Data Link Layer

DATA LINK PROTOCOLS

(Text book : Chapter 1, PP. 51 – 86,

Ref Book [1]) :Chapter 4)

I. **Basic Protocols (ARQ)**

- Stop-and-wait
- Time-out
- Acknowledgements
- Sequence numbering
- Continuous ARQ
- Select Reject vs. Go-back-N

II. **Throughput or Efficiency Analysis**

- Noiseless channel (error-free)
- Noisy channel (bit errors)

III. **HDLC (LAP-B) Protocol**

- HDLC format

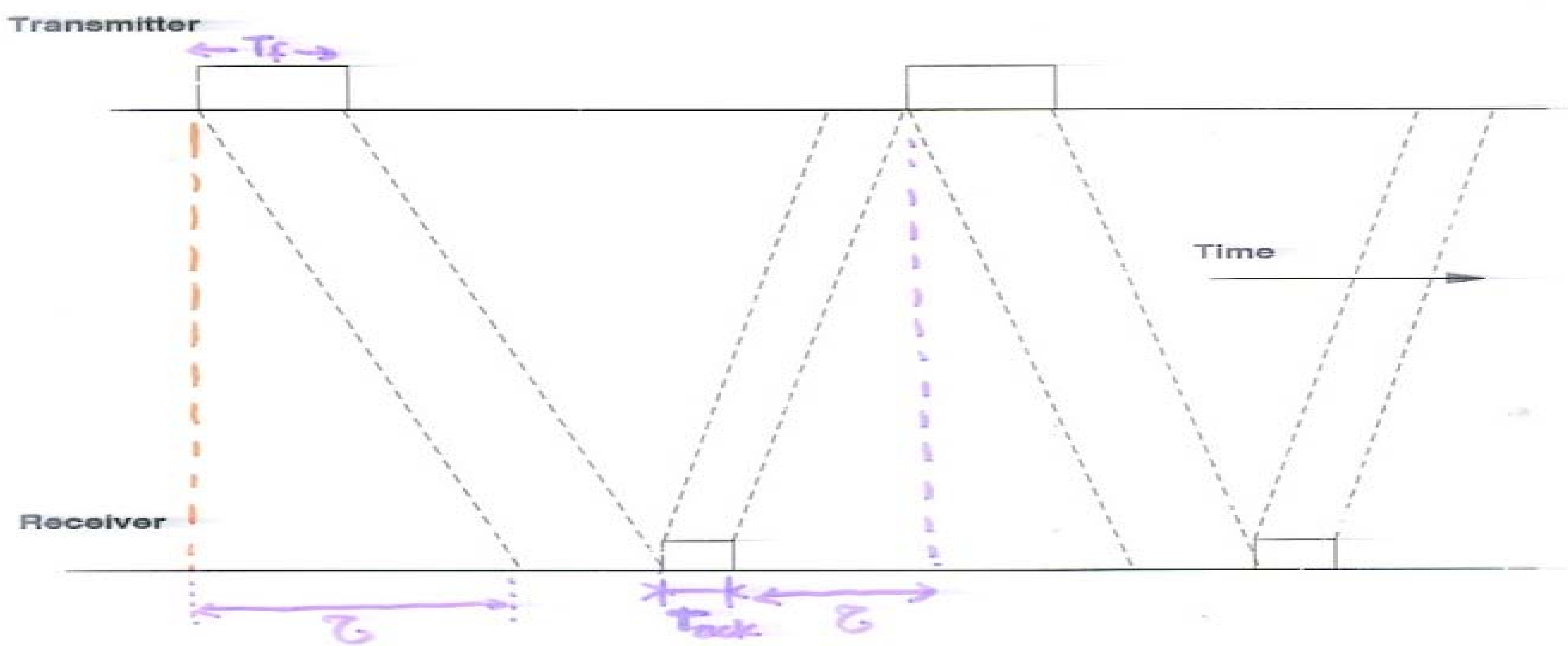

Figure 4.1: Error Free Operation of Stop and Wait ARQ

Efficiency or utilization : $\eta = \dfrac{\text{time to transmit one frame}}{\text{total time between 2 frames}}$

$$= \frac{T_f}{T_f + T_{ack} + 2\tau} \quad , \tau = \text{propagation delay}$$

$$= \frac{1}{1 + \frac{T_{ack}}{T_f} + \frac{2\tau}{T_f}}$$

2τ : round-trip prop delay.

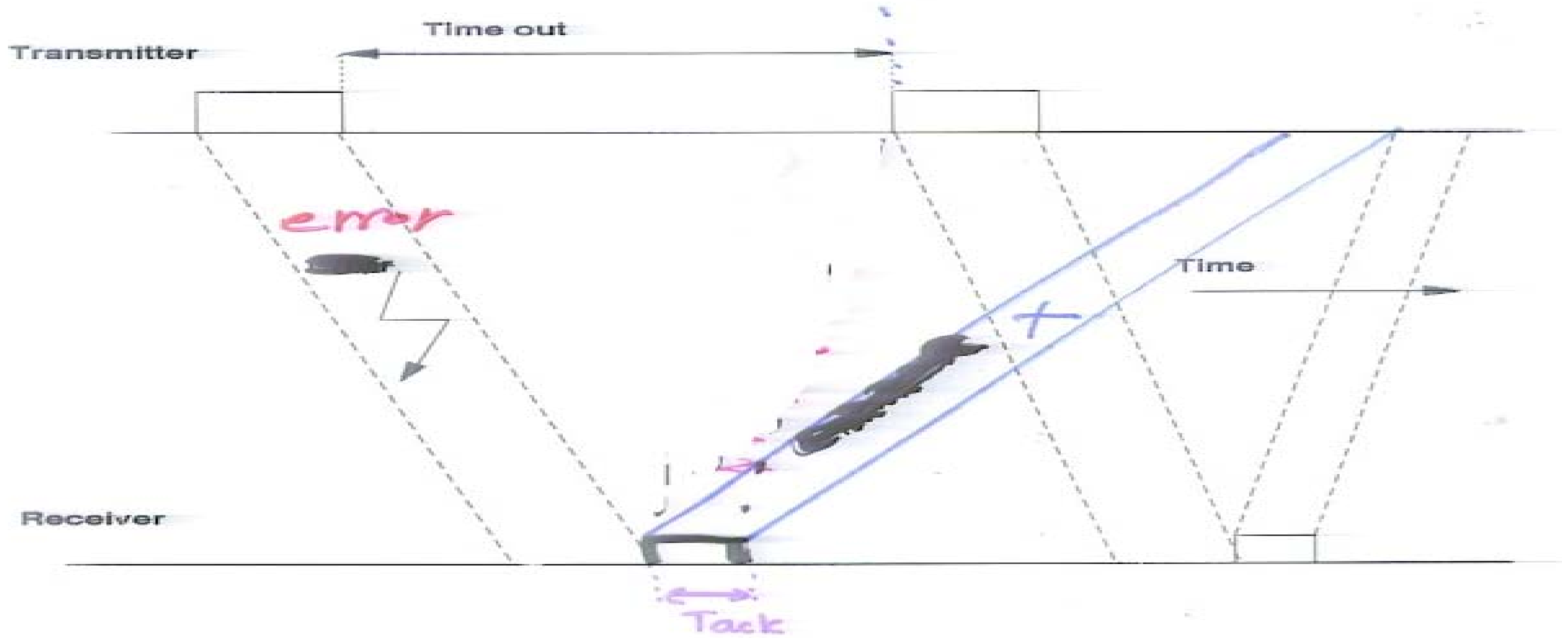

Figure 4.2: Recovery from the Loss of An Information Frame in Stop and Wait ARQ

Retransmit a fome if its ACK is not received when time-out expires.

if Time-Out is < total round trip delay = $2\tau + T_{Ack} + T_p$ error will occur

