

# *Computer Networks and Communications*

Lecture (05):

**Data Link Control**

## Network Technology

### ▪ **Basic Data Communications Theories**

- Data transmission
- Coding & Modulation
- Multiplexing & Switching
- Transmission Media

### ▪ **Local Area Networks**

- Ethernet and Token Passing Networks

### ▪ **Wide Area Networks**

- ATM and ISDN

### ▪ **Wireless Networks**

- Cellular Networks and Wireless LAN

### ▪ **Residential Area Networks**

- ADSL, Cable TV

# Network Technology

- **Basic Data Communications Theories**

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# Data Link Control

- **Data Link:**

- Sending data over communication link.
- Layer of logic above the physical layer.

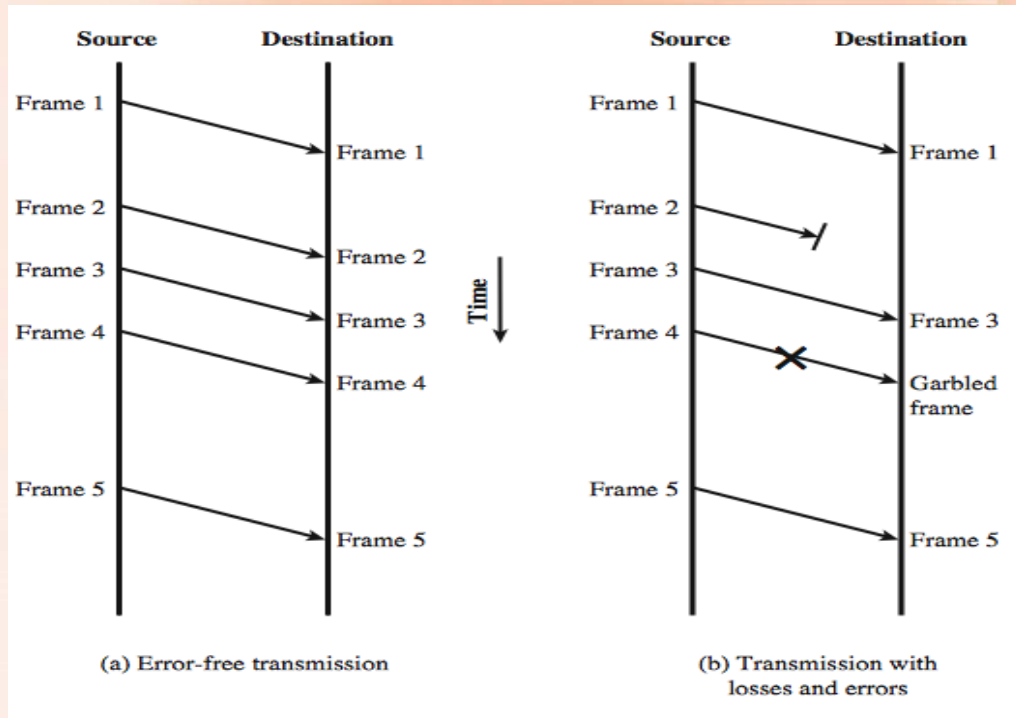
- **Frame Synchronization:** Recognize the beginning and end of data frame.
- **Flow control:** Preventing buffer overflow at the receiver.
- **Error control:** Detecting and correcting transmission errors.
- **Addressing:** Identifying multiple receivers on a multipoint line (e.g. LAN).
- **Link management:** Initiation, maintenance and termination of a sustained data exchange.

# Flow Control & Error Control

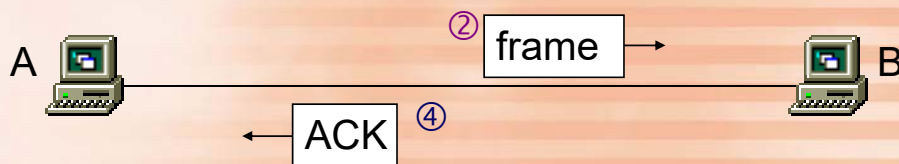
## Flow Control

- Ensuring the sending entity does not overwhelm the receiving entity.
  - Processing at receiver.
  - Preventing buffer overflow.
- Transmission time
  - Time taken to emit all bits into medium
- Propagation time
  - Time for a bit to traverse the link
- Flow control methods
  - Stop-and-Wait
  - Sliding-window

