Questions and Exercises to work out and turn in:

Grading Guidelines:

A right answer will get full credit when:

1. It is right (worth 25%)
2. It is right **AND** neatly presented making it easy and pleasant to read. (worth an **extra** 15%)
3. There is an **obvious and clear link**[1] between 1) the information provided in the exercise and in class and 2) the final answer. A clear link is built by properly writing, justifying, and documenting an answer (worth an **extra** 60%).
4. Calculation mistakes will be minimally penalized (2 to 5% of full credit) while errors on units will be more heavily penalized.

Late Submission : as specified in the syllabus. Days counting starts one minute after the deadline.
Check Your Submission: after submitting, download your submission to check whether it is the right version and it is complete.

You are welcome/encouraged to discuss exercises with other students or the instructor. But, ultimately, **personal** writing is expected.

- USE THIS FILE AS THE STARTING DOCUMENT YOU WILL TURN IN. **KEEP IN THE QUESTIONS** AND INSERT YOUR ANSWERS.
- IF USING HAND WRITING (STRONGLY DISCOURAGED), REWRITE THE QUESTIONS.
- FAILING TO FOLLOW TURN IN DIRECTIONS /GUIDELINES WILL COST A 30% PENALTY.

Objectives of this assignment:

- to compute the "Internet Checksum" on a stream of bits
- to evaluate the impact of the distance on the throughput and efficiency of stop-and-wait protocol.

What you need to do:

Answer the questions and/or solve the exercises described below.

[1] Check the appendix about what an obvious and clear link is.

Logical Link Layer

Exercise 1 (35 points)

Suppose that a message 1110 1011 1100 1100 (w_1 w_2 w_3 w_4) is transmitted using Internet Checksum (4-bit word). The objective is to compute the checksum. In order to determine the checksum follow steps

An n-bit Internet Checksum is computed as follows:

1) Break the stream of bits in n-bit words w_1, w_2, ..., and w_m. For the message 1110 1011 1100 1100, list the words w_1, w_2, ..., and w_m.

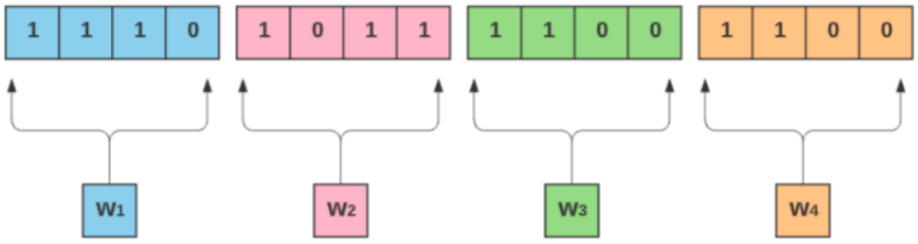


Figure 1: Message $S(w_1, w_2, w_3, w_4) = 1110\ 1011\ 1100\ 1100$

2) Compute the n-bit word S = w_1 + w_2, if there is a carry then set S = S + 1. Execute this step on Message 1110 1011 1100 1100.

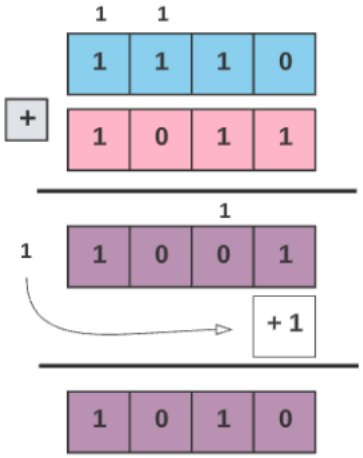


Figure 2: n-bit word $S = w_1 + w_2 = 1110 + 1011 = 1010$

3) Compute S = S + w_3, if there is a carry then set S = S + 1, Execute this step on Message 1110 1011 1100 1100.

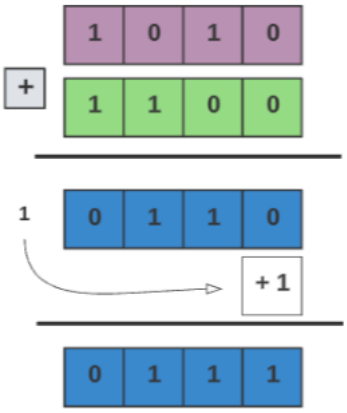


Figure 3: $S = S + w_3 = 1010 + 1100 = 0111$

n) Compute S = S + w_n, if there is a carry then set S = S + 1. Execute this step on Message 1110 1011 1100 1100.

