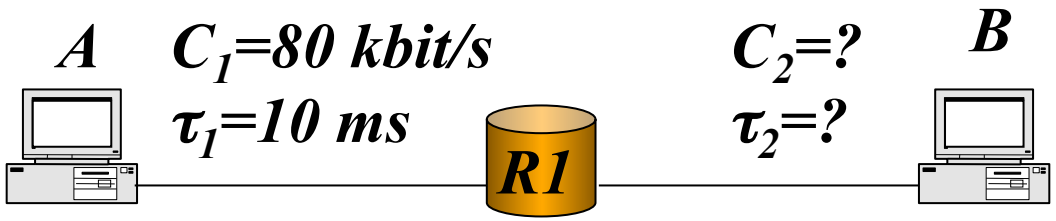
Politecnico di Milano
Scuola di Ingegneria Industriale e dell'Informazione

E8
TCP

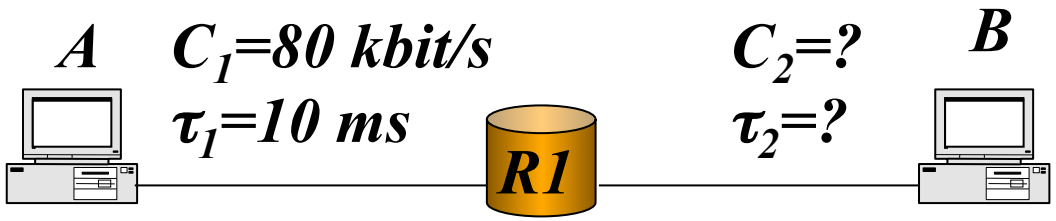
Exercises 1

- Consider the connection in the figure



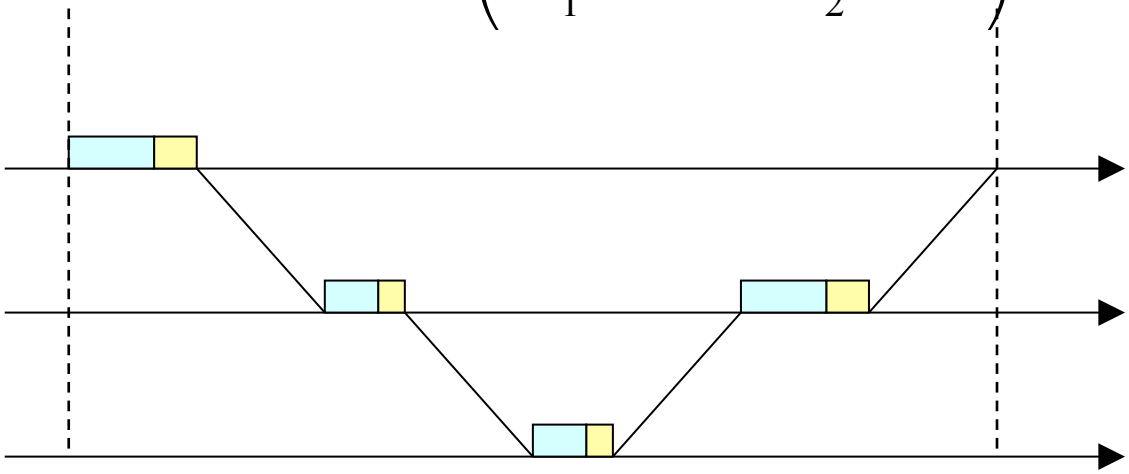
- Host A wants to know the capacity and propagation delay of link 2 and to this purpose sends to host B two echo messages: M1 length l1=1000 [byte], and M2length l2=1500 [byte]; for each of them it measures the Round-Trip-Time (RTT) equal to 780 [ms] and 1130 [ms] respectively.
- In the replies, B uses the same message lengths.
- Calculate C_2 and τ_2 assuming header legths negligible.

Solution 1

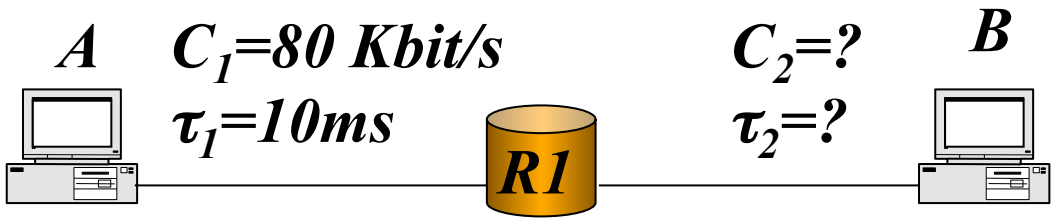


$$RTT_1 = 2\left(\frac{m_1}{C_1} + \tau_1 + \frac{m_1}{C_2} + \tau_2\right)$$

$$RTT_2 = 2\left(\frac{m_2}{C_1} + \tau_1 + \frac{m_2}{C_2} + \tau_2\right)$$

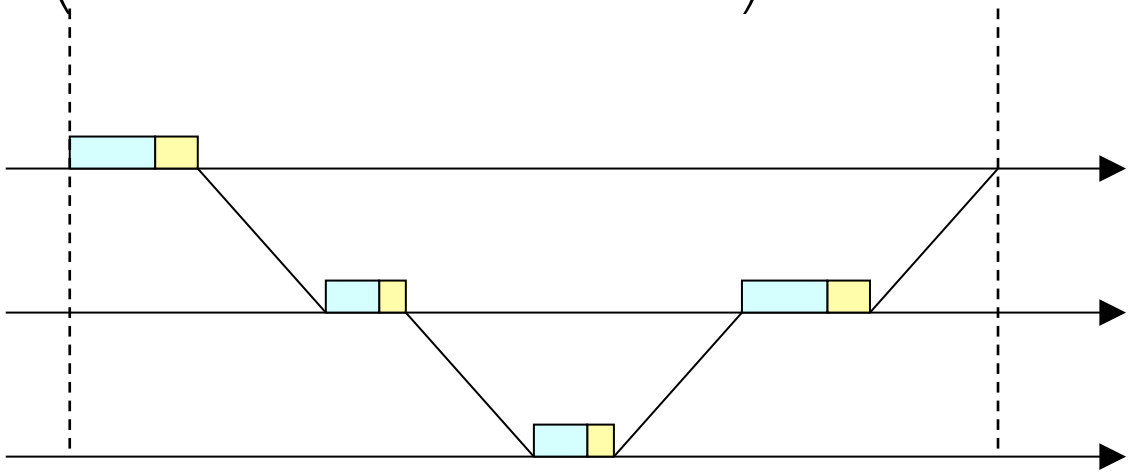


Solution 1

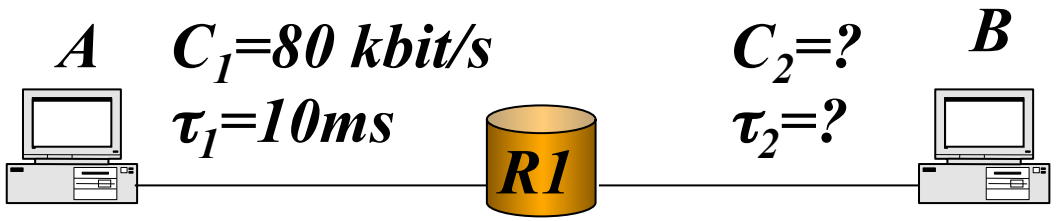


$$780 = 2\left(\frac{8000}{80} + 10 + \frac{8000}{C_2} + \tau_2\right) = 220 + \frac{16000}{C_2} + 2\tau_2$$

$$1130 = 2\left(\frac{12000}{80} + 10 + \frac{12000}{C_2} + \tau_2\right) = 320 + \frac{24000}{C_2} + 2\tau_2$$



