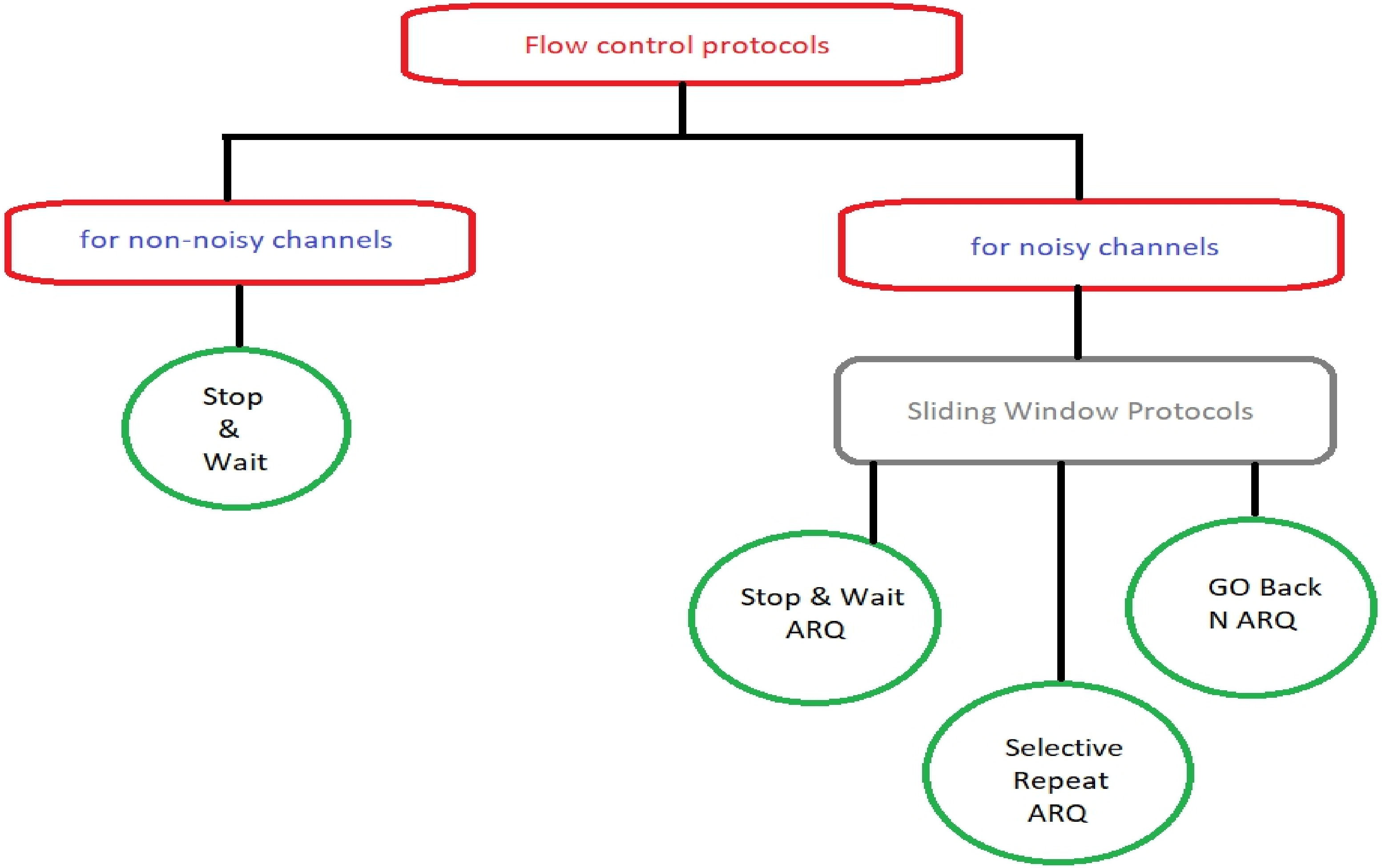
CN: WEEK 5


FLOW
CONTROL

Flow control in computer networks

- It is defined as the process of managing the rate of data transmission between two systems(nodes), this mechanism ensures that the rate of data (transmitted by the sender) is within the receiving capacity of the receiver node.

- A set of procedures which are used for restricting the amount of data that a sender can send to the receiver.



