Activities on TCP

TCP behavior (summary)

- State variables:
  - CWND = Congestion Window (Congestion Control)
  - RCWND = Receiver Window (Flow Control)
  - SSTHRESH = Slow Start Threshold
  - MSS = Maximum Segment Size
  - RTO = Retransmission TimeOut

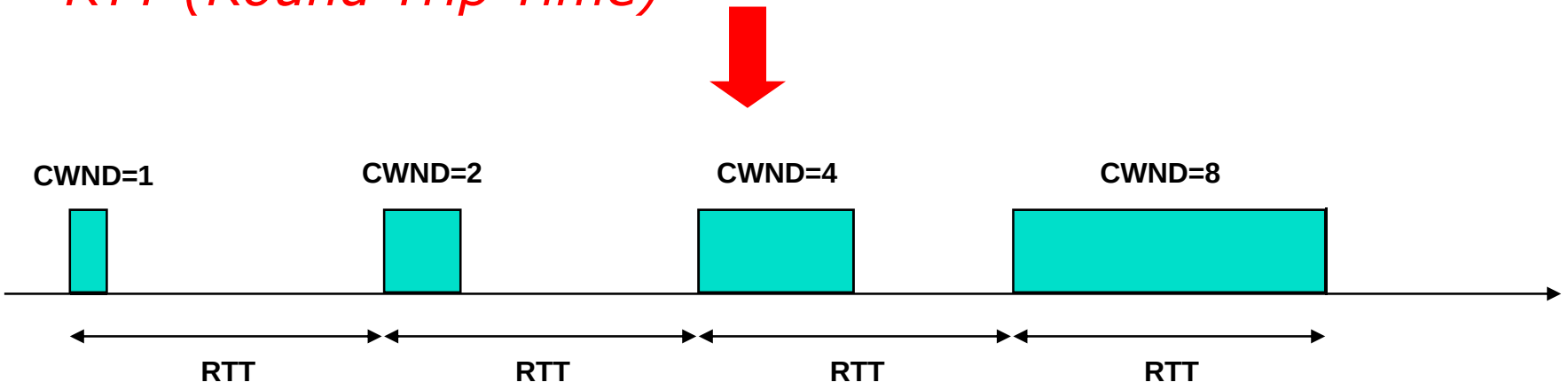
All expressed as multiples of MSS

- Initial values for all state variables (i.e., when the TCP connection is created):
  - CWND=1
  - RCWND = it depends (it's the dimension of the receiver buffer. In our exercises it will be explictly given. Otherwise, we will assume it is *infinite*)
  - SSTHRESH = infinite (sometimes, in our exercises, I will specify a finite, given value)
  - MSS = it is determined in the 3-way handshake phase (MSS option). In our excercises, its value will always be explicitly given.
  - RTO = in our excercises, its value will always be explicitly given

•For every sent packet, the sender starts a timer
•If the sender does *not* receive an ACK for a segment BEFORE the timer = RTO, the segment is considered lost and is retransmitted

TCP behavior (Slow Start)

- At the beginning of the TCP connection: CWND < SSTHRESH (in fact, 1 < infinite !!!)
- Since CWND < SSTHRESH, the TCP connection is in *Slow Start*
- *In Slow Start:*
  - *CWND is incremented by 1 for each received ACK (exponential increase)*
- *In practice: in Slow Start, the CWND doubles in each RTT (Round Trip Time)*



TCP Congestion Event (= packet loss)

