Transport Layer Protocols II

Course Code: COE 3206 Course Title: Computer Networks

Dept. of Computer Science
Faculty of Science and Technology

Lecturer No:		**Week No:**		**Semester:**	Fall 24-25
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Lecture Outline

1. Congestion in networks
2. Congestion control
   - TCP Reno
3. Error control principle
   - Sliding window technique

Congestion in networks

- **Congestion**

Congestion is a situation in a network in which the load on the network, the number of packets sent to the network, is greater than the capacity of the network, the number of packets a network can handle.

- **Congestion control**

Congestion control refers to the mechanisms and techniques to control the congestion and keep the load below the capacity [1].

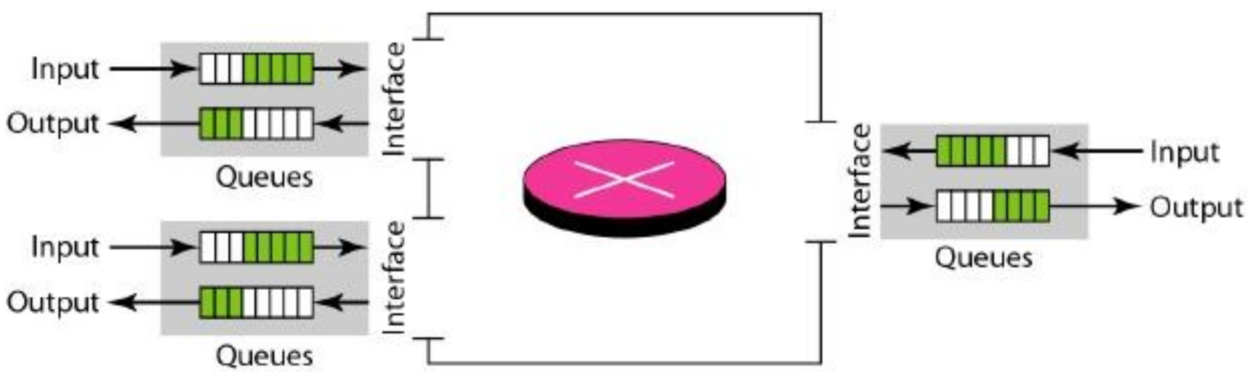
Congestion in networks…

- Congestion in a network or internetwork occurs because routers and switches have queues-buffers that hold the packets before and after processing.
- A router, for example, has an input queue and an output queue for each interface.
- When a packet arrives at the incoming interface, it undergoes three steps before departing:
  1. The packet is put at the end of the input queue while waiting to be checked.
  2. The processing module of the router removes the packet from the input queue once it reaches the front of the queue and uses its routing table and the destination address to find the route.
  3. The packet is put in the appropriate output queue and waits its turn to be sent.

Congestion in networks…

❖ **Two possible scenarios in a router:**

1. Packet arrival rate > packet processing rate,
   the input queues become longer and longer.
2. Packet departure rate < Packet processing rate,
   the output queues become longer and longer



Congestion Control

Terminology

- **Congestion Window**
  - The number of bytes the sender may have in the network at any time [2]
  - LastByteSent – LastByteAcked <= cwnd
- **Sending Rate**
  - The congestion window size divided by the round-trip time (RTT[1]) of the connection [2].

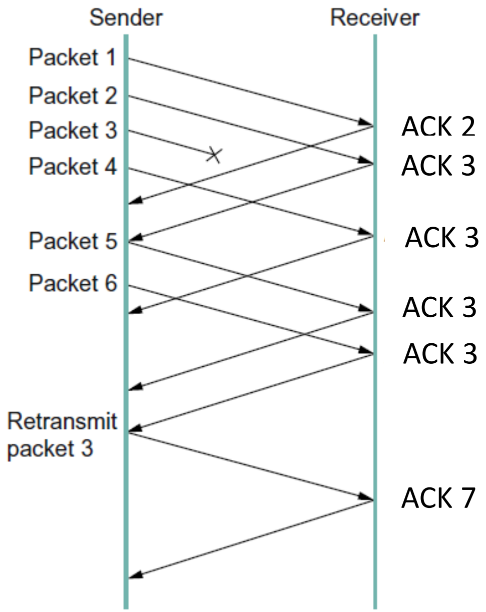
❖ *By adjusting the value of cwnd, the sender can therefore adjust the rate at which it sends data into its connection [3].*

1 The time from when a segment is sent until it is acknowledged.

Congestion Control

Terminology

- Loss Event
  - Timeout
    - Sender does not receive any acknowledgement within a predefined interval
  - 3 duplicate Acknowledgement (3 duplicate ACK)
    - Reception of the same ACK four times.
    - Indicates that the channel is not congested that much as the receiver is still receiving segments.
    - Indicates that the segment 3 is lost as it receives the dupli ACK 3
    - Receiver is receiving segment out of order.