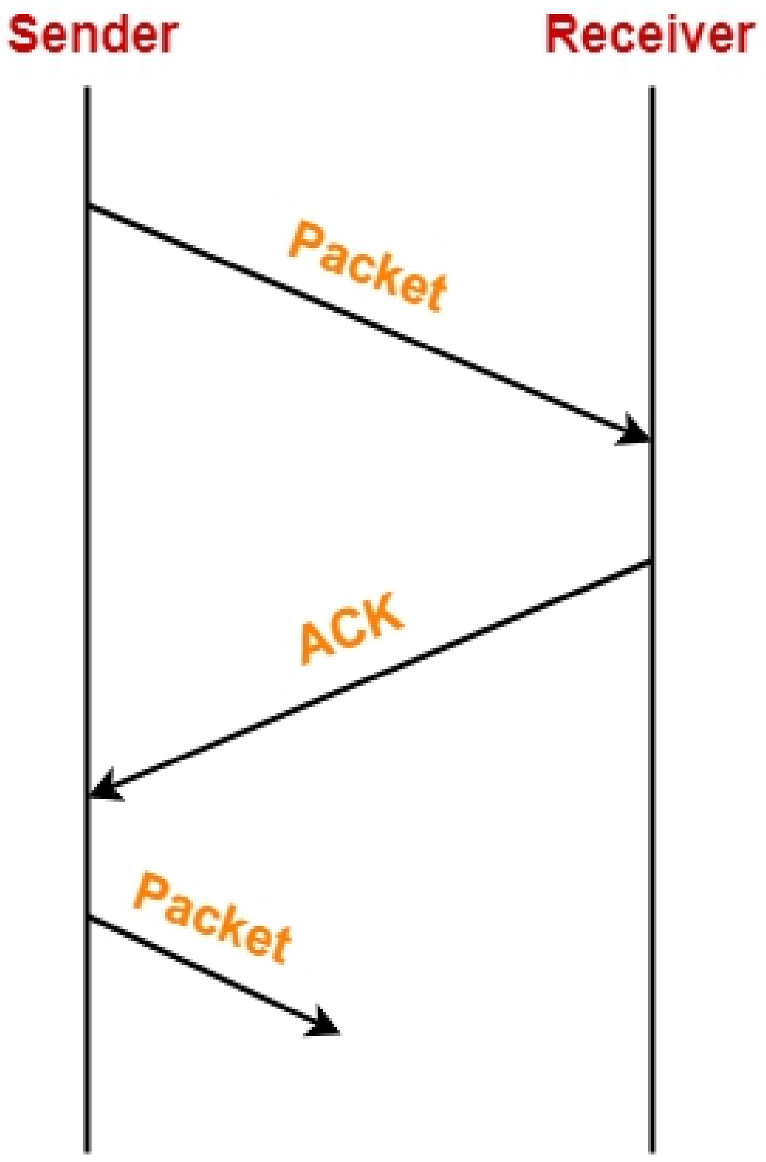
Non-noisy channel: An idealistic channel in which no frames are lost, corrupted or duplicated. The protocol does not implement error control in this category.

Stop and Wait Protocol

- Stop and Wait Protocol is the simplest flow control protocol.
- It works under the following assumptions-
  - Communication channel is perfect.
  - No error occurs during transmission.

Working Principle

- ✓ Sender sends a data packet to the receiver.
- ✓ Sender stops and waits for the acknowledgement for the sent packet from the receiver.
- ✓ Receiver receives and processes the data packet.
- ✓ Receiver sends an acknowledgement to the sender.
- ✓ After receiving the acknowledgement, sender sends the next data packet to the receiver.



Stop and Wait Protocol

Total Time

Total time taken in sending one data packet

$= (\text{Transmission delay} + \text{Propagation delay} + \text{Queuing delay} + \text{Processing delay})_{packet}$

$+$

$(\text{Transmission delay} + \text{Propagation delay} + \text{Queuing delay} + \text{Processing delay})_{ACK}$

Assume-

- Queuing delay and processing delay to be zero at both sender and receiver side.
- Transmission time for the acknowledgement to be zero since it's size is very small.

Total time taken in sending one data packet

$= (\text{Transmission delay} + \text{Propagation delay})_{packet} + (\text{Propagation delay})_{ACK}$

We know,

- Propagation delay depends on the distance and speed.
- So, it would be same for both data packet and acknowledgement.

Total time taken in sending one data packet

$= (\text{Transmission delay})_{packet} + 2 \times \text{Propagation delay}$

Efficiency

Efficiency (η) = Useful Time / Total Time

where-

- Useful time = Transmission delay of data packet = $(\text{Transmission delay})_{packet}$
- Useless time = Time for which sender is forced to wait and do nothing = 2 x Propagation delay
- Total time = Useful time + Useless time

$$\text{Efficiency } (\eta) = \frac{(\text{Transmission delay})_{packet}}{(\text{Transmission delay})_{packet} + 2 \times \text{Propagation delay}}$$

OR

$$\text{Efficiency } (\eta) = \frac{T_t}{T_t + 2T_p}$$

OR

$$\text{Efficiency } (\eta) = \frac{1}{1 + 2\left(\frac{T_p}{T_t}\right)}$$

OR

$$\text{Efficiency } (\eta) = \frac{1}{1 + 2a}\text{, where } a = \left(\frac{T_p}{T_t}\right)$$

$$\text{Efficiency } (\eta) = \frac{1}{1 + 2 \times \left(\frac{\text{Propagation delay}}{(\text{Transmission delay})_{packet}}\right)}$$

$$\text{Efficiency } (\eta) = \frac{1}{1 + 2 \times \left(\frac{\text{Distance}}{\text{speed}}\right) \times \left(\frac{\text{Bandwidth}}{\text{Packet length}}\right)}$$

Throughput-

- Number of bits that can be sent through the channel per second is called as its throughput.

Throughput = Efficiency (η) x Bandwidth

Round Trip Time-

Round Trip Time = 2 x Propagation delay

Efficiency may also be referred by the following names-

- Line Utilization
- Sender Utilization
- Utilization of Sender

Throughput may also be referred by the following names-

- Bandwidth Utilization
- Effective Bandwidth
- Maximum data rate possible
- Maximum achievable throughput

The advantages of stop and wait protocol are-

- It is very simple to implement.
- The incoming packet from receiver is always an acknowledgement.

