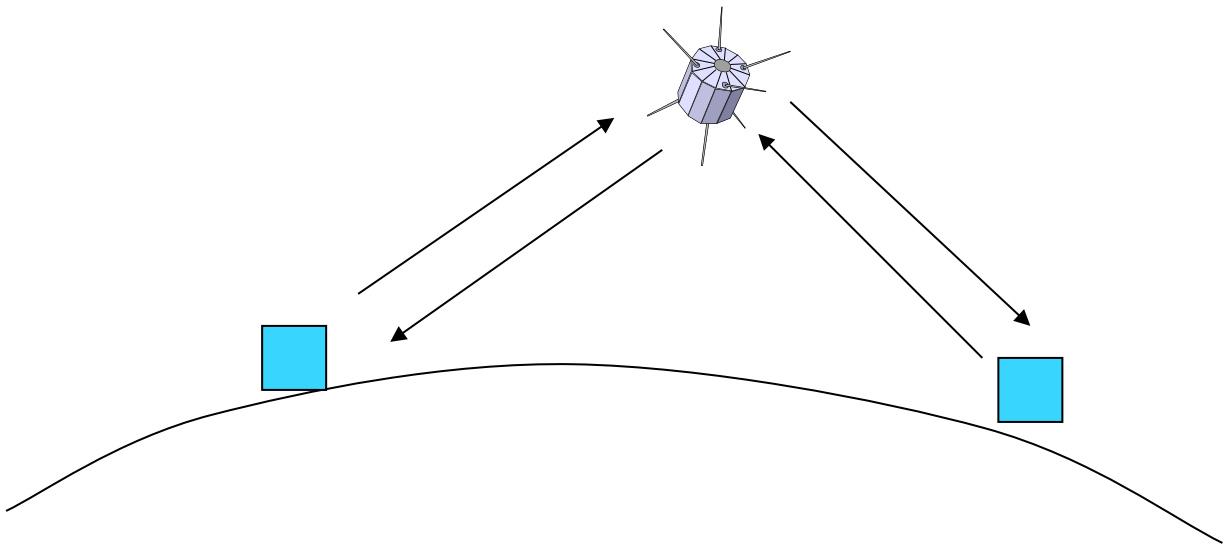
Politecnico di Milano
Scuola di Ingegneria Industriale e dell'Informazione

E3
Error and flow control

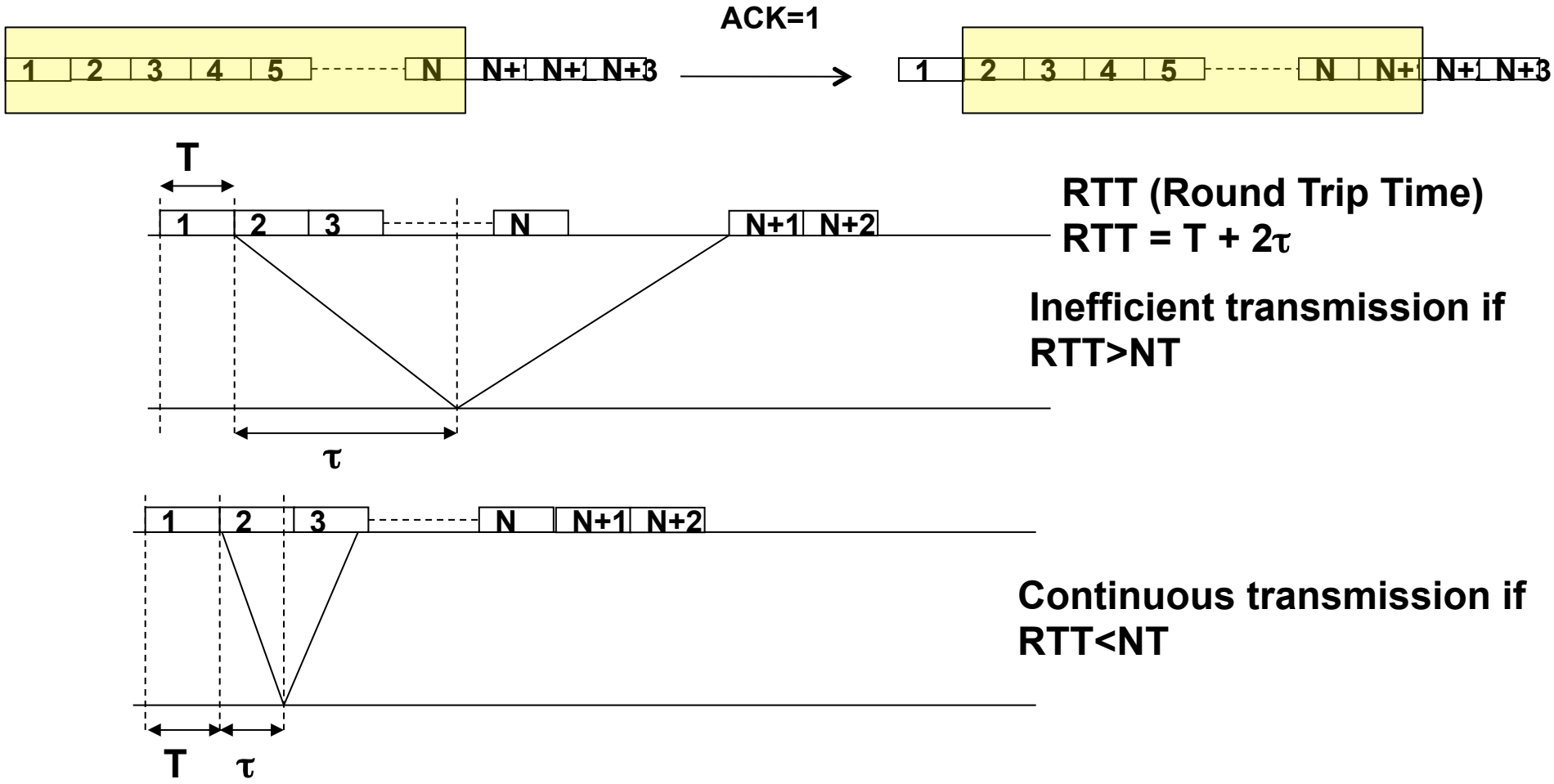
Exercise 1

- Consider a satellite channel with a rate of 1 Mb/s. Assuming that the propagation delay between earth station and satellite is 250 ms (geostationary satellite), dimension the minimum transmission window of a *Go-BACK-N* protocol (with time-out) such that the channel utilization is maximized when frames of 2000 bits are used and the channel is error free.
- Calculate the maximum efficiency that can be achieved with an ARQ protocol based on *STOP-and-WAIT.*

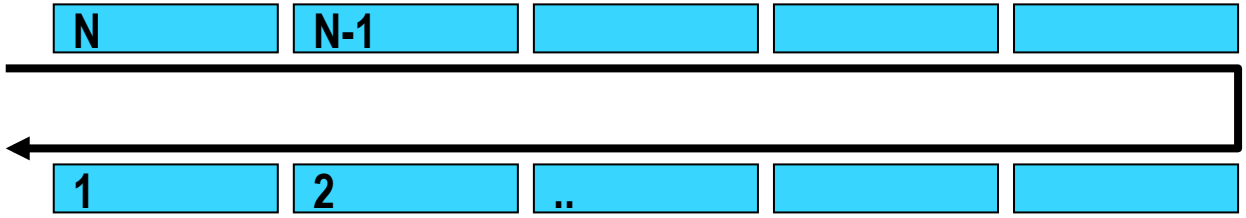


Exercise 1 - Solution

- *Go-Back-N*:
  - Sliding window



Exercise 1 - Solution



- In order to have maximum efficiency we need to ensure continuous transmission:

$$NT \geq T + 2\tau$$

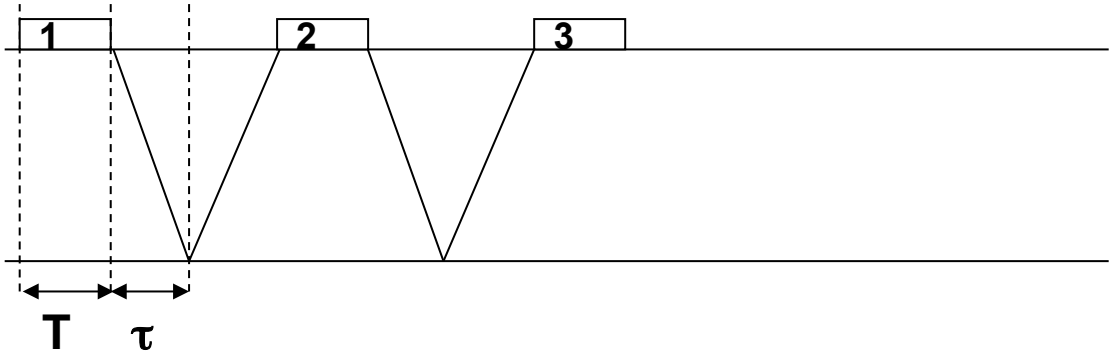
$$\tau = 2 \cdot 250ms = 500ms$$

$$T = 2000[bit] / 1Mb / s = 2ms$$

$$N \geq 1 + 2\tau / T = 1 + 2 \cdot 500 / 2 = 501$$

Exercise 1 - Solution

- Stop & Wait



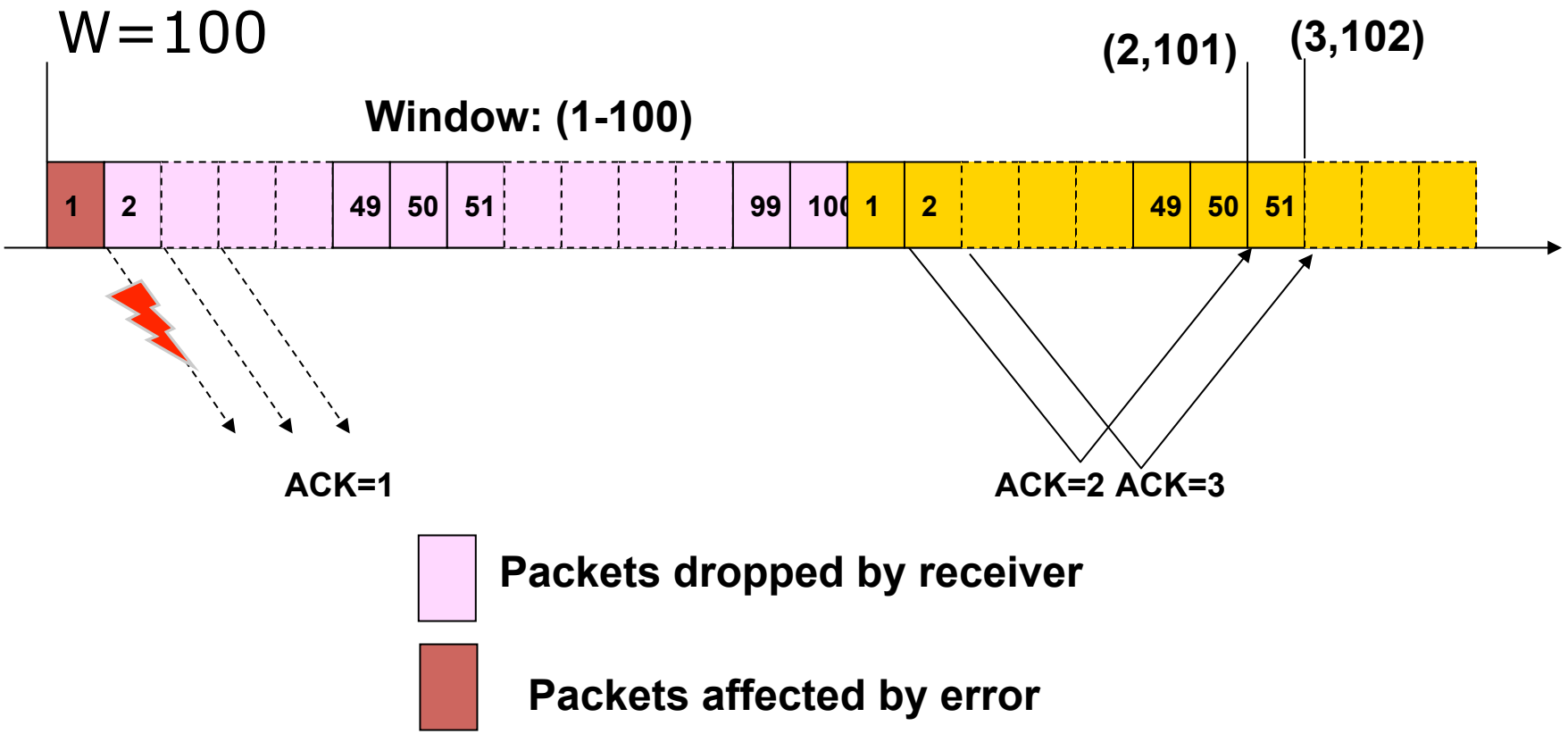
- The efficiency with *Stop-and-wait* is:

$$\eta = \frac{T}{T + 2\tau} = \frac{2}{2 + 2 \cdot 500} \cong 0.002$$

Exercise 2

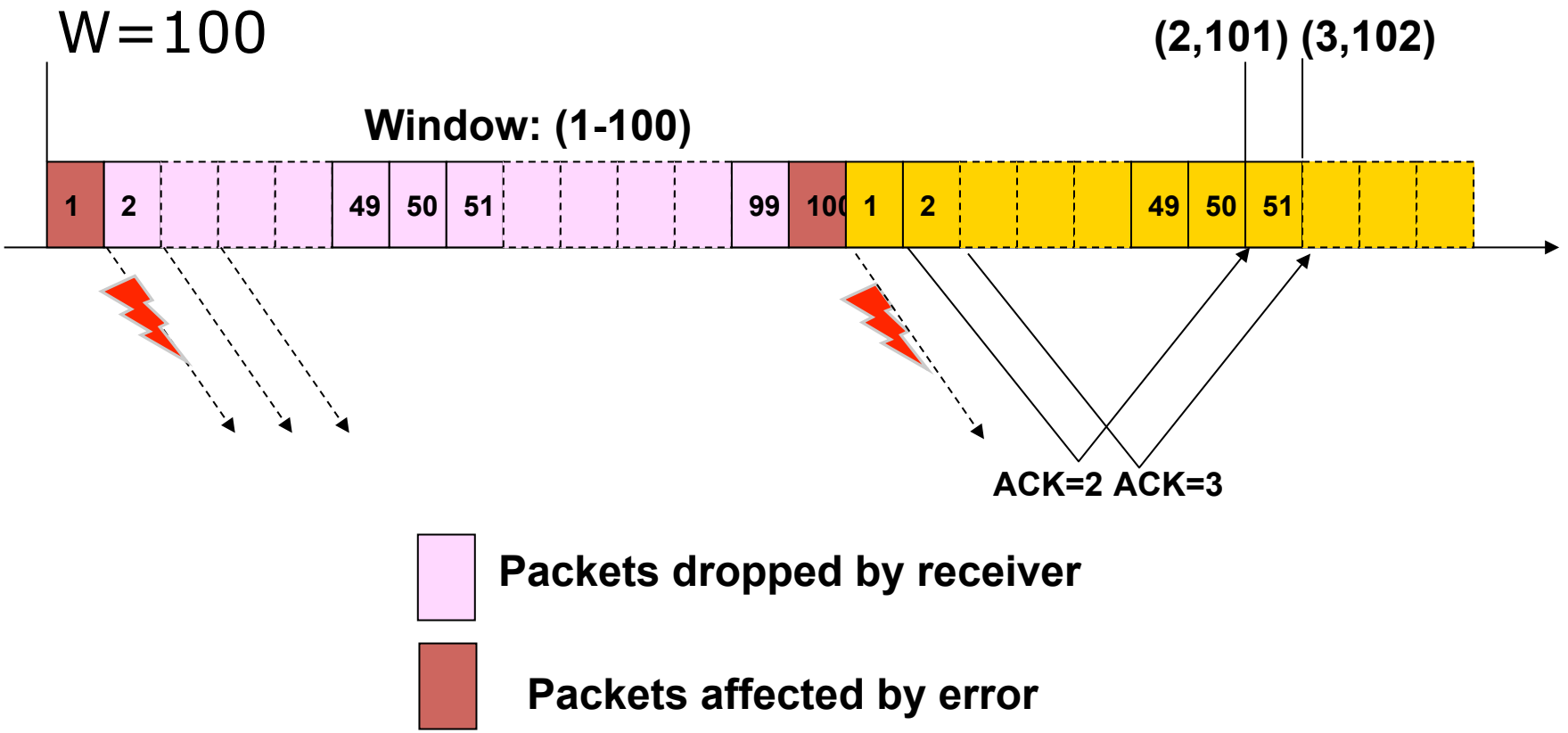
- A GO-BACK-N system is characterized by a propagation delay 24 times longer than the packet transmission. The system is used to send 1000 packets. Assuming that all packets that are correctly received are acknowledged (assume cumulative ACK and ACK transmission time = packet transmission time), calculate the number of packet transmissions that are wasted (due to error or because dropped by receiver) when:
  - a) The first packet is affected by error
  - b) First and 100^{th} packets are affected by error
  - c) The ACK of first packet is affected by error
  - d) The ACK of the first and 100^{th} packets are affected by error
- Assuming transmission window W=100