So, Set time-out > $2\tau + T_p + T_{ack}$

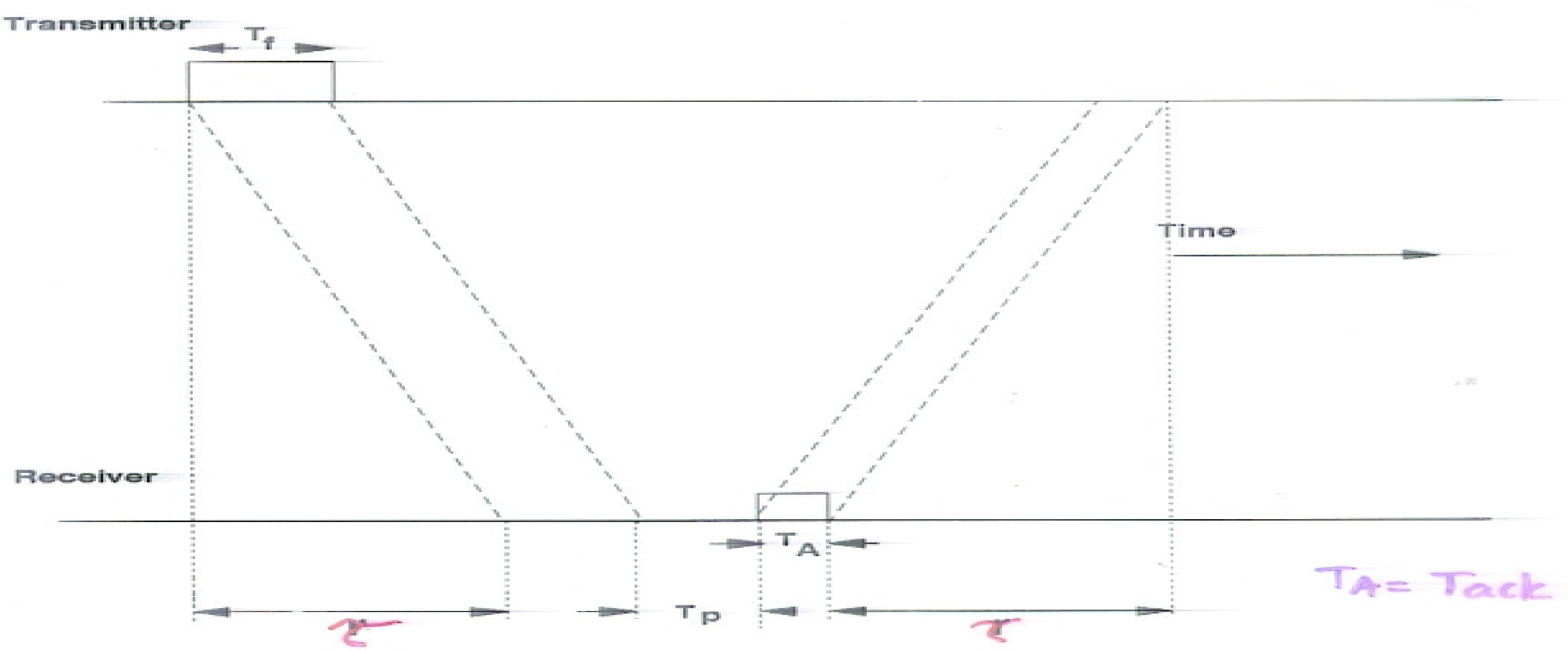

Figure 4.3: Times Involved in Transmission and Acknowledgment

$$\text{Efficiency} = \eta = \frac{T_f}{T_f + T_{ack} + T_p + 2\tau}$$

2τ = Round-trip propagation delay

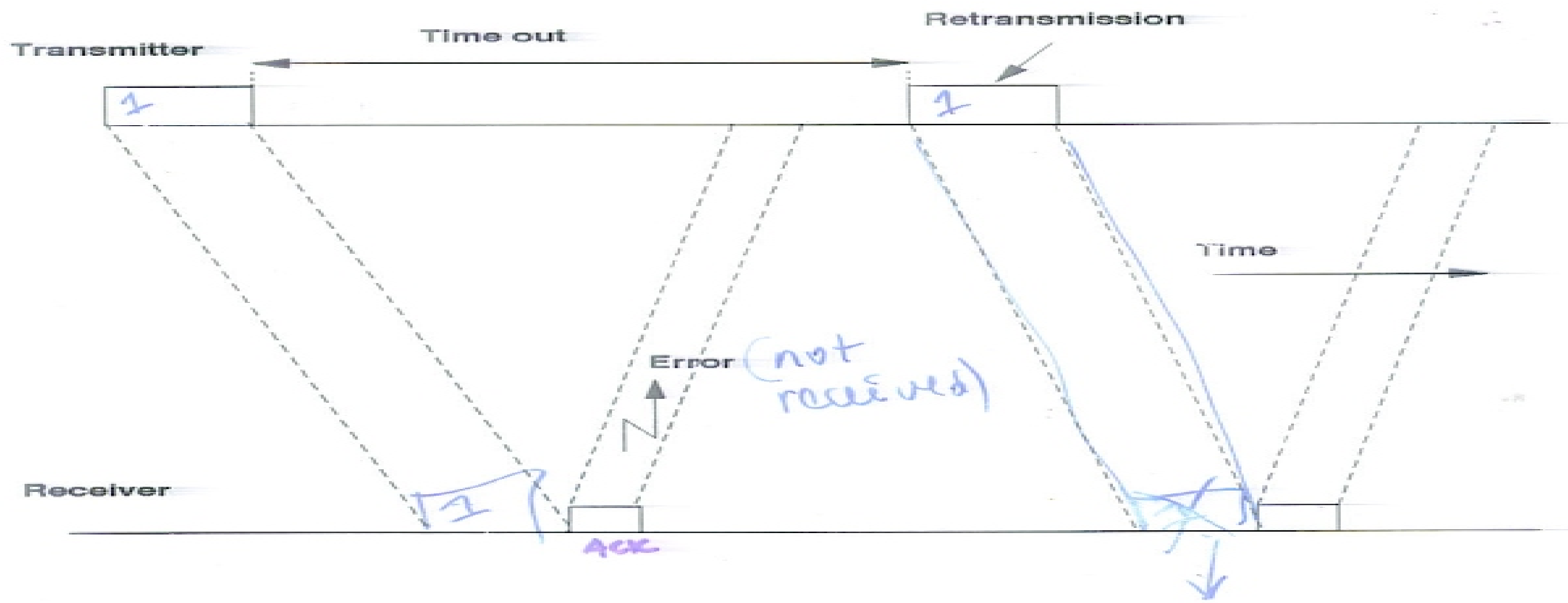

Figure 4.4: Recovery from Lost Acknowledgment in Stop-and-Wait ARQ Protocols

ACK packet in error: Discarded by transmitter

Control by time-out: retransmit the frame (even though it was received OK)

