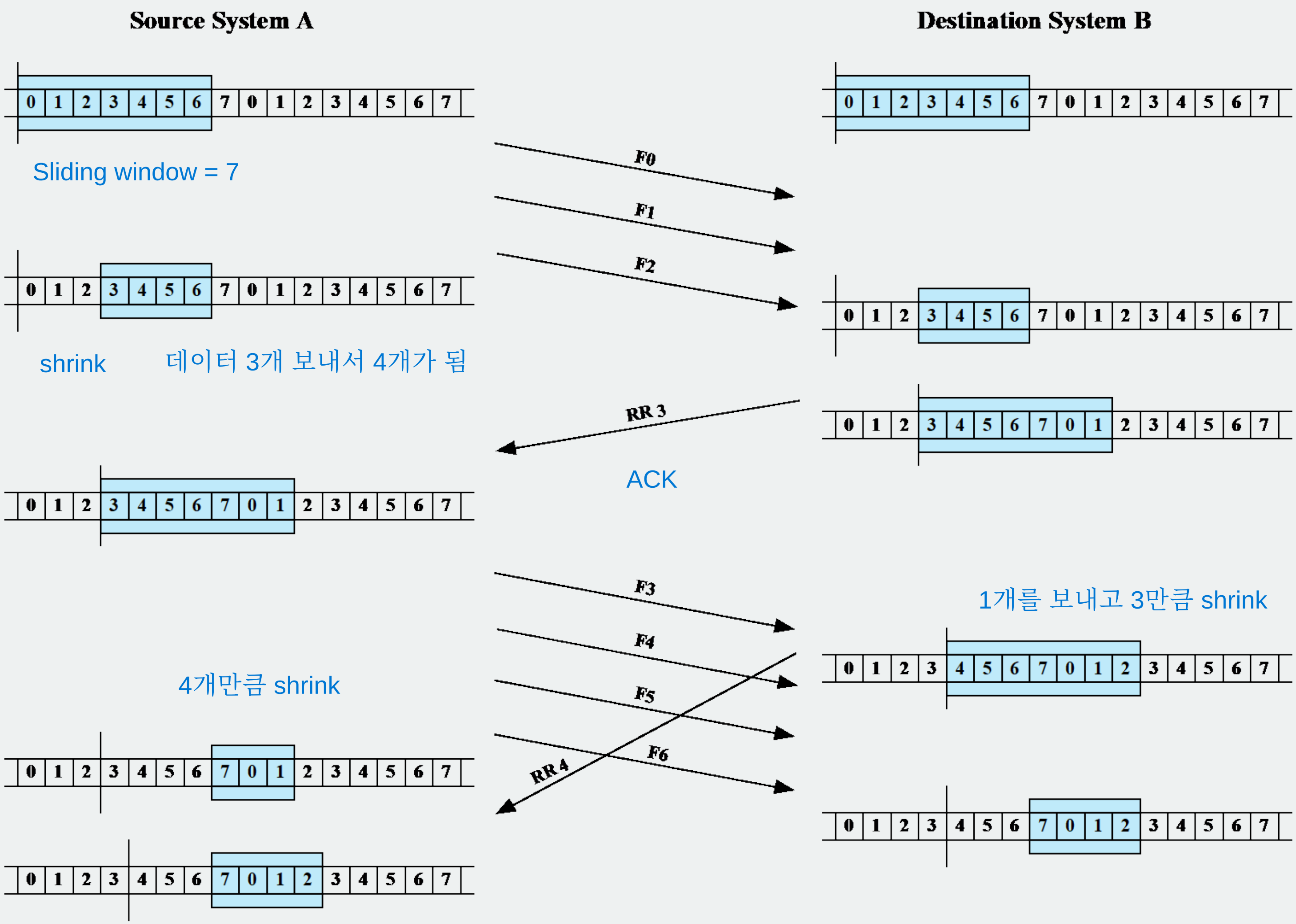
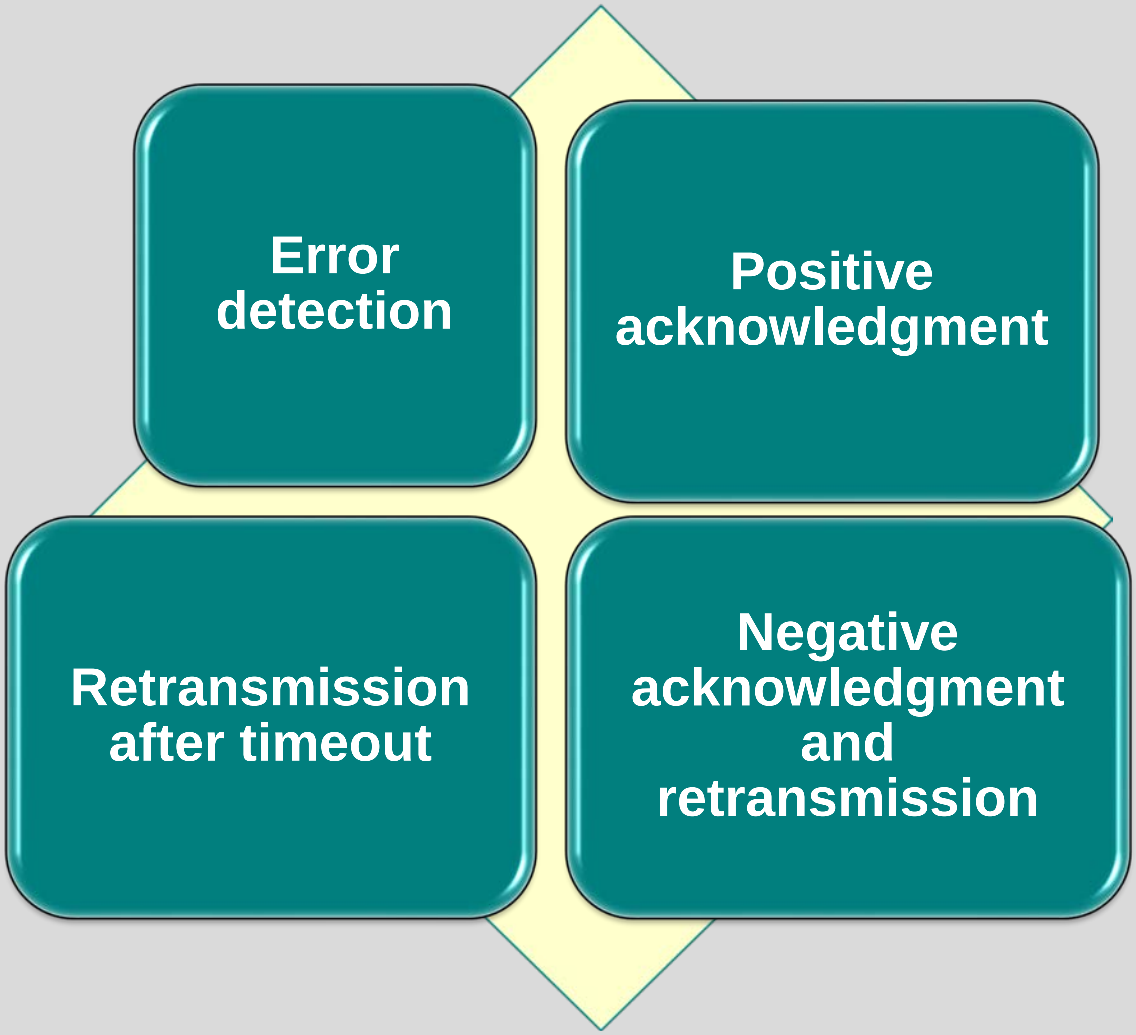