## Model of Frame Transmission



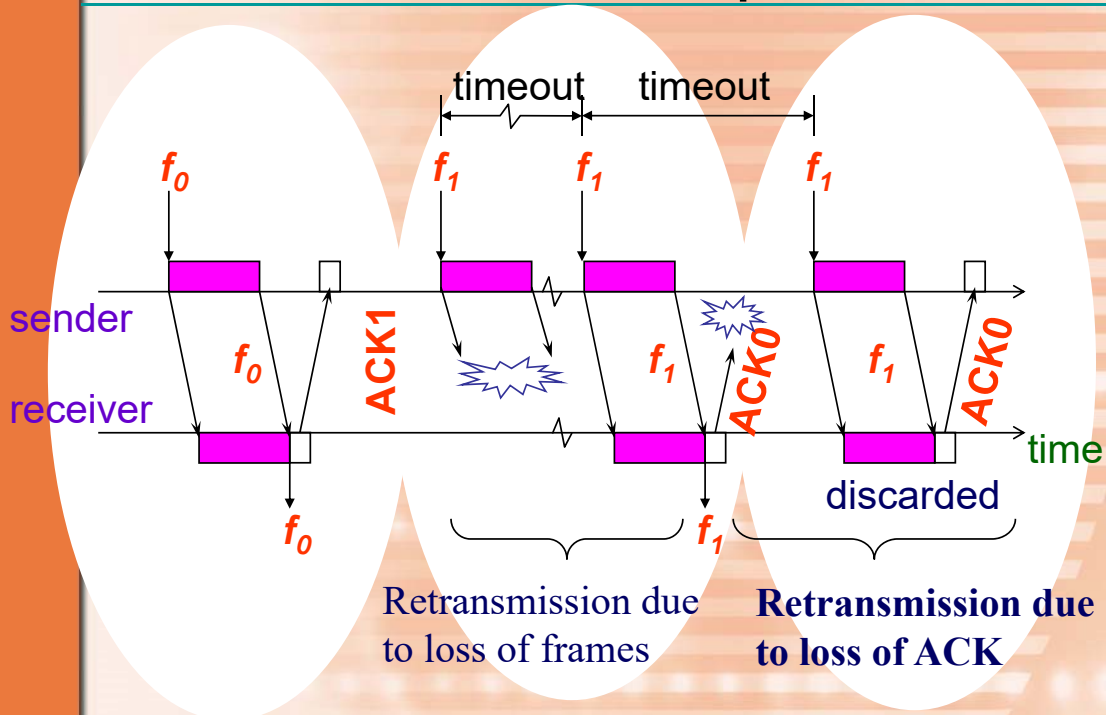
## Flow Control: Stop-and-Wait



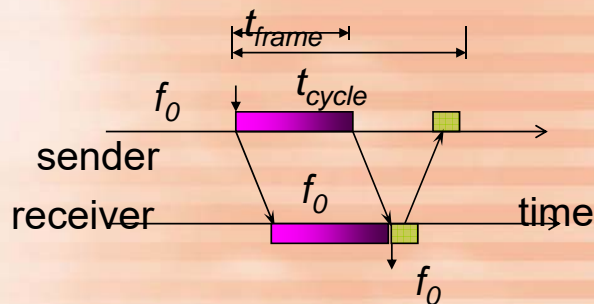
### Operations:

- ① A packs information into a frame.
- ② A sends the frame to B.
- ③ A waits for an ACK.
- ④ When B has received the frame, B sends an ACK.
- ⑤ When A has received the ACK, A repeats ①.

# Flow Control: Stop-and-Wait



# Stop-and-Wait: Performance



The time that the  
 $U$  (Channel Utilization) =  $\frac{\text{channel carries useful information}}{\text{The total time}}$

- Assumptions:
1. Input is saturated
  2. No error
  3. ACK is very short

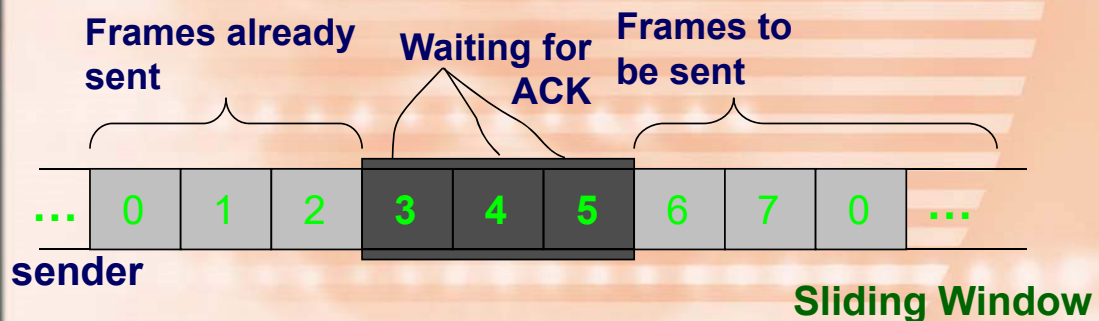
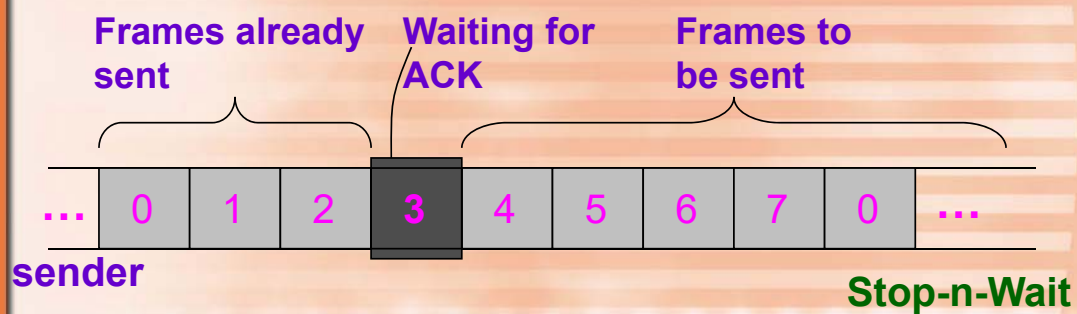
$$U = \frac{1}{1+2a}$$

Normalized propagation delay  $a = \frac{t_{Prop}}{t_{Xframe}}$

# Stop-and-Wait: Performance

- If frame or ACK is lost, long waiting time is expected.
- If the signal propagation time is long, the sender must wait a long time before it can transmit the next frame.
- Works well for a few large frames.
- Only one frame at a time can be in transit
- Fragmentation: Splitting large block of data into small frames.
  - Limited buffer size.
  - Errors detected sooner (when a frame is received).
  - On error, only a small frame(s) needs to be retransmitted.
  - Prevents one station occupying medium for long periods.