Congestion Control

TCP Reno

- **Steps of congestion window control**
  - Slow Start
  - Congestion Avoidance

Congestion Control

TCP Reno

❖Slow Start

Follows a greedy approach.

Starts sending data of size equals maximum sized segment (MSS).

If it receives an ACK for the previous transmission by next RTT → it sends 2 MSS.

After next RTT, if it receives two ACKs → it sends 2+2=4 MSS in next round.

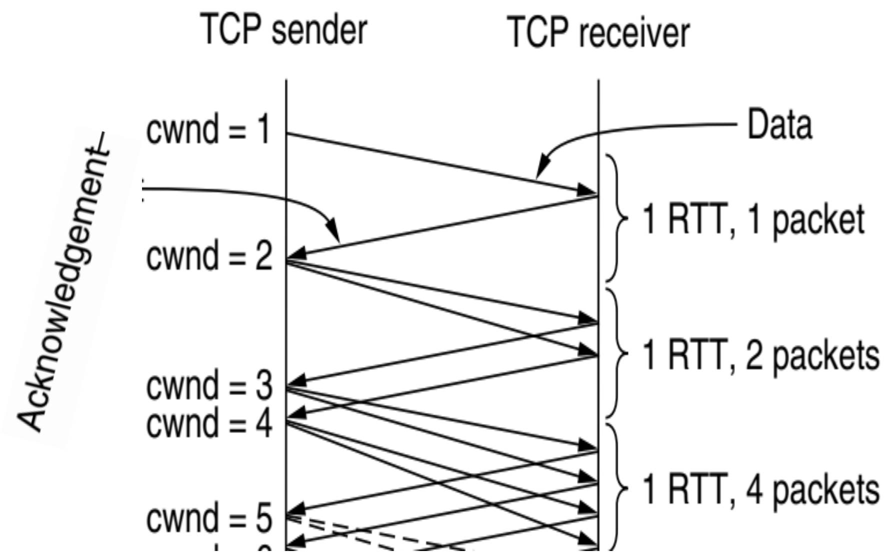


Fig. 1 Slow start from an initial congestion window of one segment [2].

Congestion Control

TCP Reno

❖Slow Start (cont.)

That is, in each round, N+M MSS in a round if it sends N MSS in the last transmission round and receives M ACK before the current round.

If it receives ACK for all the N MSS (previously sent), it sends N+N MSS this round.

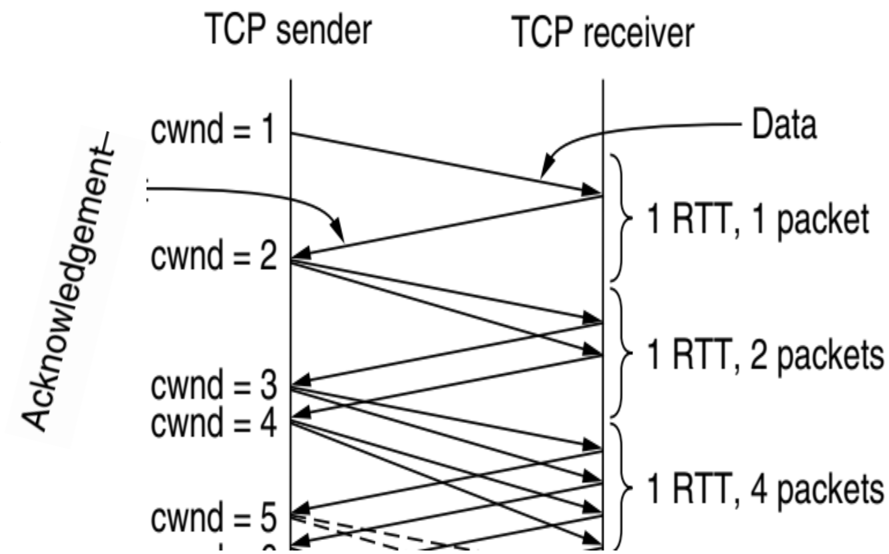


Fig. 1 Slow start from an initial congestion window of one segment [2].