Receiver: receives duplicate of same frame
Resolved by sequence numbering

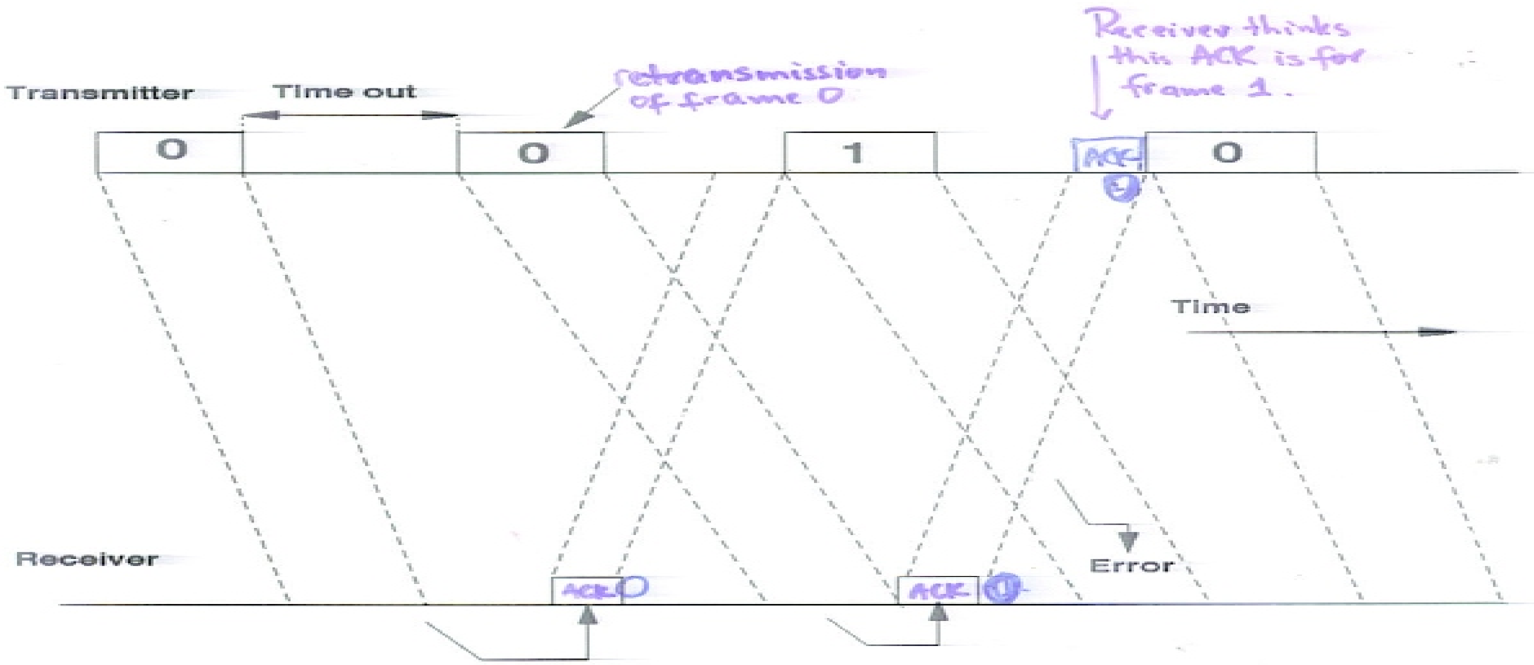

Figure 4.5: The Need for Numbering Acknowledgment

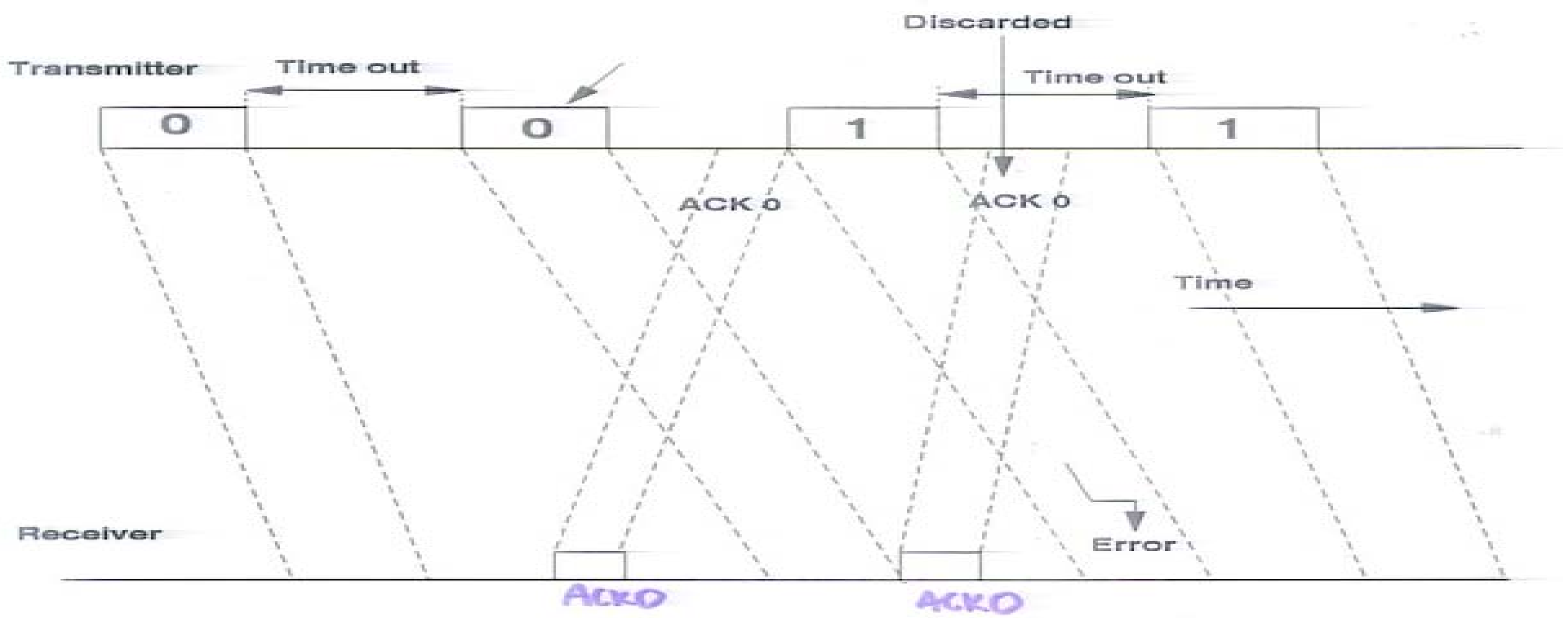

Figure 4.6: Operation with Numbered Acknowledgment

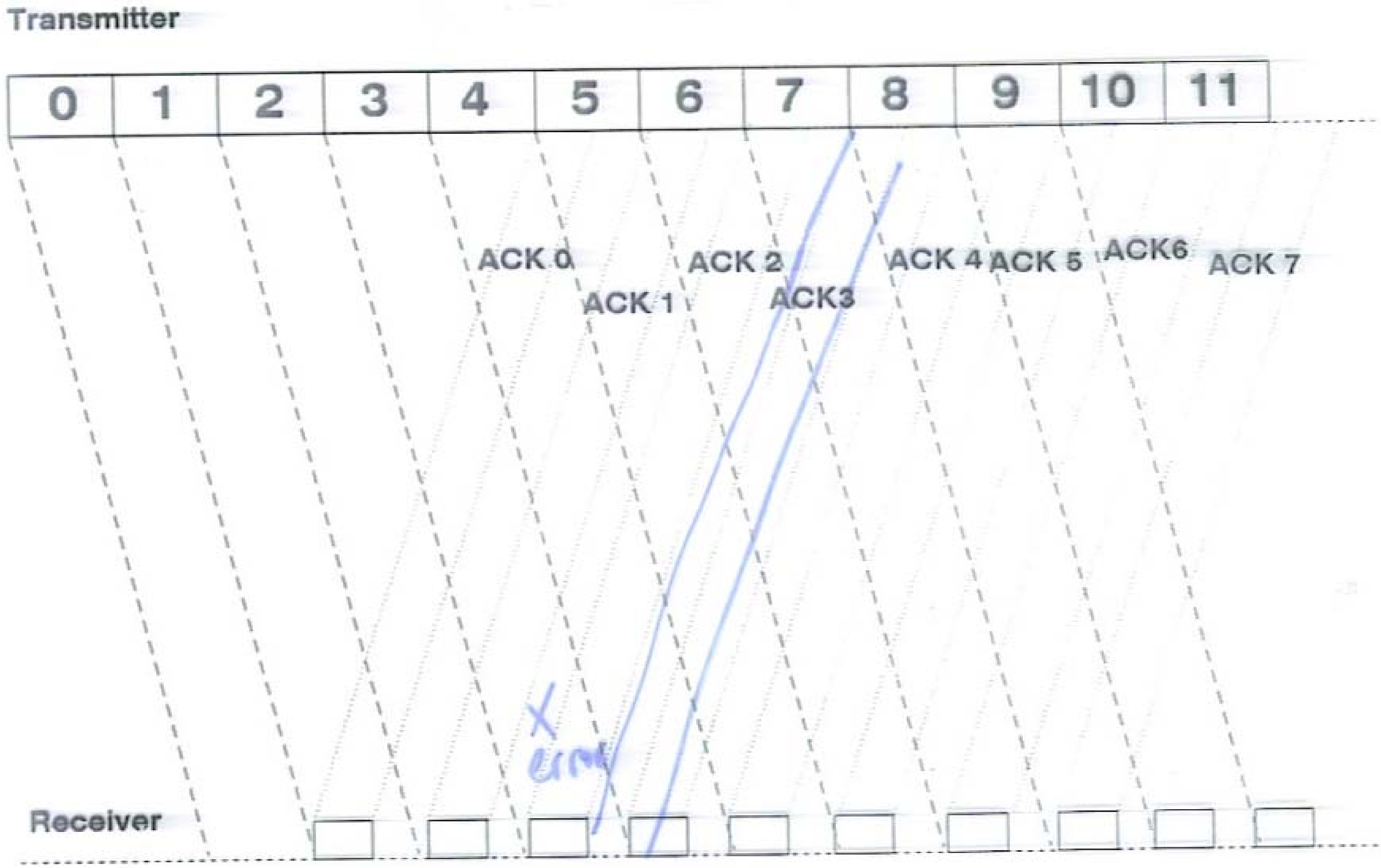

Figure 4.7: Continuous ARQ Error Free Operation

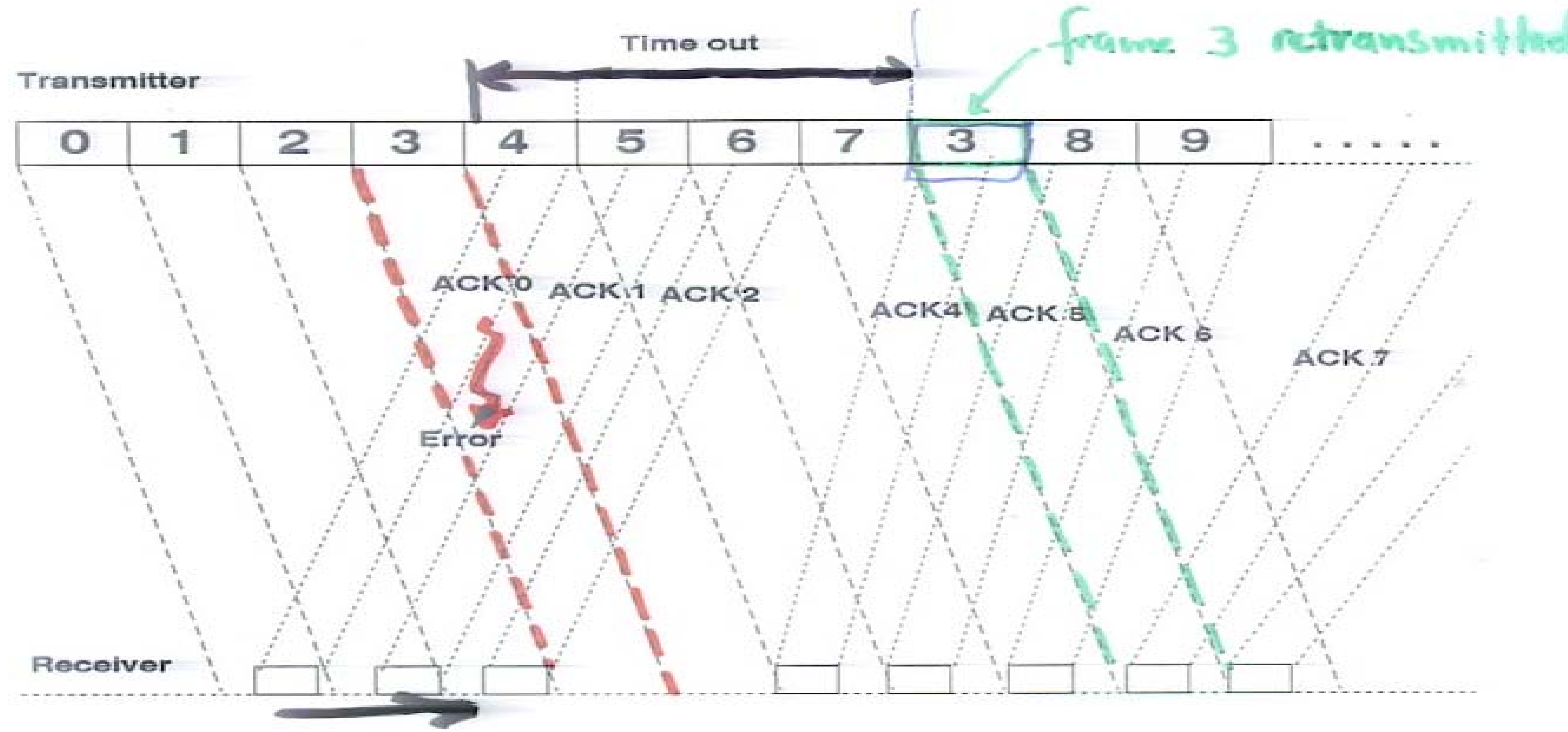

Figure 4.8: Selective Reject Lost Information Frame Recovery

- Out-of-order received frames: 0 1 2 ~~3~~ 4 5 6 7 $\boxed{3}$ 8 9 ....
  Error

- frames 4, 5, 6, 7 can't be passed to receiving application (e.g., file) because frame 3 is missing. Thus, they're stored in memory.

