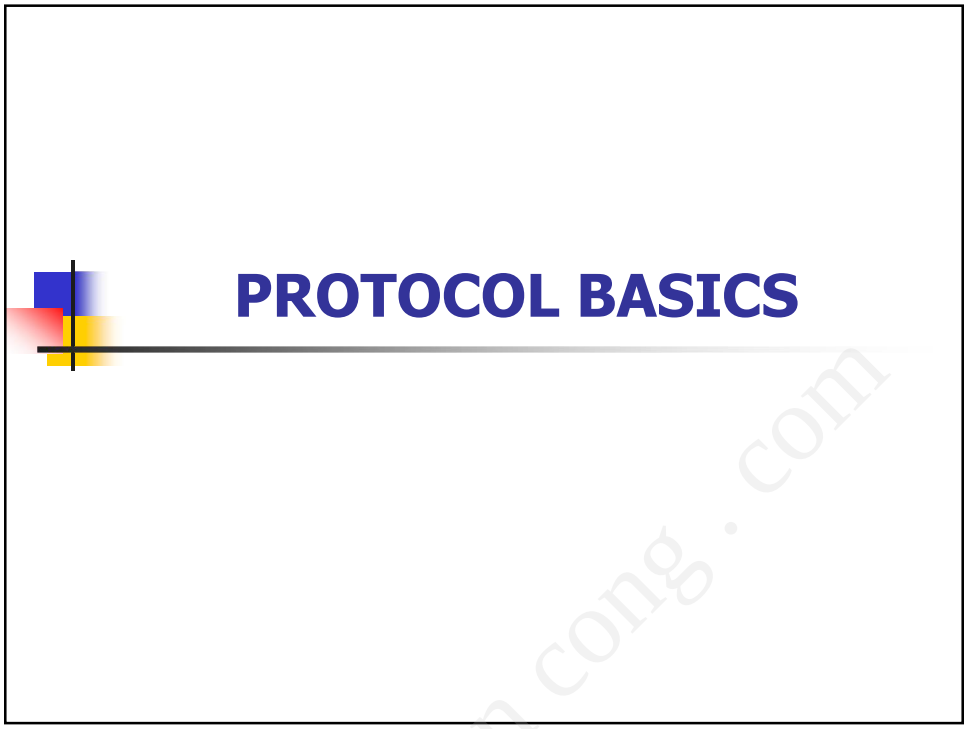
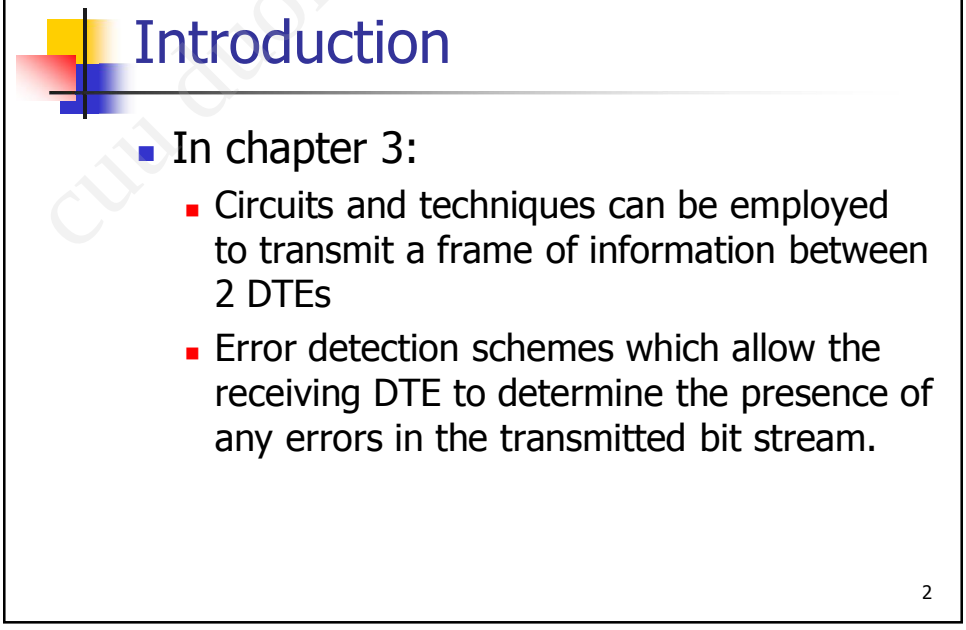


## Introduction

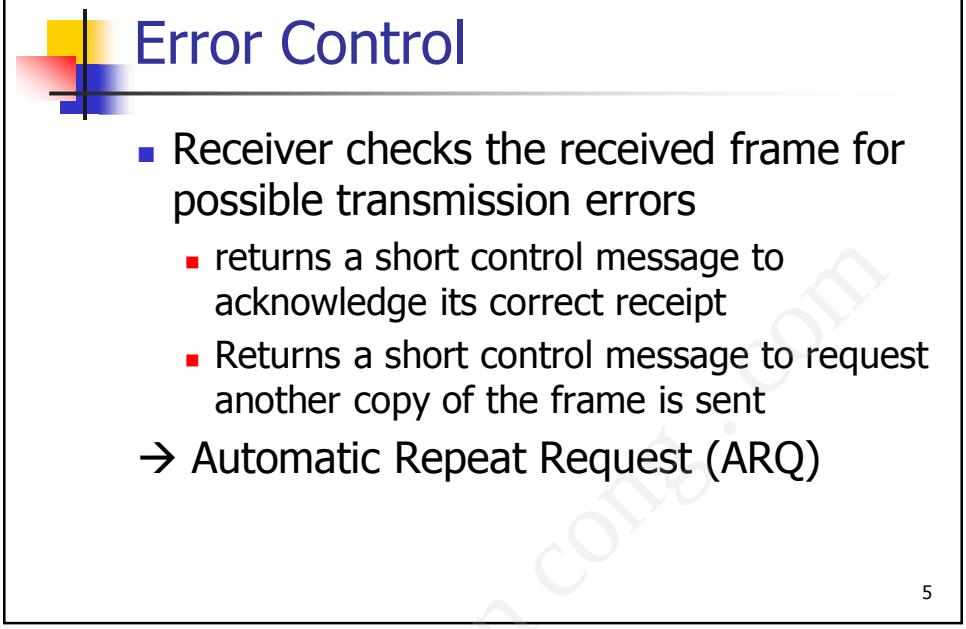
- Best-try transmission: when a transmission error is detected, the complete data block must be discard →connectionless mode transmission
- Reliable transmission: in addition to detecting when errors are present, a defined set of rules or control procedures must be adopted by both communicating parties to ensure the reliable transfer of message → connection mode transmission

3

## Introduction

- Data link control protocol:
  - The combined error detection/correction cycle is known as error control
  - Control mechanism (flow control and connection management) observed by two communicating parties
- Basic components of data link control protocols will be considered in this chapter