Figure 7.4 Example of a Sliding-Window Protocol

Error Control Techniques

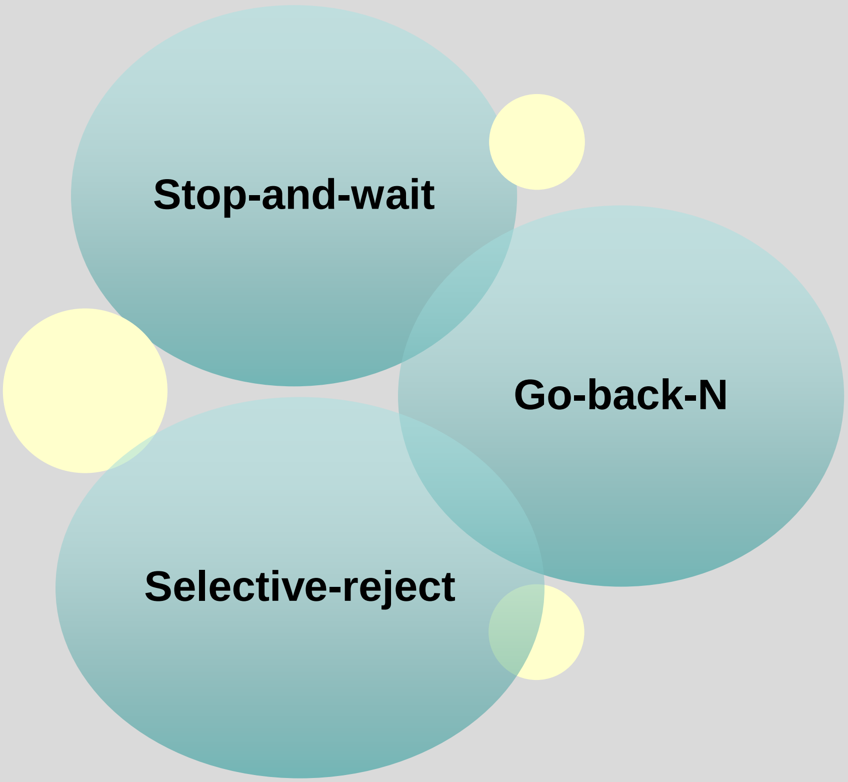


Lost frames
- a frame fails to arrive at the other side

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

1. Source transmits single frame
2. Waits for ACK
   - No other data can be sent until destination's reply arrives
3. If frame received is damaged, discard it
   - Transmitter has timeout
   - If no ACK within timeout, retransmit
4. If ACK is damaged, transmitter will not recognize
   - Transmitter will retransmit
   - Receiver gets two copies of frame
   - Use alternate numbering and ACK0 / ACK1