Congestion Control

TCP Reno

❖Congestion Avoidance

How long does cwnd continue to be increased exponentially?

$if\ cwnd \geq threshold$

Increase cwnd by1 per transmission round

That is, increase cwnd linearly[1]

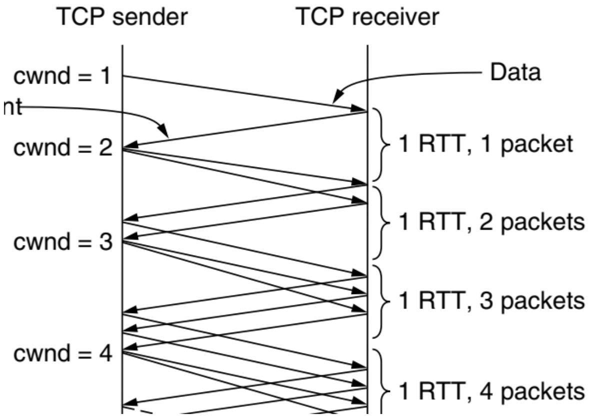


Fig. 2 Linear increase of cwnd

1. Usually timeout and 3 duplicate ACK do not happen in slow start

Congestion Control

TCP Reno

How long does cwnd continue to be increased linearly?

- Until one of two incidents happen