4

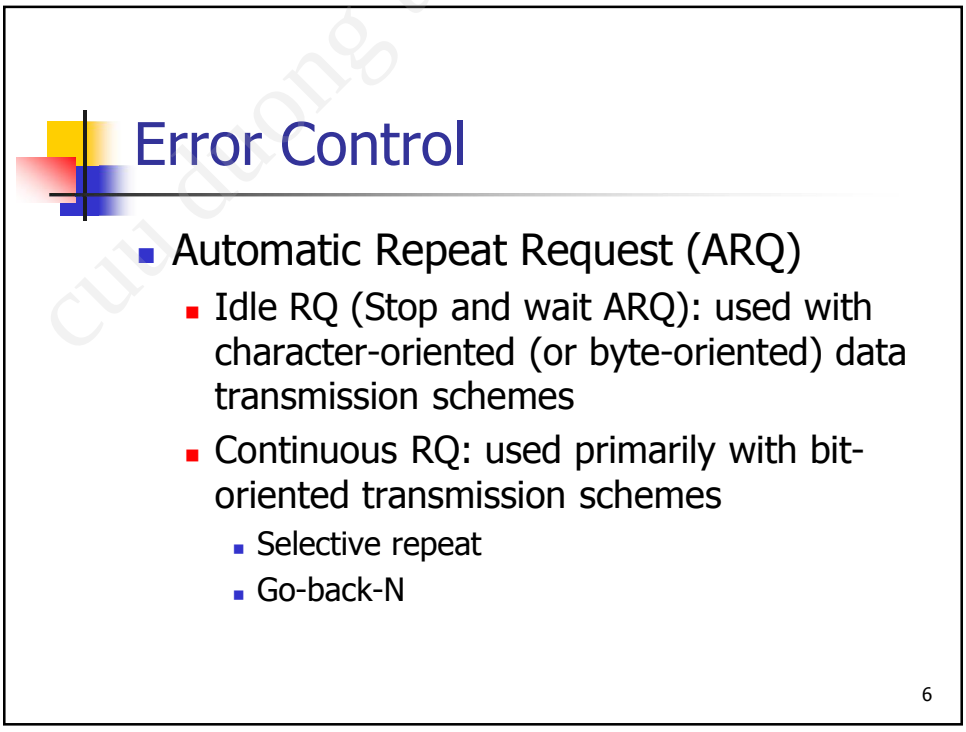


## Error Control

- Receiver checks the received frame for possible transmission errors
  - returns a short control message to acknowledge its correct receipt
  - Returns a short control message to request another copy of the frame is sent

→ Automatic Repeat Request (ARQ)

5



## Error Control

- Automatic Repeat Request (ARQ)
  - Idle RQ (Stop and wait ARQ): used with character-oriented (or byte-oriented) data transmission schemes
  - Continuous RQ: used primarily with bit-oriented transmission schemes
    - Selective repeat
    - Go-back-N

6

## Idle RQ (stop and wait ARQ)

- The idle RQ control scheme has been defined to enable blocks (frames) of printable and formatting control characters to be reliably transferred
- In idle RQ
  - The sender (source): primary (P)
  - The receiver (destination): secondary (S)
  - Information frames: I-frames

7

## Idle RQ (stop and wait ARQ)

- The idle RQ protocols operates in a half-duplex mode since the primary, after sending and I-frame, must wait until it receives and indication from the secondary as to whether the frame was correctly received or not
- 2 ways of implementing this scheme:
  - Implicit retransmission
  - Explicit retransmisison

8

## Idle RQ (stop and wait ARQ)

- Implicit retransmission: S acknowledges only correctly received frame and P interprets the absence of an acknowledgement as an indication that the previous frame was corrupted

9

## Idle RQ (stop and wait ARQ)

- Implicit retransmission:
  - P can have only one I-frame outstanding (awaiting an acknowledgement frame or ACK-frame) at a time
  - One receipt of an error-free I-frame, S returns an ACK frame to P
  - One receipt of an error-free ACK frame, P can transmit another I-frame
  - When P initiate the transmission of an I-frame it starts a timer

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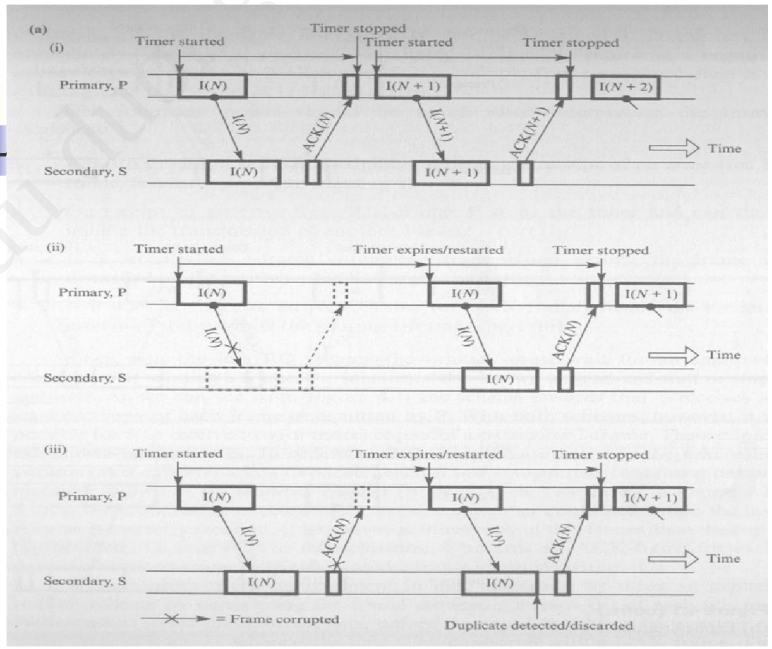
# Idle RQ (stop and wait ARQ)

- Implicit retransmission:
  - If S receives an I-frame or P receives an ACK frame containing transmission errors, the frame is discarded
  - If P does not receive an ACK frame within a predefined time interval (the timeout interval), then P retransmits the waiting I-frame
  - If an ACK frame is corrupted, then S receives another copy of the frame and hence this is rejected by S

11




12

## Idle RQ (stop and wait ARQ)

- Explicit request: when S detects that a frame has been corrupted, it returns a negative acknowledgement to request that another copy of the frame is transmitted

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## Idle RQ (stop and wait ARQ)