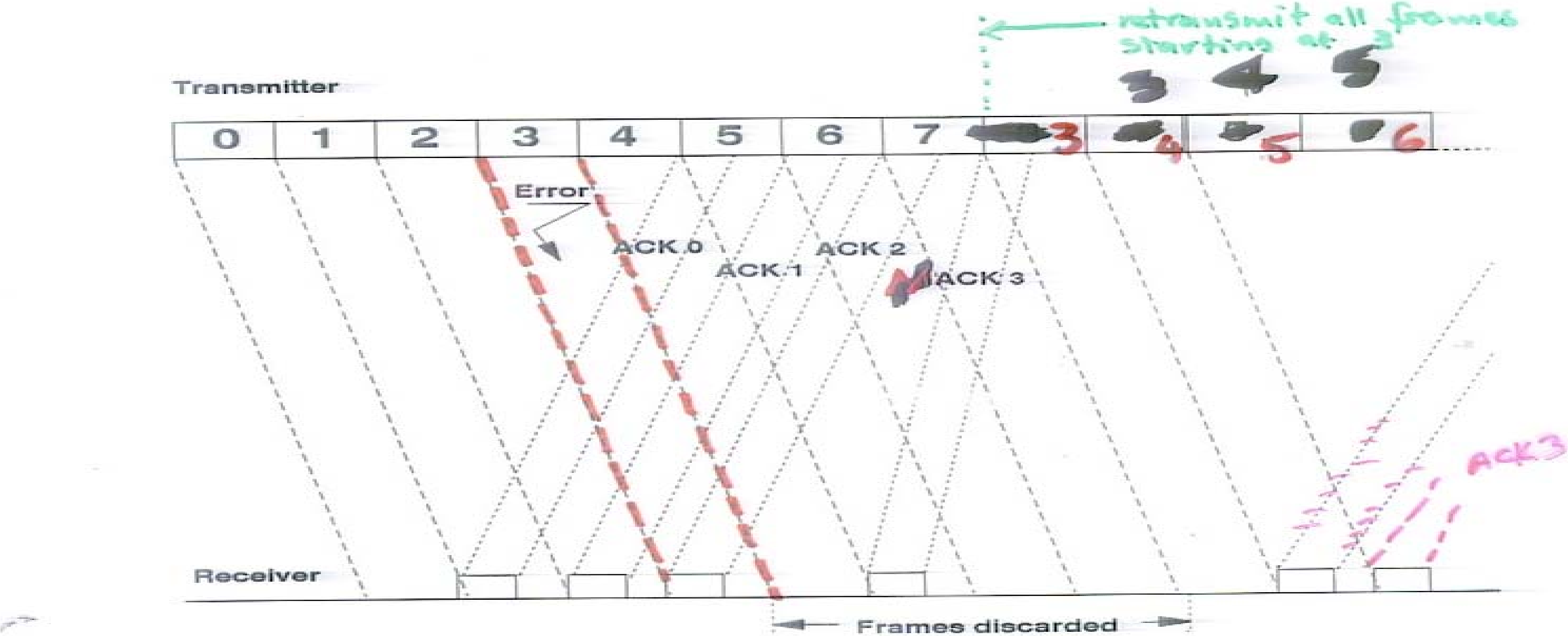

Figure 4.9: Go Back-N Recovery through Out-of-Sequence Frame Reception

Each frame has a sequence count number $N(S) = 0, 1, 2, 3, \cdots$ modulo (n

NACK 3 : Ack packet containing receive count number $N(R)$ which is the sequence number of the next frame expected.

In Fig. 4.9 : $N(R) = 3 \Rightarrow$ All frames $0, 1, 2 = N(R) - 1$ are received OK

Problem: Suppose NACK 3 is in error

Solution: Use time-out, and retransmit all frames starting at 3

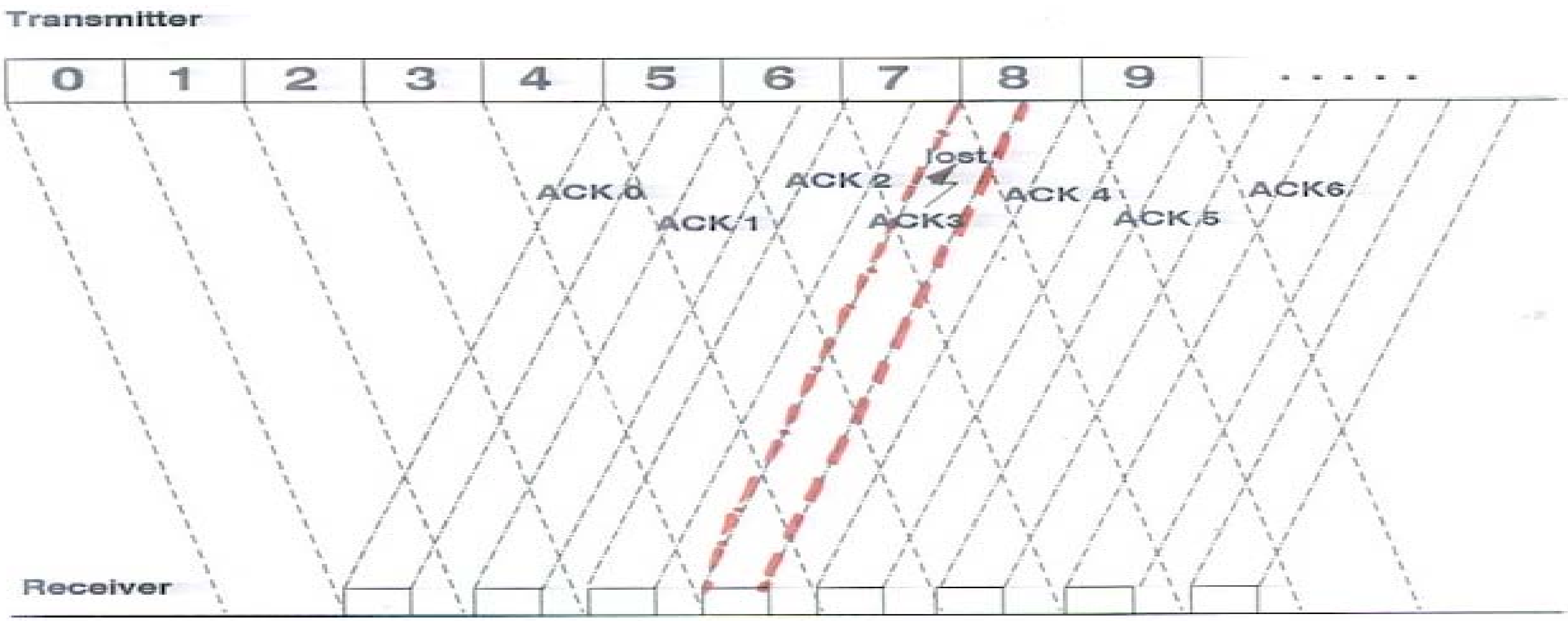

Figure 4.10: Lost Acknowledgments in Go-Back-N

- Suppose ACK 3 is lost (in error)
- A little later, ACK4 is received. This acks frames 3, 2, 1, 0, so the loss of ACK 3 is resolved.