The limitations of stop and wait protocol are-

- It is extremely inefficient because-
  - It makes the transmission process extremely slow.
  - It does not use the bandwidth entirely as each single packet and acknowledgement uses the entire time to traverse the link.

- If the data packet sent by the sender gets lost, then-
  - Sender will keep waiting for the acknowledgement for infinite time.
  - Receiver will keep waiting for the data packet for infinite time.

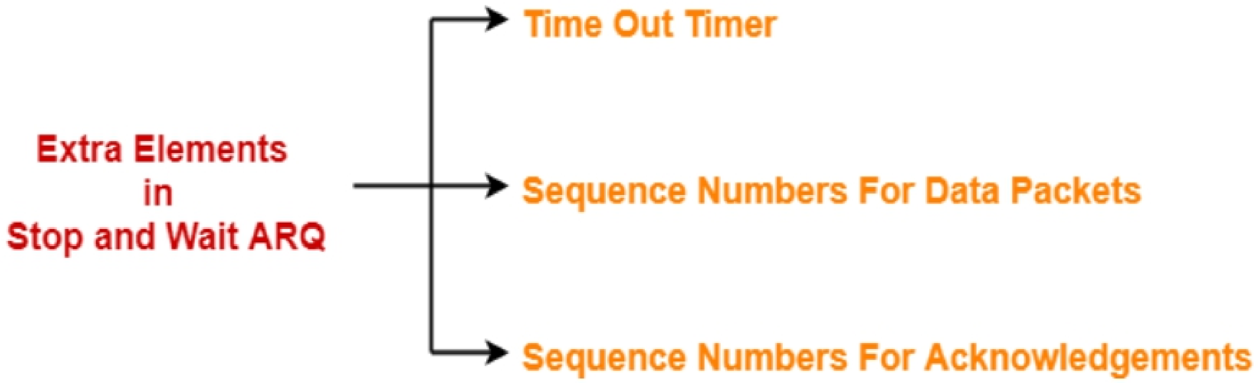
- If acknowledgement sent by the receiver gets lost, then-
  - Sender will keep waiting for the acknowledgement for infinite time.
  - Receiver will keep waiting for another data packet for infinite time.

Stop and Wait ARQ Protocol

- *The main problem faced by the Stop and Wait protocol is the occurrence of deadlock due to loss/damage of data packet & loss/delay of acknowledgement.*

- *Stop and Wait ARQ is an improved and modified version of Stop and Wait protocol.*

- *It provides a solution to all the limitations of stop and wait protocol by including the following three extra elements.*