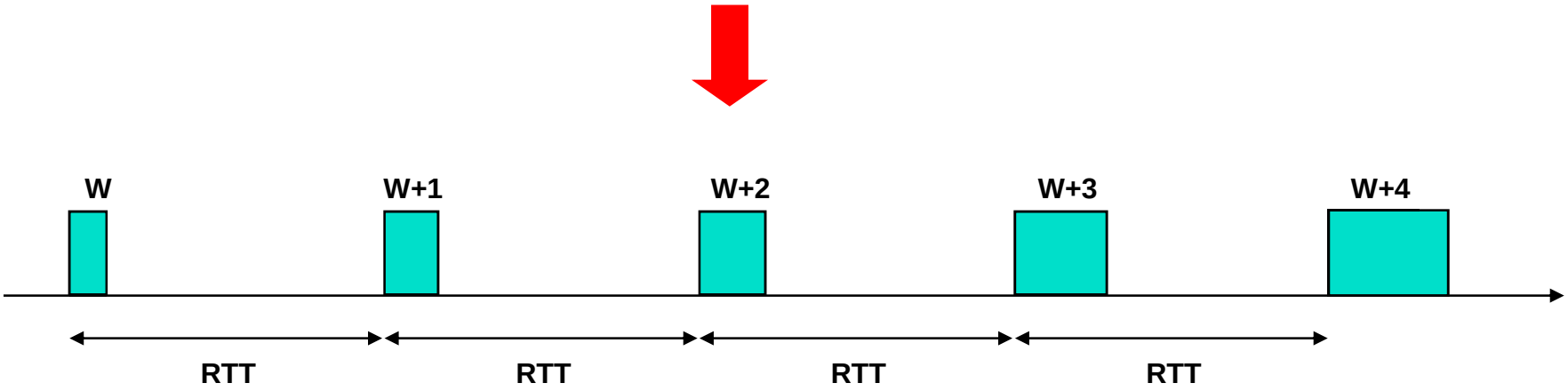
- When a packet is lost (the corresponding RTO expires), TCP performs the following operations:
  - TCP first updates the SSTHRESH value according to the following equation