Solution 1



$$\tau_2 = 280 - \frac{8000}{C_2}$$

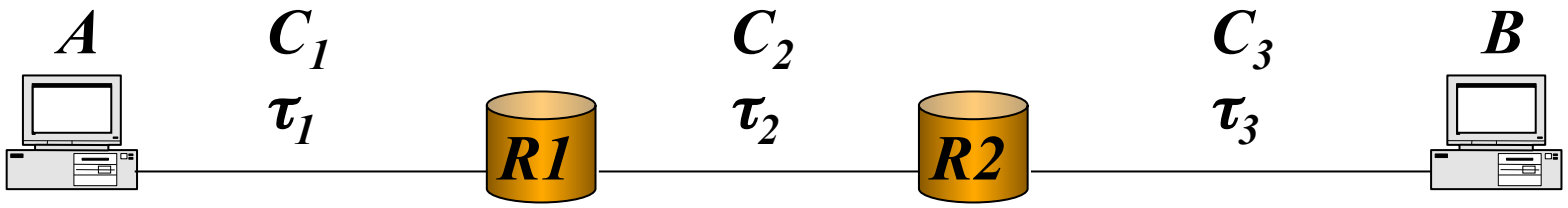
$$810 = \frac{24000}{C_2} + 2\left(280 - \frac{8000}{C_2}\right) = \frac{8000}{C_2} + 560;$$

$$C_2 = \frac{8000}{250} = 32\ kbit/s$$

$$\tau_2 = 280 - \frac{8000}{32} = 30\ ms$$

Exercises 2

- Consider the network in the figure where links are biderectional and with the same rate in both directions



$$C_1 \leq C_2 \leq C_3$$

- Between A and B a TCP connection is active and already with a stable rate.
- Assume MSS=250 [byte] and RCVWND small than CWND and equal to 4 segments

Exercises 2

- Calculate the time necessary to transfer a sequence of 104 [kbit] coming form upper layer (from transmission of first segment to reception of the last ACK). Assume
  - Length Header IP: HIP
  - Length Header TCP: HTCP
  - Length Header lower layers: HLL
  - No error
  - No interfering traffic
  - ACK length negligible
- Which is the value of the window that would allow a continuous transmission on link 1?

Solution 2

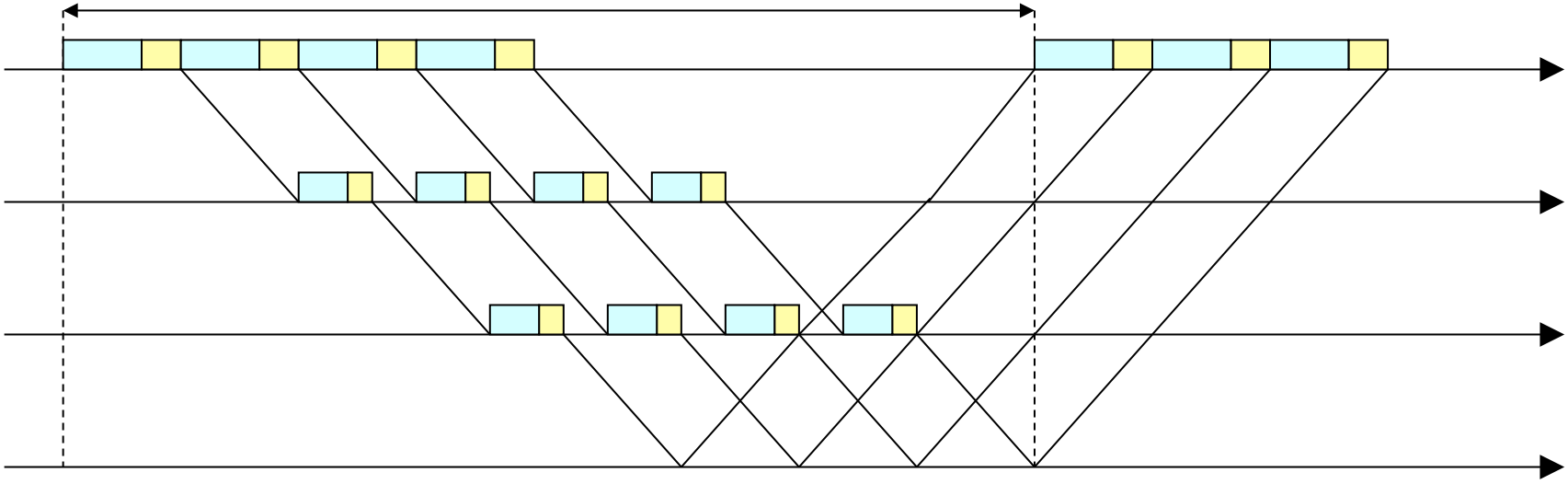
- 104 [kbit] are equal to 13000 [byte] and to 52 segments of 250 [byte] (MSS)

- Each packet on the link has a total length of
  - L=MSS+ HIP + HTCP + HLL

Solution 2

a)

$$RTT = \frac{L}{C_1} + 2\tau_1 + \frac{L}{C_2} + 2\tau_2 + \frac{L}{C_3} + 2\tau_3$$



