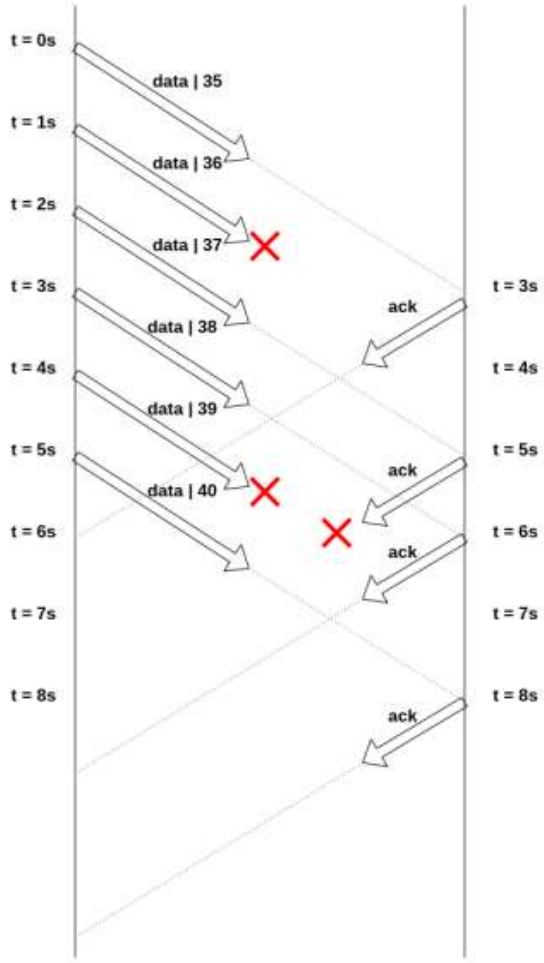
Question 1: Reliable Data Delivery [14 Marks]

"Secure Transfer Protocol" (STP) is a protocol designed to ensure that files are transferred reliably and securely. The sender and receiver use STP to communicate over a network in which packets can be lost. STP uses a **sliding window of size 6** along with an ACK-triggered loss detection mechanism where **k duplicate ACKs** are used to detect packet loss. **k is set to 2**. Assume that timers are not used for loss detection.

When a sender detects a loss, it retransmits the entire window. The receiver sends cumulative acknowledgements upon receiving packets. The first packet sent has a random sequence number, and each subsequent packet has a sequence number that is incremented by 1.

To test the reliability of STP, a company sends a document consisting of **8 packets** from its headquarters to a branch office over the Internet. The diagram below shows the sender and receiver and the state of packets and ACKs exchanged. The first packet sent has a **sequence number of 35** and is sent at **time t=0s.** The one-way delay between the sender and receiver is **3 seconds**. Packet **36** and **39** are not delivered, and the ACK for packet **37** is lost.



a) At what time, if any, would a packet loss be detected? Explain your answer. (8 marks)

1. Assuming first ACK with a sequence number also counted as duplicate:

(4 marks for correct answer + fully correct explanation)
(2 marks for correct answer + partially correct explanation)
(0 for answer without explanation)

t = 9s.

ACK for packet 35 has sequence number 36 (first duplicate). Packet 36 is lost. ACK of packet 37 does not reach the sender. ACK of packet 38 has sequence number 36, since packet 36 was lost (second duplicate). k=2 and two duplicate acks received so sender detects packet loss upon receiving the ACK for packet 38 at t = 9s.

2. Assuming first ACK with a sequence number is not counted as duplicate:

(4 marks for correct answer + fully correct explanation)
(2 marks for correct answer + partially correct explanation)
(0 for answer without explanation)

t = 11s.

ACK for packet 35 has sequence number 36. Packet 36 is lost. ACK of packet 37 does not reach the sender. ACK of packet 38 has sequence number 36 (first duplicate), since packet 36 was lost. Packet 39 is not delivered so no ACK for it. ACK for packet 40 has sequence number 36 (second duplicate). k=2 and two duplicate acks received so sender detects packet loss upon receiving the ACK for packet 40 at t = 11s.

b) List the sequence numbers of the packets that are retransmitted when the loss in (a) is detected. Explain your answer. (4 Marks)
(2 marks for correct answer)
(2 marks for correct explanation)

Entire window retransmitted.

Packets in window: 36, 37, 38, 39, 40, 41

Window slides by one step at t=6s.

c) STP developers claim that timers are not required and ACK-triggered loss detection suffices. Are they right in their claim? Explain your answer. (2 Marks)
(1 mark for correct answer)
(1 mark for correct explanation)

No.