  - Timeout
  - 3 duplicate ACK

- **Timeout**

$$Threshold = \frac{cwnd}{2}$$

$$cwnd = 1\ MSS$$

Start slow start

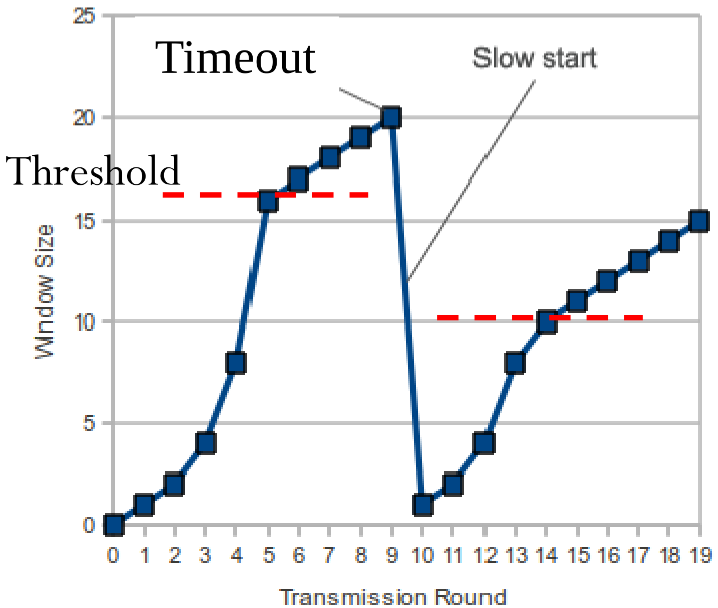


Fig. 3 Timeout

Congestion Control

TCP Reno

- **3 duplicate ACK**

$$Threshold = \frac{cwnd}{2}$$

$$cwnd = Threshold$$

Start congestion avoidance

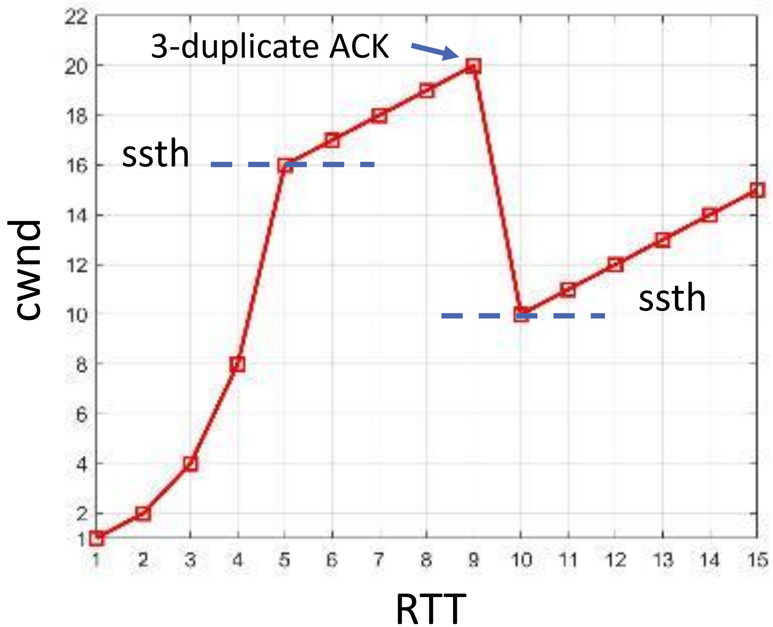


Fig. 4 3 duplicate ACK

Congestion Control

TCP Reno

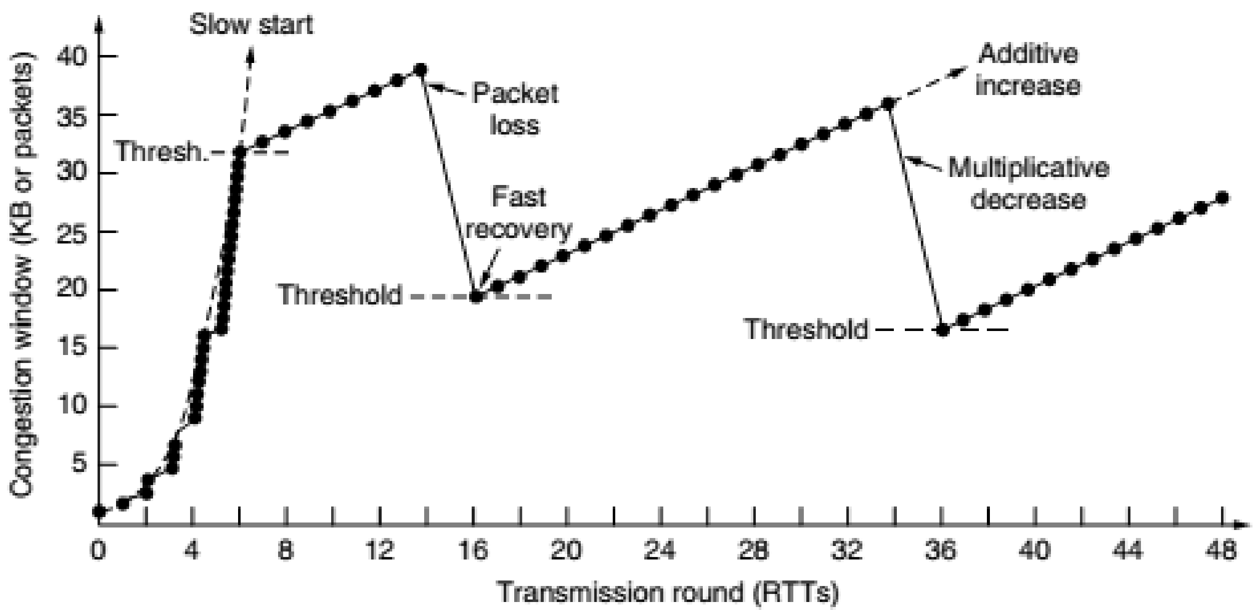
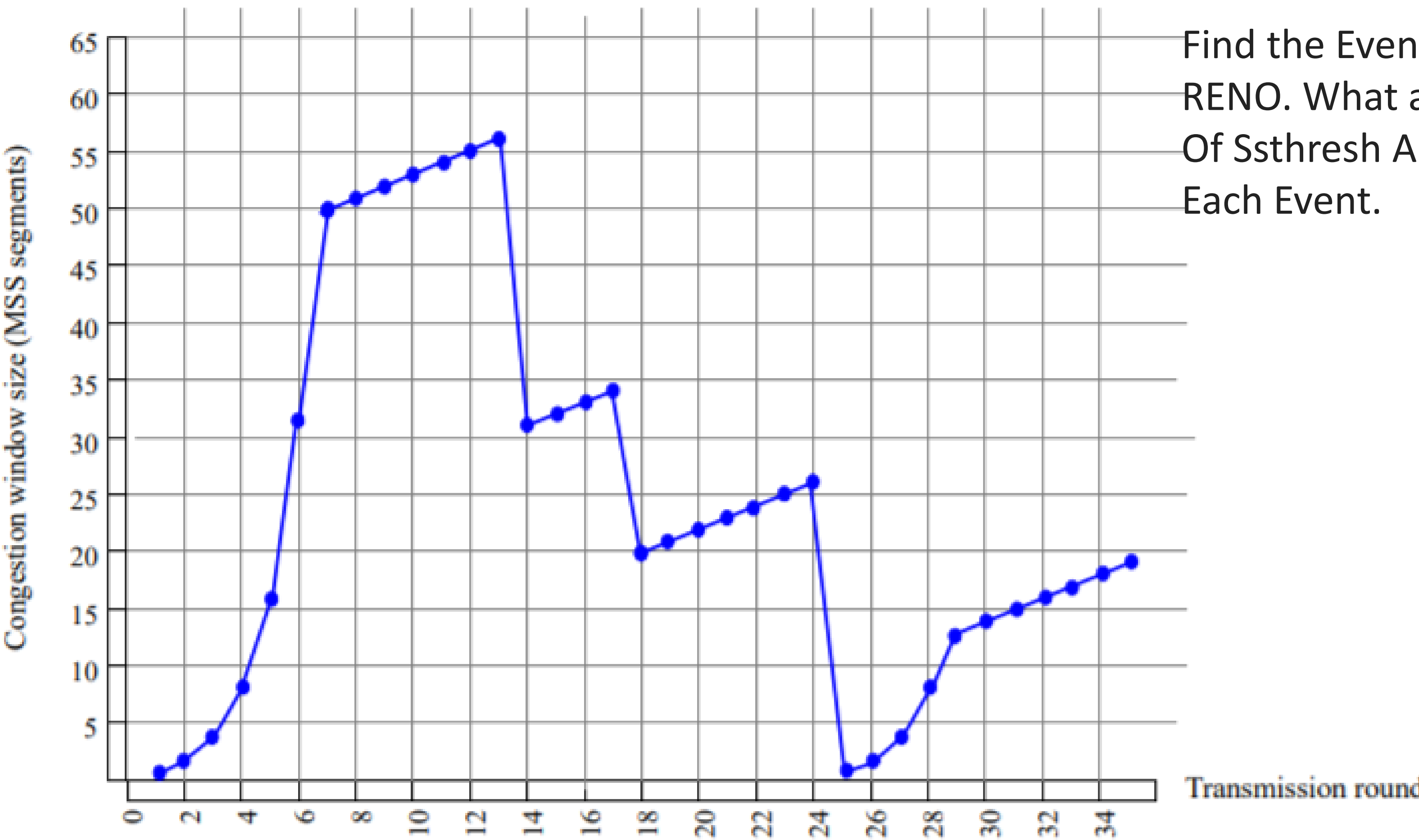