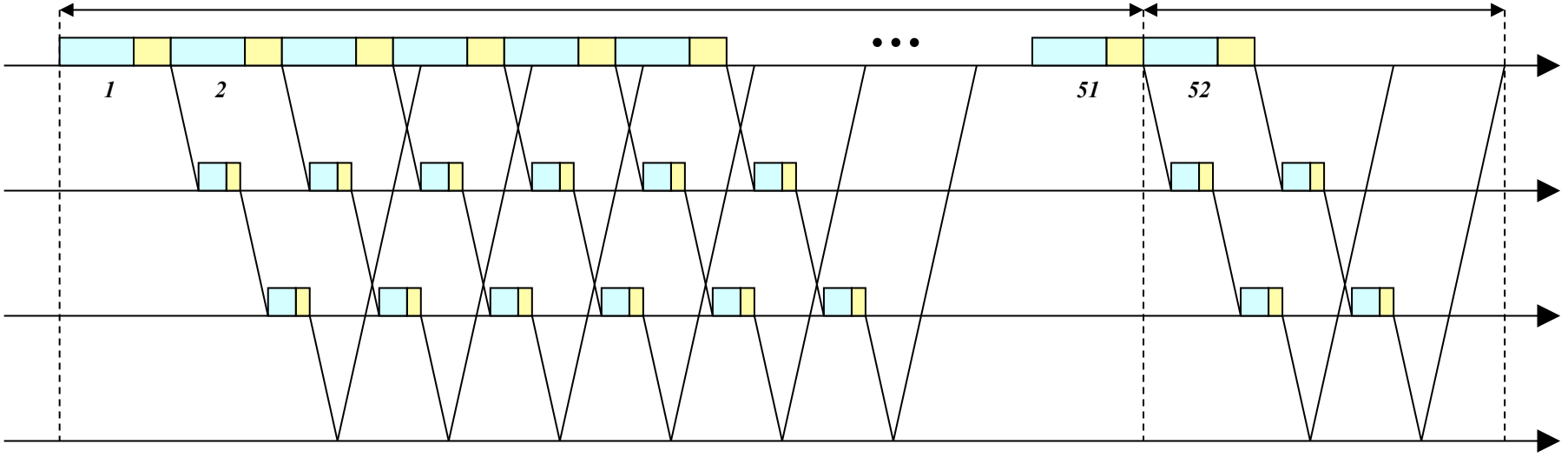
$$\textit{If}\ \ 4\frac{L}{C_1} \le RTT$$

$$Ttot = (52/4)\cdot RTT + (4-1)\frac{L}{C_1} = 13RTT + 3\frac{L}{C_1}$$

Solution 2

a)

Otherwise transmission is continuous:

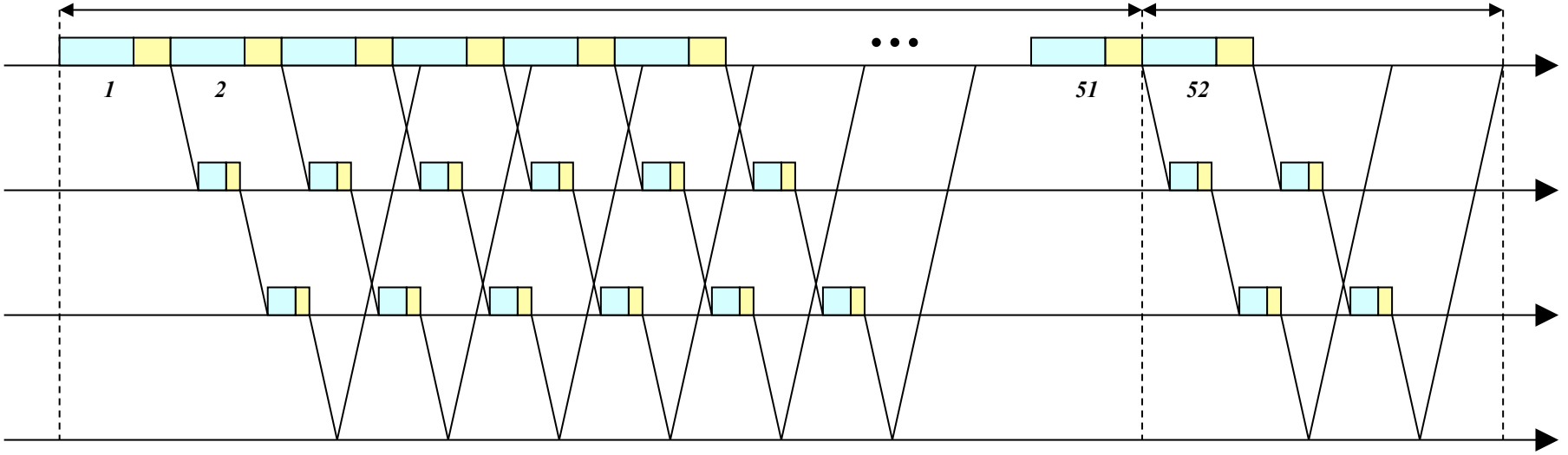


$$Ttot = 51\frac{L}{C_1} + RTT$$

Solution 3

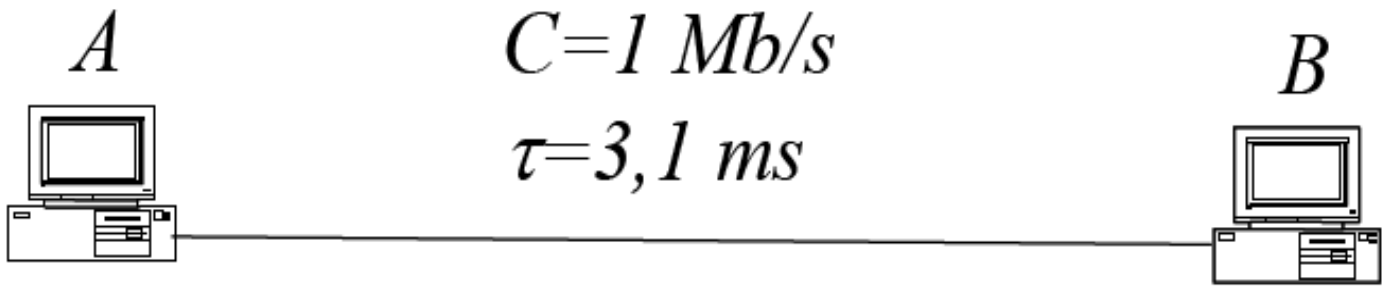
b) The minimum value of the window that allows continuous transmission can be calculated forcing RTT to be smaller that the transmission time of the window:

$$\text{RTT} \leq \text{w}\frac{\text{L}}{\text{C}_1} \qquad w = \left\lceil \frac{C_1}{L}\left(\frac{L}{C_1} + 2\tau_1 + \frac{L}{C_2} + 2\tau_2 + \frac{L}{C_3} + 2\tau_3 \right) \right\rceil$$