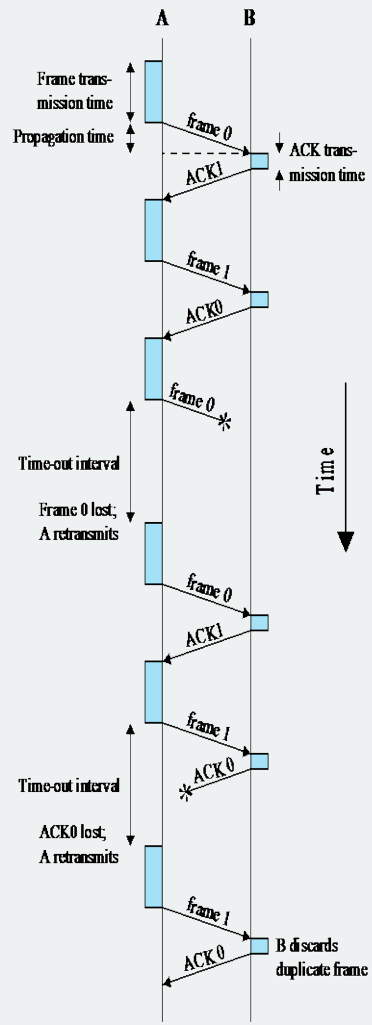


Figure 7.5 Stop-and-Wait ARQ

Go-Back-N ARQ

- Most commonly used error control
- Based on sliding-window
- 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)

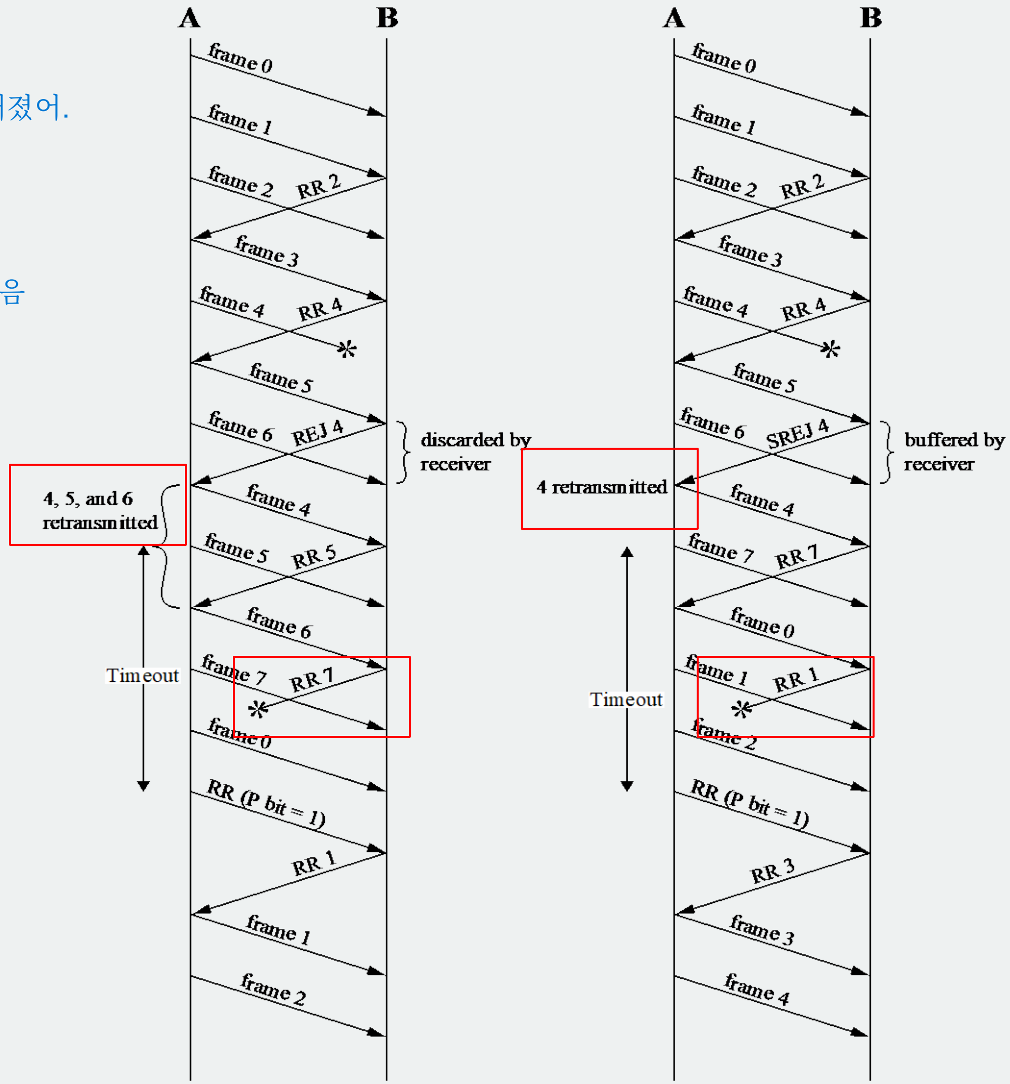
- Also called selective retransmission
- Only rejected frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered
- Minimizes retransmission
- Receiver must maintain large enough buffer
- More complex logic in transmitter
  - Less widely used
- Useful for satellite links with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