Fig. 5 TCP reno example

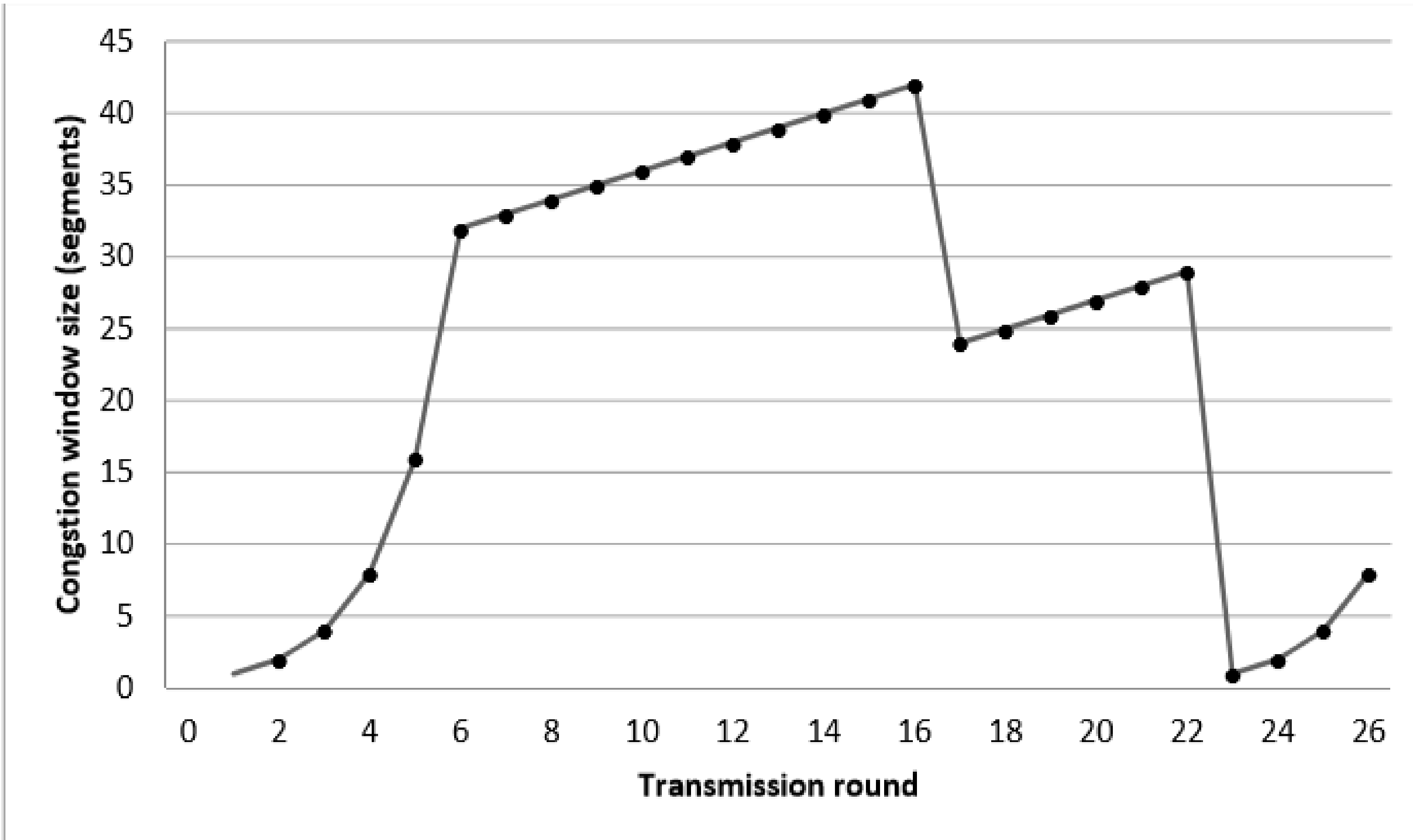
(3 points each) Consider the figure below. Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions. In all cases, you should provide a short discussion justifying your answer.



