1. In `rdt2.0` What two error cases might cause a receiver to send a negative acknowledgment (NACK)? How are they detected? What happens if the NACK is lost?

2. In what circumstances will a receiver receive a packet with the same sequence number twice? What should it do in these circumstances?

3. `rdt3.0` seems to have solved all of the key problems that result in unreliable data transfer (e.g., packet corruption, packet loss).

   (a) What is the main reason of introducing sliding windows on top of the stop-and-wait approach that `rdt3.0` uses?

   (b) Give a couple of special situations where stop-and-wait might perform similarly to a sliding-window approach.

4. Using a timing diagram to track the sequence of sent messages and acknowledgements, show that if messages can be reordered (i.e., a packet might be delayed and received after a packet that is subsequently sent), the `rdt 3.0` state machine using alternating bits will not work as designed.

5. If two hosts are connected by a 100Mbps link with a roundtrip time of 20ms, how big (in bytes) should the sliding window be to maximise link usage?

6. For TCP, the lecture notes (slide 113) make the following statement: ”receivers *can* buffer out of sequence packets”.

   (a) Why might a receiver choose NOT to do this?

   (b) Does a sender need to know whether a receiver buffers out of sequence packets? Why? Why not?

7. When TCP implementations measure the RTT, what problem are they trying to solve? What does the value α in the exponential averaging function control?

8. Consider a sliding window protocol with a window size of 5 using cumulative ACKs.

   Retransmissions: retransmissions occur under two conditions:

   - Reception of three duplicate ACKs (three identical ACKs *after* the initial ACK – this is different than TCP's duplicate ACK behaviour)

- Time out after 100msec (timer starts at the beginning of the packet transmission)

Timing:

- Data packets have a transmission time of 1 msec
- ACK packets have zero transmission time
- The link has a latency of 10msec.
- The source A starts off by sending its first packet at time t=0.

(a) Assume all packets are successfully delivered except the following:

- The first transmission of data packet #3
- The ACK sent in response to the receipt of data packet #6

When is data packet #3 first retransmitted (expressed in terms of msec after t=0)?

(b) Consider the same scenario, but with everything successfully delivered except the following:

- The first transmission of data packet #3
- The first transmission of data packet #5
- The ACK sent in response to the receipt of data packet #6

When is data packet #3 first retransmitted (expressed in terms of msec after t=0)?

9. For this question, the same sliding window algorithm as in the previous question is used and the same timings and retransmission policies apply. Assume we can only observe the ACK packets arriving at the sender.

The notation Ax is used to mean that the ACK packet acknowledges the receipt of all packets up to and including data packet x. That is, A5 is acknowledging the *receipt* of packet 5 and all packets before it (unlike TCP where ACKs specify the packet the receiver is expecting).

(a) If you observe ACK packets arriving in the following order:

[A1, A2, A3, A3, A4, A5, A6]

Which of the following five scenarios would have produced such a series of ACKs? (pick all that apply; assume that only the unusual event in the scenario occurred and everything else in the network functioned normally)

(a) Data packet number 4 was dropped.
(b) Data packet number 4 was delayed, arrived immediately after data packet 5
(c) Data packet 3 was duplicated by the network
(d) ACK packet A3 was duplicated by the network
(e) ACK packet A4 was delayed, arriving after A5

(b) With the same set up as in the previous problem, consider the following stream of ACK packets:

[A1, A2, A3, A5, A4, A6]

Which scenarios would have produced such a series of ACKs? (pick all that apply)

(a) Data packet number 4 was dropped.
(b) Data packet number 4 was delayed, arrived immediately after data packet 5
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(e) ACK packet A4 was delayed, arriving after A5

(c) With the same set up as in the previous problem, consider the following stream of ACK packets:

[A1, A2, A3, A3, A5, A6]

Which scenarios would have produced such a series of ACKs? (pick all that apply)

(a) Data packet number 4 was dropped.
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