sliding window 개수만큼 처리

REJ n = n이 깨졌어.

RR n = n까지 받음

Selective Rej
= 내가 선택해서 Rej 한다



(a) Go-back-N ARQ

(b) Selective-reject ARQ

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

패킷

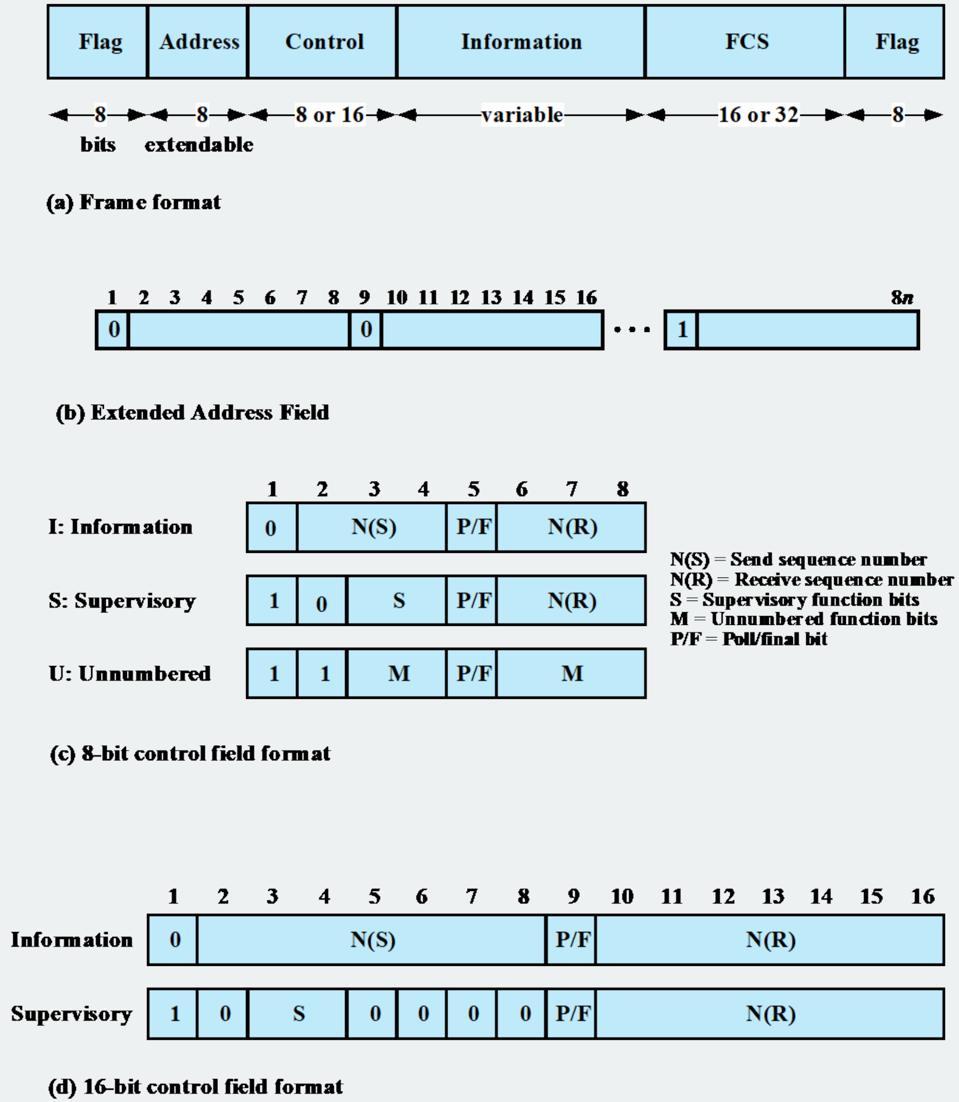


Figure 7.7 HDLC Frame Structure

Original Pattern:

1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 1 1 1 0 1 1 1 1 1 1 0

After bit-stuffing

1 1 1 1 1 0 1 1 1 1 1 0 1 1 0 1 1 1 1 1 0 1 0 1 1 1 1 1 0 1 0

Figure 7.8 Bit Stuffing

1이 일정 개수가 될 때 마다 0을 끼워 넣어주는 것을 일컫는다.