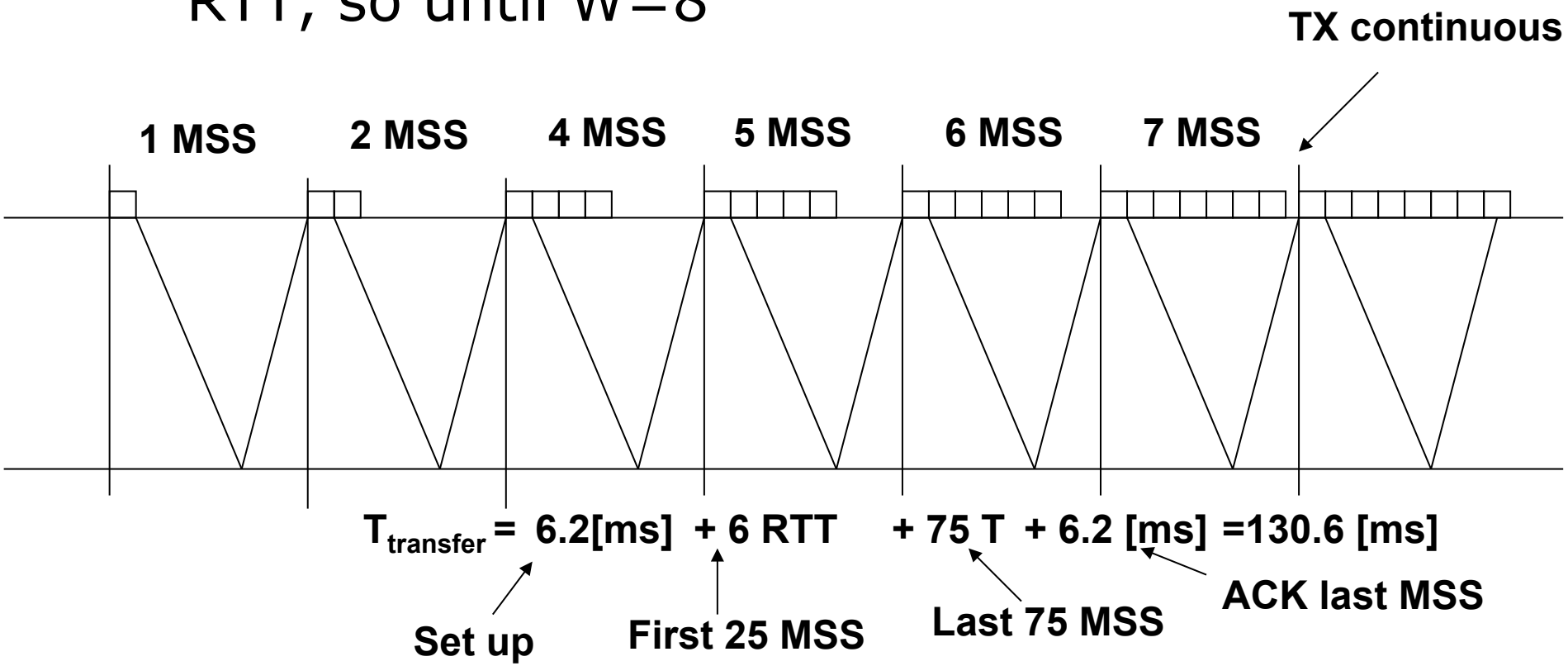
Exercises 3

- Consider the connection in the figure between two hosts A and B. A has to transfer a sequence of 100 segments of maximum length using TCP. Calculate the time necessary assuming:
  - MSS=1000 [bit]
  - Header lengths at all layers negligible
  - Connection is open by A and the length of control packets for connection setup is negligible
  - ACK length neglible
  - SSTHRESH equal to 5 MSS



Solution 3

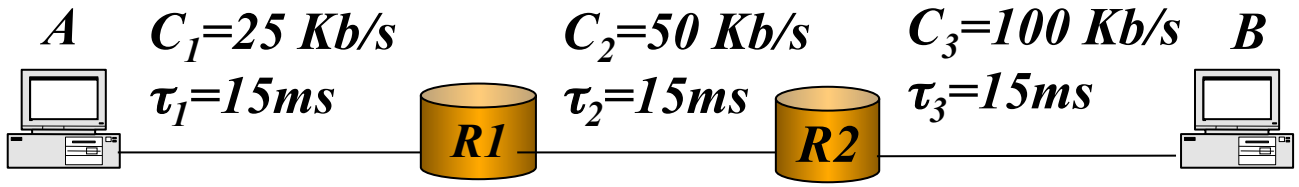
- T=1000 [bit] / 1 [Mb/s] = 1 [ms]
- RTT = 6.2 [ms] + T = 7.2 [ms]
- Transmission is discontinuous until WT < RTT, so until W=8



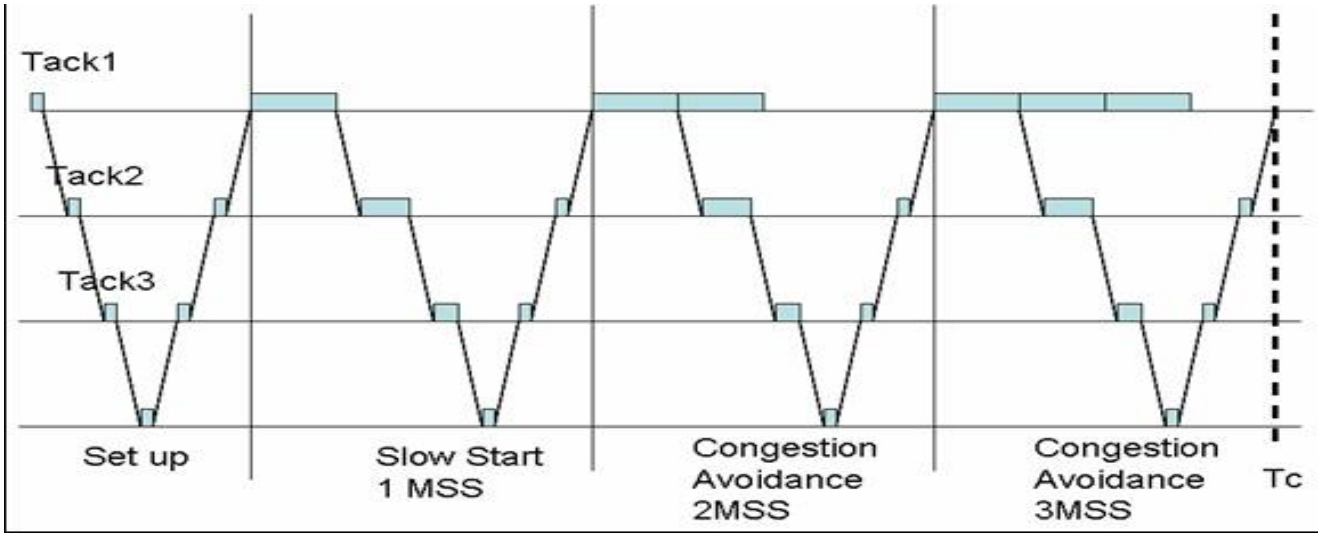
Exercises 4

- At time 0 a TCP connection between *host* A and l'*host* B is activated. Calculate the time when transmission on link 1 becomes continuous assuming
  - Header lengths negligible
  - *Bidirectional and symmetric links*
  - RCWND = 4000 [byte] and SSTHRESH = 400 [byte]
  - MSS = 200 [byte]
  - ACK size = setup control packet size = 20 [byte]
  - Connection open by host A
- How much time does it takes to transfer a file of 2 [kbyte] (from connection setup to reception of last ACK)?