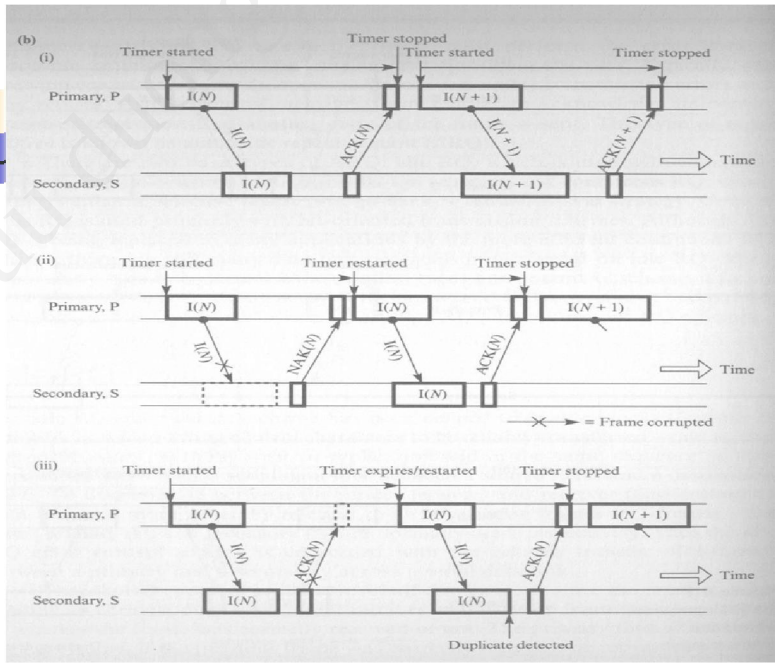
- Explicit request
  - On receipt of an error-free I-frame, S returns an ACK-frame to P
  - On receipt of an error-free ACK-frame, P stops the timer and can initiate the transmission of another I-frame

14

# Idle RQ (stop and wait ARQ)

- Explicit request
  - If S receives an I-frame containing transmission errors, the frame is discarded and it returns a NAK-frame
  - If P does not receive an ACK-frame (or NAK-frame) within the timeout interval, P retransmits the waiting I-frame

15




16

## Idle RQ (stop and wait ARQ)

- The scheme ensure that S receives at least one copy of each frame transmitted by P
- It is possible for S to receive two (or more) copies of a particular I-frame – known as duplicates

→ S must discriminate between the next valid I-frame and a duplicate

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## Idle RQ (stop and wait RQ)

- To discriminate between the next valid I-frame and a duplicate:
  - Each frame transmitted contains a unique identifier known as sequence number
  - S must retain a record of the sequence number contained within the last I-frame it correctly received
  - If S receives another copy of this frame, the copy is discarded
  - To enable P to resynchronize, S returns an ACK-frame for each correctly received frame with the related I-frame identifier within it

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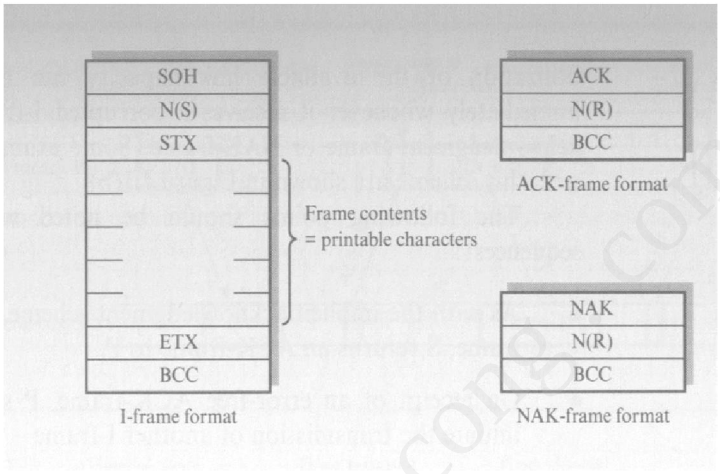
# Idle RQ (stop and wait ARQ)




19

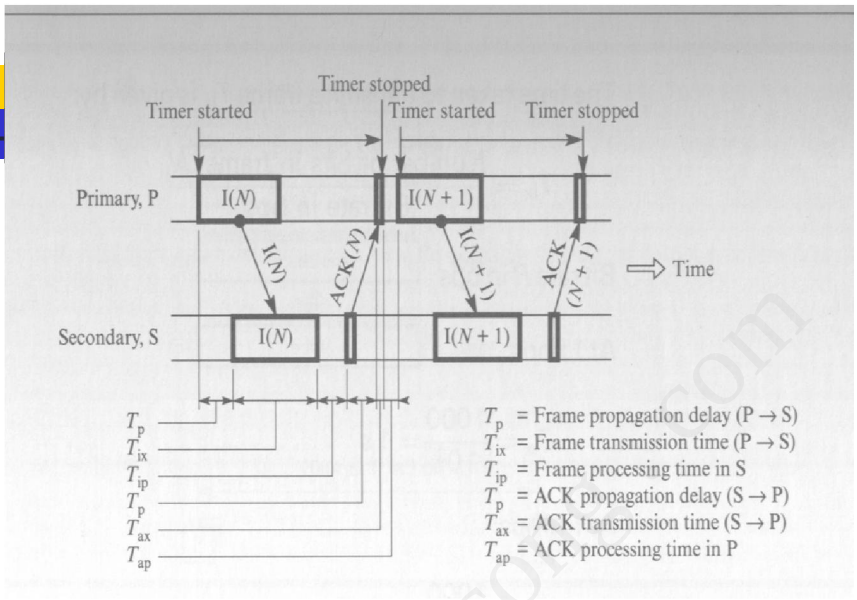
# Idle RQ (stop and wait ARQ)

- Link utilization:
  - The efficiency of utilization $U$ is a ratio of two times, each measured from the point in time the transmitter starts to send a frame

$$U = \frac{T_{ix}}{T_t}$$

  - $T_{ix}$ is the time for transmitter to transmit a frame
  - $T_t$ equals $T_{ix}$ plus any time the transmitter spends waiting for an acknowledgement

20




21

# Idle RQ (stop and wait ARQ)

- Error-free: no transmission errors
  - $T_p$ is propagation delay
  - $T_{ix}$ is frame transmission time
  - $T_{ip}$ is the time to process an I-frame
  - $T_{ax}$ is ACK transmission time
  - $T_{ap}$ is the time to process an ACK-frame
  - Assume $T_{ip}$, $T_{ax}$, $T_{ap}$ << $T_{ix}$, $T_p$

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## Idle RQ (stop and wait ARQ)

$$U = \frac{T_{ix}}{T_{ix} + 2T_p} = \frac{1}{1 + 2\,T_p / T_{ix}}$$

$$U = \frac{1}{1 + 2a} \quad \text{with} \quad a = \frac{T_p}{T_{ix}}$$

23

## Idle RQ (stop and wait ARQ)

- Errors occurs in transmission
  - $N_r$ is an average transmission attempts will be required to transmit a frame successfully
  - $P_f$ is the probability that a frame is received with errors