⇒ Group acknowledgement

Reduce ack overhead

* Group acknowledgement (an ACK is sent back for group of pkts)

* Piggybacking

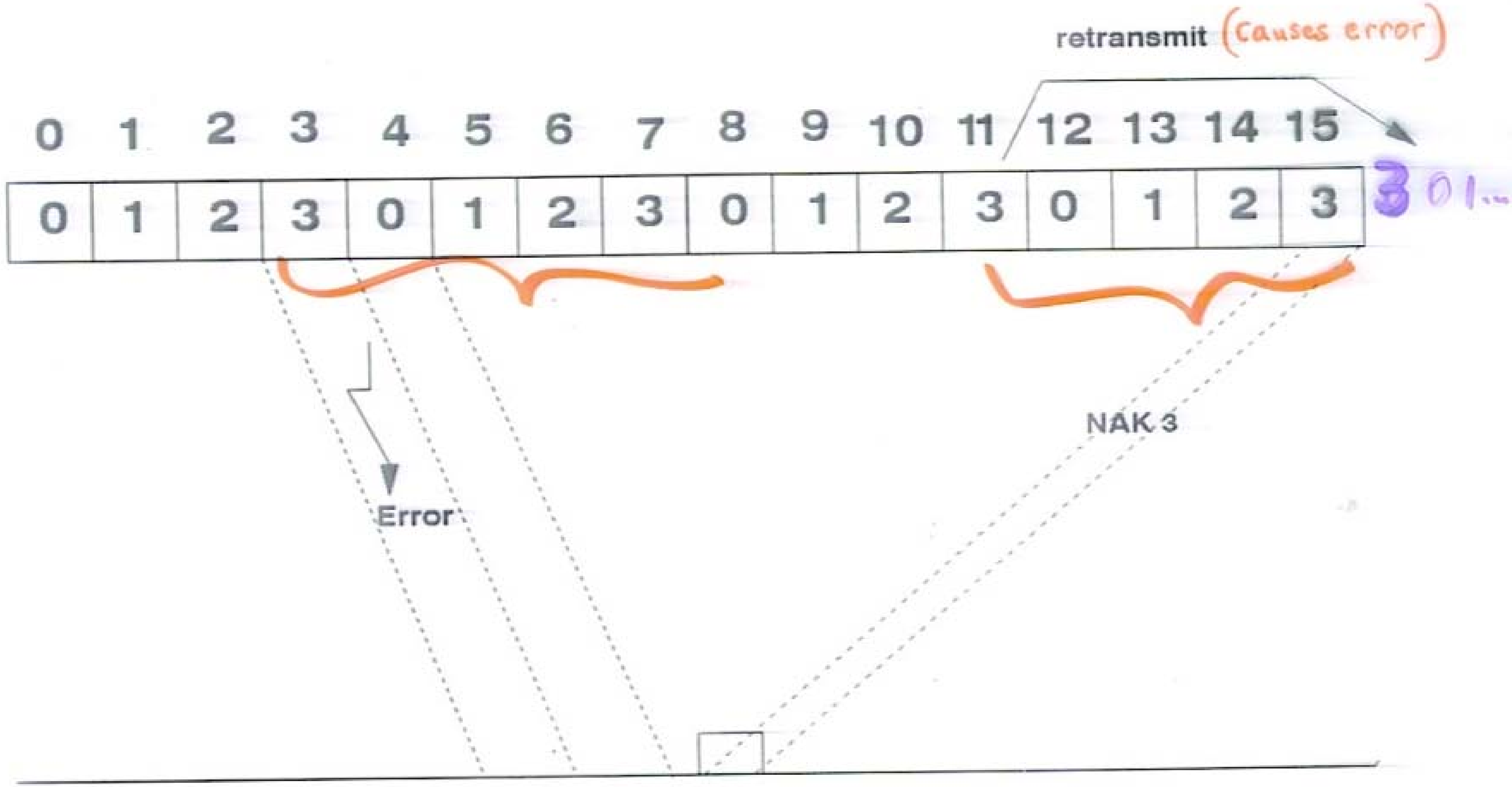

Figure 4.11: Two-Bit Sequence Number ARQ

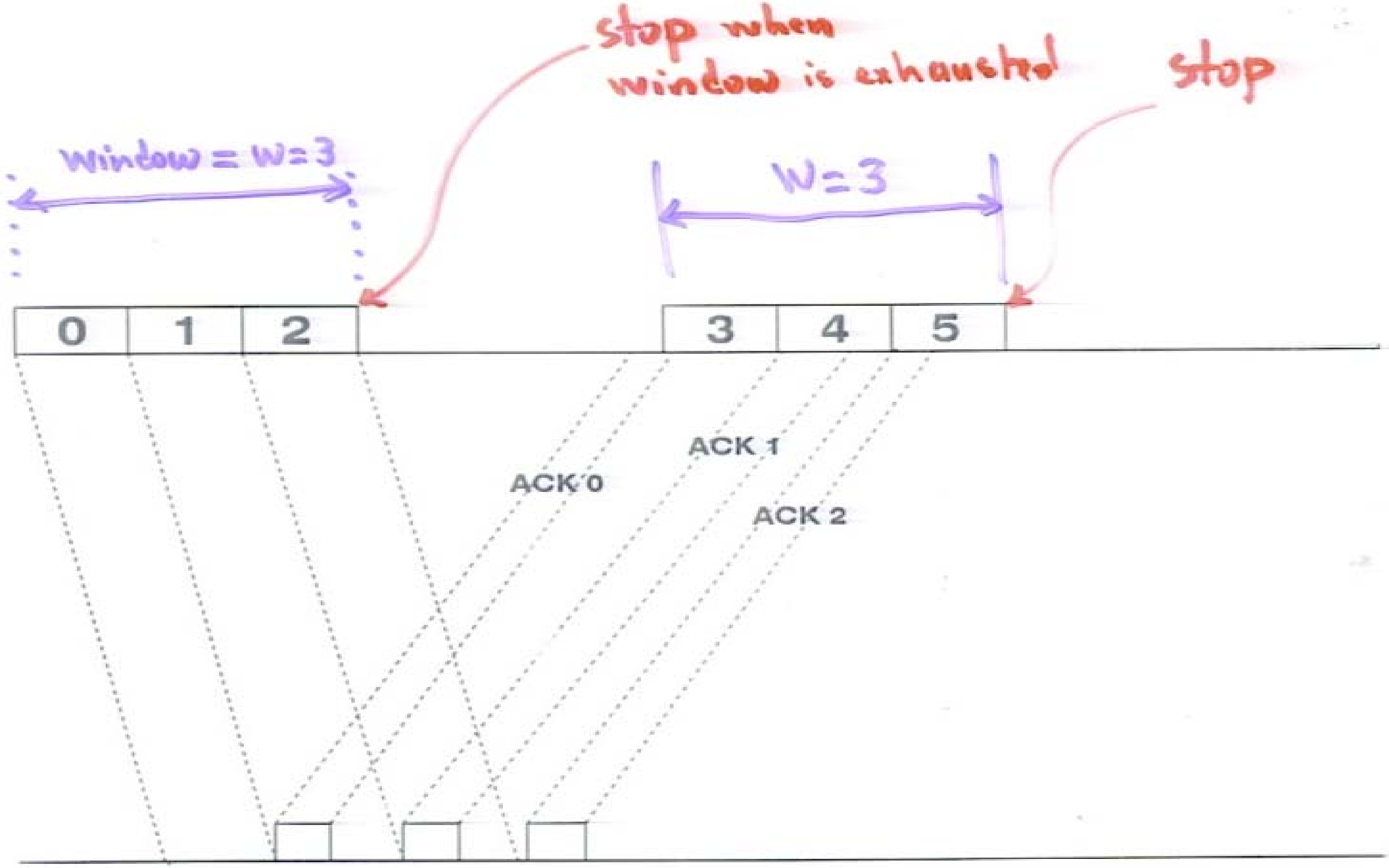

Figure 4.12: Continuous ARQ with W=3

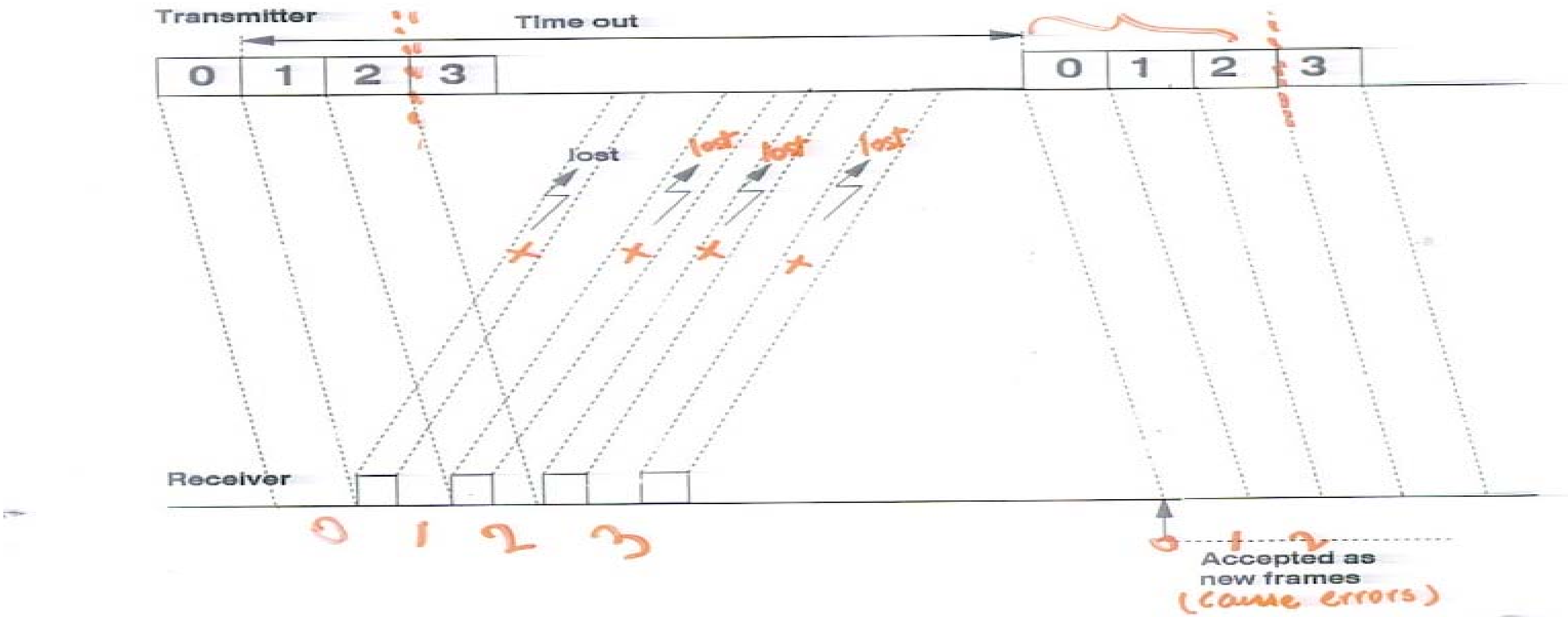

Figure 4.13: Lost Acknowledgments Can Cause Incorrect Op
for W=4

Sequence space : 0,1,2,3
modulo M=4

- frames 0,1,2,3 : received OK
  their ACK's are lost

- transmitter resends frames 0,1,2,3

- Receiver accepts the resent frames as NEW frames ⇒ ERROR