Exercise 2 - Solution (1)



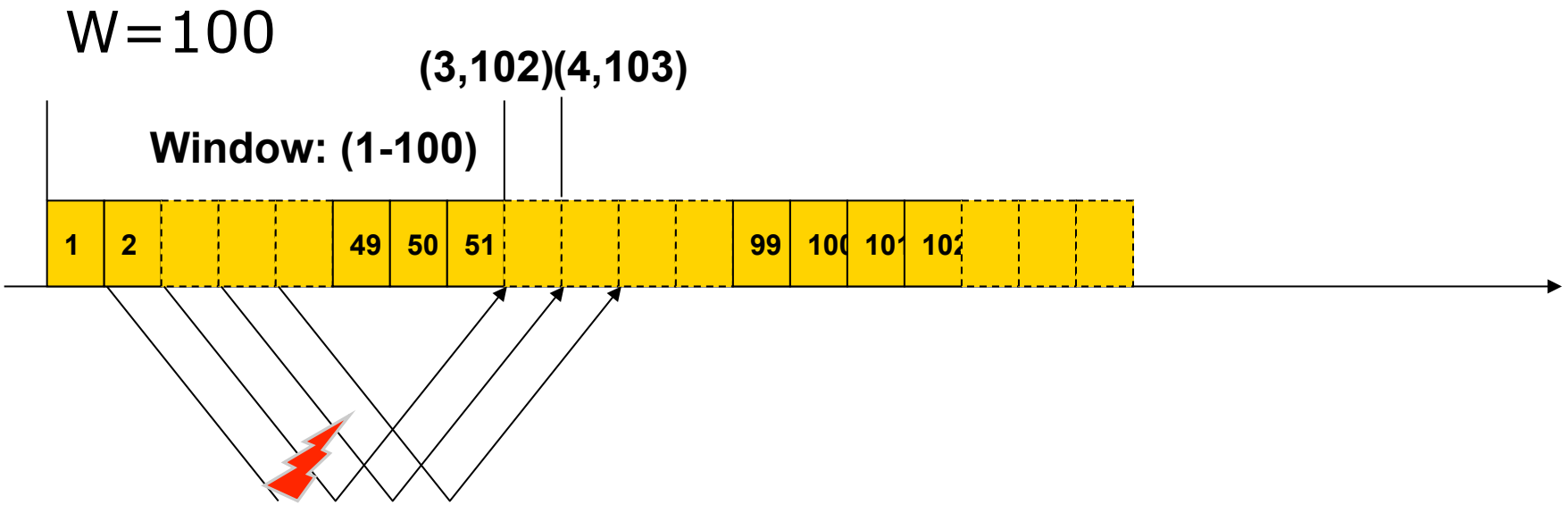
a) Total packets wasted = 100

Exercise 2 - Solution (2)



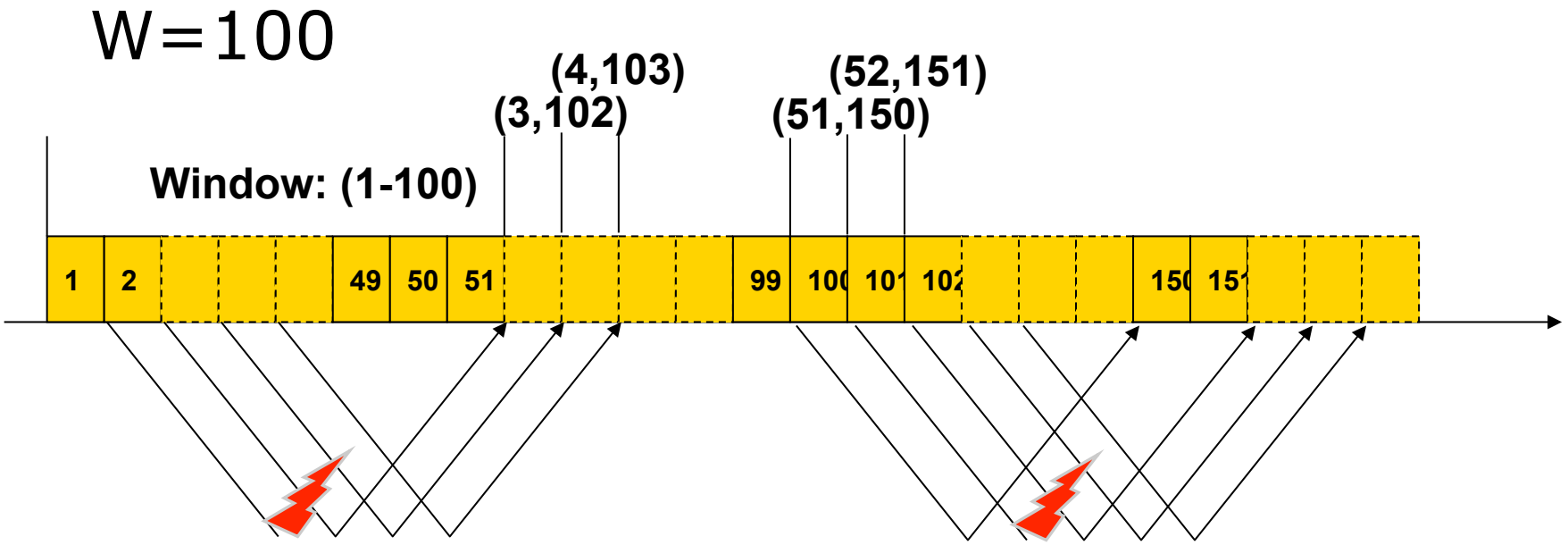
b) Like in a) total packets wasted = 100

Exercise 2 – Solution (3)



c) Due to the use of cumulative ACK, no packet transmission is wasted

Exercise 2 - Solution (4)



d) As in case c) the loss of ACKs for packet 1 and 100 do not affect the protocol operation.

Exercise 3

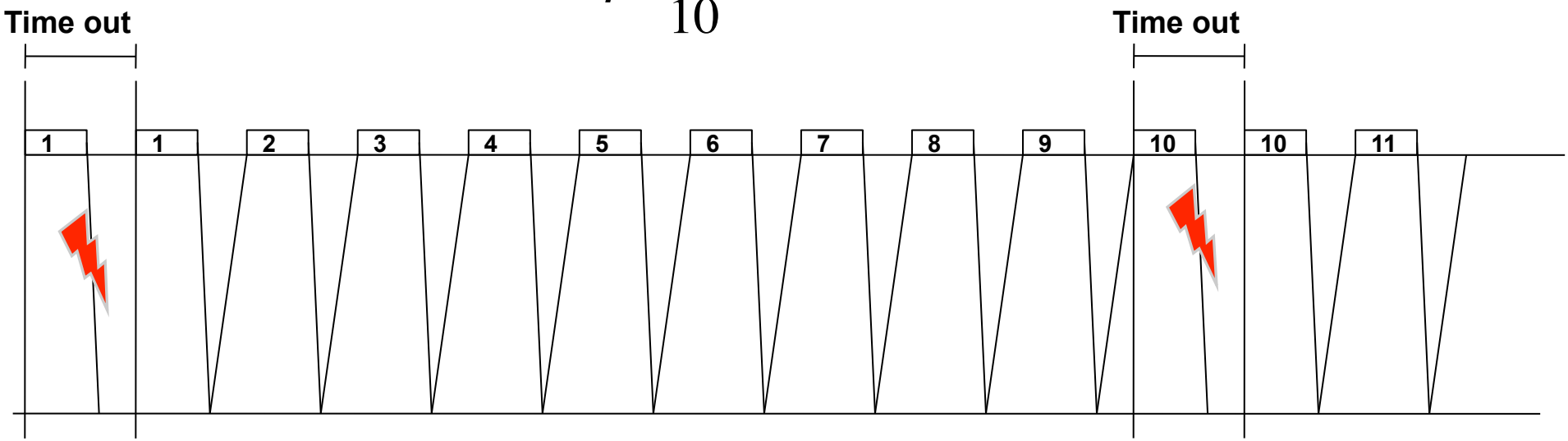
a) A communication channel generates error on 1 out of 10 packets, while all ACK packets are correctly received. Calculate the efficiency of the system (# of correct packets/tot # of transmitted packets) in case of Stop-and-wait with minimum *time-out*.