Thus, we can say-

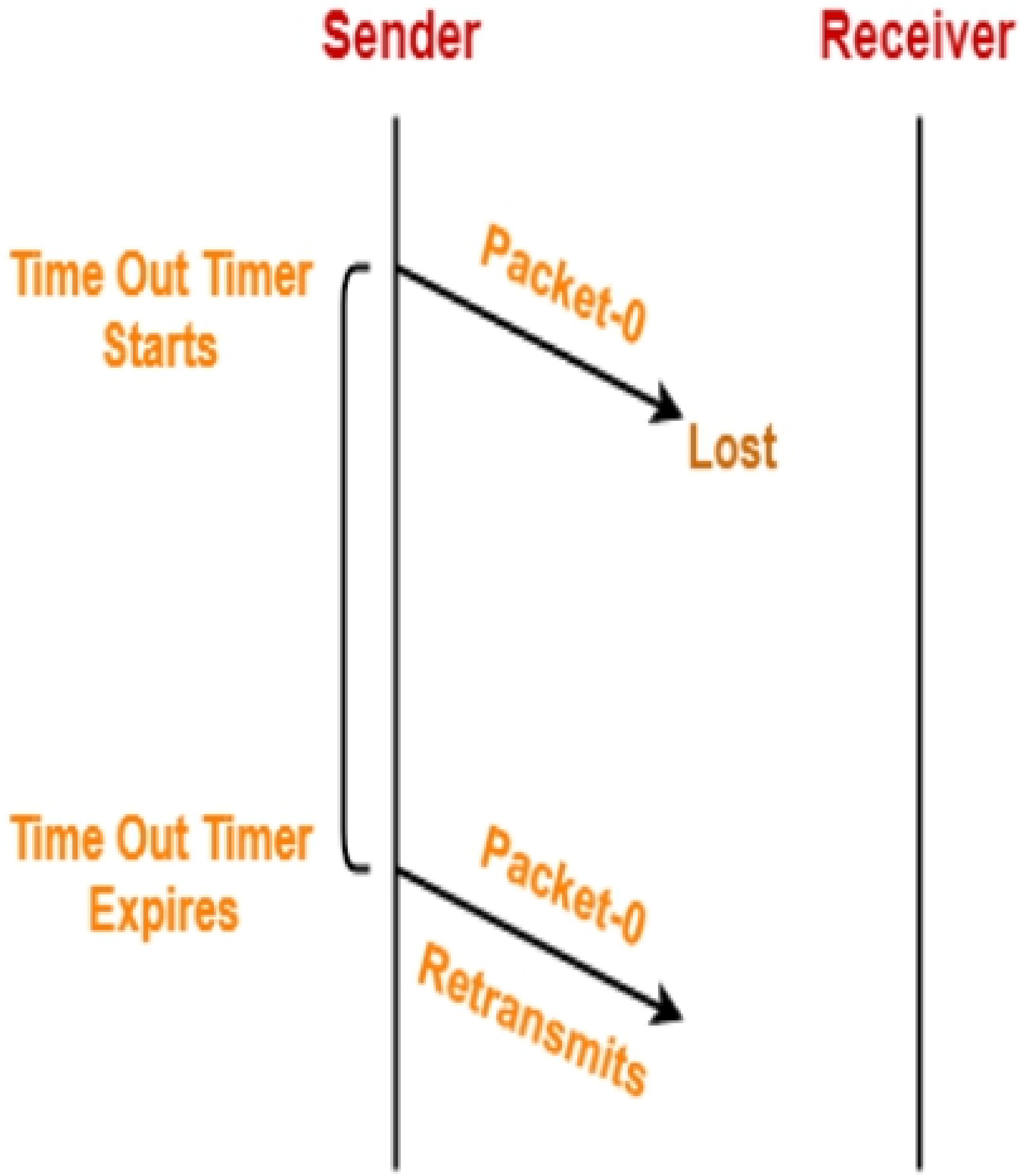
Stop and Wait ARQ

= Stop and Wait Protocol + Time Out Timer + Sequence Numbers for Data Packets and Acknowledgements

How Stop and Wait ARQ solves All Problems?

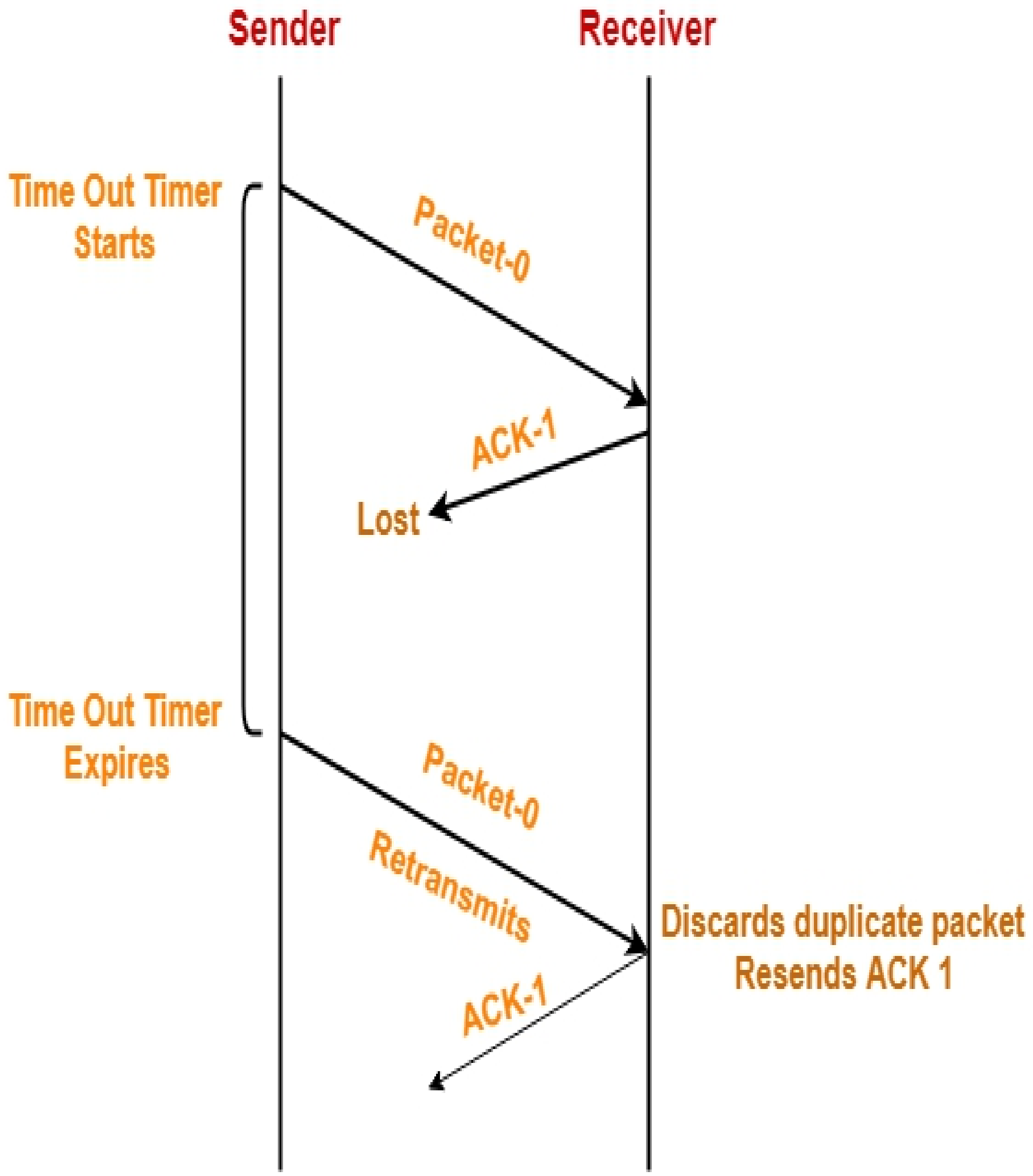
Problem of Lost Data Packet-

- Time out timer helps to solve the problem of lost data packet.
- After sending a data packet to the receiver, sender starts the time out timer.
- If the data packet gets acknowledged before the timer expires, sender stops the time out timer.
- If the timer goes off before receiving the acknowledgement, sender retransmits the same data packet.
- After retransmission, sender resets the timer.
- This prevents the occurrence of deadlock.