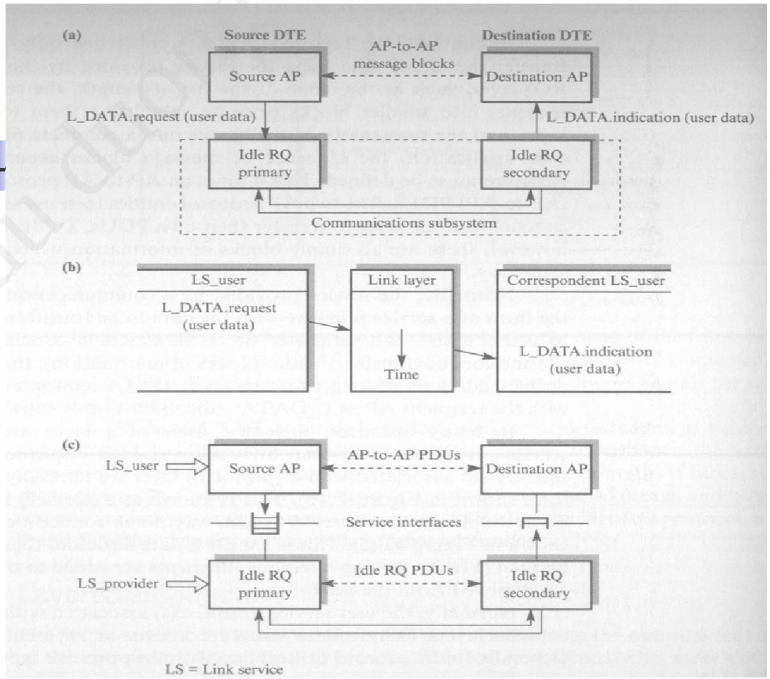
$$N_r = \frac{1}{1 - P_f}$$

24

# Idle RQ (stop and wait ARQ)

$$U = \frac{1}{N_r(1+2a)} = \frac{1-P_f}{1+2a}$$

25

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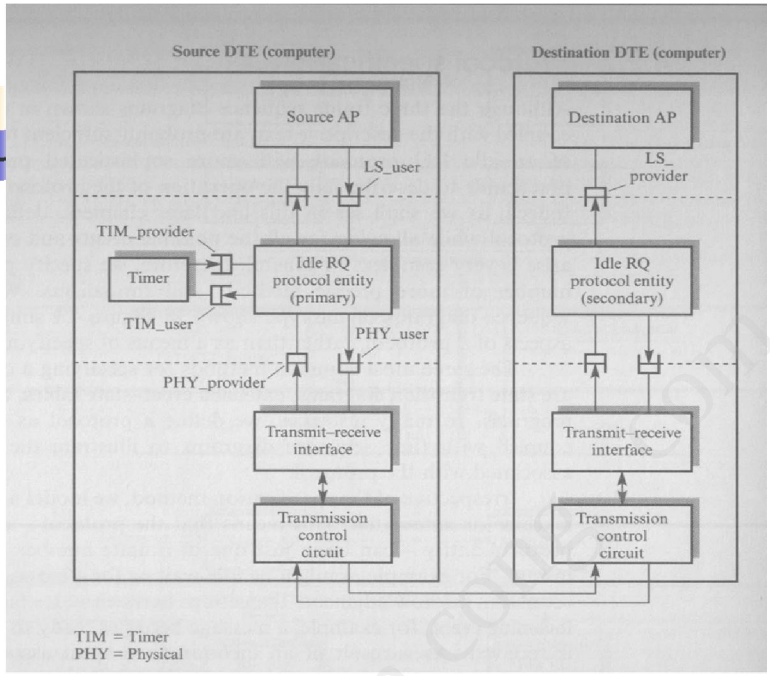


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# Continuous RQ

- P sends I-frames continuously without waiting for and ACK-frame to be returned
- Since more than one I-frame is waiting acknowledgement, P retains a copy of each I-frame transmitted in a retransmission list that operate on a FIFO queue disciplines
- S returns an ACK-frame for each correctly received I-frame
- Each I-frame contains a unique identifier which is returned in the corresponding ACK-frame

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# Continuous RQ

- On receipt of an ACK-frame, the corresponding I-frame is removed from the retransmission list by P
- Frames received free of errors are place in the link receive list to await processing
- On receipt of the next in-sequence I-frame expected, S delivers the information content within the frame to the upper layer immediately it has processed the frame
- In the event of frames being received out of sequence, S retains these in the link receive list until the next in-sequence frame is receive

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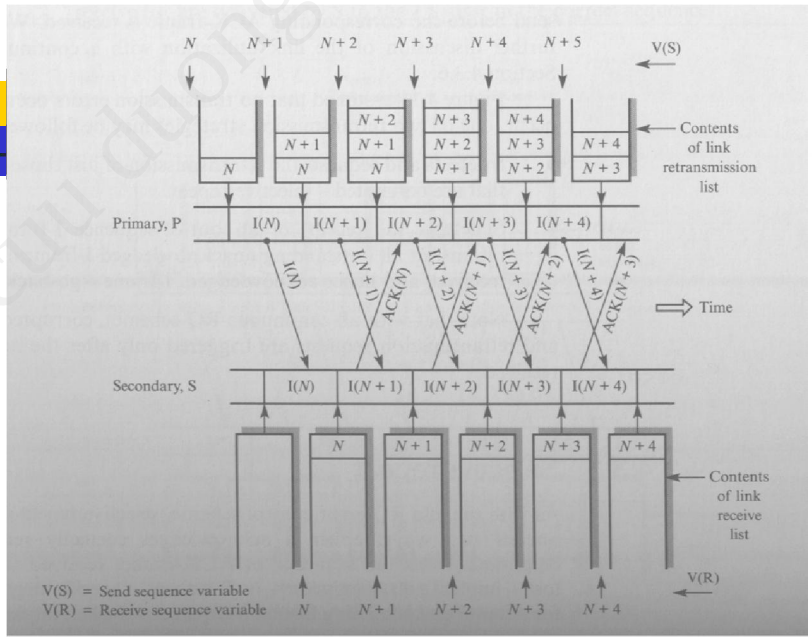


30

## Continuous RQ

- When an error does occur, one of two retransmission strategies may be followed:
  - S detects and requests the retransmission of just those frames in the sequence that are corrupted → selective repeat
  - S detects the receipt of an out of sequence I-frame and request P to retransmit all outstanding unacknowledged I-frame from the last correctly received, and hence acknowledge, I-frame → Go-back-N

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## Continuous RQ – Selective Repeat

- Selective repeat: can be implemented in one of two ways
  - Implicit retransmission: S acknowledges correctly received frames and P determines from the sequence of ACK-frames received that a frame has been lost
  - Explicit request: S returns a specific negative acknowledgement for a frame that is missing from the sequence