0과 1의 논리 오류를 해결하기 위해 사용함... ?

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

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

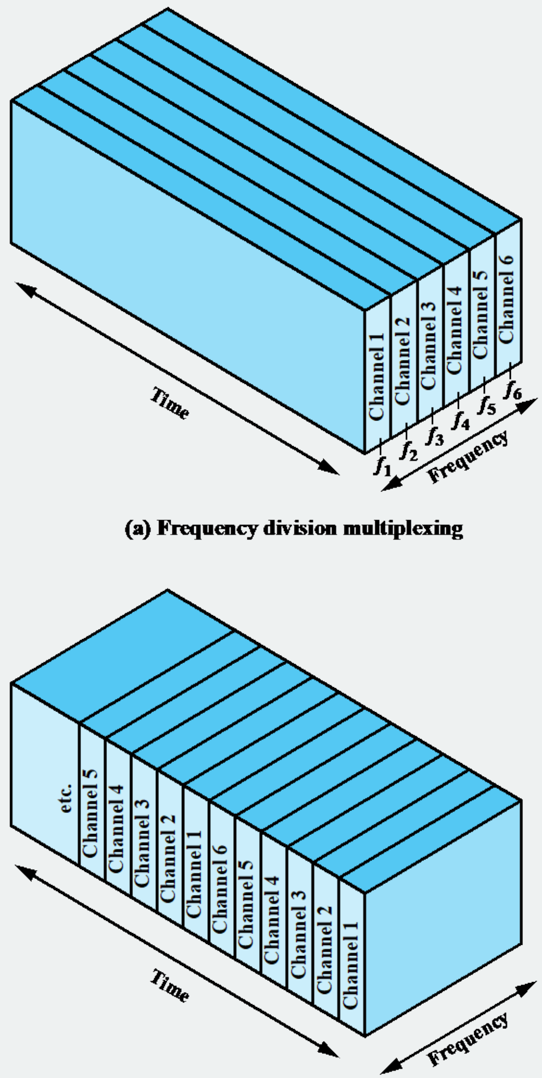
The normal code is the 16 bit CRC-CCITT

Optional 32-bit FCS, using CRC-32, may be employed if the frame length or the line reliability dictates this choice

CHAPTER 8

Multiplexing

Figure 8.1 Multiplexing



(a) Frequency division multiplexing

(b) Time division multiplexing

Figure 8.2 FDM and TDM

시간에 따라 division을 나누는 것.