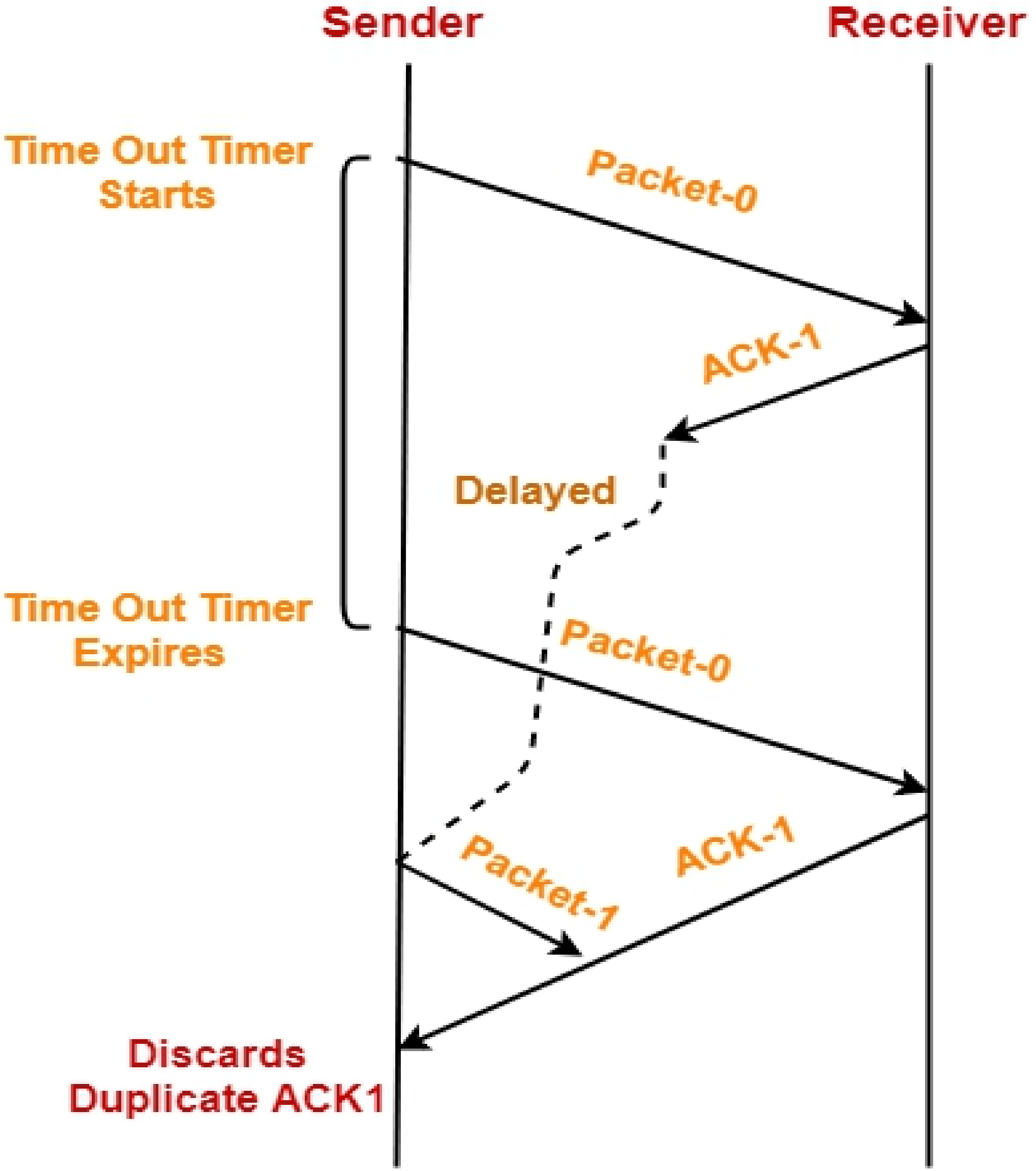
Problem of Lost Acknowledgement-

- Sequence number on data packets help to solve the problem of delayed acknowledgement.
- Consider the acknowledgement sent by the receiver gets lost.
- Then, sender retransmits the same data packet after its timer goes off.
- This prevents the occurrence of deadlock.
- The sequence number on the data packet helps the receiver to identify the duplicate data packet.
- Receiver discards the duplicate packet and re-sends the same acknowledgement.