(Note that: 1 byte = 8 bit, 1 kbyte= 1000 byte = 8000 bit)



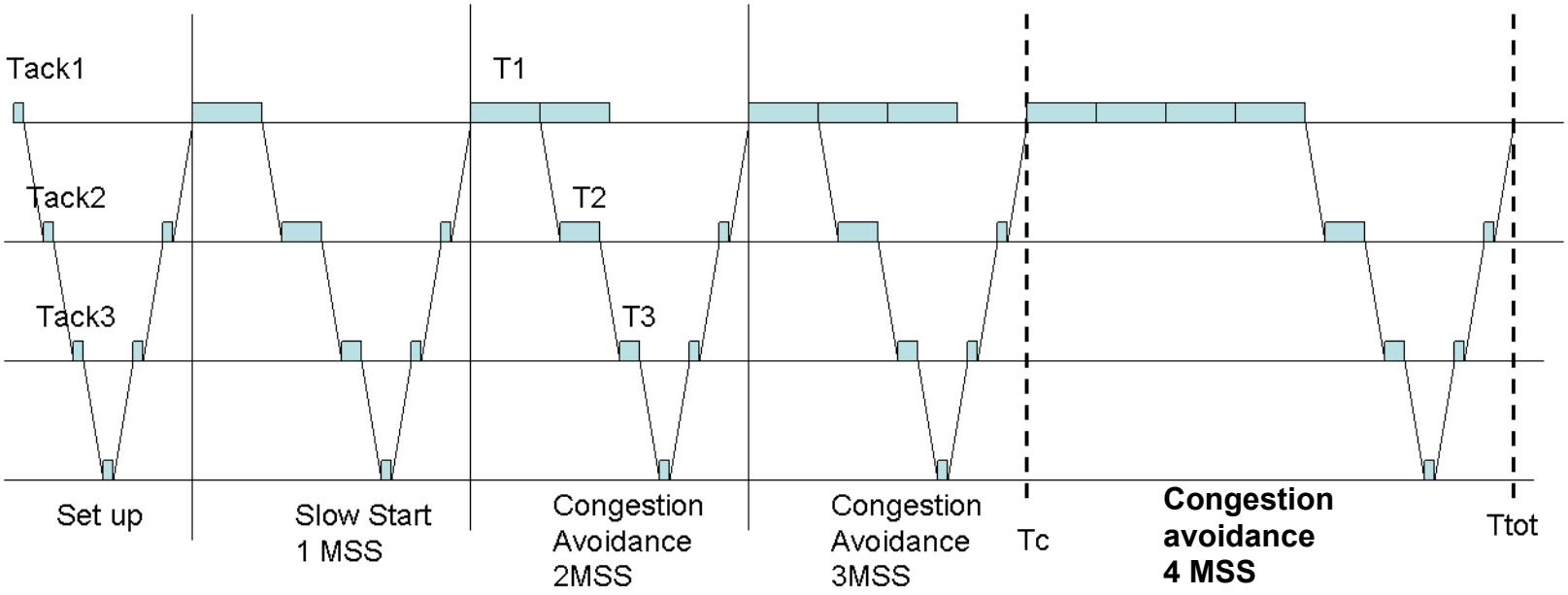
Solution 4



- We have:
  - T_1=200 x 8 [bit] / 25 [kbit/s] =64 ms, T_2=½ T_1 =32 ms, T_3= ½ T_2= 16 ms
  - RTT= T_1+ T_2+T_3+ 2(τ_2+τ_1+τ_3)+ (Tack1 + Tack2 + Tack3) = 213.2ms
  - T_{setup} = 2(Tack1 + Tack2 + Tack3) + 2(τ_2+τ_1+τ_3) = 112.4 ms
- Link 1 is the bottleneck and transmission is continuous when:
  - WT_1 > RTT
- so
  - W > RTT/ T_1=3,3
- The time transmission becomes continuous is
  - T_c= T_{setup} + 3 RTT =112.4 [ms] +649.6 [ms] = 752 [ms]

Solution 4

- File to transfer is 2 [kbyte], equal to 10 MSS.
- The time necessary is:
  - $T_c = T_{setup} + 4\ RTT + 3\ T_1 = 1.15$ [s]



Exercises 5

- A TCP connection is used to transfer a file of 39.5 [kbyte] using the following parameters:
  - MSS=500 [byte]
  - RTT = 500 [ms]
  - timeout T1 = 2*RTT.
- Assume the initial conditions are:
  - RCWND = 12 [kbyte]
  - SSTHRESH = 8 [kbyte]
  - CWND = 500 [byte]
- Assume also that:
  - There is an error at time 3 [s] (all segments are lost)
  - At time 4,5 [s] receiver indicates RCWND = 2 [kbyte]