$$SSTHRESH = \max\left(2, \frac{\text{CWND}}{2}\right)$$

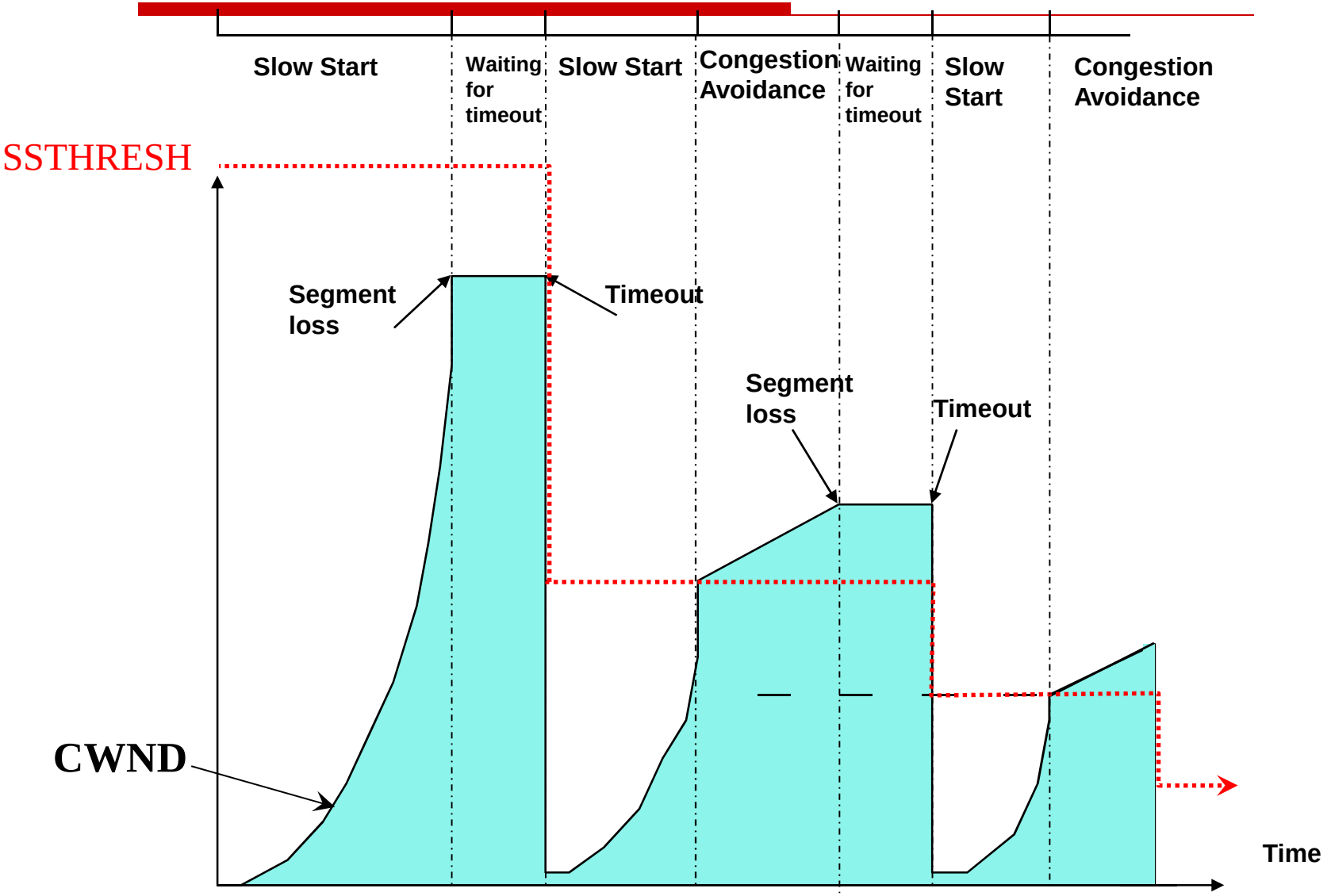
  - And then sets CWND = 1

TCP behavior (Congestion Avoidance)

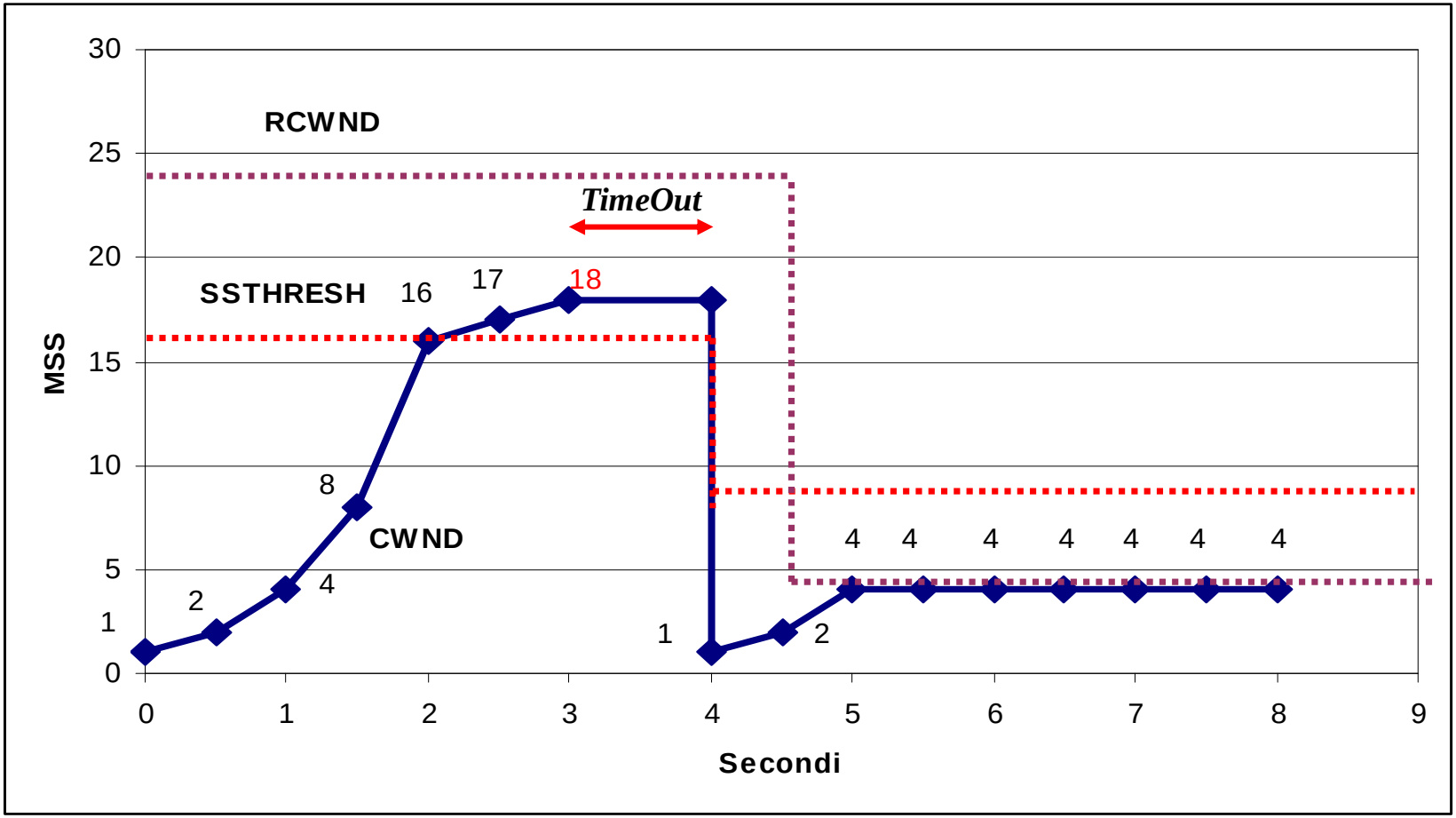
- If CWND <= SSTHRESH, TCP is in the so-called *Congestion Avoidance* phase
- In *Congestion Avoidance*:
  - CWND is incremented by 1/CWND for each received ACK (linear increase)
- In other words, the CWND increases by 1 in each RTT (linear increase)