b) Calculate the efficiency (time used for transmitting correct packets/total time) in the case the propagation time is *n* times the packet transmission time T and ACK transmission time is also equal to T.

Exercise 3 - Solution

a) Stop-and-wait: 1 wrong packet out of 10.
Transmission efficiency is then:

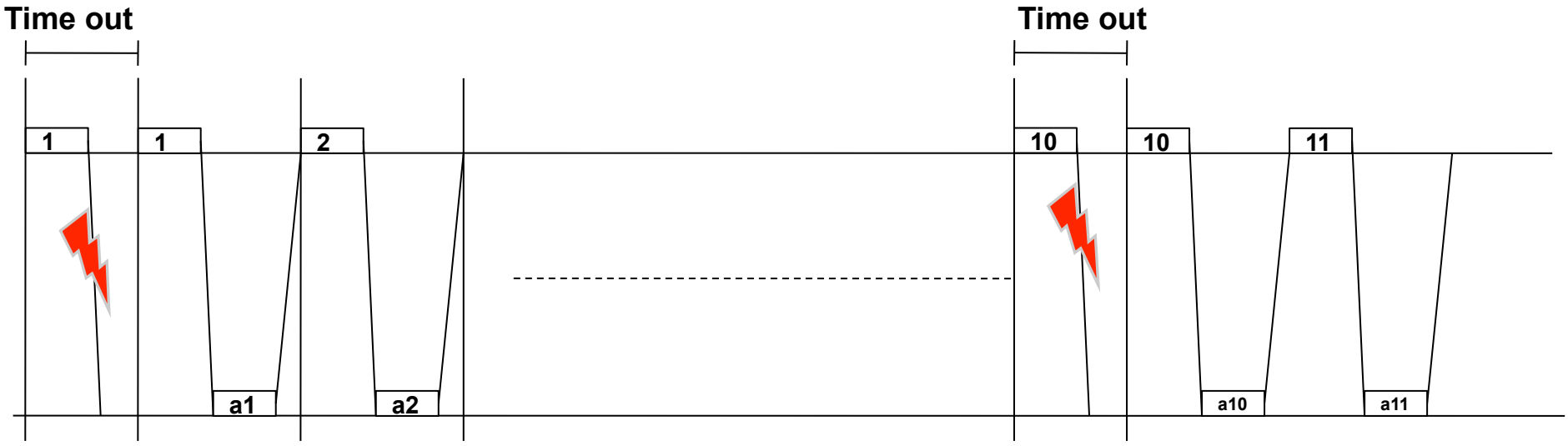
$$\eta = \frac{9}{10} = 0.9$$



Exercise 3 – Solution

b) Total efficiency: 9T spent in transmission of correct packets on a total time of 10 RTT

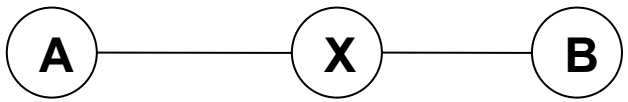
$$\eta = \frac{9T}{10(2T + 2\tau)} = \frac{9T}{10T \cdot (2 + 2n)} = \frac{9}{20 \cdot (1 + n)}$$



RTT= T + T +nT +nT

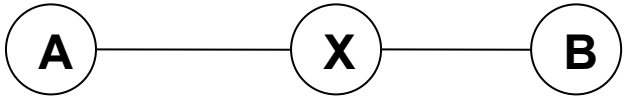
Exercise 4

- Two stations, A and B, communicate with a chain of two link with rates 100 and 200 Mb/s respectively, and propagation delay of 500 [*μs*] per link. The *forwarding* mechanism is *store and forward* without *processing* delay. A file of 1250 *Mbytes* is transferred between the two nodes in 10000 *bits* packets with a *header* of negligible length. Calculate the total transfer time (between transmission first bit to reception of last bit) in the following cases:
  a) Packets are transmitted without error control one after the other
  b) Packets are transferred with a Stop and Wait ARQ on each link
  c) Packets are transferred with a Stop and Wait ARQ executed end-to-end (ACK length equal to packet length).
- Assume error free transmissions.

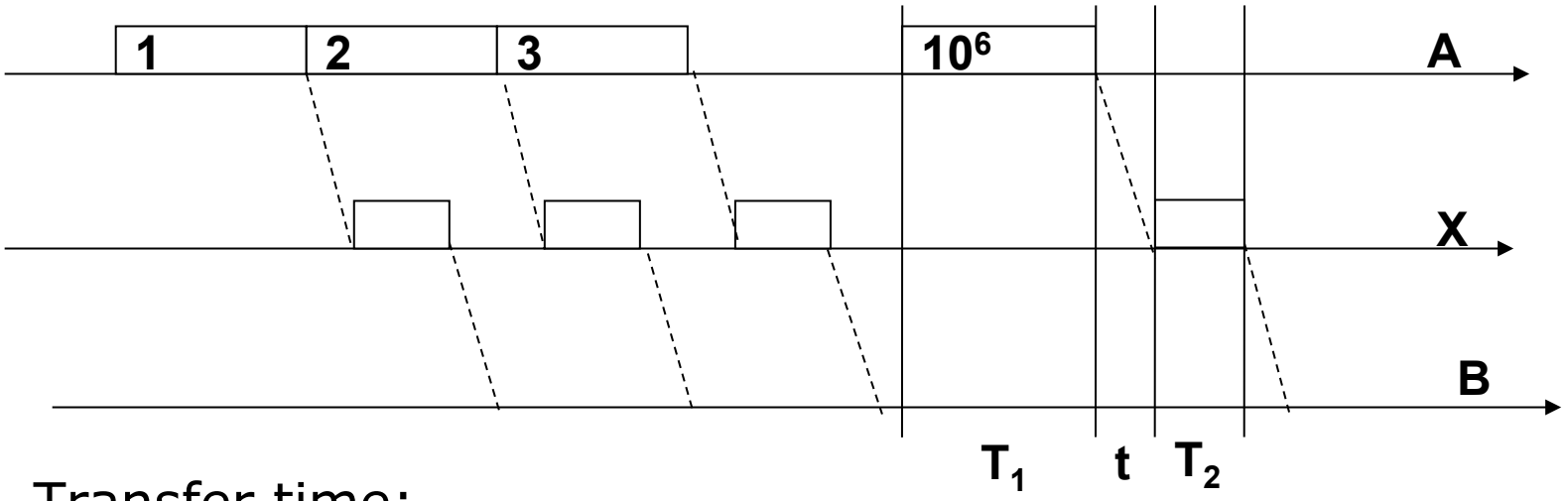


Exercise 4 – Solution (a)

- # of packets:
  - N= (1250 x 8 x 10^6)/10000 = 10^6



- Transmission times:
  - T_1=10000[bit]/100 [Mb/s]=100 [μs] , T_2=T_1/2= 50 [μs]



- Transfer time:
  - T_{tot}=NT_1+2τ+T_2 = 10^6 100 [μs] +2 500[μs] + 50 [μs] = = 100,0015 [s]

Exercise 4 – Solution (b)