a) Draw the evolution over time of:
  - CWND
  - SSTHRESH
  - RCWND

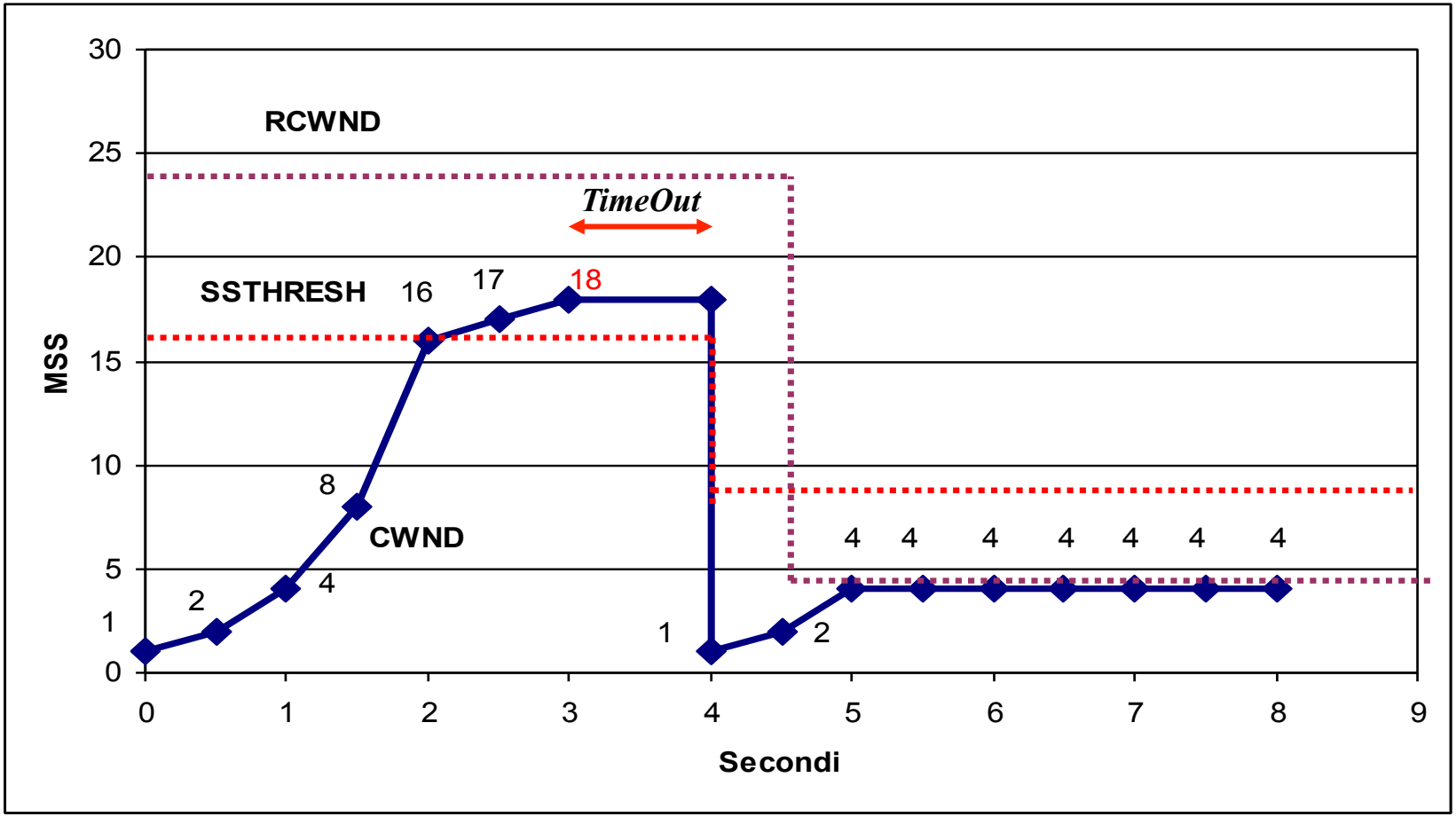
b) Calculate the time to transfer the file.

Solution 5

We have:

- # segments = 39,5 [Kbyte] / 500 [byte] = 79 MSS
- RCWND = 12 [Kbyte] / 500 [byte] = 24 MSS
- SSTHRESH = 8 [Kbyte] / 500 [byte] = 16 MSS
- Time Out = 1 s

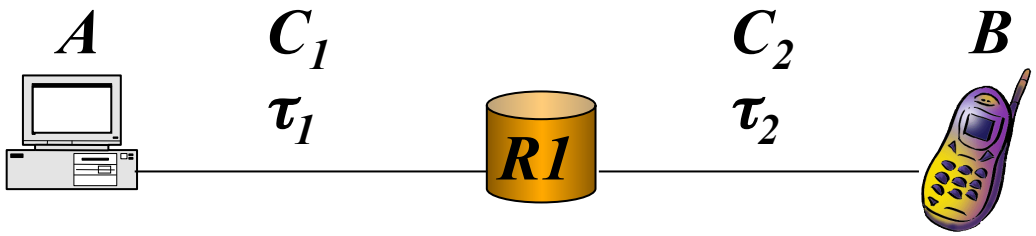
Solution 5



- Transfer time T=8.5s

Exercises 6

- Consider the following connection

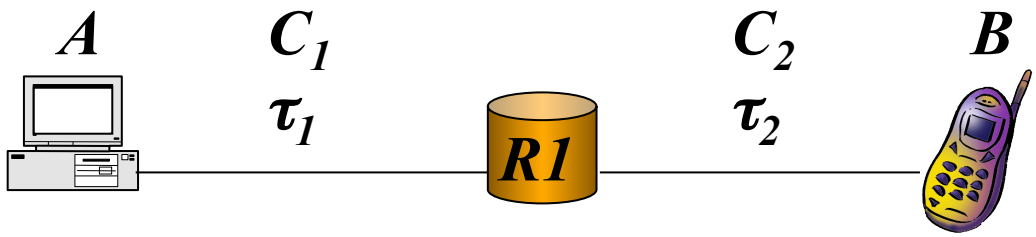


$C_1 \leq C_2$

- A has to transfer an application message of M bytes to B using UDP

  a) Assuming the maximum length of UDP segments is *m* bytes (data only), and denoting with *HLL*, *HIP*, *HUDP* header length of lower layers, IP and UDP respectively, calculate the time necessary to transfer the message

Exercises 6

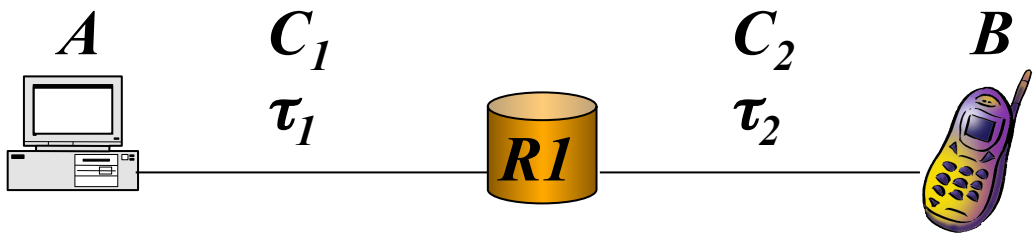


$C_1 \leq C_2$

b)

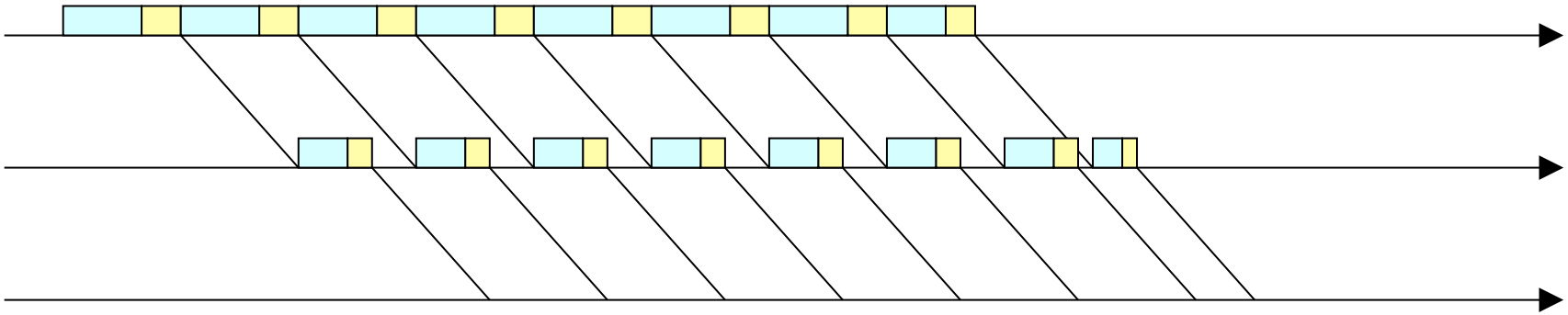
As in a) but assuming on link 2 is active a layer 2 protocol with ARQ mechanism of stop-and-wait type (ACK length negligible)