Solution : set window size $\boxed{W \leq M-1}$, say W = 3

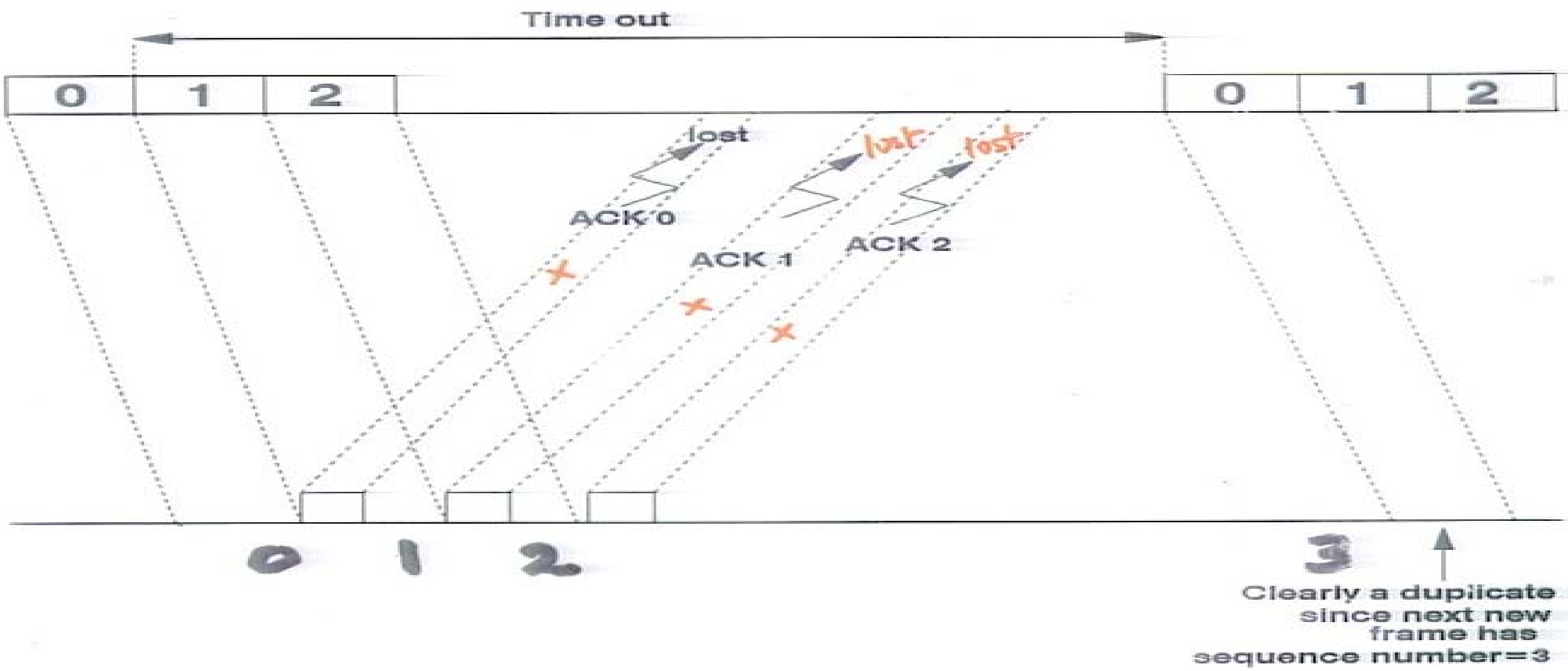

Figure 4.14: Making W=3 Resolves Confusion

Window size selection Rule:

$$\boxed{W \leq M-1}$$

W = Window size

M = Sequence number space $(0, 1, \ldots M-1)$

HDLC : High Level Data Link Control

Three Modes:

1) **NRM** : Normal Response Mode

   pt.-to-pt. or multi-point

   one primary station ; one or more secondary station

2) **ARM** : Asynchronous Response Mode

   pt.-to-pt. or multi-point

   one primary station ; one or more secondary station

3) **ABM** : Asynchronous Balanced Mode

   only pt.-to-pt.