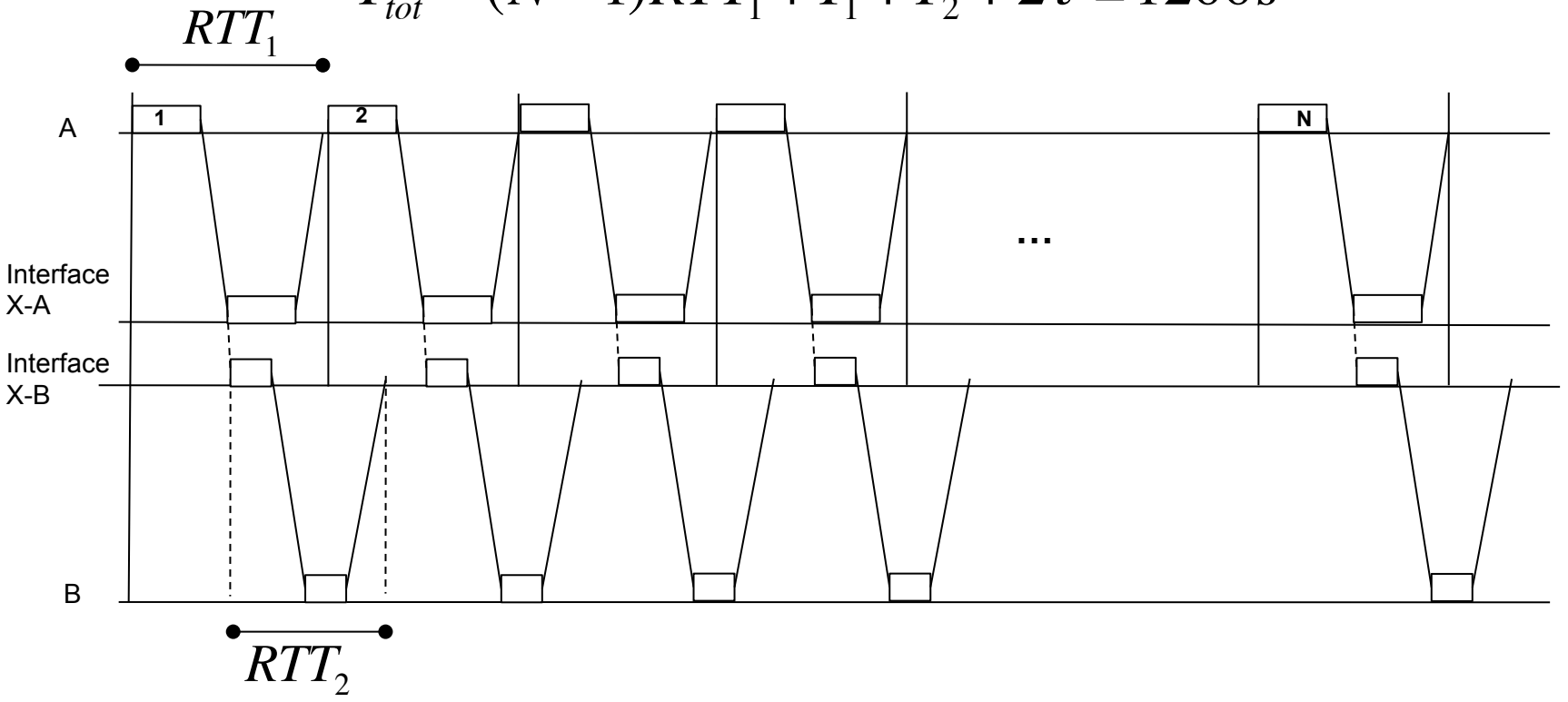
Transmission time of a single packet on first link is

$$RTT_1 = 2T_1 + 2\tau = 1.2ms$$

While on the second link, it is:

$$RTT_2 = 2T_2 + 2\tau = 1.1ms$$

And then: $T_{tot} = (N-1)RTT_1 + T_1 + T_2 + 2\tau \cong 1200s$



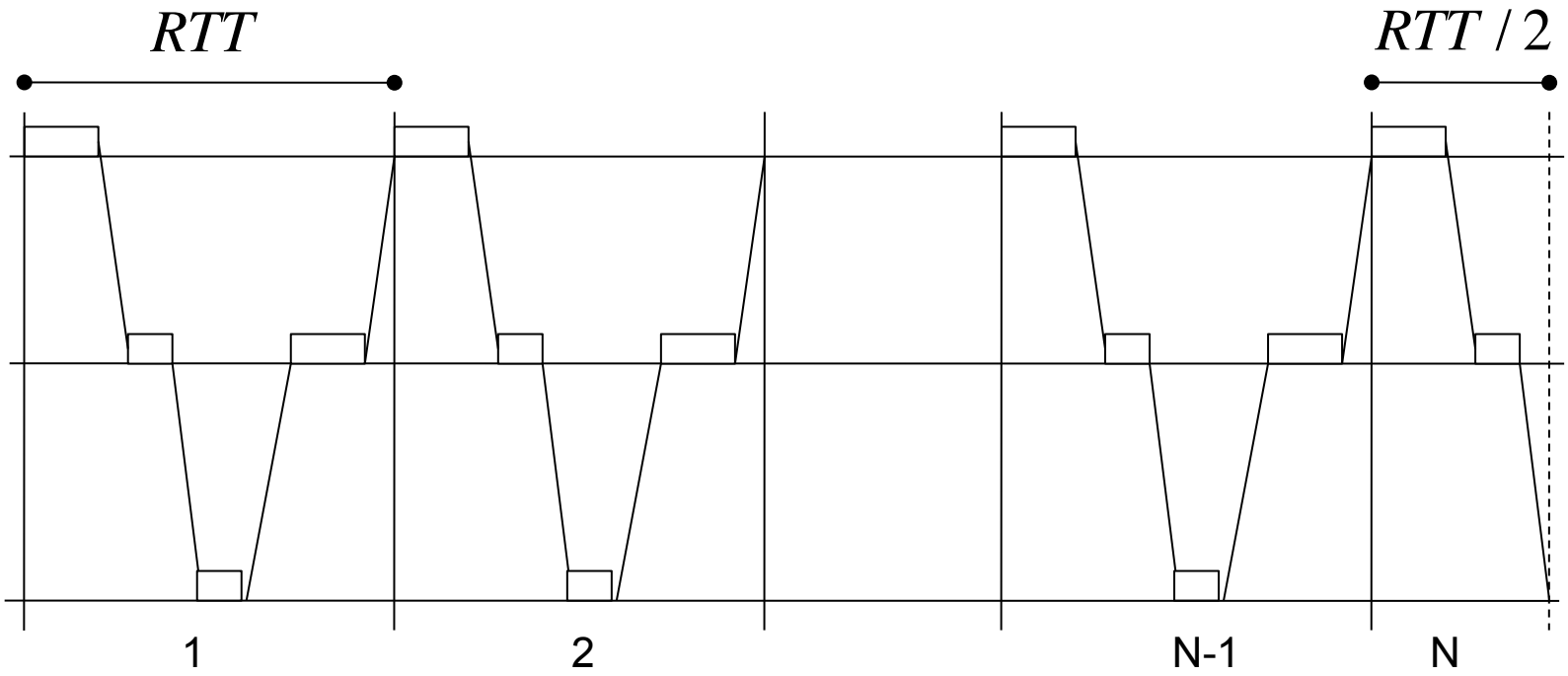
Exercise 4 – Solution (c)

Transmission time of a single packet is:

$$RTT = 2T_1 + 2T_2 + 4\tau = 2.3ms$$

Then we have:

$$T_{tot} = (N-1)RTT + /2 \cong 2300s$$

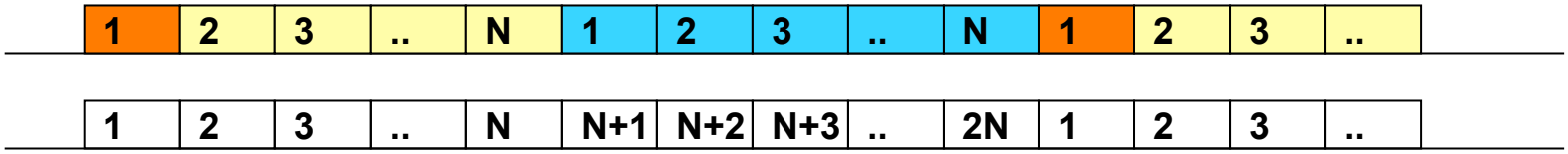


Exercise 5

- A Go-back-N system, with window N>>1 and continuous transmission, experiences 1 error every 2N packets.
- Calculate the efficiency of the system (time used to transmit correct packet over total time), assuming propagation time is equal to the transmission time of N/4 packets, in the following cases:
  - a) Transmission of ACK packets only
  - b) Use of NAK
  - c) Use of Selective Repeat instead of Go-back-N