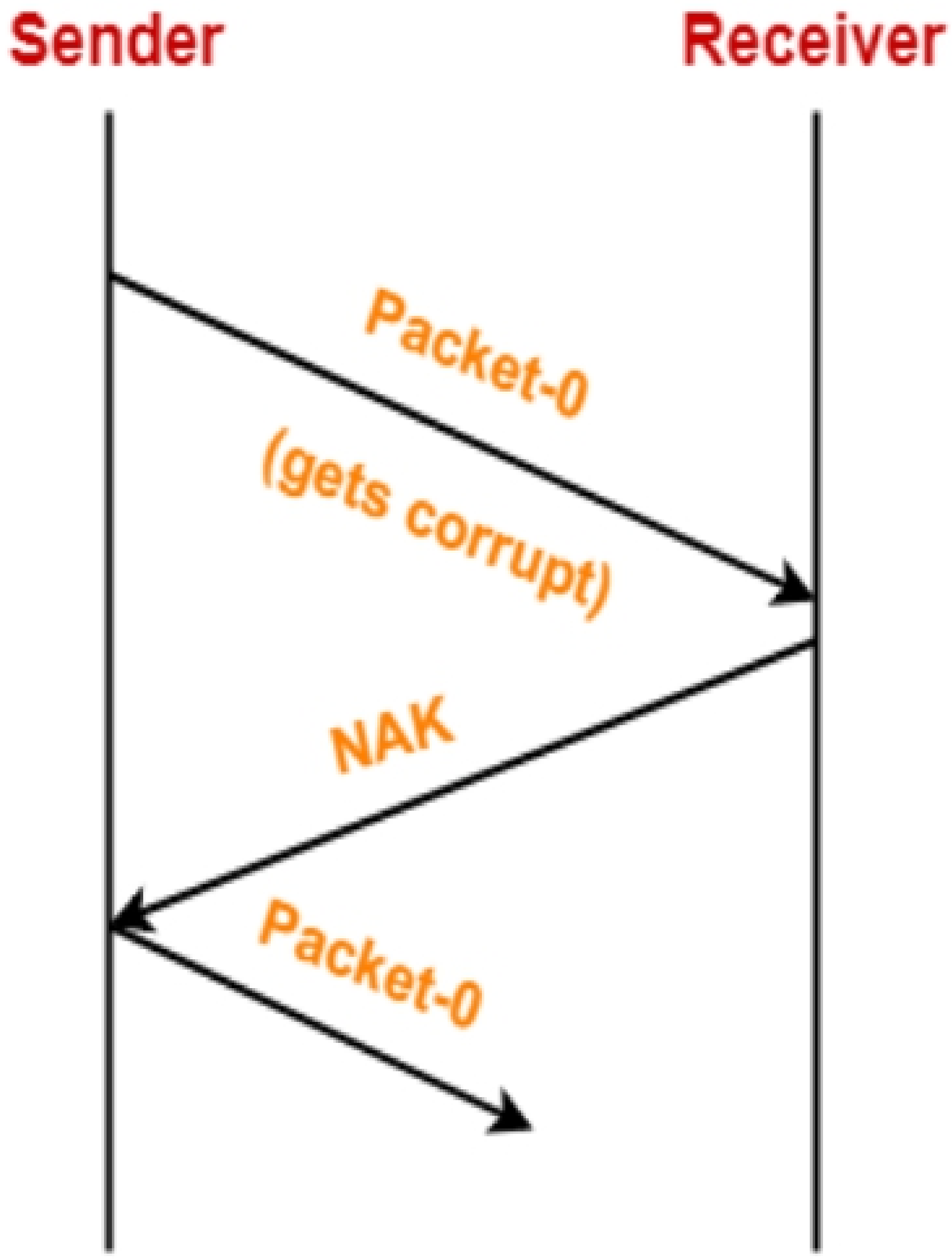
Problem of Delayed Acknowledgement-

- Sequence number on acknowledgements help to solve the problem of delayed acknowledgement.
- Sequence numbers allotted to the acknowledgements prove to be useful for identifying duplicate acknowledgements and discarding them.