   two combined stations

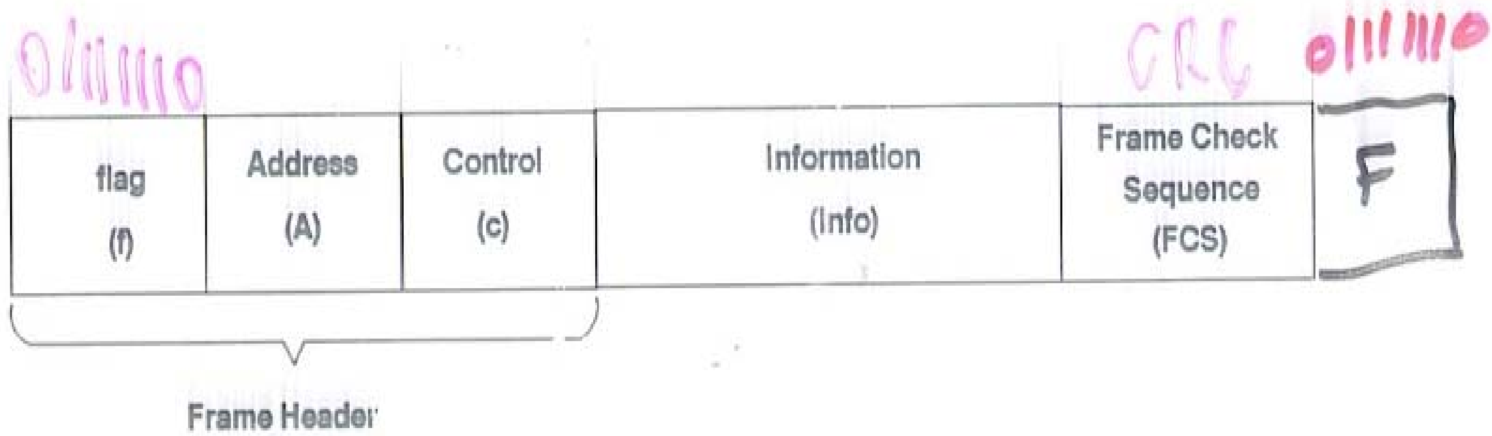

Fig. 4.16 The basic bit-oriented data link format

Global (broadcast) address = A = 11111111

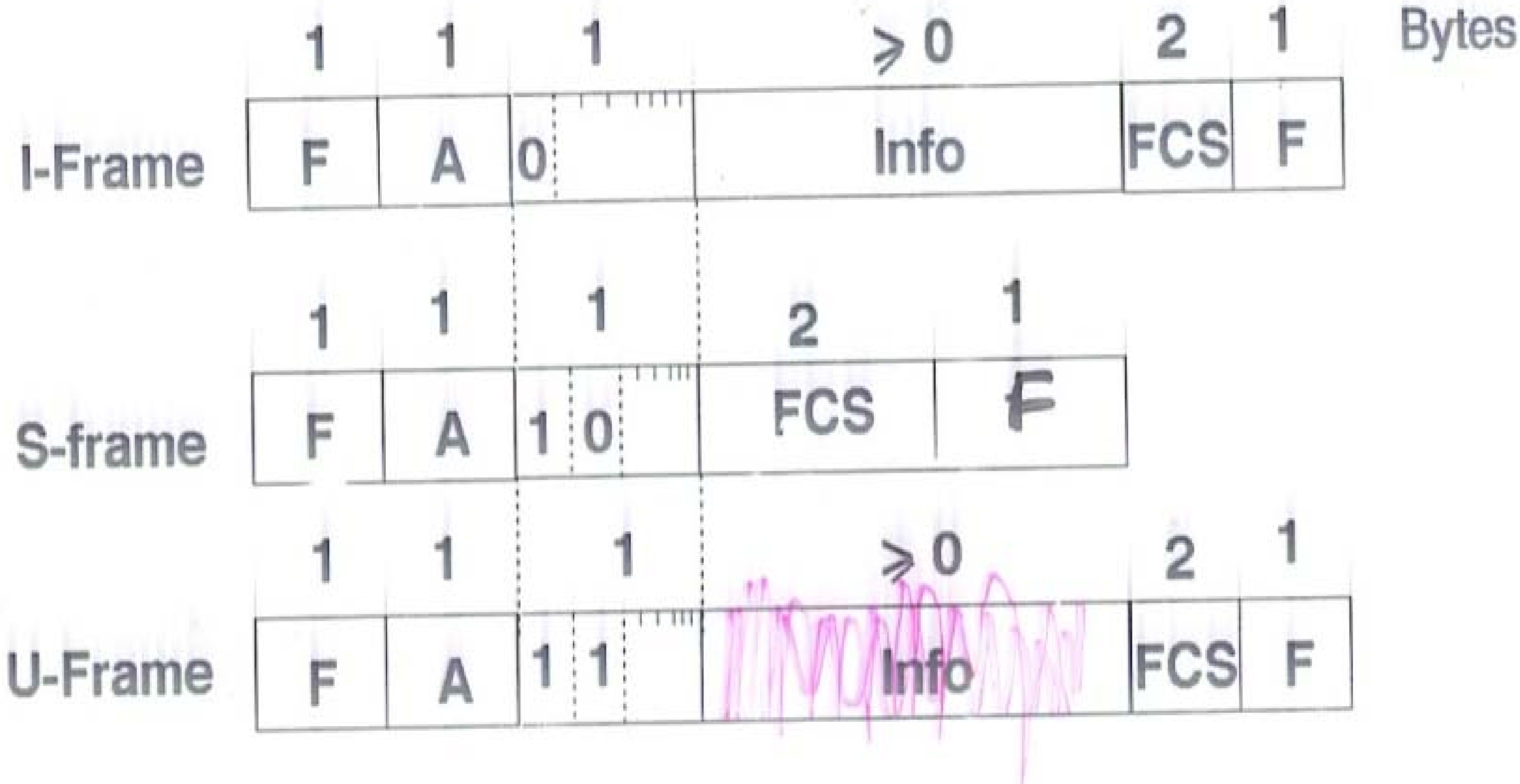

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Fig 4.9 Types of frames

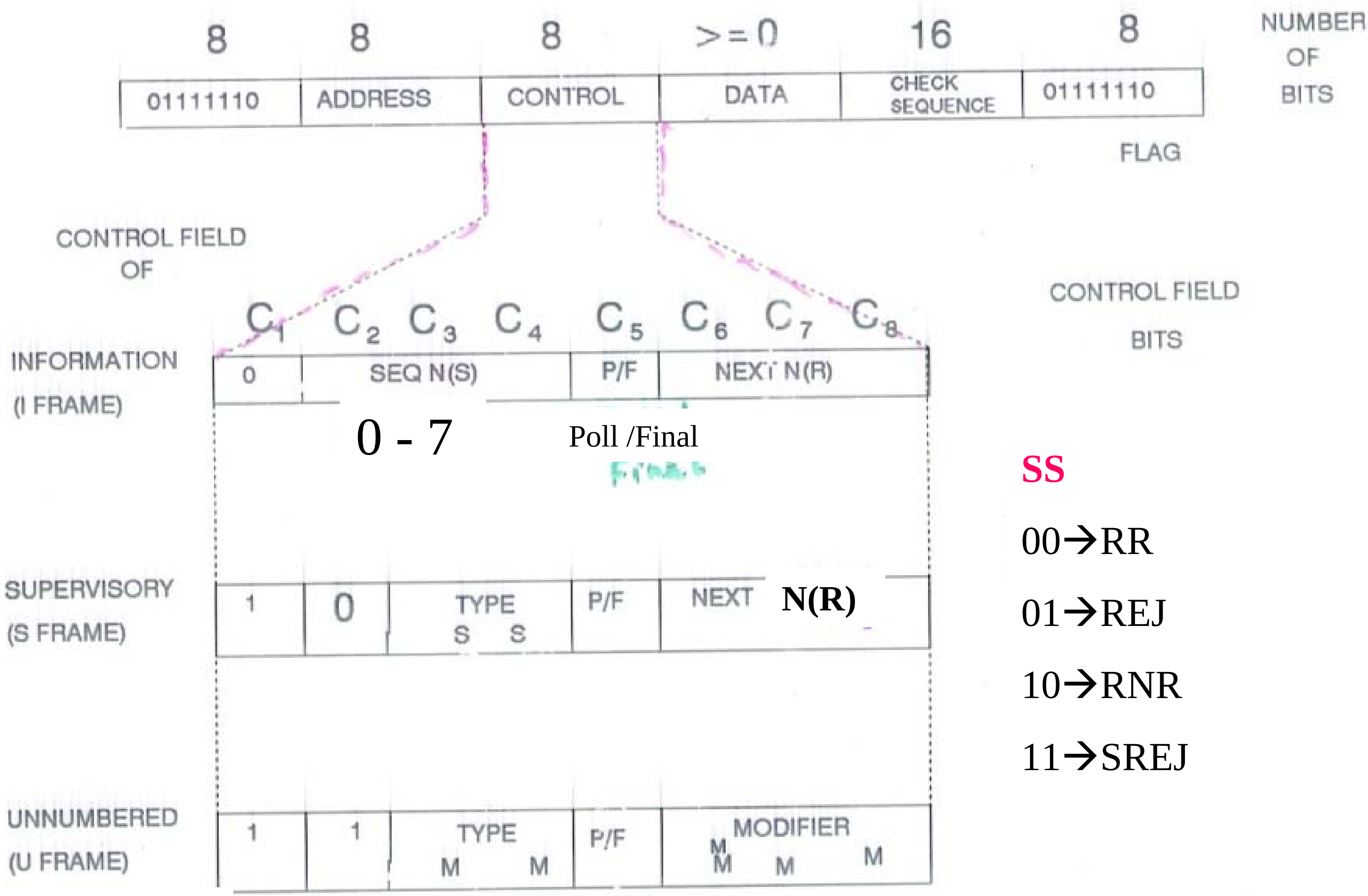


Fig 4.17 FIELD FORMAT FOR BIT ORIENTED PROTOCOLS

NEXT : Number of the next frame expected

P / F : Poll / Final

Type :

00 : ACK frame , i.e. Receive Ready (RR)

01 : Negative ACK , i.e. Reject (REJ)

10 : Receive Not Ready (RNR)

11 : Selective Reject (SREJ)

Asks for transmission of only the frame specified

UNNUMBERED FRAMES

Unextended Numbering set Mode:

SNRM : Set Normal Response Mode
SARM : Set Asynchronous Response Mode
SABM : Set Asynchronous Balanced Mode

Extended Numbering Set Mode:

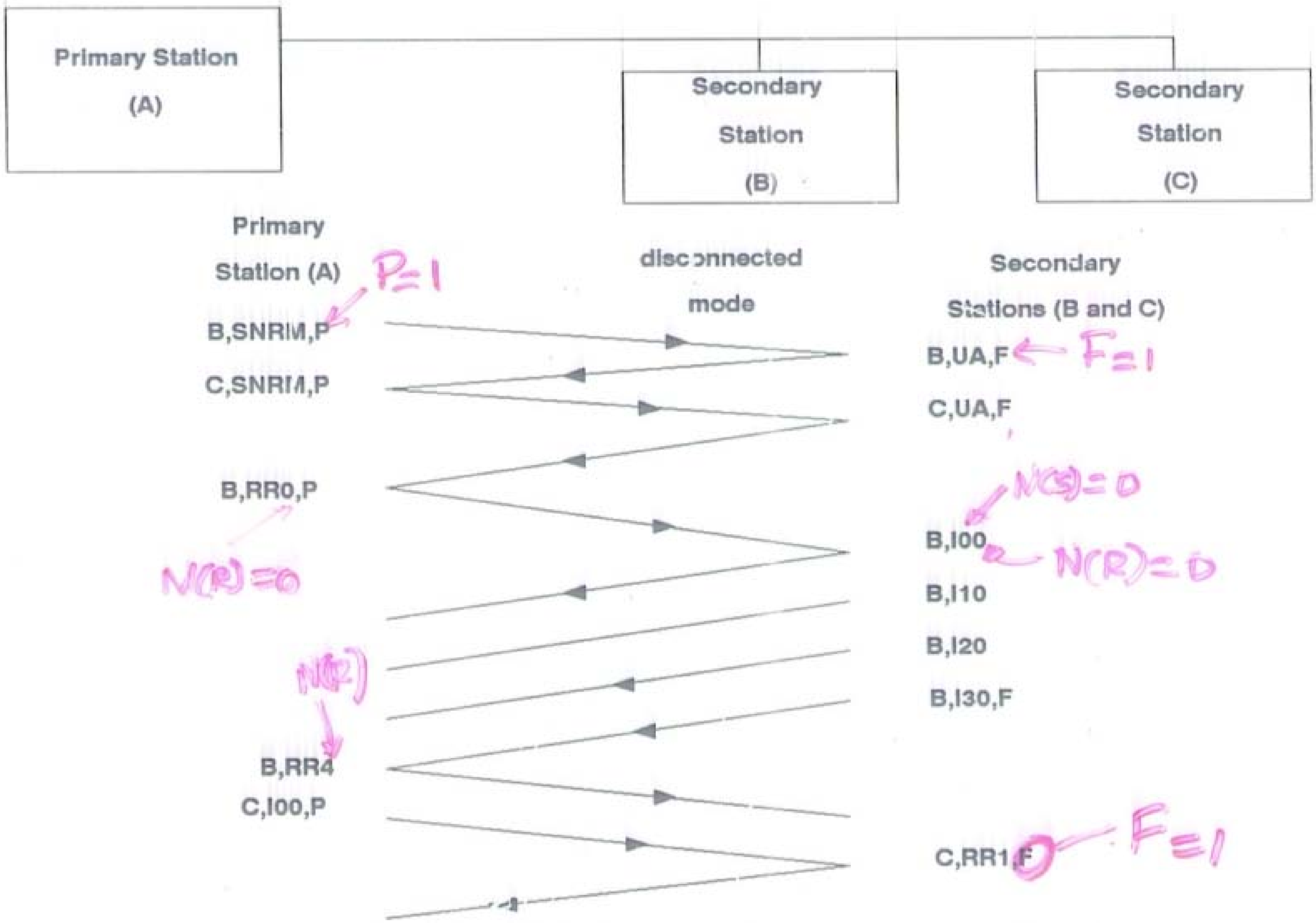
SNRME
SABME
SARME

FRMR : FRaMe Reject

UA : Unnumbered Acknowledgement

DISConnect.