Exercise 5 - Solution (a)

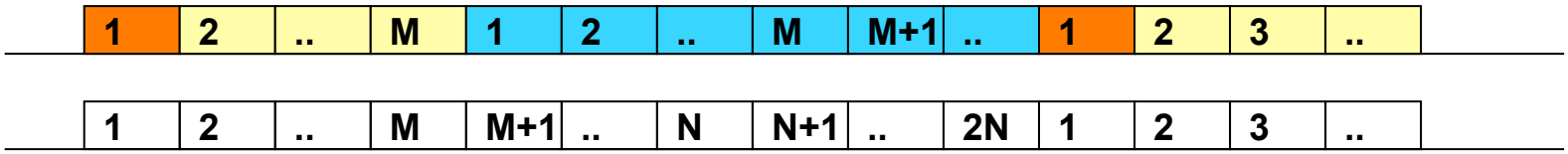
After an error, the remaining N-1 packets are transmitted, and then the N packets are all retransmitted.
After that N packets are correctly received and then cycle repeats



$$\eta = \frac{N}{2N} = 0.5$$

Exercise 5 - Solution (b)

Since propagation time is N/4 transmission times, time for receiving the ACK back is 2 x N/4 + 2 = N/2+2 transmission times, while the time for receiving the NAK in case of error is M=N/2+3 (receiver must wait one more packet to reveal out-of-sequence and transmit NACK)

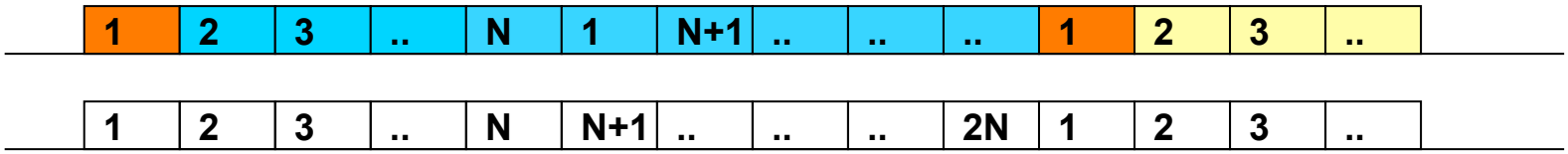


For each error we have M useless transmissions, and (2N-M) correct transmission. Therefore efficiency is:

$$\eta = \frac{2N - M}{2N} = \frac{2N - N/2 - 3}{2N} = \frac{3N - 6}{4N} \approx 3/4$$

Exercise 5 - Solution (c)

In case of Selective Repeat only wrong packets are retransmitted

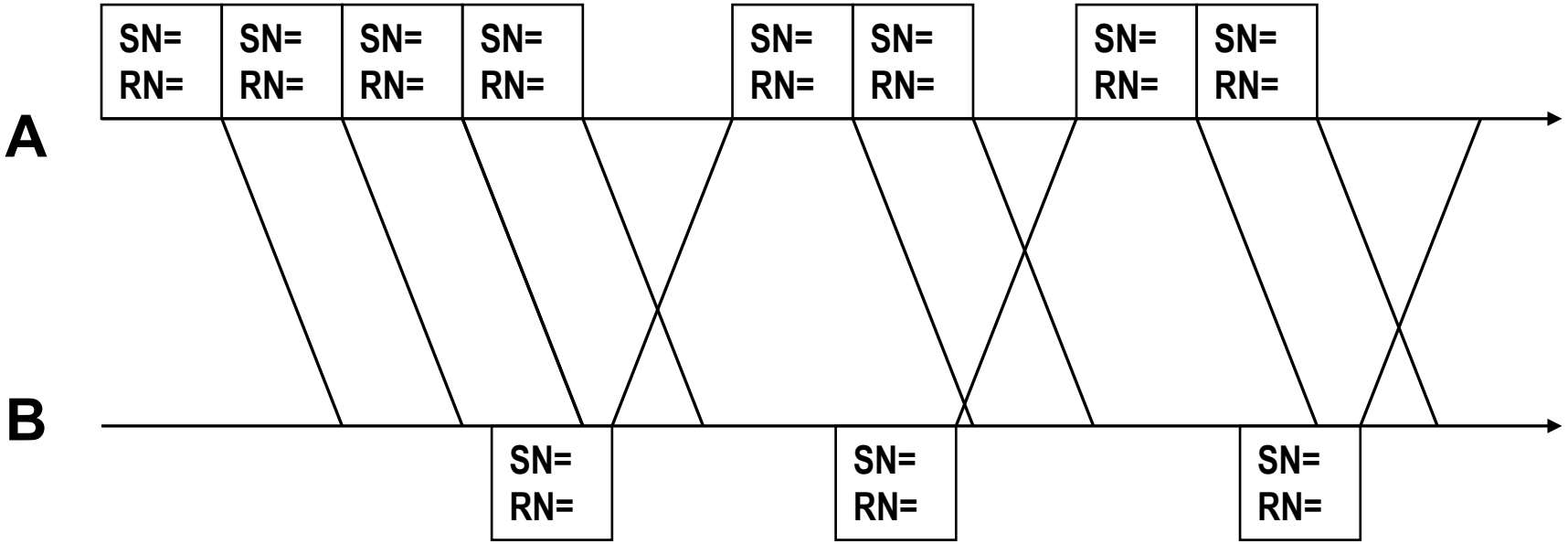


Therefore efficiency is:

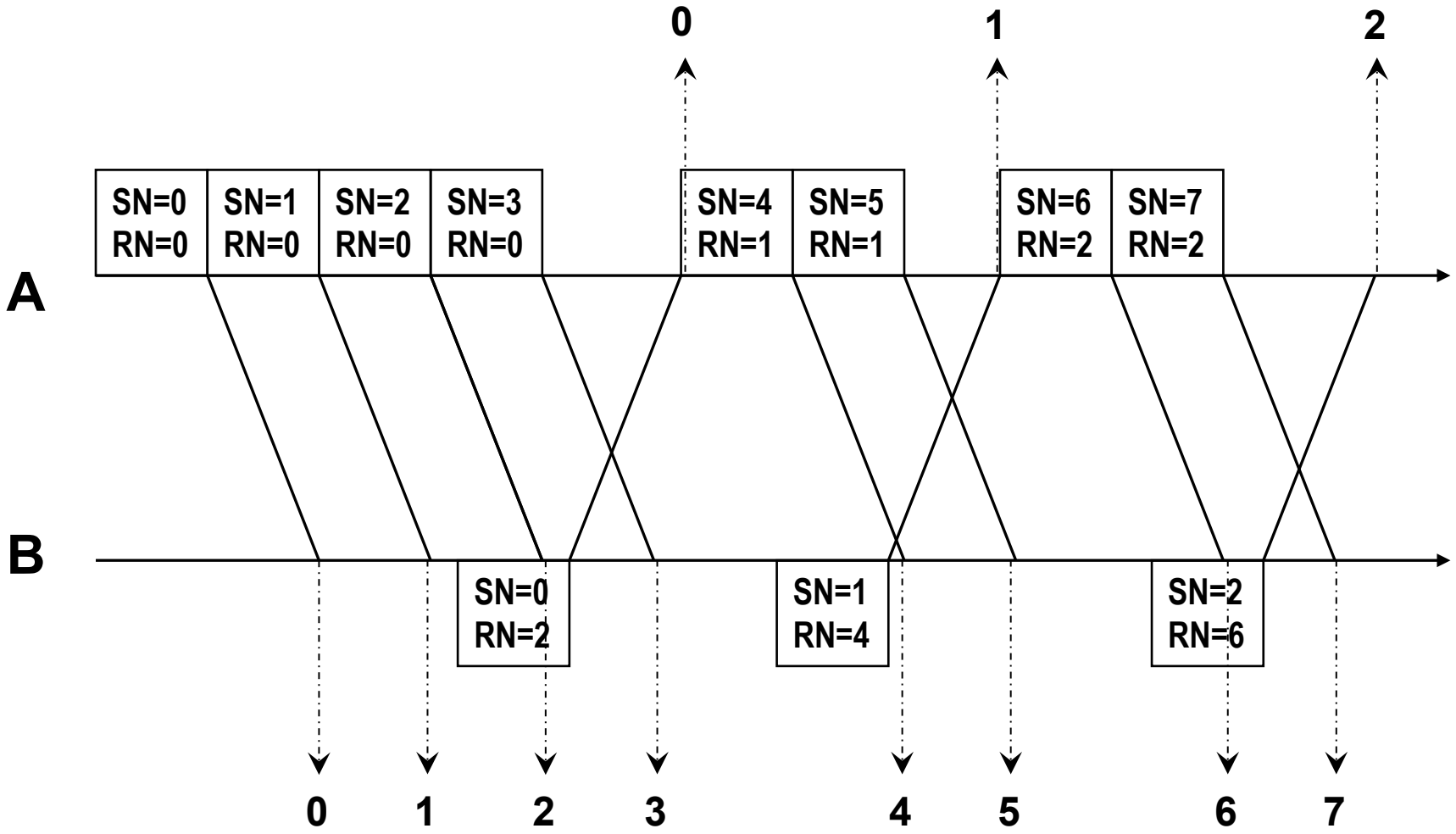
$$\eta = \frac{2N-1}{2N} \cong 1$$

Exercise 6

- Consider Go-BACK-N protocol
- Assume N=4 and time-out equal to 5 packet transmission time
- Complete figure according to protocol rules

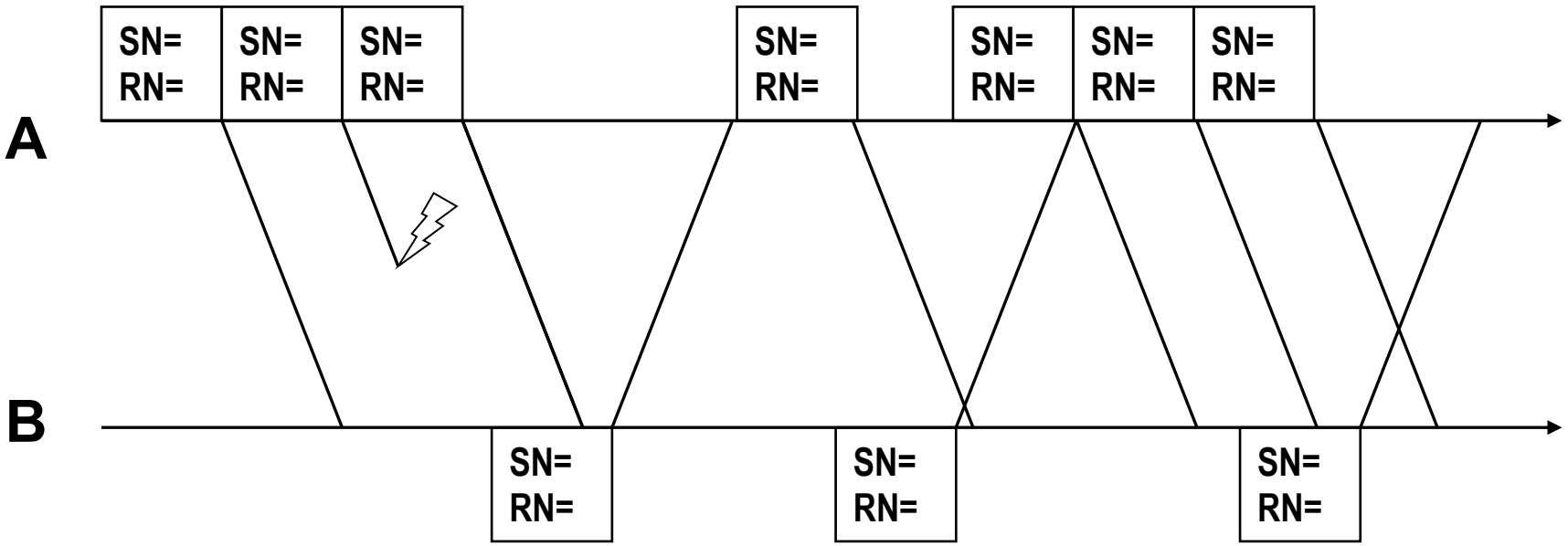


Exercise 6 - Solution

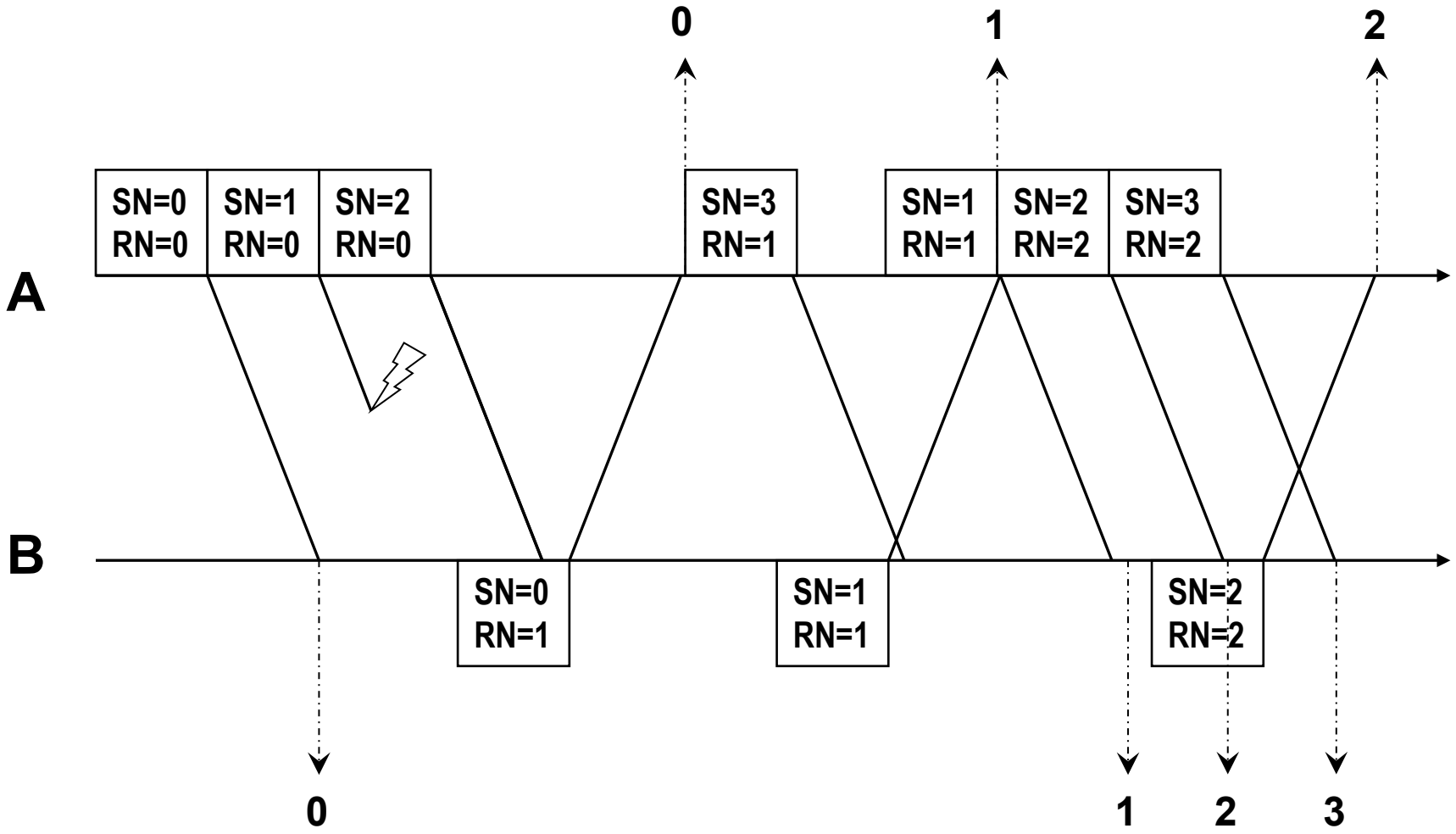


Exercise 7

- Consider Go-BACK-N protocol
- Assume N=3
- Complete figure according to protocol rules