TCP Connection Lifetime: example 1 (here RCWND = Infinite)

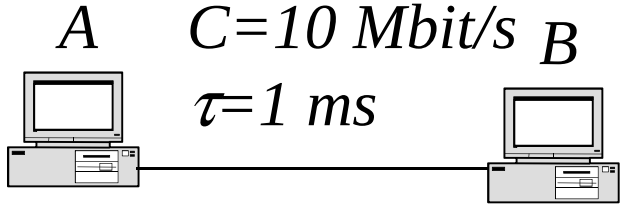


TCP Connection Lifetime: example 2 (here both SSTHRESH and RCWD are GIVEN)



Activity 2 ("Warm Up")

A single-hop TCP connection, running since long time (*steady state*) on a single link of capacity C and propagation delay τ, is characterized by the following parameters:



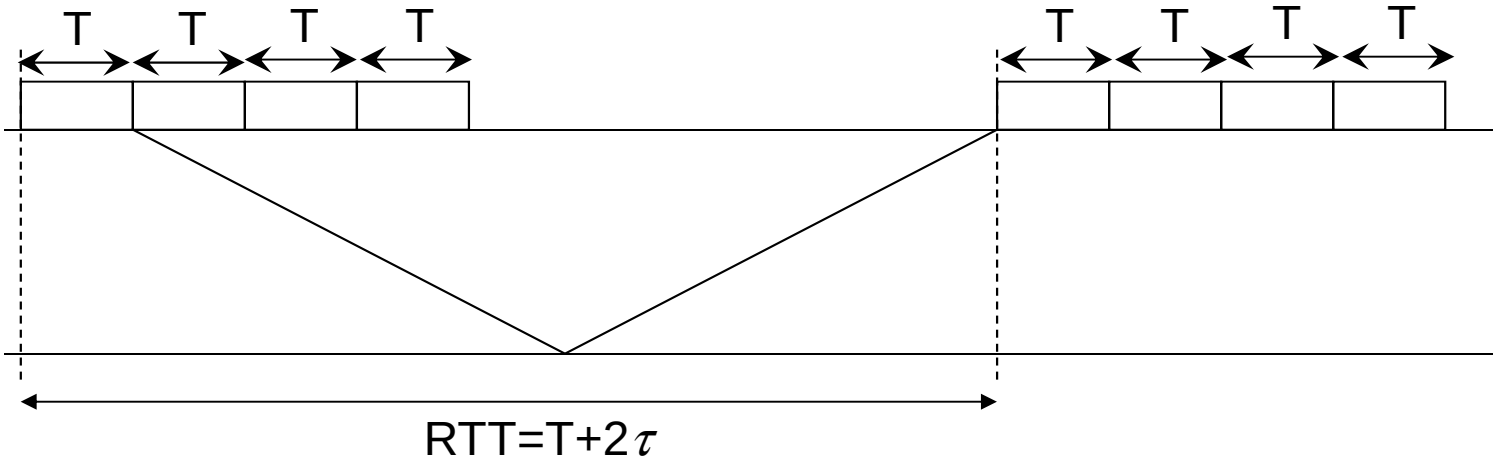
1. Link capacity C = 10 [Mbit/s]
2. Propagation delay τ = 1 [ms]
3. MSS = 100 [byte]
4. RCWND = 4 MSS and RCWND << CWND (this means that the connection is "dominated" by flow control, that is, by the RCWND value)
5. Let us assume the TCP *ACK* segments have negligible length (i.e., length = 0)