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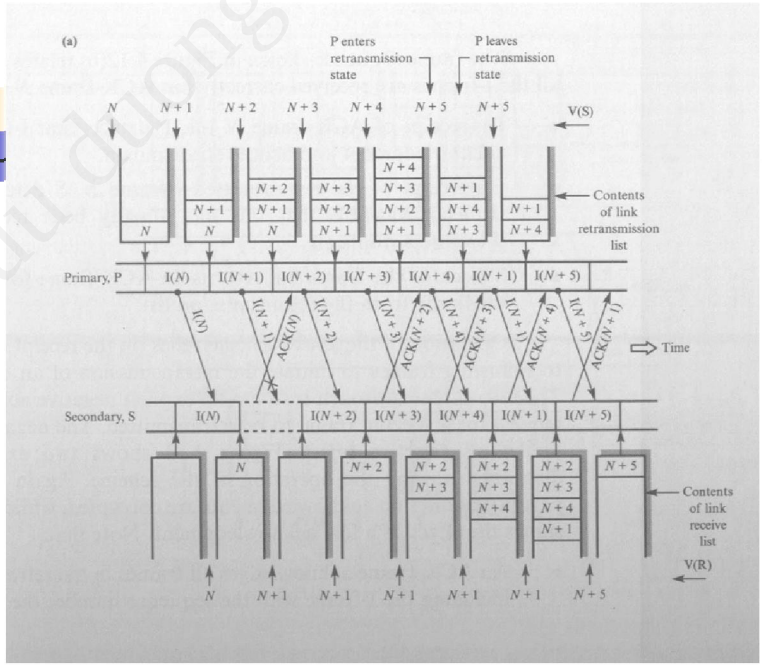
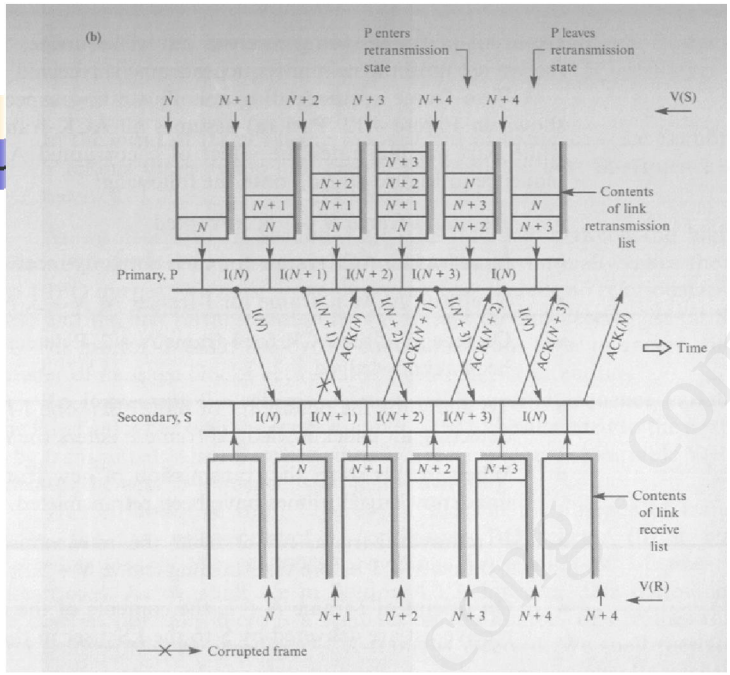
# Continuous RQ – Selective Repeat

- Implicit retransmission
  - To allow for the possibility of more than one I-frame being corrupted, on detecting an unacknowledged frame P enters the retransmission state
  - When in this state, the transmission of new frames is suspended until all unacknowledged frame has been retransmitted

33




34

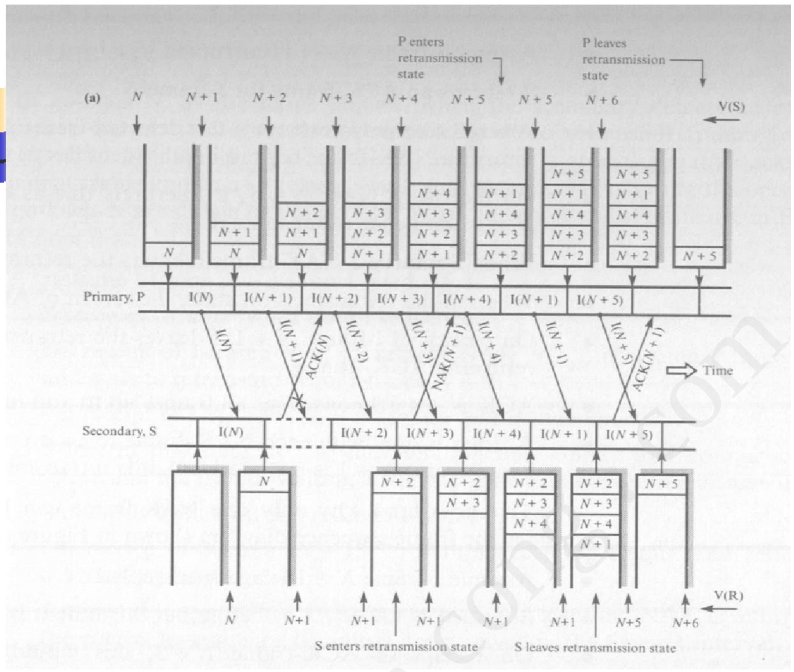



35

# Continuous RQ – Selective Repeat

- Explicit request
  - An ACK-frame acknowledges all frames in the retransmission list up to and including the I-frame with the sequence number the ACK contains
  - When S returns a NAK-frame it enters the retransmission state
  - When in retransmission state, the return of ACK-frame is suspended
  - On receipt of waiting I-frame , S leaves the retransmission state and resumes returning ACK-frame
  - The timer is used with each NAK-frame to ensure that if it is corrupted, it is retransmitted

36

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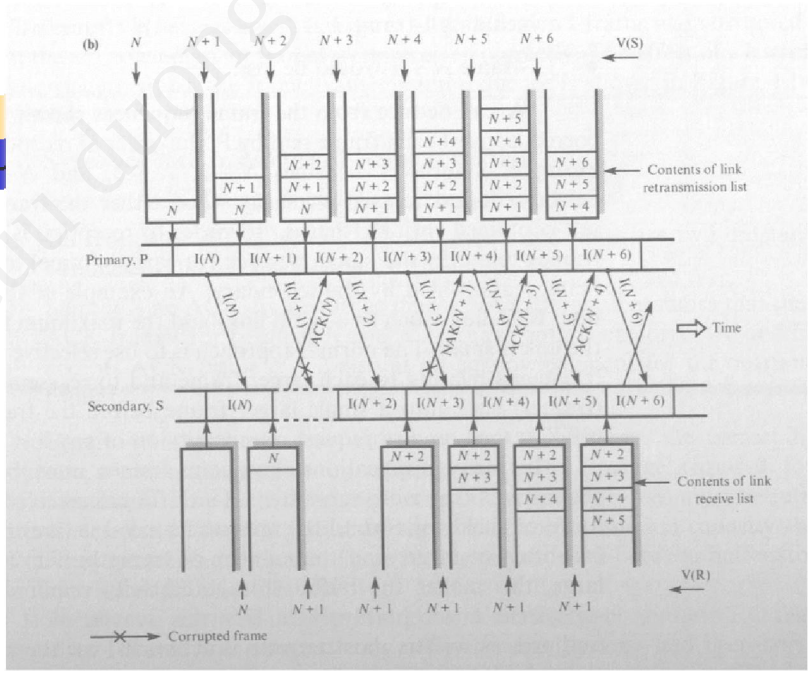