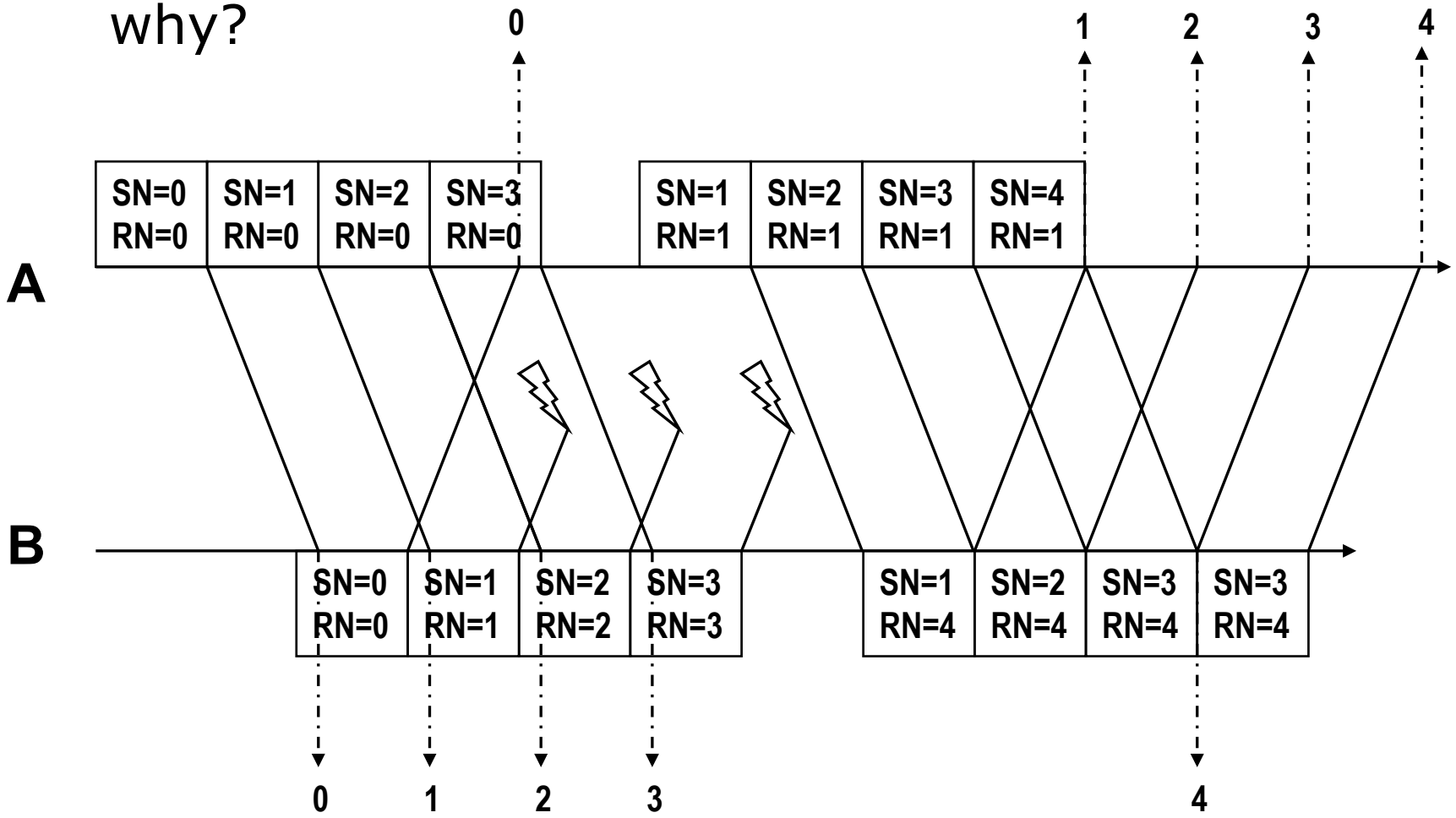


Exercise 7 - Solution



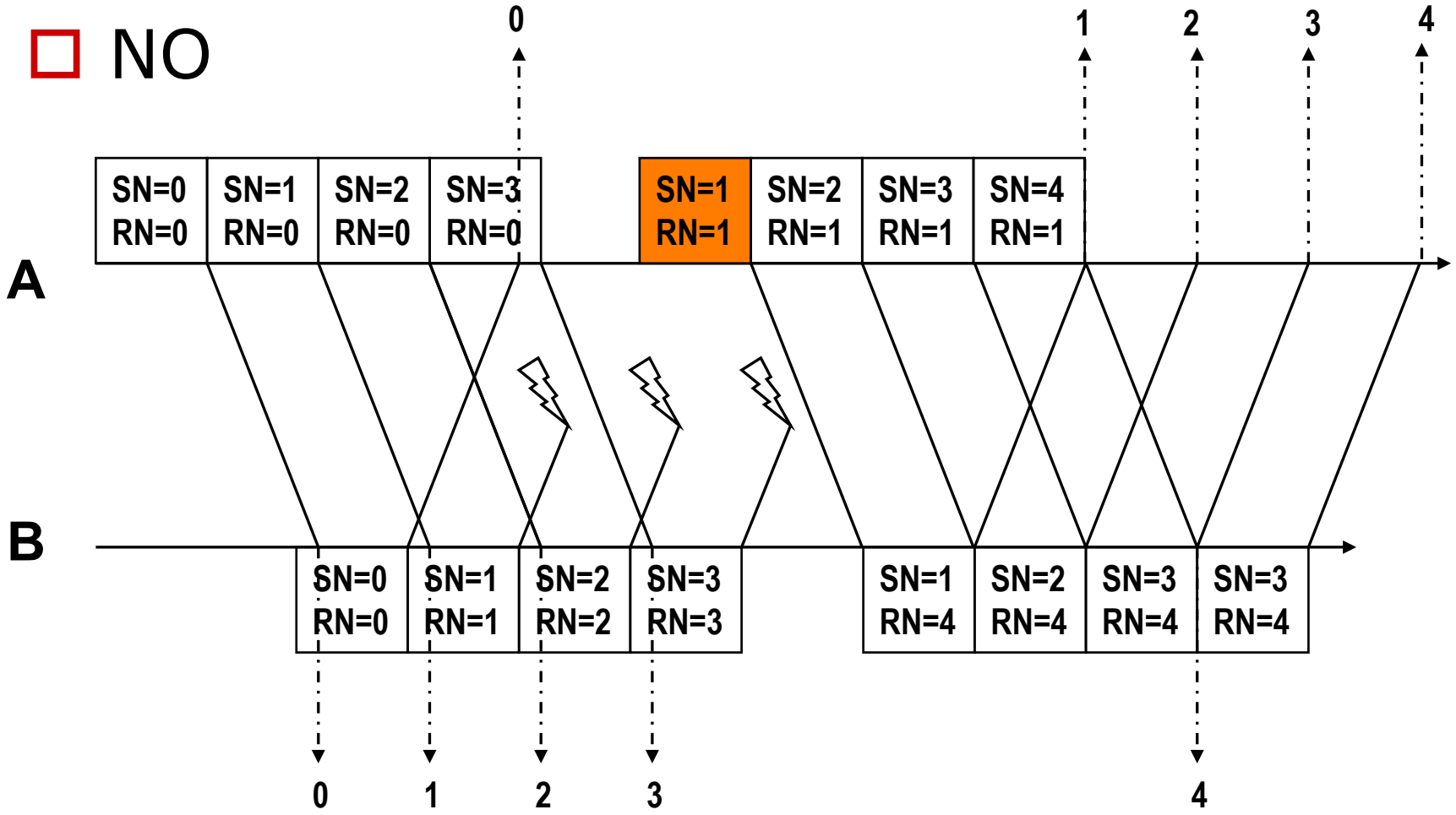
Exercise 8

- Consider Go-back-N protocol with N=4.
- Is the example in the figure correct? If not, why?



Exercise 8 - Solution

- NO



Exercise 8 - Solution