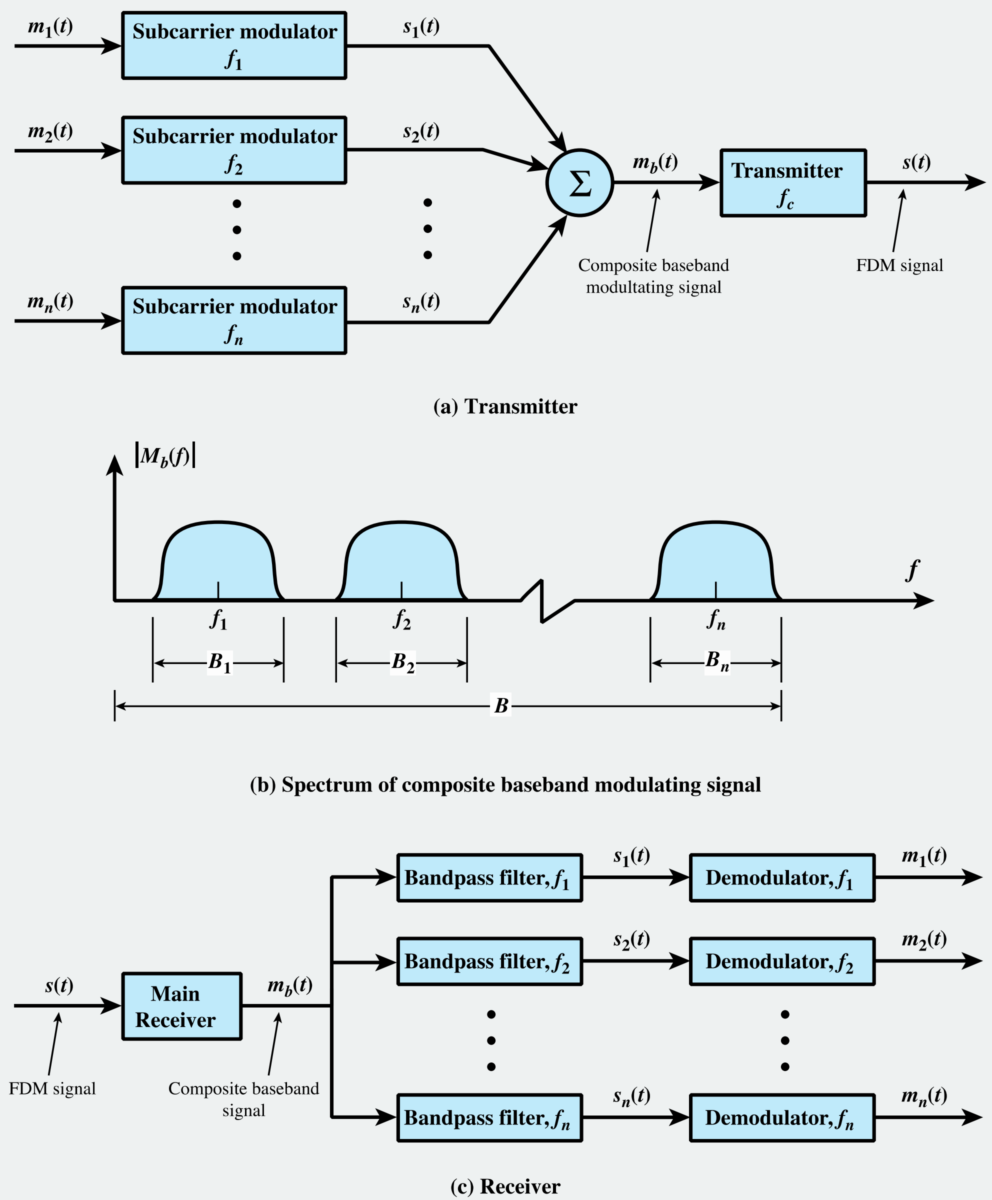


Figure 8.3 FDM System

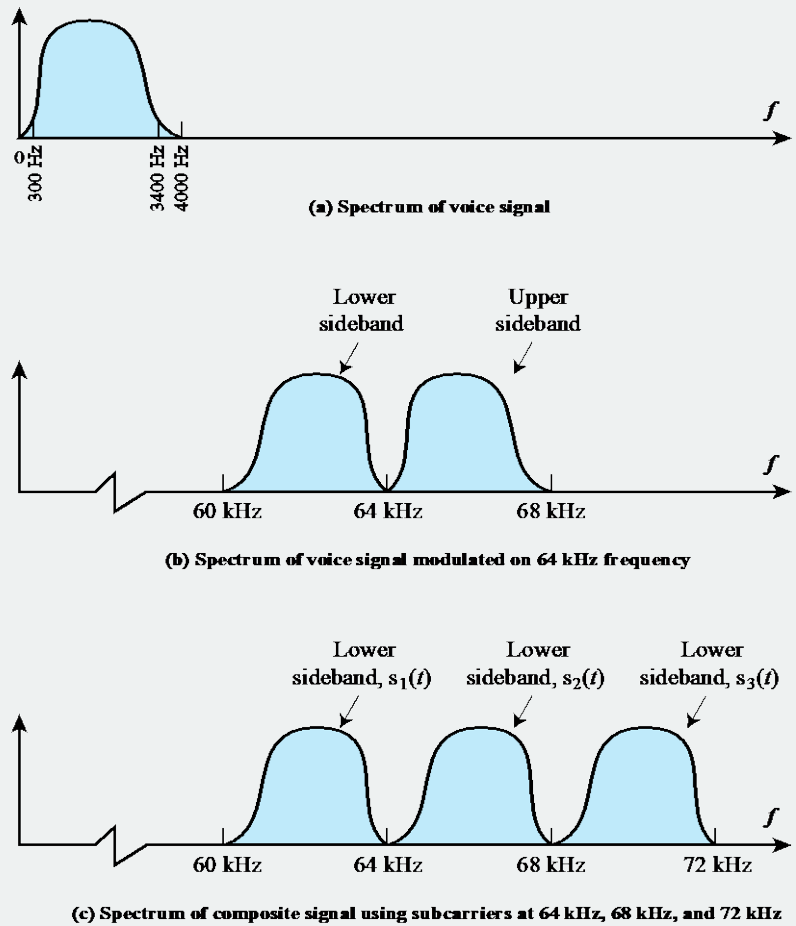


Figure 8.4 FDM of Three Voiceband Signals

Wavelength Division Multiplexing (WDM)

Multiple beams of light at different frequencies

Carried over optical fiber links

- Commercial systems with 160 channels of 10 Gbps
- Lab demo of 256 channels 39.8 Gbps

Architecture similar to other FDM systems

- Multiplexer consolidates laser sources (1550nm) for transmission over single fiber
- Optical amplifiers amplify all wavelengths
- Demultiplexer separates channels at destination