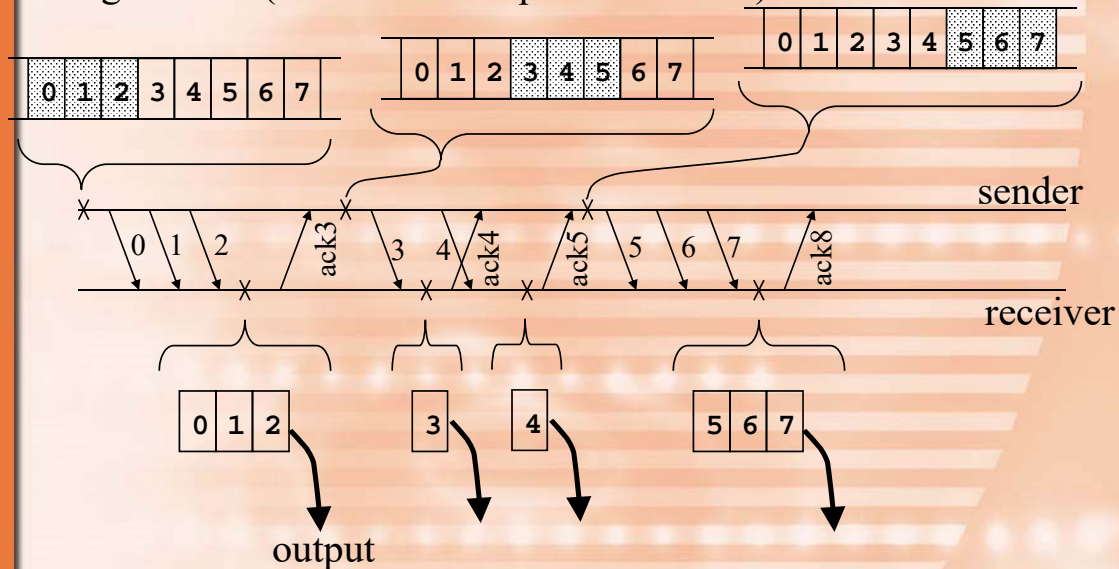
# Flow Control: Sliding Window



# Sliding Window: Operations

Window Size,  $N = 3$

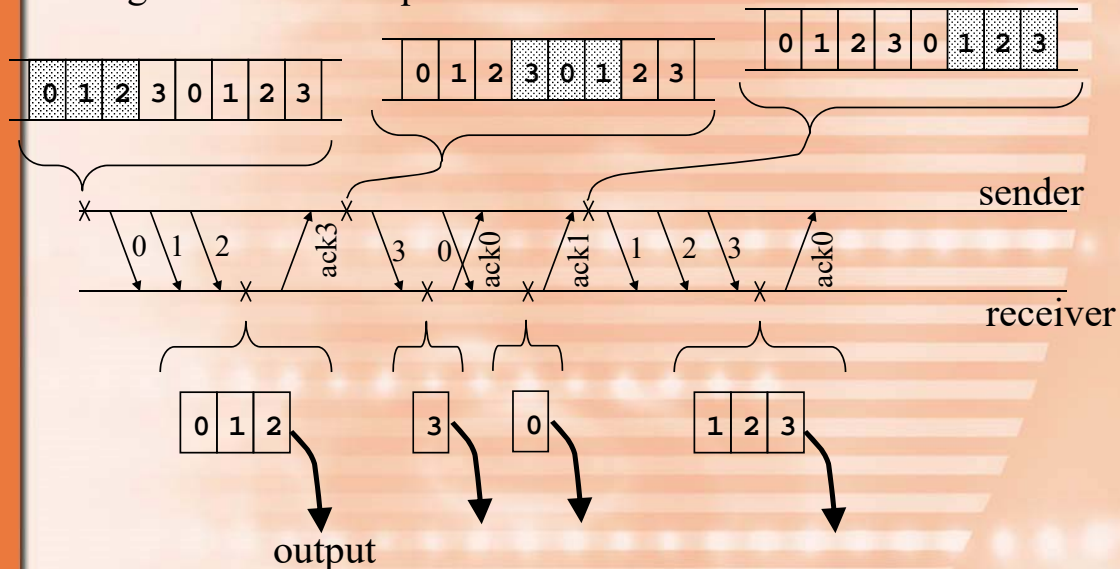
Using  $0 \dots 255$  ( $k=8$  bits for sequence number) to label frames