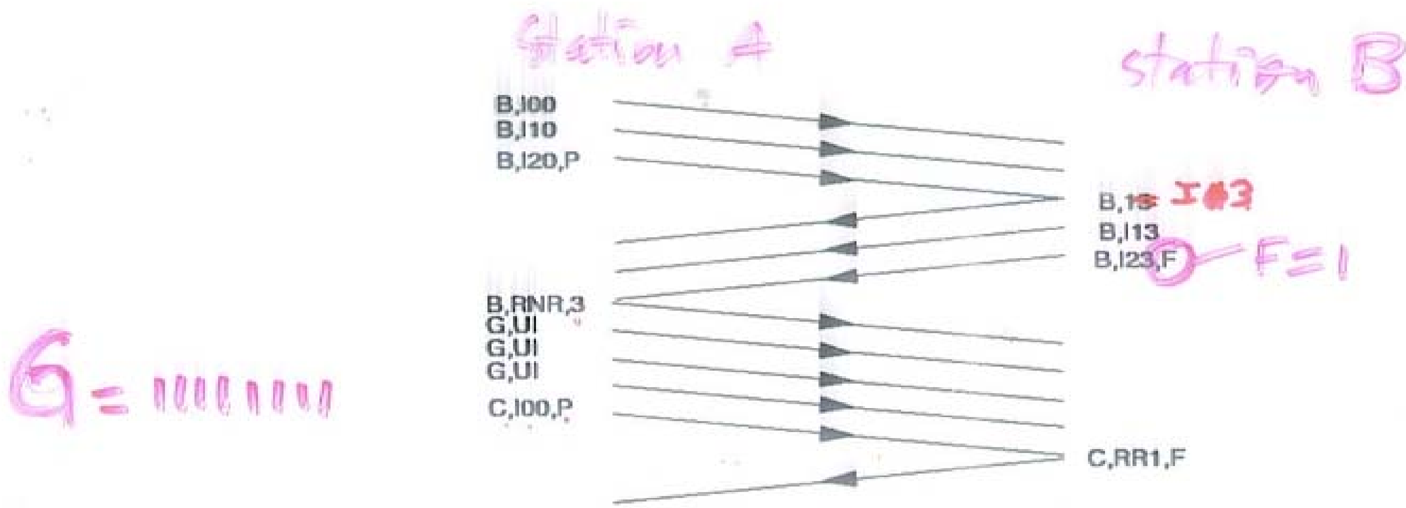
UI : Unnumbered Information



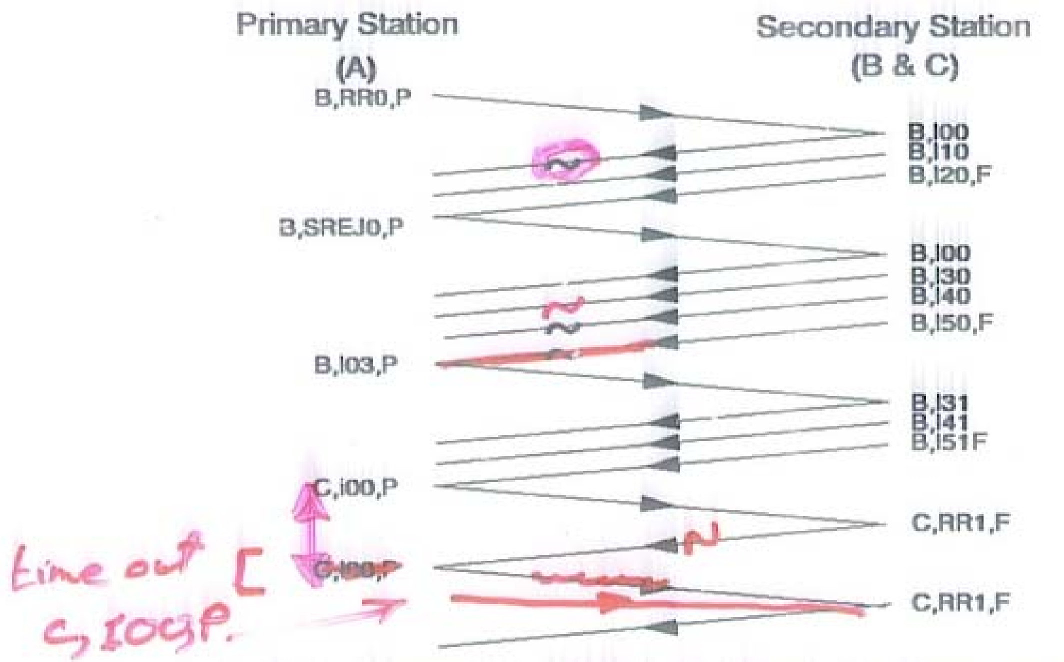
Example (a); Link Set - up and Sequence Numbers

[halfduplex, error free Line]

Fig. 4.~~17~~ 4.18 Examples of Typical operations of Bit Oriented Protocols



Example (b), RNR, RR Frames and Global Addressing

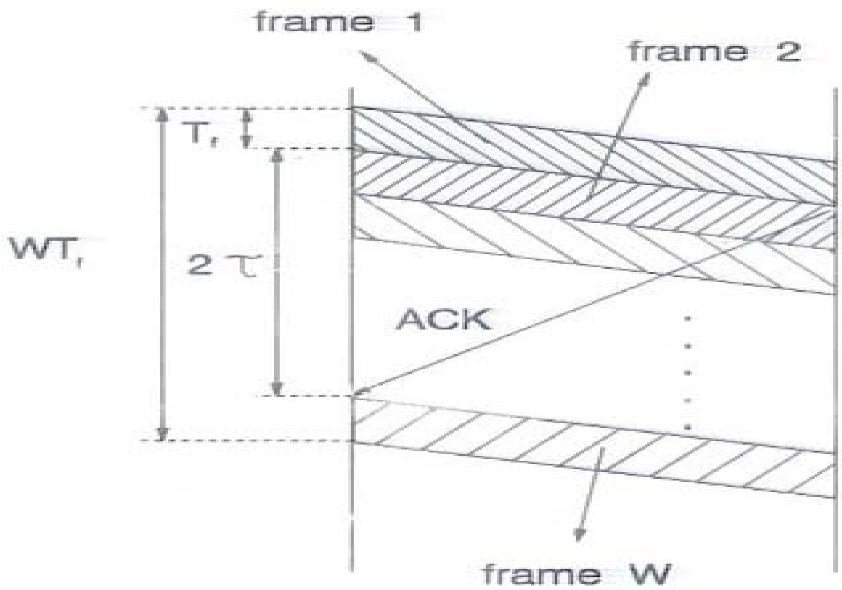


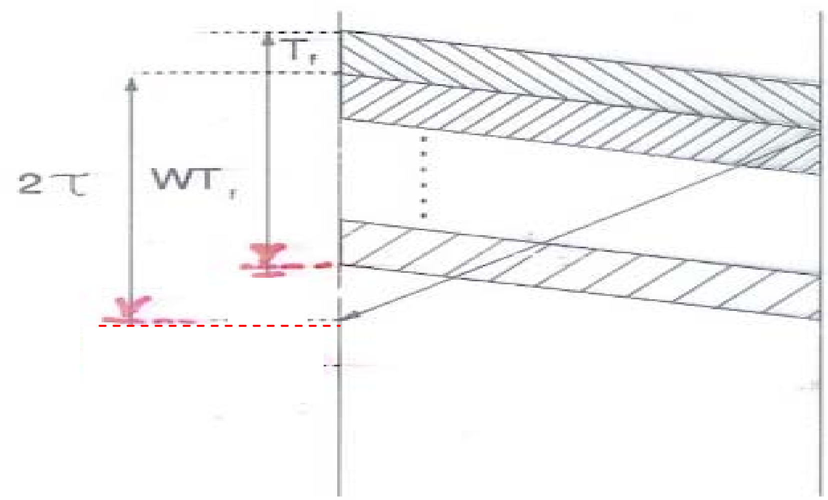
(c) Error Recovery (SREJ, Go-Back-N, Time out)

~ = Error in the transmitted frame

Fig. 4-11 (contineud)

Throughput (efficiency) analysis of D.L. Protocols





$$\eta = 1$$

(a) $W T_f > 2\tau + T_f$

$$\text{efficiency} = \frac{W T_f}{T_f + 2\tau} = \frac{W}{1 + 2a}$$

(b) $W T_f < 2\tau + T_f$

$$a = \frac{\tau}{T_f}$$

<u>Fig. 4.13 Sliding Window Protocol, error-free Link</u>