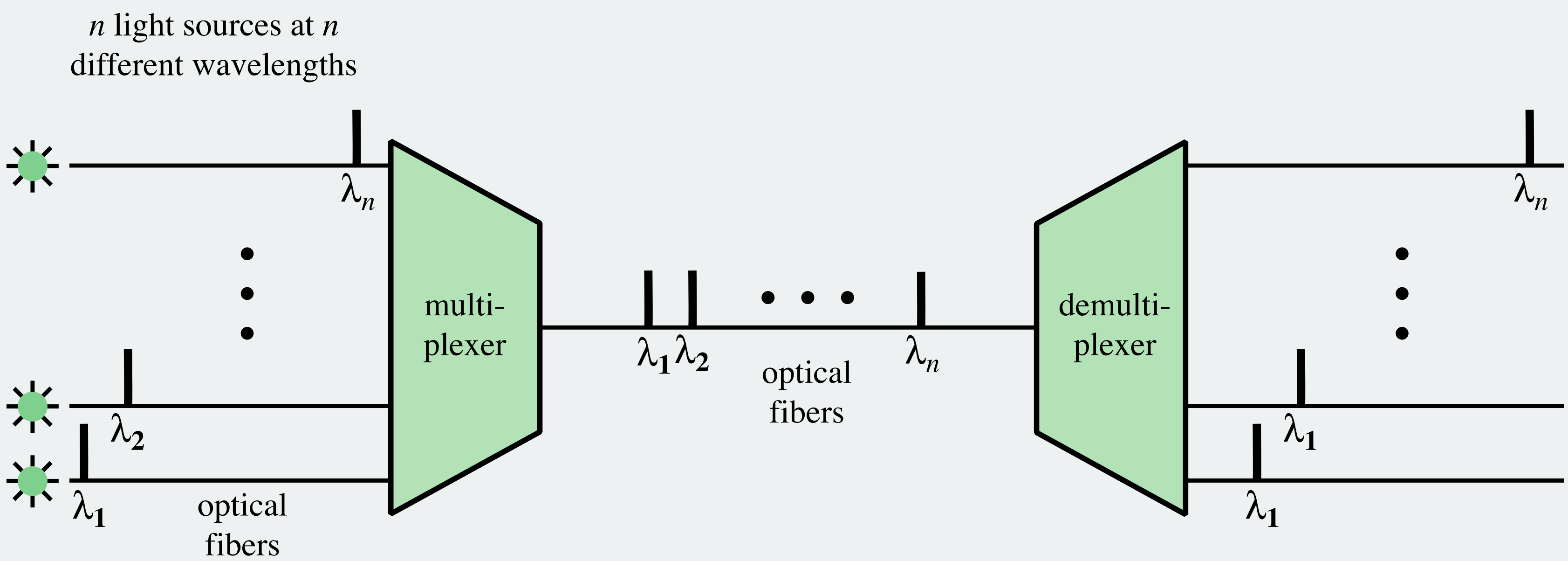


Figure 8.5 Wavelength Division Multiplexing

(a) Configuration

Input$_1$ • • • • • • • • • • • F_1 f_1 f_1 d_1 d_1 d_1 C_1 A_1 F_1 f_1 f_1 d_1 d_1 d_1 C_1 A_1 F_1

Input$_2$ • • • F_2 f_2 f_2 d_2 d_2 d_2 d_2 C_2 A_2 F_2 f_2 f_2 d_2 d_2 d_2 d_2 C_2 A_2 F_2

(b) Input data streams

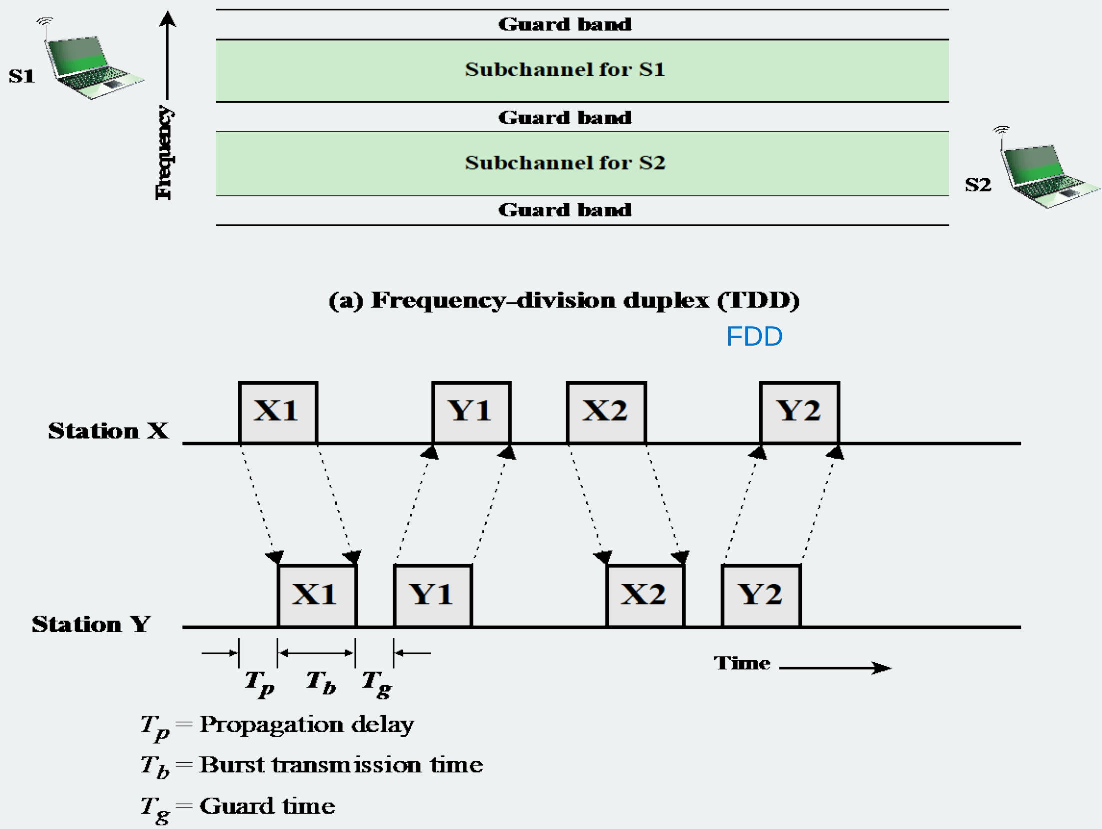
• • • f_2 F_1 d_2 f_1 d_2 f_1 d_2 d_1 d_2 d_1 C_2 d_1 A_2 C_1 F_2 A_1 f_2 F_1 f_2 f_1 d_2 f_1 d_2 d_1 d_2 d_1 d_2 d_1 C_2 C_1 A_2 A_1 F_2 F_1