# Sliding Window: Operations

Window Size,  $N = 3$

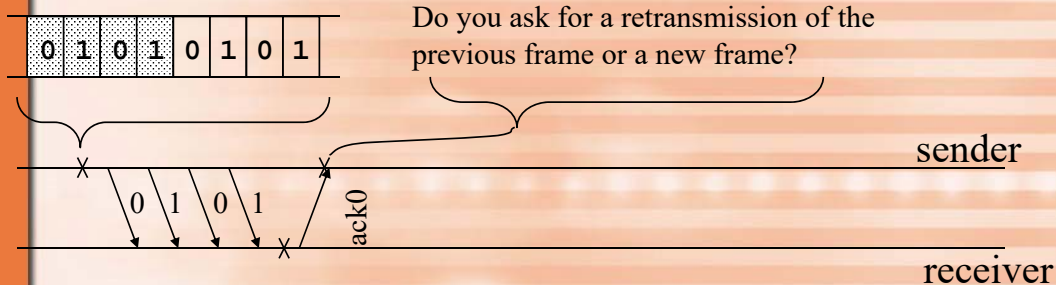
Using  $k=2$  bits for sequence number



# Sliding Window: Operations

Window Size,  $N = 4$

Using  $k=1$  bit for sequence number



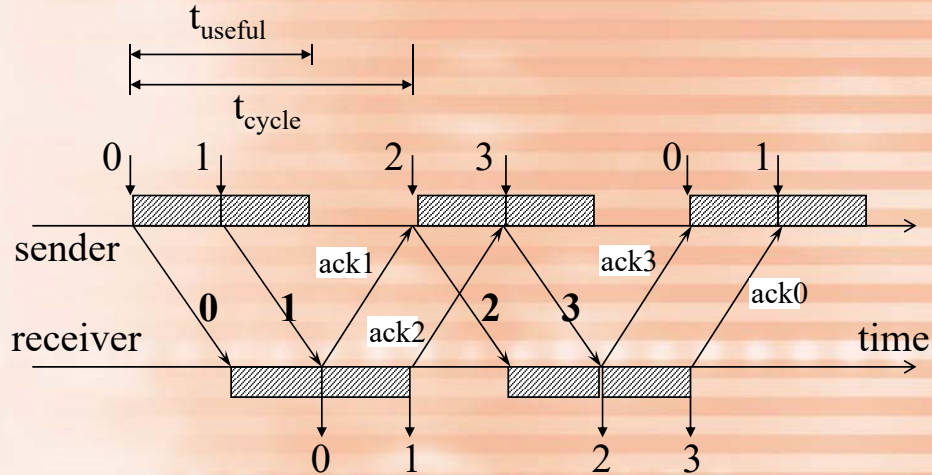
- Is the second **0** a new frame or the retransmitted frame?
- Which frame is to be transmitted next after receiving ack?

**Hence Window Size  $N < 2^k$**

# Sliding Window: Operations

- Allow multiple frames to be in transit at a time.
- Receiver has to buffer  $N$  frames long.
- Transmitter can send up to  $N$  frames without ACK.
- Each frame is numbered - sequence number.
- ACK includes number of next frame expected.
  - Indicates the readiness for next  $N$  frames from the specified number.
- Multiple frames may be acknowledged at one time.
- Sequence number is bounded by the size of the field used to transmit ( $k$ -bits).
  - Frames are numbered modulo  $2^k$ .

# Sliding Window: Performance



Window Size =  $N$

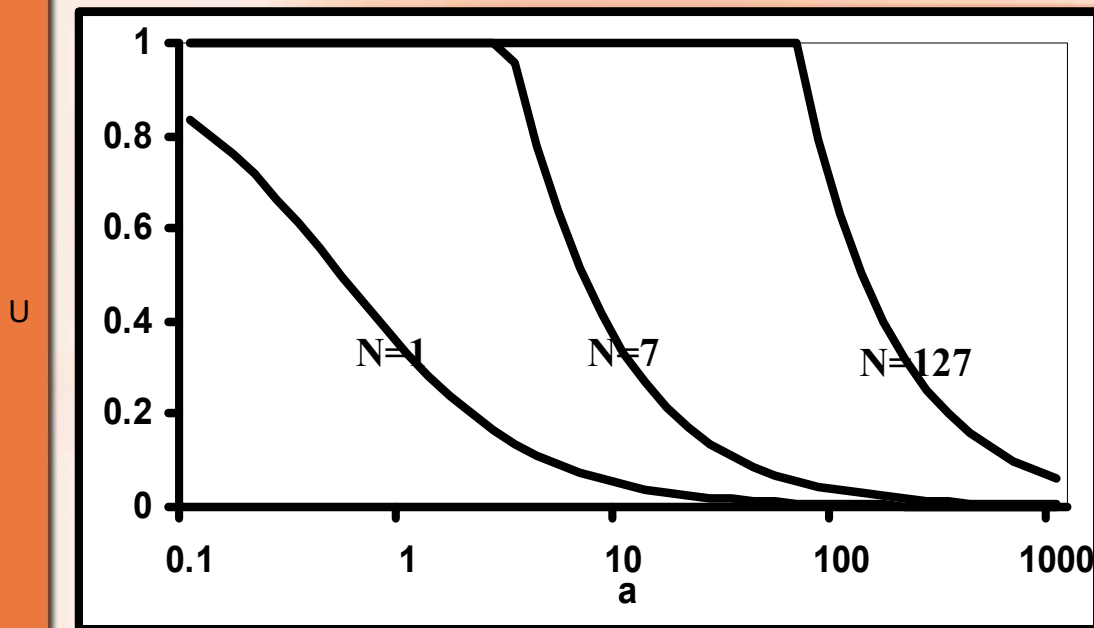
$$t_{\text{useful}} = N * t_{\text{frame}}$$