In the case all packets/ACKs are lost, we won't receive any duplicate ACKs. In such cases the sender keeps waiting endlessly since there are no timers for loss detection.

Question 2: TCP's Flow Control [4 Marks]

Mutahar is sending a large file to Ahmed over a network using the TCP protocol. Ahmed has a **receive buffer** of **8KB**. The **last byte received** by Ahmed is **24,096**, and the **last byte read** is **20,000**. Calculate the size of the advertised receive window in Bytes.
(4 marks for fully correct answer)
(2 marks for partially correct)

The value of the advertised receive window in bytes can be calculated using the formula:

Advertised Receive Window = RcvBuffer – (LastByteRcvd – LastByteRead)

Given the following values:

RcvBuffer = 8KB = 8192 Bytes OR 8000 Bytes

LastByteRcvd = 24096 LastByteRead = 20000

Advertised Receive Window = 8192 – (24096 – 20000) = 4096 Bytes OR

Advertised Receive Window = 8000 – (24096 – 20000) = 3904 Bytes

Therefore, the value of the advertised window is 4096 Bytes OR 3904 Bytes.

Question 3: TCP's Congestion Control [10 Marks]

Two TCP connections, one using the TCP Reno congestion control algorithm and the other using the TCP Tahoe congestion control algorithm, are sharing a network link with a capacity of 10 Mbps (megabits per second) and a Round-Trip Time (RTT) of 100 ms. Connection A (TCP Reno) uses an initial congestion window (CWND) of 10 segments, each segment is 1500 bytes. Connection B (TCP Tahoe) uses an initial CWND of 8 segments, each segment is 1200 bytes.

a. Calculate the bandwidth-delay product (BDP) for each connection. Delay is RTT. [2 Marks]

*For Connection A (TCP Reno): BDP_A = (10 Mbps) * (100 ms) = 1,000,000 bits / 8 (to convert bits to bytes) = 125,000 bytes*

*For Connection B (TCP Tahoe): BDP_B = (10 Mbps) * (100 ms) = 1,000,000 bits / 8 (to convert bits to bytes) = 125,000 bytes*

b. Determine the maximum achievable throughput for each connection assuming no packet loss and a fair network. Throughput is BDP/RTT. [2 Marks]

For Connection A (TCP Reno): Throughput_A = BDP_A / RTT = 125,000 bytes / 0.1 seconds = 1,250,000 bytes per second or 10 Mbps.

For Connection B (TCP Tahoe): Throughput_B = BDP_B / RTT = 125,000 bytes / 0.1 seconds = 1,250,000 bytes per second or 10 Mbps.

Both Connection A (TCP Reno) and Connection B (TCP Tahoe) can achieve a maximum throughput of 10 Mbps, given the network conditions and assuming no packet loss.

c. Explain how the slow start and congestion avoidance phases affect the CWND for each connection as they adapt to the network, considering the specific behaviors of TCP Reno and TCP Tahoe. [6 Marks]

- **Connection A (TCP Reno):**
  - In the Slow Start phase, TCP Reno will double the CWND with each successful RTT until congestion is detected. If congestion occurs, it enters the Fast Recovery phase.
  - In Fast Recovery, TCP Reno reduces the CWND by half (referred to as "fast recovery threshold") and enters the Congestion Avoidance phase, where the CWND increases linearly.
  - TCP Reno will reduce the CWND more aggressively upon detecting congestion, which can lead to a more conservative approach during congestion control.
- **Connection B (TCP Tahoe):**

- In the Slow Start phase, TCP Tahoe will double the CWND with each successful RTT until congestion is detected. If congestion occurs, it enters the Slow Start phase again, resetting the CWND to the initial value.
- Unlike TCP Reno, TCP Tahoe does not have a separate fast recovery phase. It reverts to Slow Start upon congestion, resulting in a more aggressive reduction of the CWND.

Both connections will adapt their CWND sizes to find the optimal sending rate without causing congestion, but TCP Tahoe tends to be more conservative by resetting to the initial CWND upon congestion. TCP Reno, on the other hand, has a more refined approach with the Fast Recovery phase before entering Congestion Avoidance.

