ESD5 – Fall 2024
Problem Set 1 – Solutions

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Problem 1 – The Price of a Protocol

(a)

$$\text{min. number of frames} = \left\lceil \frac{5000}{64} \right\rceil = 79.$$

Alternative answer: since we have the flexibility of deciding the packet length, we can assume that we could have transmitted the following fractional number of frames:

$$\frac{5000}{64} = 78.125 \text{ frames}.$$

(b) A frame consists of 536 bits (64 byte $\times$ 8 [bit/byte]). To transmit a frame with a data rate of 1 kbit/s we need 0.536 s. Then, we need 42.344 s to transmit the 79 frames.

Alternative answer: Following (a), it would take 41.875 ms to transmit the 78.125 frames.

(c) Each frame has 512 bits of the payload information. The efficiency is: $\frac{512}{536} \approx 0.96$. The goodput is then $1 \cdot 10^3 \cdot 0.96 = 960$ bit/s.

(d) By excluding the packet length field the sequence numbers (used for piggybacking) and CRC, we get a new frame whose size is 520 bits. The new efficiency is $\frac{512}{520} \approx 0.98$; goodput of 980 bit/s. Consequently, we have an efficiency gain of approximately 2%.

Note: You could naturally remove more or less which would yield yet again a different efficiency. Fundamentally the point is you should only add in as much control data as you need to operate correctly, otherwise there will be a waste. Of course, if operations are not correct you need control to ensure a desirable behavior.

Problem 2 – Feedback Latency

(a) The minimum is 10 ms and the maximum is 40 ms. Note that we are defining the data rate of the channel when giving the time that the message arrives at the receiver. Hence, we are substituting the value of 1 kbit/s used in the first exercise.

(b) The average throughput is:

$$\text{avg. throughput} = \frac{79 \cdot 536 \text{ bits}}{79 \cdot (10 + 10) \cdot 10^{-3}} = 26.8 \text{ kbit/s}.$$

The numerator is the number of bits that Alice wants to transmit, where one should recall that the number of frames to transmit 5,000 bytes is 79 frames From Problem 1 – (a). The numerator corresponds to the time needed to Alice transmit a frame and receive an ACK from Bob, which is considered to be always successful.

(c) 100 re-transmissions if we assume that the re-transmitted frames are received successfully.

Alternative and more complete answer: By thinking recursively, from the 100 re-transmissions, we will have one more in error. Hence, we would have a total of 101 re-transmissions.

(d) The transmission time can be computed as follows:

$$\text{Tx time} = (\underbrace{2 \cdot 10,000 \cdot 10 \cdot 10^{-3}}_{\text{time to Alice transmit and Bob ACK/NACK}} + \underbrace{2 \cdot 100 \cdot 10 \cdot 10^{-3}}_{\text{time to Alice re-transmit and Bob ACK}}) = 202 \text{ s}.$$

Problem 3 – RS-232

(a) The diagram is shown below. Note that we did not consider the parity bit. If we consider it, it should be placed between "`b7`" and the "`stop`" bits. *The calculation of the parity bit does not consider the start bit, just the data bits.* **Assumptions.** Voltage levels: "`0`"$\leftarrow$3 V and "`1`"$\leftarrow -3$ V. We also specify that the binary word is written from the Most Significant Bit (MSB) to the Least Significant Bit (LSB). We assume that before the transmission the link is in the "`idle`" state (0 V). According to the standard the payload data of an RS-232 frame consists of 8 bits.

With that, the transmitter should transmit: '0011010001', where the blue bit is the start one while the red one is the stop. Thus, we obtain the following diagram:

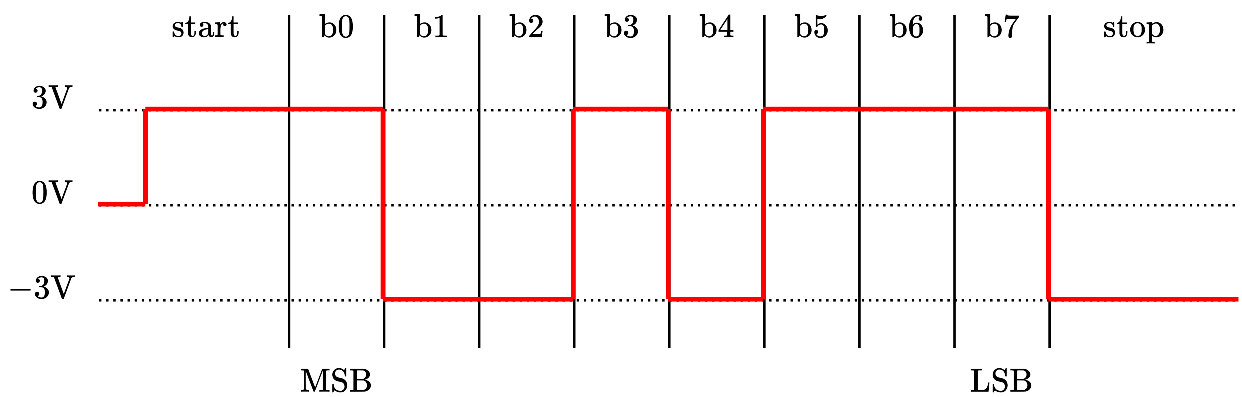

Figure 1: Diagram for (a). The signal is in red.

Alternative answer: one could also have considered the inverse form for the assignments of the voltage levels and the direction in which the payload data is interpreted. Moreover, one could also have assumed the parity bit[1].

(b) It would take $\frac{11 \cdot 10}{9600} = 0.011$ s.

(c) The character is "`a`" and the parity would be "`1`".

(i) "`q`"; yes.

(ii) "`u`"; no.

[1]See on `https://en.wikipedia.org/wiki/RS-232` that the voltage levels can range from ± 3 V to ± 15 V and that the direction in which the payload data is read is not readily specified by the standard.

Problem 4 – ARQ with Limited Retransmissions

(a) For $K = 1$, $P_\mathrm{s} = \sum_{i=1}^{2} p_\mathrm{PER}^{(i-1)}(1 - p_\mathrm{PER}) = 1 - p_\mathrm{PER}^2 = 1 - 0.1^2 = 0.99$

For $K = 2$, $P_\mathrm{s} = \sum_{i=1}^{3} p_\mathrm{PER}^{(i-1)}(1 - p_\mathrm{PER}) = 1 - p_\mathrm{PER}^3 = 1 - 0.1^3 = 0.999$

(b) For $K = 1$, $G = \frac{1\times 0.99}{1+1} = 0.495$ packet/slot

For $K = 2$, $G = \frac{1\times 0.999}{1+2} = 0.333$ packet/slot

(c) Increasing the number of retransmissions leads to a higher probability of successful packet transmission for a single packet, while it deteriorates the throughput.

(d) If the set number of retransmissions makes the total number of transmissions for the 2 packets higher than 5 slots, then the reliability is zero. Notice that the reliability also depends on Bob successfully receiving the data packets. Hence, if the total number of transmissions for the 2 packets is below 5 slots, the communication reliability is defined by the packet error rate.