$$t_{\text{cycle}} = t_{\text{frame}} + 2 * t_{\text{prop}}$$

$$U = \frac{N}{1 + 2a} \text{ for } N < 2a + 1$$

$$= 1 \text{ for } N \geq 2a + 1$$

# Channel Utilization

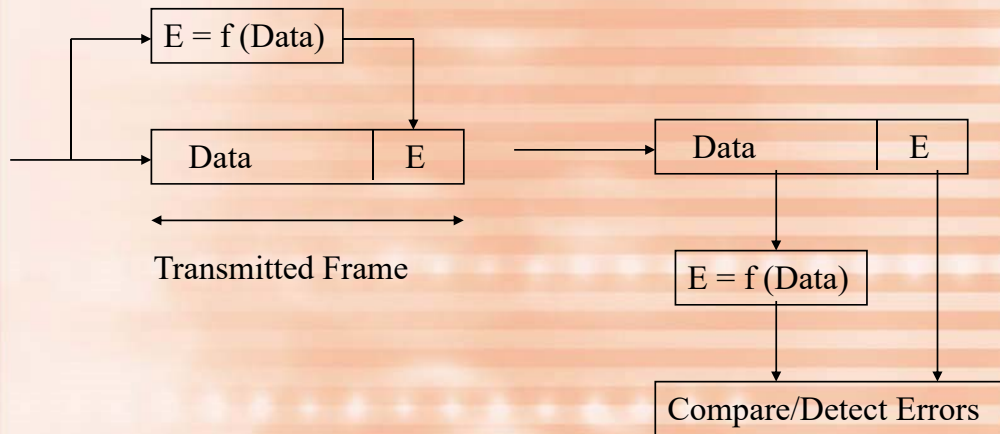


$N$ =window size

$$a = T_p/T_x$$

# Error Detection

- Additional bits added by transmitter for error detection code.



- Error detection schemes:
  - Parity Check.
  - Cyclic Redundancy Check (CRC).

# Parity Check

- Value of parity bit is such that character has even (even parity) or odd (odd parity) number of ones.

1 0 0 1 1 0    ?

• 10011010 – Even parity

• 10011011 – Odd parity

- Even number of bit errors goes undetected.

Even Parity

1 0 0 1 1 0 1 0

1 0 1 1 1 0 1 0

single bit error

Message corrupted

double bits error

1 0 1 1 1 0 0 0

No errors

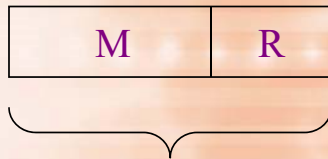
# Cyclic Redundancy Check (CRC)

- For a block of  $m$  bits transmitter generates  $n$  bit sequence, which is exactly divisible by some number.
- Receiver divides frame by that number
  - If no remainder, assume no error

M = Message ( $m$  bits)

R = Redundant information ( $r$  bits)

T = Transmitted data ( $n$  bits) ie.  $n = m + r$



this  $n$  bits frame is  
used for transmission

Example:

M = 11101

G = 1001 (generator)

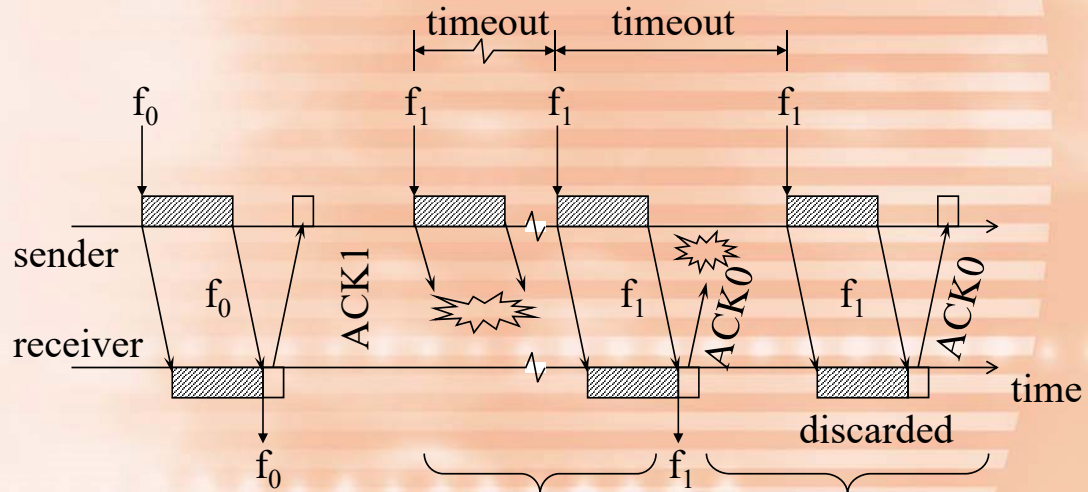
R = 110 (CRC size = 3 bits)

$\therefore T = \underline{11101} \underline{110}$   
M R

# Flow control & Error Control

- Automatic Repeat Request (ARQ):
  - Error detection (lost frames and damaged frames).
  - Flow control.
  - Positive acknowledgements.
  - Retransmission after timeout.
  - Negative acknowledgement and retransmission.
- ARQ schemes.
  - Stop-and-Wait.
  - Go-back-N (retransmission from error frame).
  - Selective Repeat (selective retransmission).
- ARQ efficiency:
  - Unnecessary waiting and sending unnecessary transmission.