D1. What is the average transmission rate of the TCP connection?

D2. Answer to the same question assuming MSS=1000 byte.

Solution 2 ("Warm Up")

- T = 100x8 [bits] / 10 [Mbit/s] =0.08 ms,
- RTT = T + 2τ =2.08 ms
- Hence 4T < RTT (see figure below). Consequently, the transmission is *never* continuous, in this case.

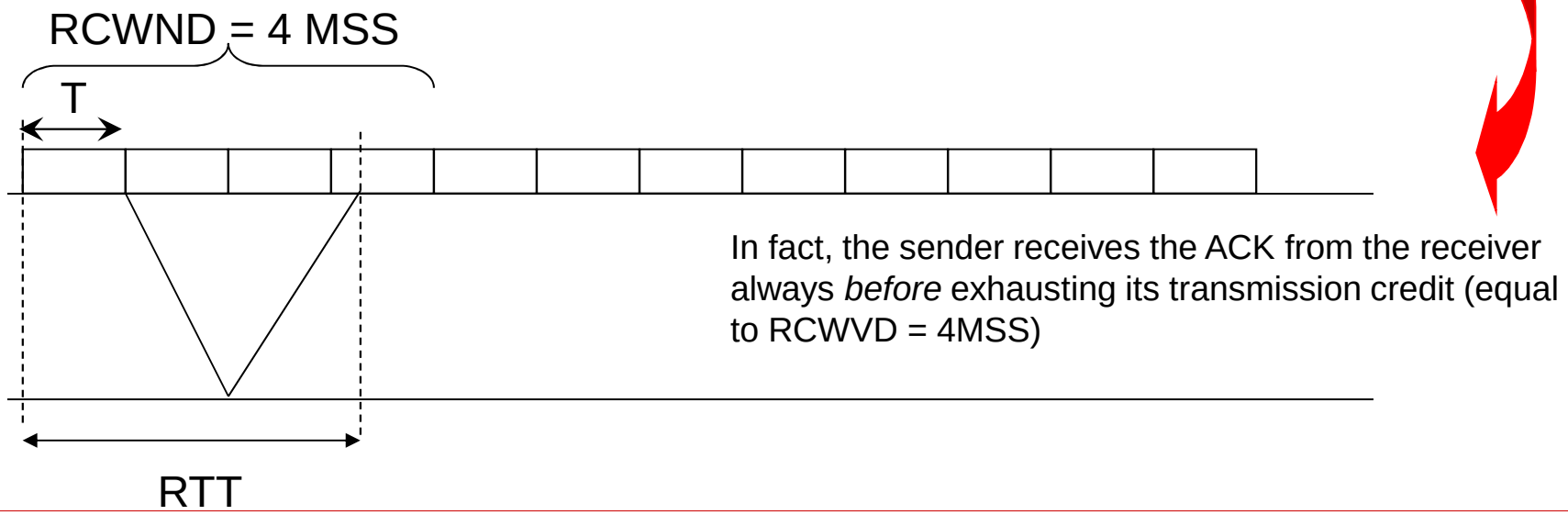


- Thus, the connection delivers 4 MSS for each RTT. Therefore, the average transmission rate, *R*, is:

$$R = \frac{4 \cdot (100 \cdot 8) bit}{RTT} = \frac{3200 bit}{2.08 ms} \approx 1.54 Mbit / s$$

Solution 2 ("Warm Up")

- In the second case
  - T = 1000x8 [bits] / 10 [Mbit/s] =0.8 ms,
  - RTT = T + 2τ =2.8 ms
  - Hence, 4T = 3.2 ms. Therefore, 4T > RTT, and consequently the transmission is <u>continuous</u> and the rate is R = C = 10 Mbit/s.



Activity 3

- A TCP connection is used to transfer a 39.5 [kbyte] file.
  - MSS=500 [byte]
  - RTT = 500 [ms]
  - Retransmission TimeOut RTO = 2*RTT.
- Assume the following parameter setting:
  - RCWND = 12 [kbyte]
  - SSTHRESH = 8 [kbyte]
  - CWND = 500 [byte]
- And further,
  - All the segments transmitted at time 3 [s] are lost
  - At time 4,5 [s] the receiver signals to the sender that RCWND = 2 [kbyte]

1. Plot the time behavior of the following state variables:
   - CWND
   - SSTHRESH
   - RCWND

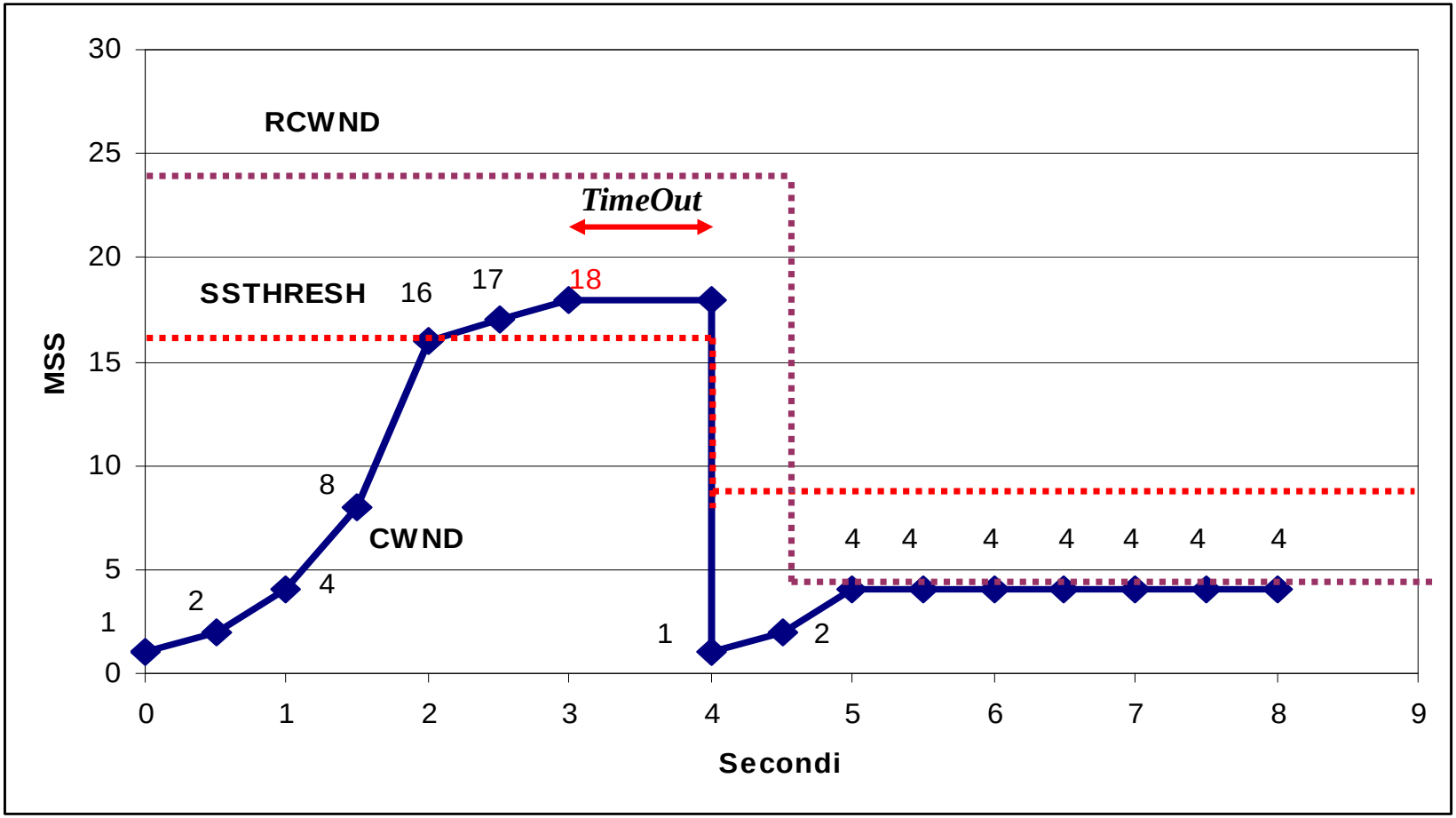
2. Find out the total delivery time for the aforementioned file.