Find the Events in the TCP RENO. What are The Values Of Ssthresh And Cwnd at Each Event.

Task 2

Identify Timeout/3 duplicate ACK incidence. Also identify slow start, congestion avoidance period.



Flow control

- The TCP stores the data that needs to be sent in the send buffer and the data to be received in the receive buffer. Flow control makes sure that no more packets are sent by the sender once the receiver's buffer is full as the messages will be dropped and the receiver won't be able to handle them. In order to control the amount of data sent by the TCP, the receiver will create a buffer which is also known as Receive Window.
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Flow control

- Send window
  - Sequence of byte numbers of which some are sent but yet to be acknowledged while others are waiting to be sent
  - Maintained by sender

- Receive window
  - Sequence of byte numbers which are expected to be received
  - Maintained by receiver

References

[1] B. A. Forouzan, *Data Communication and Networking*, *4*th ed., Tata McGraw Hill Companies, Inc., New Delhi, 2010, pp. 385.

[2] A. S. Tanenbaum and D. J. Wetherall, *Computer Networks*, 5th ed., Pearson Education India, 2013, pp. 571-572.

[3] J. F., Kurose and K. W. Ross, *Computer Networking: A Top-Down Approach*, 7th ed., Pearson Education, Inc., USA, 2017, pp. 274-277.

[4] D. Medhi and K. Ramassamy, Network Routing Algorithms, Protocols and Archtectures, 2nd ed., Elsevier Inc., 2018, pp. 607-608.

[5] D. Runemalm , D. M. Sarwar and M. Shalbaf, "Decreasing the Hybrid-ARQ bandwidth overhead through the Multiple Packet NAK (MPN) protocol", https://www.researchgate.net/publication/267554658 , [Accessed: April. 22, 2020].

[6] B. A. Forouzan, *TCP/IP Protocol Suite*, *4*th ed., McGraw Hill Companies, Inc., USA, 2010, pp. 457-462.

Recommended Books

1. **Data Communications and Networking**, *B. A. Forouzan*, McGraw-Hill, Inc., Fourth Edition, 2007, USA.
2. **Computer Networking: A Top-Down Approach**, *J. F., Kurose, K. W. Ross*, Pearson Education, Inc., Sixth Edition, USA.
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4. **CCNA Routing and Switching**, *T. Lammle*, John Wily & Sons, Second Edition, 2016, USA.
5. **TCP/IP Protocol Suite**, *B. A. Forouzan*, McGraw-Hill, Inc., Fourth Edition, 2009, USA.
6. **Data and Computer Communication**, *W. Stallings*, Pearson Education, Inc., Tenth Education, 2013, USA.