# ARQ: Stop-and-Wait



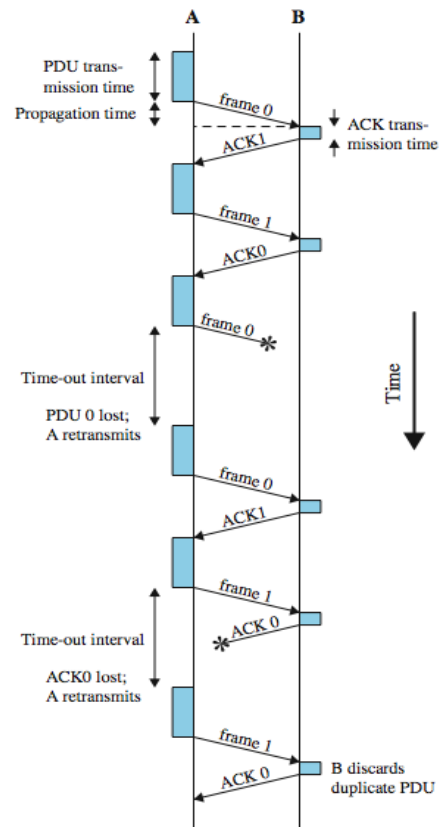
- Based on stop-and-wait flow control method.

# ARQ: Stop-and-Wait

- Source transmits single frame.
- Wait for ACK.
- If received frame damaged, discard it.
  - Transmitter has timeout.
  - If no ACK within timeout, retransmit.
- If ACK damaged, transmitter will not recognize it.
  - Transmitter will retransmit.
  - Receiver gets two copies of frame.
  - Use  $ACK0$  &  $ACK1$  (or  $ACK$  &  $NAK$ ) frames..
- Frames received in order.
- Receiver buffer size = 1.
- Simple but inefficient.

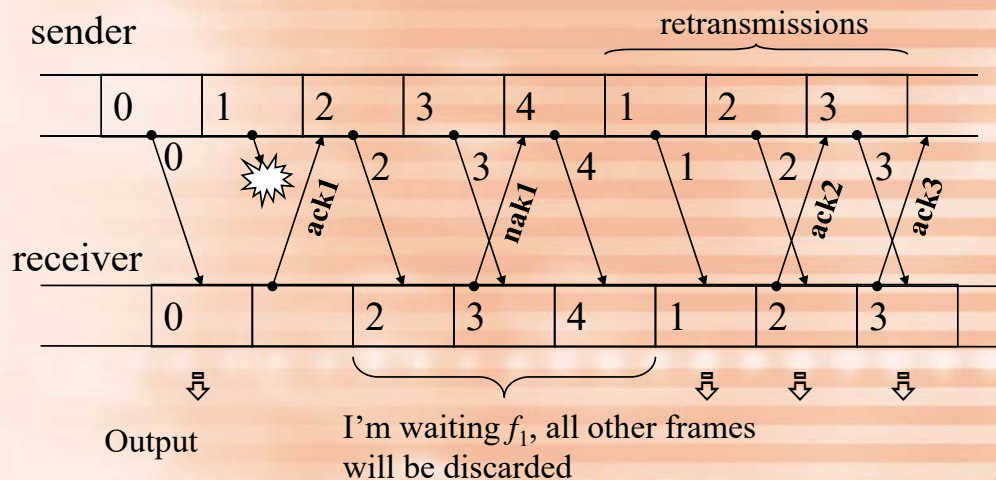
# Stop and Wait

- see example with both types of errors
- pros and cons
  - simple
  - inefficient



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# ARQ: Go-back-N



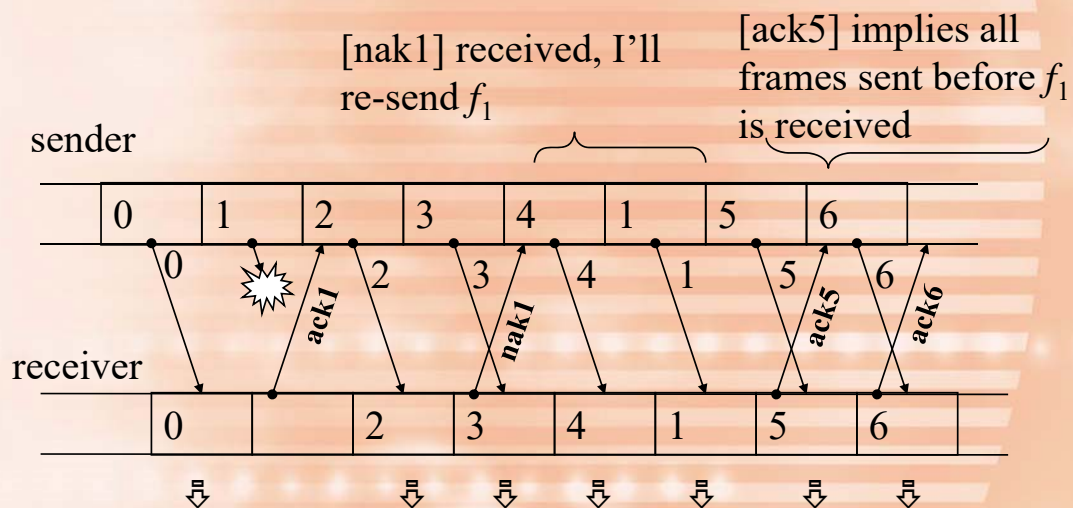
- Based on sliding window flow control method.
- Used in various standards: HDLC, SDLC, LAPB & ADCCP.
- Successive packets can be sent without waiting for an ACK.
- Buffer size = 1.