Solution 3

- File dimension (in MSS) = 39,5 [kbyte] / 500 [byte] = 79 MSS
- Total delivery time = time to transfer 79 MSS

- RCWND = 12 [kbyte] / 500 [byte] = 24 MSS
- SSTHRESH = 8 [kbyte] / 500 [byte] = 16 MSS
- Time Out = 1 [s]

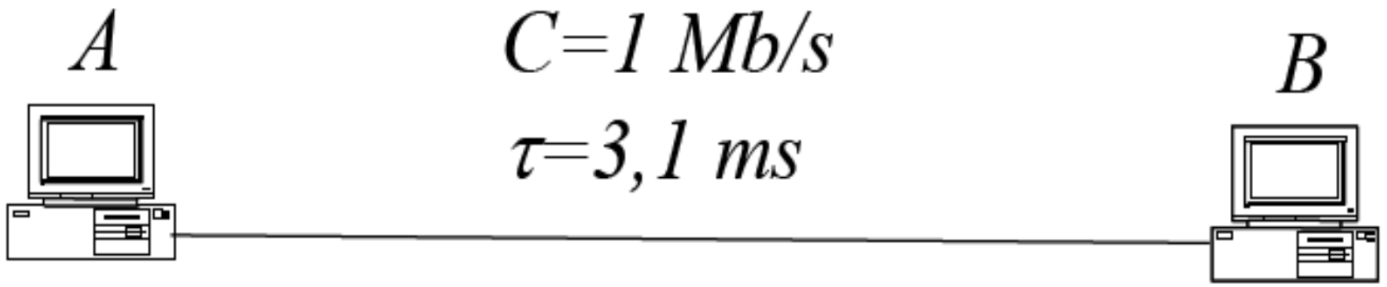
Solution 3



- Total delivery time, T=8.5s

Activity 4

- A must transfer 100 MSS segments to B through a TCP connection. Find out the total data delivery time, assuming:
  - MSS=1000 [bit]
  - Negligible headers
  - Connection is initiated by A, connection opening segment of negligible length
  - ACK segment length negligible
  - SSTHRESH = 5 MSS



Solution 4

- T=1000 [bit] / 1 [Mbit/s] = 1 [ms]
- RTT = T+2tau = T +2*3.1 [ms] = 7.2 [ms]
- Transmission is continuous when WT > RTT, hence until W=8