Q1. Network unreliability: Selective acknowledgement enables a more fine-grained signal of which packets have arrived, and its major benefit is that it provides at least as much information as cumulative acknowledgement. Are there any benefits to cumulative acknowledgement over selective acknowledgement?

Q2. Fairness: Consider a network ecosystem in which there is a transport protocol A used by 50% of users, and transport protocol B by the other 50%. Why is it important that both transport protocols are equally aggressive in growing its window size $W$ (representing its rate)?

Q3. Sliding window: A sliding window is used in a transport protocol to enable high throughput. Part of such a transport protocol is to negotiate the sender window size and receiver window size. Why is it a desirable property that $\text{sender window} \leq \text{receiver window}$?

Q4. Window to rate: If Alice and Bob are connected via a 100 Mbps connection, which has a constant 5 ms RTT, what would be the ideal congestion window size $W$ in kilobytes?

Q5. Sliding window strategies: true or false?

1. Go-Back-N acknowledges only the last in-order packet it has received.

2. The amount of state kept at a Selective Repeat sender is more than in a Go-Back-N sender.

3. Go-Back-N senders maintain a timer for each packet sent out.

4. If a Selective Repeat receiver receives an out-of-order packet, it is possible to move the sliding receiver window along.
Q6: Reliable transport (exam-style question).

Consider a Go-Back-N sender and receiver directly connected by a 10 Mbps link with a propagation delay of 100 milliseconds. The retransmission timer is set to 3 seconds and the window has a length of 4 segments.

Draw a time-sequence diagram (see Fig. 1) showing the transmission of 10 segments (each segment contains 10000bits). An ACK is transmitted as soon as the last bit of the corresponding data segment is received and the size of the ACK is very small.

1. Draw the time-sequence diagram for the case where there are no losses.

2. Draw the time-sequence diagram for the case where the 3rd and last segments are lost once.

![Figure 1: Time-sequence diagram: how long would it take?](image)
Q7: Reliable transport\textsuperscript{2} (exam-style question).

On the next page you see the beginning of a communication between two end-points using Go-Back-N protocol with Selective Repeat. Consider that the sender has infinitely many data segments to send and they are immediately available.

We ask you to fill in the missing values in the two tables. Stop if you either reach the bottom of the tables or the sender is no longer able to send new data segments because its buffer is full. Start with the blue row indicated on the left.

Note: Please read the entire question carefully!

Set-up:

- Every table row corresponds to one time-slot. The sender and receiver can send one data segment respectively ACK segment in every time-slot;

- Consider that the Sender buffer contains all the sent but unacknowledged segments, while the Out-of-order buffer contains all the messages which has been received... out-of-order;

- If the sender receives an ACK in one time-slot, it first processes the ACK (e.g. removes segments from the sender buffer) and then sends the data segment for this timeslot. Similarly, the receiver will first analyse the received data segment and then send a corresponding ACK;

- The link between the sender and receiver is not reliable. The first data segment with a sequence number of 3 and all data segments with a sequence number of 5 are dropped and do not reach the receiver.

Sender-behavior:

- The sender uses Selective Repeat after receiving 3 duplicate ACKs. That means as soon as the sender receives an ACK with the same sequence number for the third time, it will retransmit the missing segment in the same time-slot (instead of a new data segment);

- The sender can store at most 5 unacknowledged segments in its sender buffer.

- The sender sends nothing in all other cases, i.e. if it cannot do a selective repeat because it did not receive a third duplicate ACK and the sender buffer is full.

Assumptions:

- You will not reach the maximal sequence number. No overflow;
- The timeout value is very long and will not occur;
- The receiver out-of-order buffer can store an unlimited number of segments.

Fill the following table starting from the blue row on the left.

<table>
<thead>
<tr>
<th>Sender buffer</th>
<th>Data segment to send</th>
<th>Received ACK number</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0]</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>[1]</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Received data segment</th>
<th>ACK number to send</th>
<th>Out-of-order buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>[-]</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>[-]</td>
</tr>
</tbody>
</table>
Q8. **(Exam FS16)**: Which of the following fields does an IP router typically modify before forwarding the packet to the next hop?

1. Destination MAC address
2. Destination IP address
3. Time-to-live (TTL) field
4. IP checksum

Q9. **(Exam FS16)**: List three signals that warn about congestion in the network, and mention one advantage and one disadvantage of using each signal.