Problem of Damaged Data Packet-

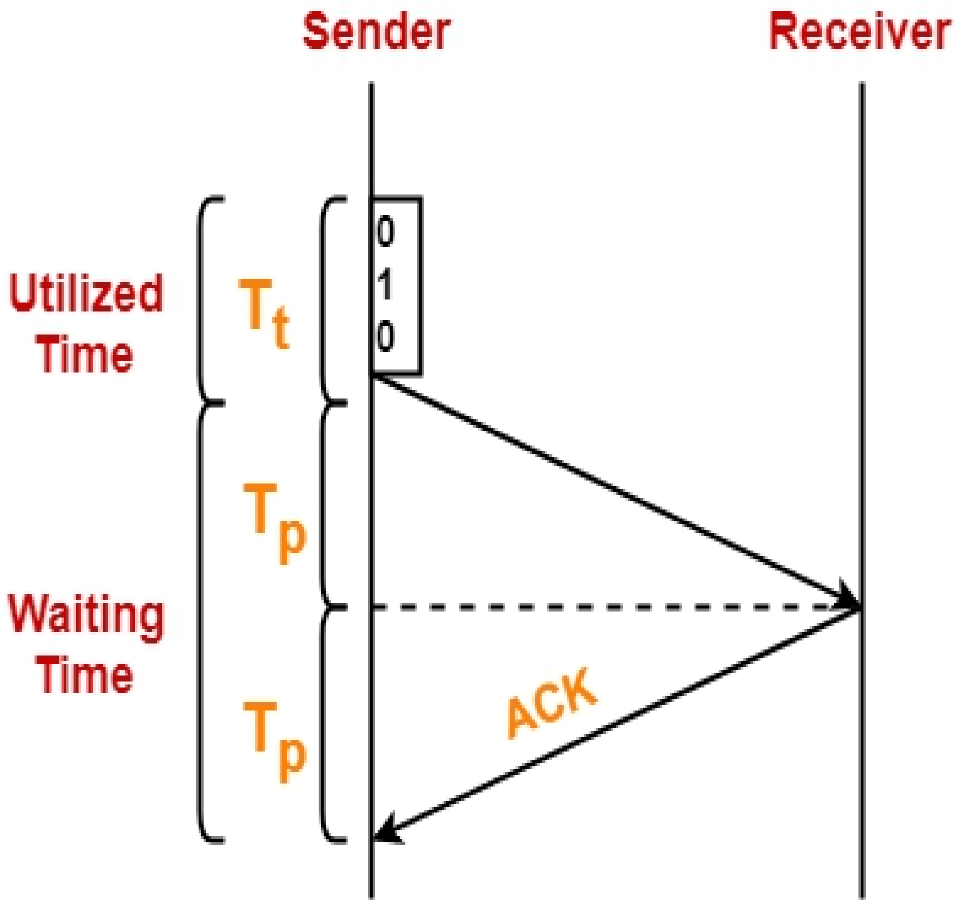
- If receiver receives a corrupted data packet from the sender, it sends a negative acknowledgement (NAK) to the sender.
- NAK requests the sender to send the data packet again.



Stop and Wait Protocol	Stop and Wait ARQ
It assumes that the communication channel is perfect and noise free.	It assumes that the communication channel is imperfect and noisy.
Data packet sent by the sender can never get corrupt.	Data packet sent by the sender may get corrupt.
There is no concept of negative acknowledgements.	A negative acknowledgement is sent by the receiver if the data packet is found to be corrupt.
There is no concept of time out timer.	Sender starts the time out timer after sending the data packet.
There is no concept of sequence numbers.	Data packets and acknowledgements are numbered using sequence numbers.

The major limitation of Stop and Wait ARQ is its very less efficiency.

- ***Sender sends one frame and then waits until the sent frame gets acknowledged.***
- ***After receiving the acknowledgement from the receiver, sender sends the next frame.***



Here,

- Sender uses T_t time for transmitting the packet over the link.
- Then, sender waits for 2 x T_p time.
- After 2 x T_p time, sender receives the acknowledgement for the sent frame from the receiver.
- Then, sender sends the next frame.
- This 2 x T_p waiting time is the actual cause of less efficiency.

PRACTICE PROBLEMS BASED ON STOP AND WAIT PROTOCOL

Question 1:

If the bandwidth of the line is 1.5 Mbps, RTT is 45 msec & packet size is 1 KB, find the link utilization in stop and wait.

Given-

- Bandwidth = 1.5 Mbps
- RTT = 45 msec
- Packet size = 1 KB

Calculating Transmission Delay-

Transmission delay (T_t)

= Packet size / Bandwidth

= 1 KB / 1.5 Mbps

= (2^{10} x 8 bits) / (1.5 x 10^6 bits per sec)

= 5.461 msec

Calculating Propagation Delay-

Propagation delay (T_p)

= Round Trip Time / 2

= 45 msec / 2

= 22.5 msec

Calculating Value Of 'a'-

a = T_p / T_t

a = 22.5 msec / 5.461 msec

a = 4.12

Calculating Link Utilization-

Link Utilization or Efficiency (η)

= 1 / 1+2a

= 1 / (1 + 2 x 4.12)

= 1 / 9.24

= 0.108

= 10.8 %

Question 2:

A channel has bit rate of 4 Kbps & propagation delay of 20 msec. It uses stop and wait protocol. The transmission time of acknowledgement frame is negligible. To get a channel efficiency of at least 50%, the minimum frame size should be-
120 bits
80 bits
160 bits

Given-

- Bandwidth = 4 Kbps
- Propagation delay (T_p) = 20 msec
- Efficiency >= 50%

Let the required frame size = L bits.

Calculating Transmission Delay-

Transmission delay (T_t)

= Packet size / Bandwidth

= L bits / 4 Kbps

Calculating Value Of 'a'-

$a = T_p / T_t$

a = 20 msec / (L bits / 4 Kbps)

a = (20 msec x 4 Kbps) / L bits

Condition For Efficiency To Be At least 50%-

For efficiency to be at least 50%, we must have-

1 / 1+2a >= 1/2

a <= 1/2

Substituting the value of 'a', we get-

(20 msec x 4 Kbps) / L bits <= 1/2

L bits >= (20 msec x 4 Kbps) x 2

L bits >= (20×10^{-3} sec x 4×10^{3} bits per sec) x 2

L bits >= 20 x 4 bits x 2

L >= 160

From here, frame size must be at least 160 bits.

Thus, Correct Option is (D).

Question 3:

If the packet size is 1 KB and propagation time is 15 msec, the channel capacity is 10^9 b/sec, then find the transmission time and utilization of sender in stop and wait protocol.