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# ARQ: Go-back-N

- Based on sliding window.
- If no error, ACK as usual with next frame expected.
- Use window to control number of outstanding frames.
- If error, reply with rejection:
  - Discard that frame and all future frames until error frame received correctly.
  - Transmitter must go back and retransmit that frame and all subsequent frames.
- For a damaged frame:
  - Receiver detects error in frame  $i$ .
  - Receiver sends rejection- $i$ .
  - Transmitter gets rejection- $i$ .
  - Transmitter retransmits frame  $i$  and all subsequent frames.
- Frames received in order.

# ARQ: Selective Repeat

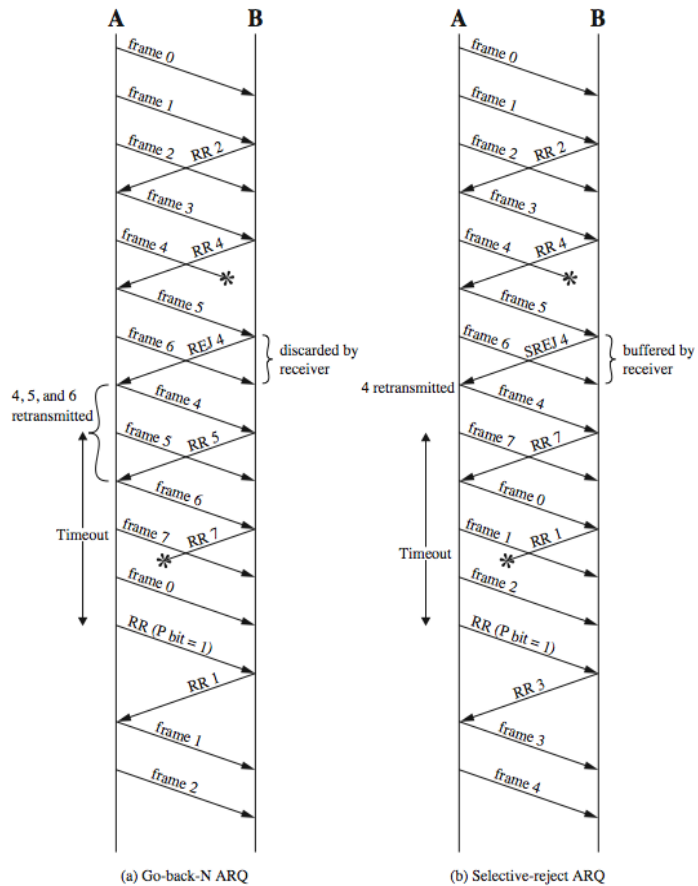


- Based on sliding window flow control method.
- Receiver must be equipped with enough buffer to hold all frames.
- Buffer size = N.

# ARQ: Selective Repeat

- 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.
- More efficient than Go-back-N, but by not very significant for small error probability.
- Selective Repeat has less applications than Go-back-N.

## Go Back N VS Selective Reject



# ARQ: Performance

- Frame Error Probability =  $P$ 
  - If  $P=0.1$ , it is expected that 1 out of 10 transmitted frames will be corrupted.

**Stop-and-Wait:** 
$$U = \frac{1 - P}{1 + 2a}$$

**Selective Repeat:** 
$$U = \begin{cases} 1 - P & , N \geq 2a + 1 \\ \frac{N(1 - P)}{1 + 2a} & , N < 2a + 1 \end{cases}$$

**Go-back-N:** 
$$U = \begin{cases} \frac{1 - P}{1 + 2aP} & , N \geq 2a + 1 \\ \frac{N(1 - P)}{(1 + 2a)(1 - P + NP)} & , N < 2a + 1 \end{cases}$$

- Assumption: ACK, NAK will never be corrupted.

# High Level Data Link Control (HDLC)

- ISO 33009 and ISO 4335.
- Widely used and basis for many other DLC protocols.
- Define three types of stations, two link configurations and three data transfer modes of operations.
- Three station types:
  - Primary station:
    - Controls operation of link.
    - Frames issued are called commands.
    - Maintains separate logical link to each secondary station.
  - Secondary station:
    - Under control of primary station.
    - Frames issued called responses.
  - Combined station:
    - May issue commands and responses.

# HDLC Link Configurations

- Two link configurations:
  - Unbalanced:
    - One primary and one or more secondary stations.
    - Supports full duplex and half duplex.
  - Balanced
    - Two combined stations.
    - Supports full duplex and half duplex.

# HDLC Transfer Modes

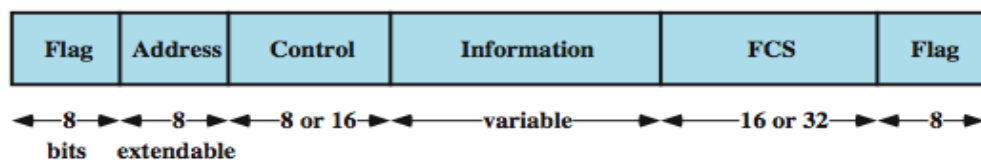
- Normal Response Mode (NRM):
  - Unbalanced configuration.
  - Primary initiates transfer to secondary.
  - Secondary may only transmit data in response to command from primary.
  - Used on multi-drop lines (Host computer as primary and Terminals as secondary).
  - Sometimes used on point-to-point links.
- Asynchronous Balanced Mode (ABM)
  - Balanced configuration.
  - Either station may initiate transmission without receiving permission.
  - Most widely used (full-duplex point-to-point).
  - No polling overhead.