(c) Multiplexed data stream

Legend:
F = flag field
A = address field
C = control field
d = one octet of data field
f = one octet of FCS field

Figure 8.7 Use of Data Link Control on TDM Channels

-> = uplink
<- = downlink

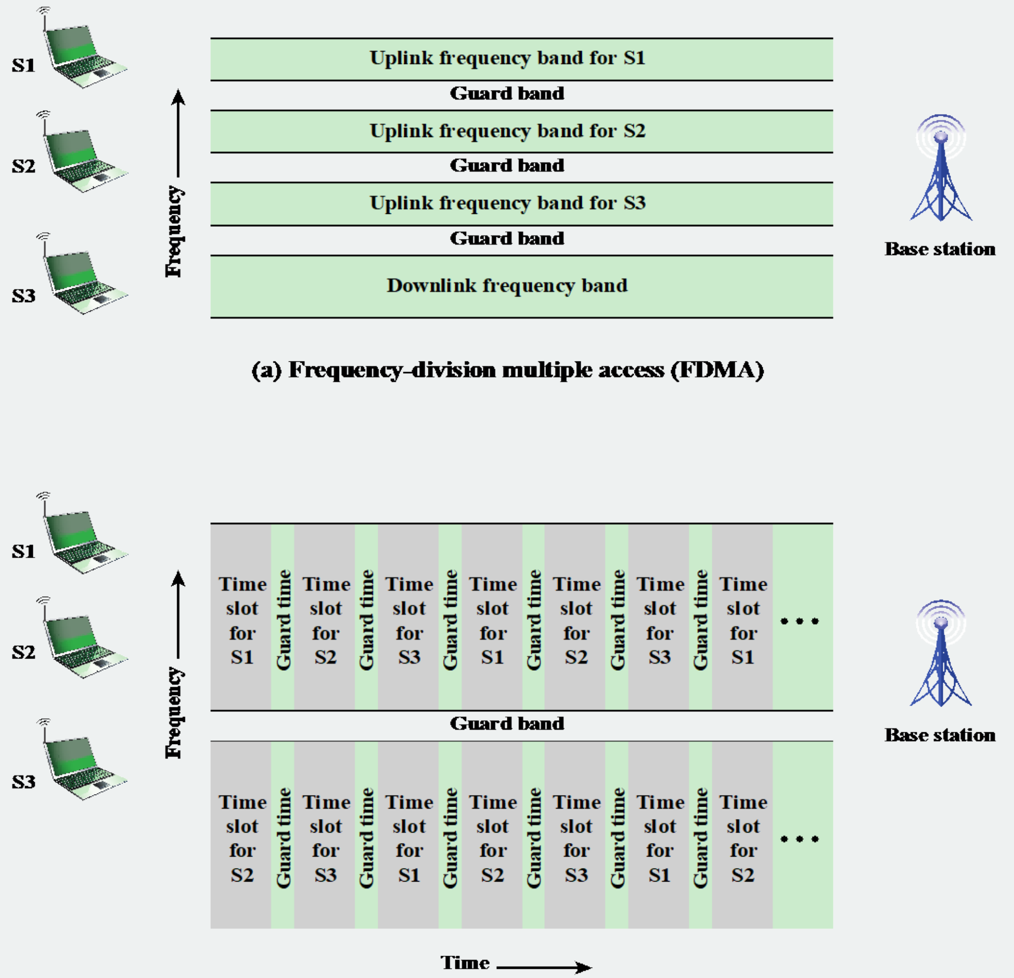


(a) Frequency-division duplex (TDD)

FDD

(b) Time-division duplex (TDD)

Figure 8.18 Duplex Access Techniques



(a) Frequency-division multiple access (FDMA)

(b) Time-division multiple access (TDMA)

Figure 8.19 Multiple Channel Access Techniques