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## Continuous RQ – Go-back-N

- An ACK-frame acknowledges all frames in the retransmission list up to and including the I-frame with the sequence number the ACK contains
- When detecting an out-of-sequence frame, S returns NAK-frame informing P to go back and start to retransmit corrupted frame

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## Continuous RQ – Go-back-N

- On receipt of NAK-frame, P enters the retransmission state
- When in this state it suspends sending new frames and commences to retransmit the frames waiting acknowledgement in the retransmission list
- A timeout is applied to NAK-frames by S and a second NAK is returned if the correct in-sequence I-frame is not received in the timeout interval

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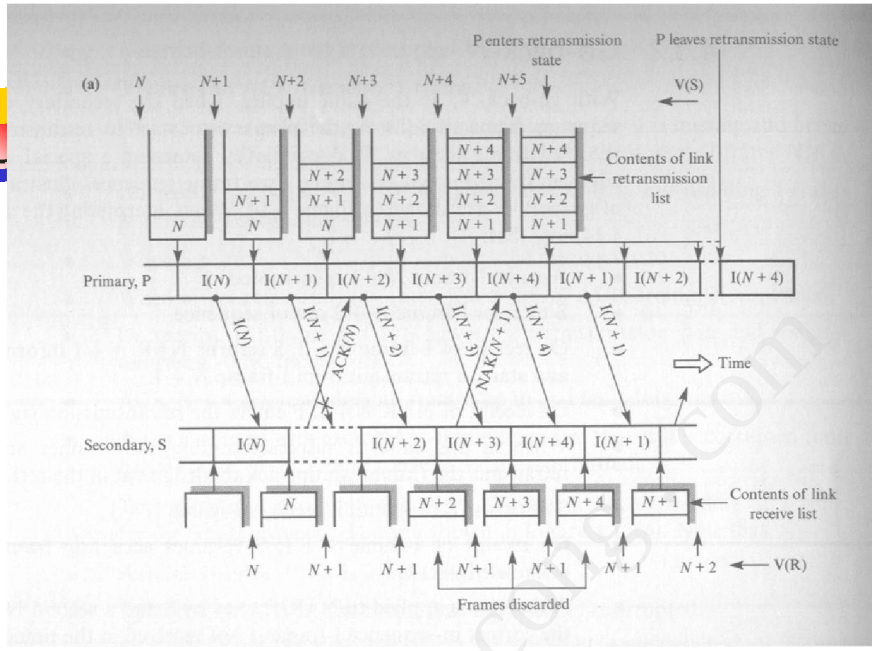


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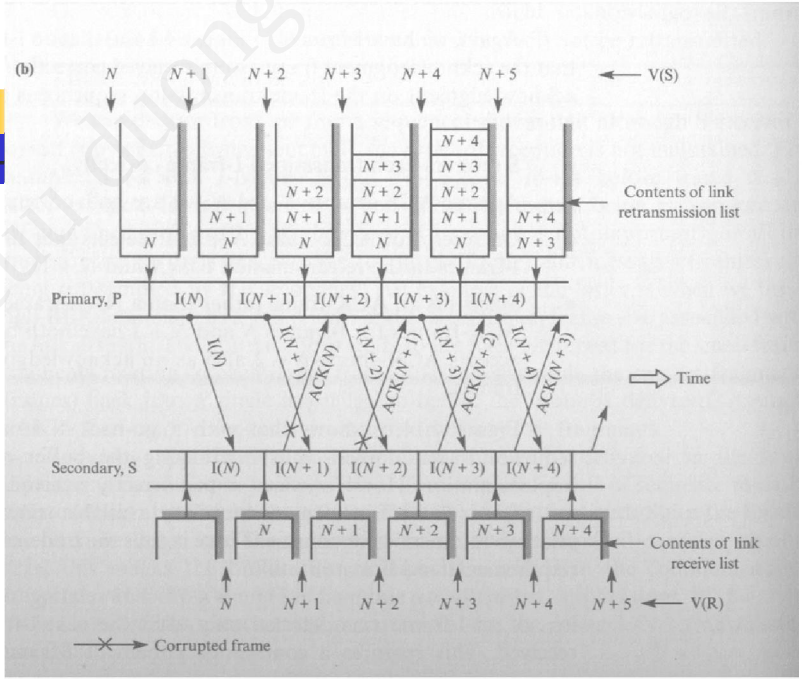


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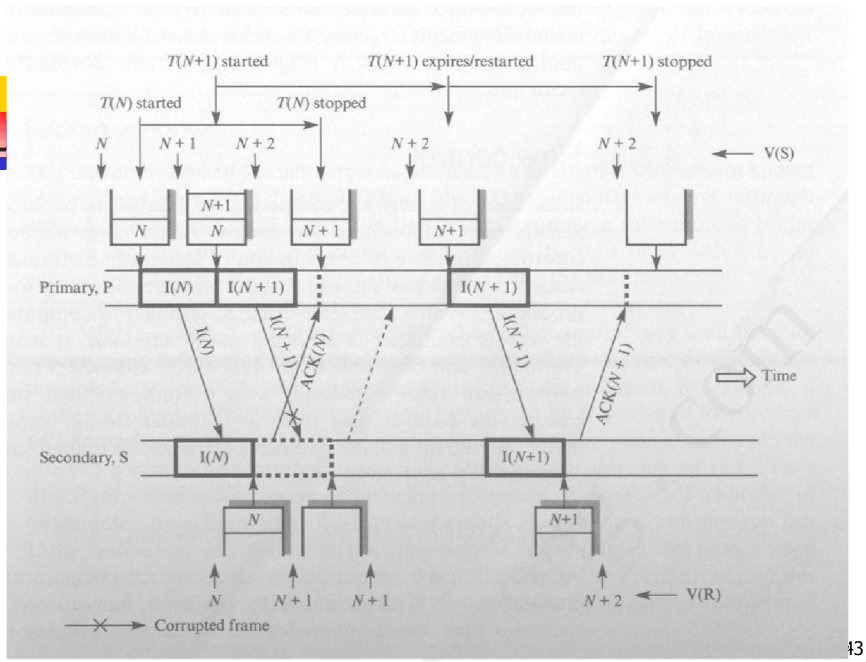