# HDLC Transfer Modes

- Asynchronous Response Mode (ARM):
  - Unbalanced configuration.
  - Secondary may initiate transmission without permission from primary.
  - Primary is responsible for line (initializations, error recovery and logical disconnection).
  - Rarely used.

# HDLC: Frame Structure

- Synchronous transmission.
- All transmissions in frames.
- Single frame format for all data and control exchanges.



(a) Frame format

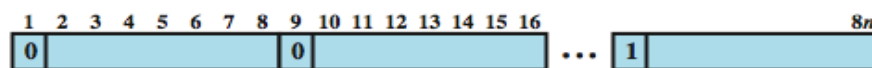


# HDLC: Flag Fields

- Delimit frame at both ends.
- Unique pattern: 01111110.
- Single flag may close one frame and open another.
- Receiver hunts for flag sequence to synchronize to the start of a frame.
- Bit stuffing used to avoid confusion with data containing 01111110.
  - 0 inserted after every sequence of five 1s.
  - If receiver detects five 1s it checks next bit.
  - If 0, it is deleted.
  - If 1 and seventh bit is 0, accept as flag.
  - If sixth and seventh bits are 1, sender is indicating an abort condition.

# HDLC: Address Field

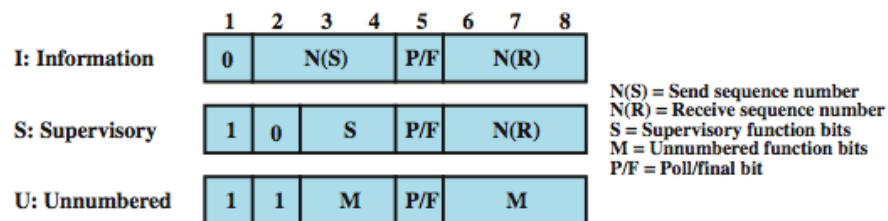
- Identifies secondary station that transmitted or is to receive the frame.
- Not required for point-to-point links but always included.
- Usually 8 bits long.
- May be extended to multiples of 8 bits.
  - Left most bit of each octet indicates that it is the last octet (1) or not (0).
  - Remaining 7 bits of each octet form part of the address.
- All ones (11111111) is broadcast.



(b) Extended Address Field

# HDLC: Control Field

- Three different formats for different frame types.
  - Information:
    - - data to be transmitted to user (next layer up).
    - - flow and error control piggybacked on information frames.
  - Supervisory: ARQ when piggyback not used.
  - Unnumbered: supplementary link control.
- First one or two bits of control field identify frame type.



(c) 8-bit control field format

# HDLC: Information Field

- Only in information and some unnumbered frames.
- Must contain integral number of octets.
- Variable length to some system defined maximum.

## HDLC: Frame Check Sequence (FCS) Field

- Error detecting code calculated from the remaining bits of the frame (exclusive of flags).
- Normal code is 16-bit CRC-CCITT.
- Optional 32 bit CRC-32.

## Other DLC Protocols

- Link Access Procedure, Balanced (LAPB):
  - Part of X.25 packet-switching network (ITU-T).
  - Subset of HDLC using only ABM
  - Point to point link between a system and a packet switching network node.
  - Frame format is same as HDLC.
- Link Access Procedure, D-Channel (LAPD):
  - Defined by ITU-T as a part of recommendations on ISDN.
  - Always use ABM with 7-bit sequence number (no 3-bit).
  - 16-bit address field contains two sub-addresses:
    - One for the device and one for the user (next layer up).

## Other DLC Protocols

- Logical Link Control (LLC):
  - Part of the IEEE 802 LAN family.
  - Different frame format from HDLC.
  - Link control functions are divided between medium access layer (MAC) and LLC layer (on top of MAC).
  - No primary and secondary: All stations are peers.
  - Two addresses needed: Sender and receiver.
  - Error detection at MAC layer: 32-bit CRC
  - At LLC layer, destination and source access points (DSAP, SSAP) to identify logical user of LLC.
  - LLC control field uses the same format as HDLC with 7-bit sequence numbers.

## Other DLC Protocols: Frame Relay

- Streamlined capability over high speed packet switched networks.
- Used in place of X.25.
- Uses Link Access Procedure for Frame-Mode Bearer Services (LAPF). Two protocols:
  - Control:
    - similar to HDLC.
    - uses ABM with 7-bit sequence numbers (like LAPB).
    - 16 bit CRC.
  - Core:
    - subset of control.
    - 2, 3 or 4 octet address field.
- LAPF core has no control field: no flow and error control, but is more streamlined operation.

## Other DLC Protocols: ATM

- Asynchronous Transfer Mode (ATM)
- Streamlined data transfer capability across high speed networks.
- Not HDLC based.
- Frame format called “cell” (provides minimum processing overhead).
- Fixed 53 octet (424 bit).

# Required Reading

**Data and Computer Communications,  
10<sup>th</sup> Edition by William Stallings,  
(c) Pearson Education - Prentice Hall, 2013**

**>> Chapter 7 –**

**Data Link Control Protocol**