Solution 6

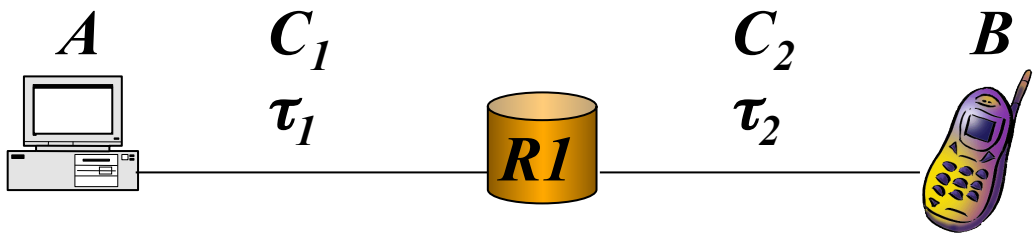


$C_1 \leq C_2$

- # of maximum length segments: $n = \left\lfloor \frac{M}{m} \right\rfloor$
- Length of last segment: $l = M - m\left\lfloor \frac{M}{m} \right\rfloor$



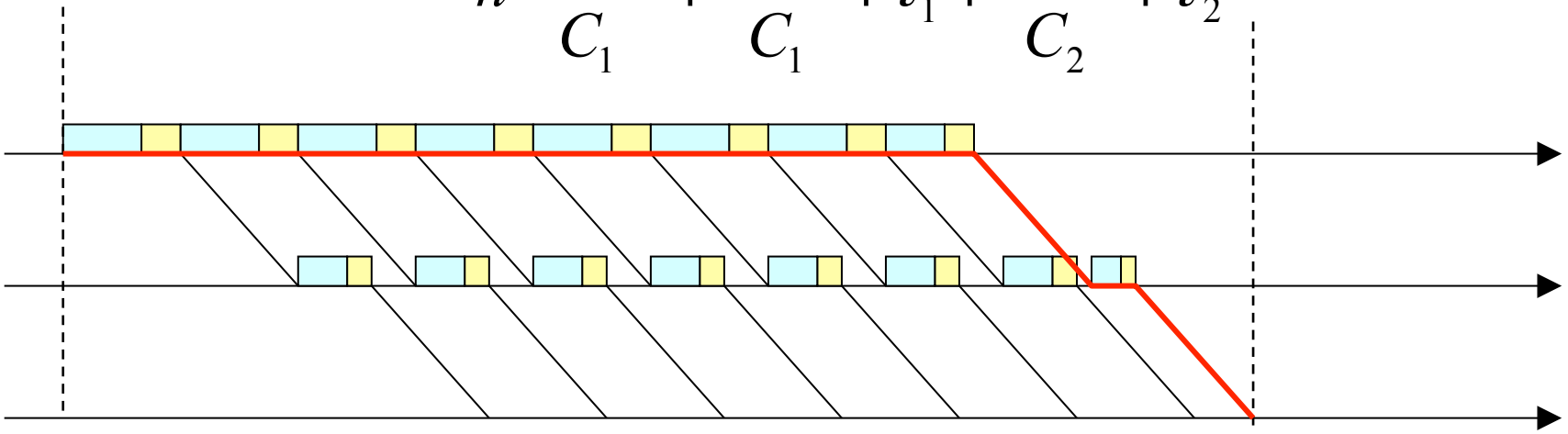
Solution 6



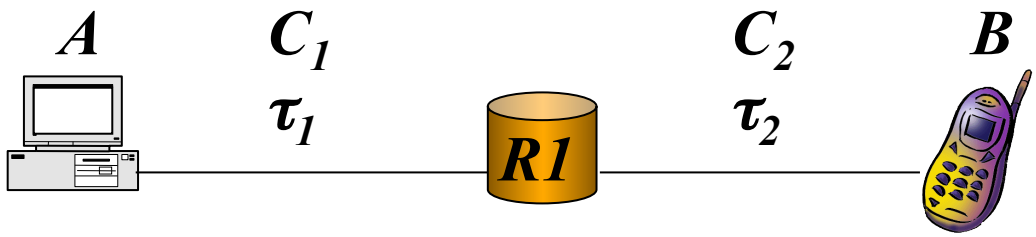
$C_1 \leq C_2$

a) Transfer time: if $\frac{l+h}{C_1} \geq \frac{m+h}{C_2}$

$$n\frac{m+h}{C_1} + \frac{l+h}{C_1} + \tau_1 + \frac{l+h}{C_2} + \tau_2$$



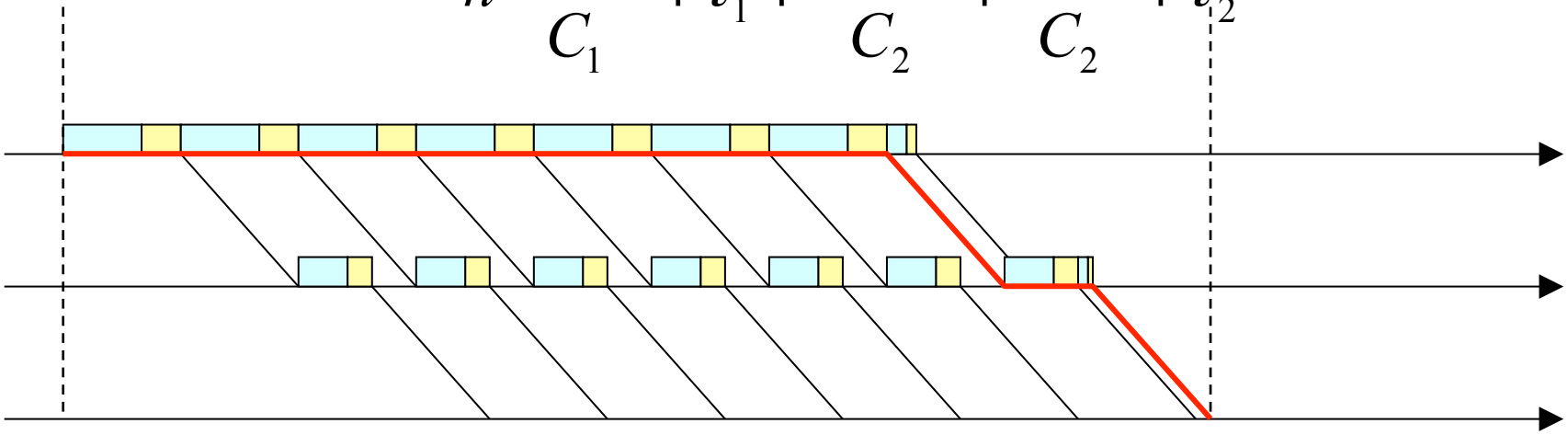
Solution 6



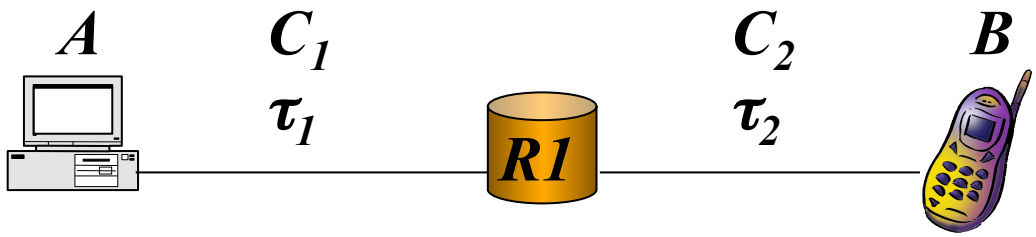
$C_1 \leq C_2$

a) Transfer time: $if \quad \frac{l+h}{C_1} \leq \frac{m+h}{C_2}$

$$n\frac{m+h}{C_1} + \tau_1 + \frac{m+h}{C_2} + \frac{l+h}{C_2} + \tau_2$$