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# Continuous RQ - Flow control

- Flow control is concerned with controlling the rate of transmission of characters or frames on a link so that the receiver always has sufficient buffer storage resources to accept them prior to processing.
- Two most common flow control schemes:
  - X-on / X-off
  - Sliding window

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## Continuous RQ - Flow control

- X-on / X-off (in-band flow control)
  - X-off → cease transmission
  - X-on → restart transmission

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## Continuous RQ - Flow control

- Sliding window
  - A maximum limit is set on the number of I-frames that can be awaiting acknowledgement and hence are outstanding in the retransmission list → send window K
  - The maximum number of frame buffers required at S is known as the received window

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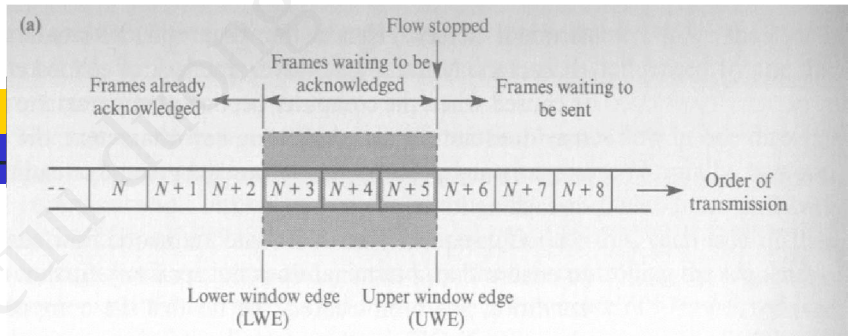
# Continuous RQ - Flow control

- Sliding Window
  - As each I-frame is transmitted, the upper window edge (UWE) is incremented by unity
  - As each I-frame is acknowledge, the lower window edge (LWE) is incremented by unity
  - The acceptance of any new frames is stopped if the difference between UWE and LWE becomes equal to the send window K

47




(b)

| Protocol | Send window | Receive window |
|---|---|---|
| Idle RQ | 1 | 1 |
| Selective repeat | $K$ | $K$ |
| Go-back-N | $K$ | 1 |

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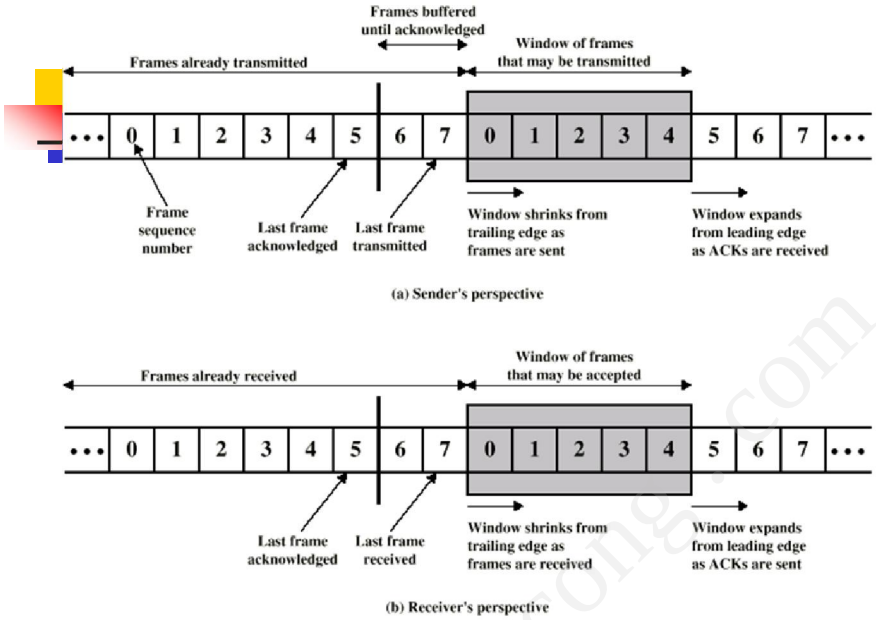


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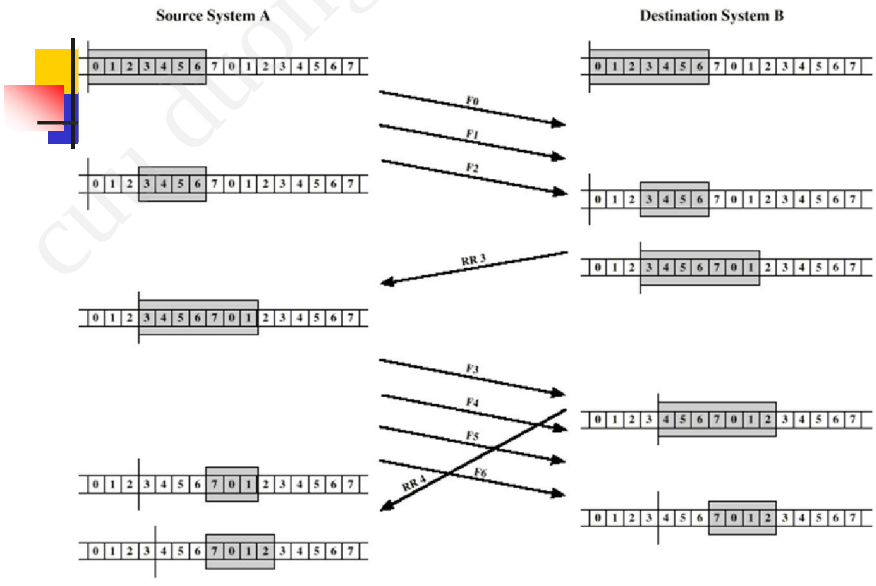
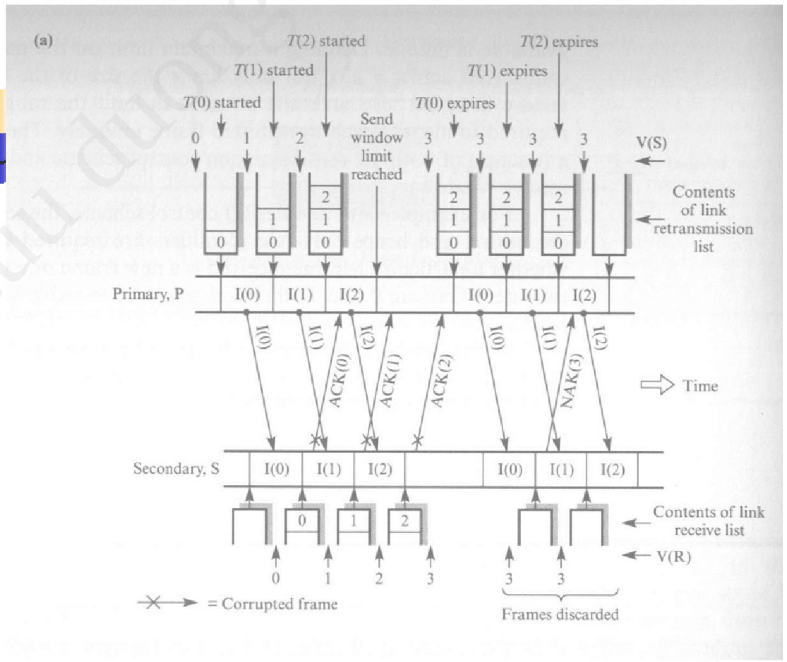