Question 4: MCQs [7 Marks]

1. Which of the following statement is TRUE in relation to difference between Application and Transport Layers?
    a) Application layer uses IP+Port numbers and the Transport layer only uses port numbers.
    b) They both are only implemented at the end systems.
    c) Transport layer provides process-to-process communication while the Application layer provides program-to-program communication.
    d) All of the above
    e) None of the above

For the next two MCQs, assume that in the case of a pipelined, reliable transport protocol, for which the sender can have up to N=4 unacknowledged packets, packets with sequence numbers 0-3 are transmitted. Only the packet with sequence number 3 gets lost during the transmission. **Answer the following two questions:**

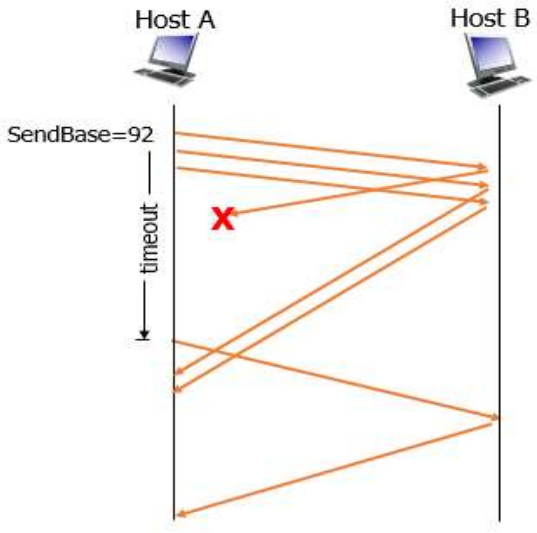
2. What are the sequence numbers of the packets that are retransmitted in the case of Go-Back-N?
    a) 2
    b) 2, 3, and 4
    c) 3
    d) 2 and 3
3. What are sequence numbers of the packets that are retransmitted in the case of Selective Repeat?
    a) 2
    b) 2, 3, and 4
    c) 3
    d) 2 and 3
4. The transfer of data from one sender to many receivers is possible using TCP?
    a) TCP connection is point to point. So it is not possible
    b) Yes, I think so.
    c) It depends on the OS installed on the end-system
    d) None of the above
5. What is the relation between a Process and Sockets?
    a) A process can create multiple sockets.
    b) A socket can be associated with multiple processes on an end system. However, the socket must be TCP and we can then use port numbers to identify sockets.
    c) All of the above
    d) There is no relation between a process and a socket.
6. Which operating systems use rdt 3.0 (with or without pipelining)?
    a) Linux - All versions including Ubuntu
    b) Windows - only 7 and 10
    c) Mac OS X - All versions

d) All of the above

e) **None of the above**

7. Which of the following is **FALSE** in relation to TCP and UDP:
   - **a) Both are network layer protocols providing multiplexing and demultiplexing**
   - b) It is possible to design and implement a new protocol that is hybrid of both TCP and UDP, i.e. provides some (not all) services as provided by TCP.
   - c) All of the above
   - d) None of the above
8. Packet forwarding in computer networks is:
   - a) End-to-End delivery of the Packet.
   - b) Determining route taken by packets from source to destination
   - **c) Moving packets from router's input interface to appropriate router output interface.**
   - d) All of the above.
9. In rdt 3.0 a packet is retransmitted if:
   - a) Timeout event occur
   - b) Packet is corrupted
   - **c) both a) and b)**
   - d) None of the above
10. Suppose host A sends host B one segment with sequence number 38 and 4 bytes of data. Then in the same segment the acknowledgement number is necessarily 42.
    - a) True
    - **b) False**
11. What is the three-way handshake sequence used to initiate TCP connections?
    - a) ACK, SYN/ACK, ACK
    - **b) SYN, SYN/ACK, ACK**
    - c) SYN, SYN, ACK/ACK
    - d) ACK, SYN/ACK, SYN
12. Which of the following statement is Not True about Go-Back-N protocol?
    - a) Sender can have up to N unAcked packets in pipeline
    - b) Discard out of order packets at receiving end
    - c) All of the above
    - **d) Receiver send individual ACK**

Suppose Host A is sending some data to Host B using TCP and send three segments back-to-back as shown in the following scenario. Consider initial timeout is of 0.3sec and Send Base of Host A is 92. (Answer the following two MCQS)



13. What will be the sequence numbers of these first three segments given that the number of bytes of data in them equal to 20, 30, and 40 respectively?
    a) 92, 102, 122
    b) 20, 30, 40
    c) 102, 122, 162
    d) None of the above
14. What will be the acknowledgment numbers in the three acknowledgement packets if these segments are successfully received by Host B (when selective repeat is in practice)?
    a) Either 93, 103, 103
    b) Either 102, 122, 147
    c) Either 91, 101, 121
    d) None of the above