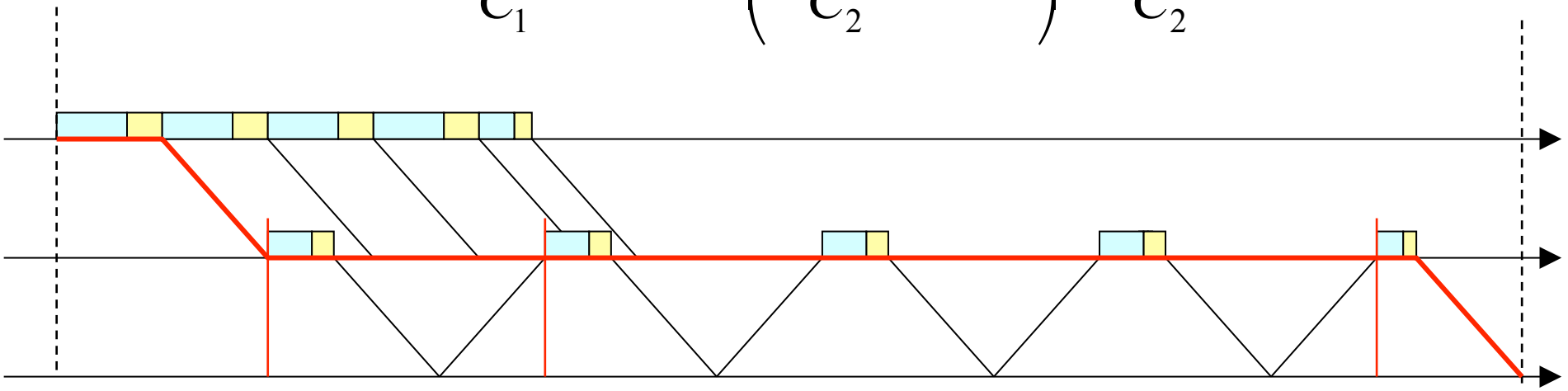
Solution 6



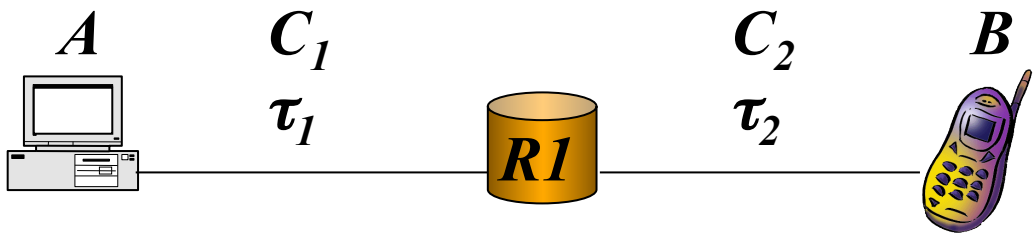
$$C_1 \leq C_2$$

b) Transfer time: if $\frac{m+h}{C_1} \leq 2\tau_2 + \frac{m+h}{C_2}$

$$\frac{m+h}{C_1} + \tau_1 + n\left(\frac{m+h}{C_2} + 2\tau_2\right) + \frac{l+h}{C_2} + \tau_2$$



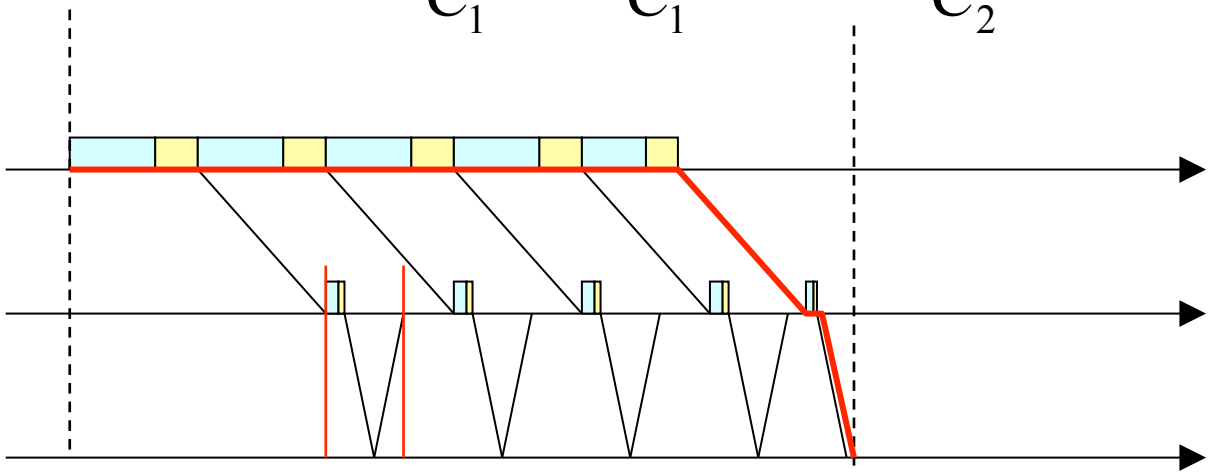
Solution 6



$C_1 \leq C_2$

b) Transfer time: if $\frac{m+h}{C_1} \geq 2\tau_2 + \frac{m+h}{C_2}$

$$n\frac{m+h}{C_1} + \frac{l+h}{C_1} + \tau_1 + \frac{l+h}{C_2} + \tau_2$$



Notations and Measure units

- 1 [byte] = 8 [bit]
- 1 [kbyte] = 1000 [byte] = 8000 [bit]
- 1 [Mbyte] = 8 [Mbit]

- 1 [ms] = 10^{-3} [s]
- 1 [μs] = 10^{-6} [s]
- 1 [ns] = 10^{-9} [s]