50

# Continuous RQ - Flow control

- Sequence number in sliding window:
  - the number of identifier is a function of both the retransmission control scheme and the size of the send and receive windows
  - In practice, since the identifier of a frame is in binary form, a set number of binary digits must be reserved for its use.

51

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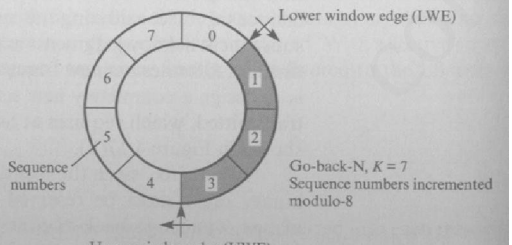
(b)

| Protocol | Maximum number of frame identifiers |
|---|---|
| Idle RQ | 2 |
| Selective repeat | $2K$ |
| Go-back-N | $K + 1$ |

(c)

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# Continuous RQ - Link Utilization

- $U$ - link utilization
- $K$ - send window
- $T_{ix}$ - frame transmitted time
- $T_p$ - frame propagation delay
- $N_r$ - an average transmission attempts will be required to transmit a frame successfully
- $P_f$ - the probability that a frame is received with errors
- and $a = \frac{T_p}{T_{ix}}$

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## Continuous RQ - Link Utilization

- Error-free
  - *K ≥ 1 + 2a*

$$U = 1$$

  - *K < 1+ 2a*

$$U = \frac{KT_{ix}}{T_{ix} + T_p} = \frac{K}{1+2a}$$

55

## Continuous RQ - Link Utilization

- Selective repeat, errors occur in transmission
  - *K ≥ 1 + 2a*

$$U = 1 - P_f$$

  - *K < 1+ 2a*

$$U = \frac{K}{N_r(1+2a)} = \frac{K(1-P_f)}{1+2a}$$

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# Continuous RQ - Link Utilization

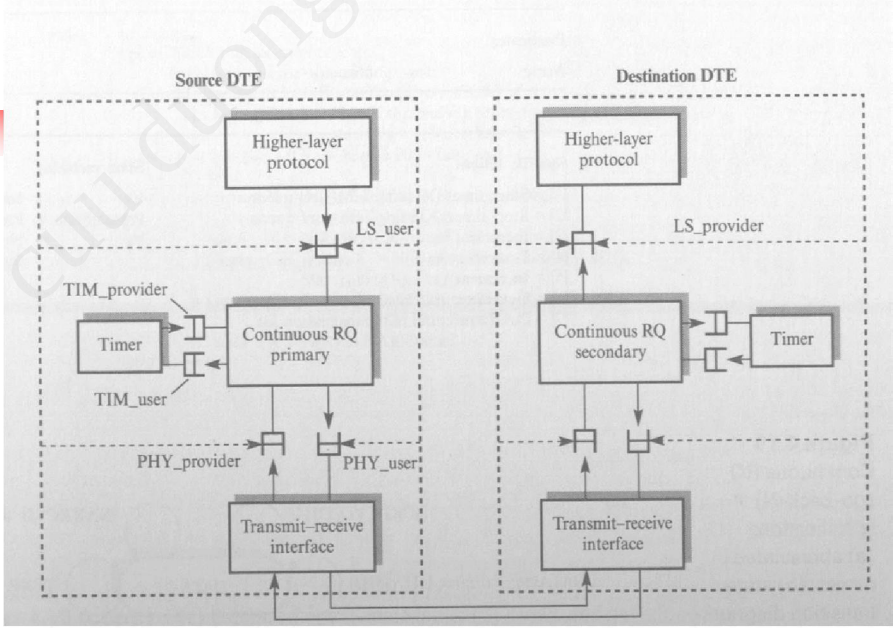
- Go-back-N, errors occur in transmission
  - *K ≥ 1+ 2a*

$$U = \frac{1 - P_f}{1 + P_f (K - 1)}$$

  - *K < 1+ 2a*

$$U = \frac{K(1 - P_{f)}}{(1 + 2a)(1 + P_f (K - 1))}$$

57

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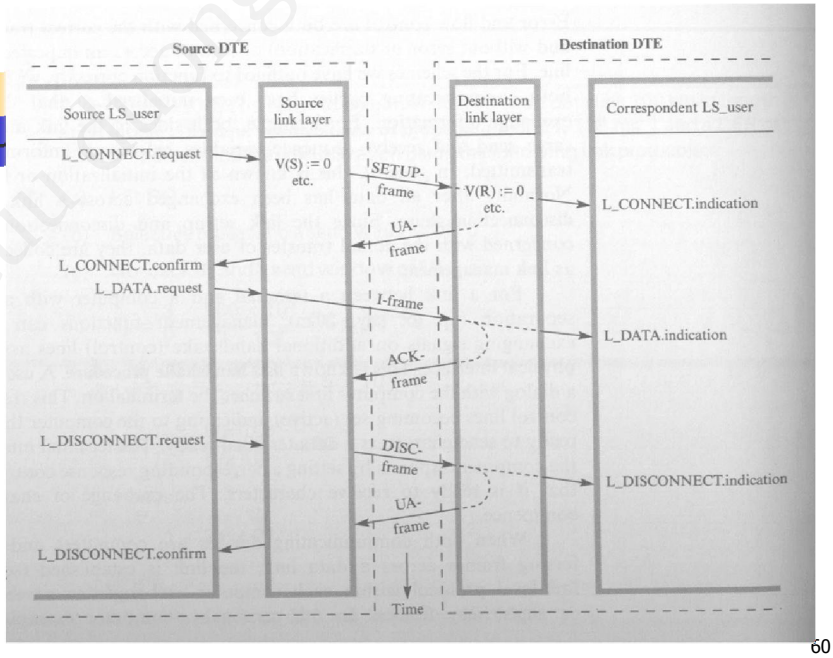
# Link Management

- Handshake procedure
  - Link setup phase
  - Link disconnect phase

59




60