Given-

- Packet size = 1 KB
- Propagation time (T_p) = 15 msec
- Channel capacity = Bandwidth (here) = 10^9 b/sec

Calculating Transmission Delay-

Transmission delay (T_t)

= Packet size / Bandwidth

= 1 KB / 10^9 bits per sec

= 2^{10} bits / 10^9 bits per sec

= 1.024 μsec

Calculating Value Of 'a'-

$a = T_p / T_t$

a = 15 msec / 1.024 μsec

a = 15000 μsec / 1.024 μsec

a = 14648.46

Calculating Sender Utilization-

Sender Utilization or Efficiency (η)

= 1 / 1+2a

= 1 / (1 + 2 x 1468.46)

= 1 / 29297.92

= 0.0000341

= 0.00341 %

Question 4:

Consider a MAN with average source and destination 20 Km apart and one way delay of 100 µsec. At what data rate does the round trip delay equals the transmission delay for a 1 KB packet?

Given-

- Distance = 20 Km
- Propagation delay (T_p) = 100 µsec
- Packet size = 1 KB

We need to have-

Round Trip Time = Transmission delay

2 x Propagation delay = Transmission delay

Substituting the values in the above relation, we get-

2 x 100 µsec = 1 KB / Bandwidth

Bandwidth = 1 KB / 200 µsec

Bandwidth = (2^{10} x 10^6 / 200) bytes per sec

Bandwidth = 5.12 MBps or 40.96 Mbps

Question 5:

The values of parameters for the stop and wait ARQ protocol are as given below-
Bit rate of the transmission channel = 1 Mbps
Propagation delay from sender to receiver = 0.75 ms
Time to process a frame = 0.25 ms
Number of bytes in the information frame = 1980
Number of bytes in the acknowledge frame = 20
Number of overhead bytes in the information frame = 20
Assume that there are no transmission errors. Calculate the transmission efficiency (in %) of the stop and wait ARQ protocol for the above parameters.

Given-

- Bandwidth = 1 Mbps
- Propagation delay (T_p) = 0.75 ms
- Processing time ($T_{process}$) = 0.25 ms
- Data frame size = 1980 bytes
- Acknowledgement frame size = 20 bytes
- Overhead in data frame = 20 bytes

Calculating Useful Time-

Useful data sent

= Transmission delay of useful data bytes sent

= Useful data bytes sent / Bandwidth

= (1980 bytes – 20 bytes) / 1 Mbps

= 1960 bytes / 1 Mbps

= (1960 x 8 bits) / (10^6 bits per sec)

= 15680 μsec

= 15.680 msec

Calculating Total Time-

Total time

= Transmission delav of data frame + Propagation delay of data frame
+ Processing delay of data frame + Transmission delay of acknowledgement
+ Propagation delay of acknowledgement

= (1980 bytes / 1 Mbps) + 0.75 msec + 0.25 msec + (20 bytes / 1 Mbps) + 0.75 msec

= 15.840 msec + 0.75 msec + 0.25 msec + 0.160 msec + 0.75 msec = 17.75 msec

Calculating Efficiency-

Efficiency (η) = Useful time / Total time = 15.680 msec / 17.75 msec

= 0.8833 = 88.33%

Question 6:

A sender uses the stop and wait ARQ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 Kbps. Size of an acknowledgement is 100 bytes and the transmission rate at the receiver is 8 Kbps. The one way propagation delay is 100 msec. Assuming no frame is lost, find out the sender throughput.

Given-

- Frame size = 1000 bytes
- Sender bandwidth = 80 Kbps
- Acknowledgement size = 100 bytes
- Receiver bandwidth = 8 Kbps
- Propagation delay (T_p) = 100 msec

Calculating Transmission Delay Of Data Frame-

Transmission delay (T_t)

= Frame size / Sender bandwidth

= 1000 bytes / 80 Kbps

= (1000 x 8 bits) / (80 x 10^3 bits per sec)

= 0.1 sec

= 100 msec

Calculating Transmission Delay Of Acknowledgement-

Transmission delay (T_t)

= Acknowledgement size / Receiver bandwidth

= 100 bytes / 8 Kbps = 100 msec

Calculating Useful Time-

Useful Time = Transmission delay of data frame

= 100 msec

Calculating Total Time-

Total Time

= Transmission delay of data frame + Propagation delay of data frame

+ Transmission delay of acknowledgement + Propagation delay of acknowledgement

= 100 msec + 100 msec + 100 msec + 100 msec = 400 msec

Calculating Efficiency-

Efficiency (η) = Useful time / Total time

= 100 msec / 400 msec = 1 / 4 = 25%

Calculating Sender Throughput-

Sender throughput

= Efficiency (η) x Sender bandwidth

= 0.25 x 80 Kbps = 20 Kbps

= (20 x 1000 / 8) bytes per sec

= 2500 bytes/sec

Question 7:

Using stop and wait protocol, sender wants to transmit 10 data packets to the receiver. Out of these 10 data packets, every 4th data packet is lost. How many packets sender will have to send in total?

The packets will be sent as-

1, 2, 3, **4**, 4, 5, 6, **7**, 7, 8, 9, **10**, 10

The lost packets are- 4, 7 and 10.

Thus, sender will have to send 13 data packets in total.

END