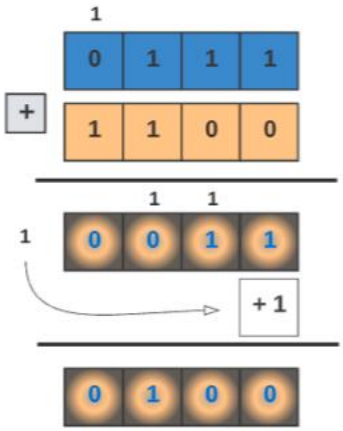


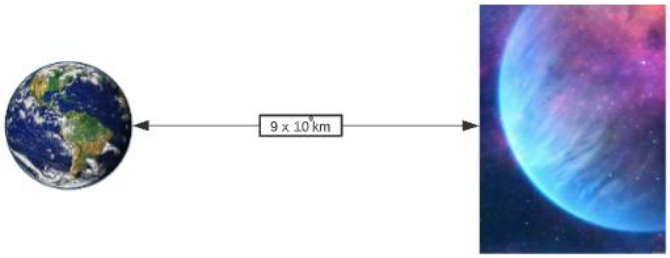
Figure 4: $S = S + w_4 = 0111 + 1100 = 0100$

Finally, the Internet Checksum = ~S (one-complement of S)

Internet Checksum (~S) = S(1's complement of S) = 1011

Exercise 2 (65 points)

The objective of this exercise is to realize how high distance and high bandwidth affect the performance of stop and wait.



The distance from Earth to a distant planet is approximately 9 x 10^9 km. Assume that the frame size is 10 Kbits and the speed of light is 3 10^8 m/s. Assume that the bit rate is 4 Mbps.

a) (10 points) What is the efficiency (channel utilization) if a stop-and-wait protocol is used?

$$Efficiency\ (channel\ utilization) \Rightarrow \eta = \frac{T_d}{T_d + 2T_p} \tag{1}$$

If a stop-and-wait protocol is used, we can find the efficiency η (channel utilization) using the following formula. We must first compute the transmission delay as well as the propagation delay.

$$Transmission\ Delay\ (T_d) = \frac{frame\ size}{bit\ rate} = \frac{10\ Kbits}{4\ Mbps} = 0.0025\ s \tag{2}$$

$$Propagation\ Delay\ (T_p) = \frac{distance}{speed} = \frac{9 \times 10^9\ km \cdot 10^3}{3 \times 10^8 \frac{m}{s}} = 3 \times 10^4\ s \tag{3}$$

From here, we simply plug in our values...

$$Efficiency\ (channel\ utilization) \Rightarrow \eta = \frac{0.0025\ s}{0.0025\ s + 2(3 \times 10^4\ s)} = 4.17 \times 10^{-8} \tag{4}$$

b) (20 points) Suppose we use a window protocol. What should be the window size in frames to achieve the maximal efficiency (channel utilization)?

If a window protocol is used, we are able to find the window size frames to achieve the maximal efficiency (channel utilization) using the following formula:

$$Window\ size\ in\ frames\ \Rightarrow x = 1 + 2(\frac{T_p}{T_d}) = 1 + \frac{6 \times 10^4\ s}{0.0025\ s} = 24000001 \tag{1}$$

Lastly, by taking the base 2 logarithm, we can find the approximate window size in frames:

$$log_2(24000001) \approx 25\ bits \tag{2}$$

c) (17.5 points) Plot the efficiency versus the distance when the bit rate is set to 4 Mbps. The x-axis will have distances from 0km to 9 x 10^{10} km. I recommend you to use a graphing tool (e.g., Excel). Discuss this plot. We are interested in the impact of distance over the efficiency. **Avoid hand-made plots.**

d) (17.5 points) Plot the efficiency versus the bit rate when distance is set to 9 x 10^{9} km. The x-axis will have bit rates from 0 bit/s to 5 Gbps. I recommend you to use a graphing tool (e.g., Excel). Discuss this plot. We are interested in the impact of bitrate over the efficiency. **Avoid hand-made plots.**

What you need to turn in:

- Electronic copy of this file (including your answers) (standalone). Submit the file as a Microsoft Word or PDF file.

- Recall that answers must be well written, documented, justified, and presented to get full credit.

- How this assignment will be graded:
- A right answer will get full credit when:
- It is right (worth 25%)
- It is right AND neatly presented making it easy and pleasant to read. (worth 15%)
- There is an obvious and clear link between 1) the information provided in the exercise and in class and 2) the final answer. A clear link is built by properly writing, justifying, and documenting an answer (worth 60%).
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- You are welcome/encouraged to discuss exercises with other students or the instructor. But, ultimately, personal writing is expected.

Appendix: Grading: What is an OBVIOUS and CLEAR LINK?

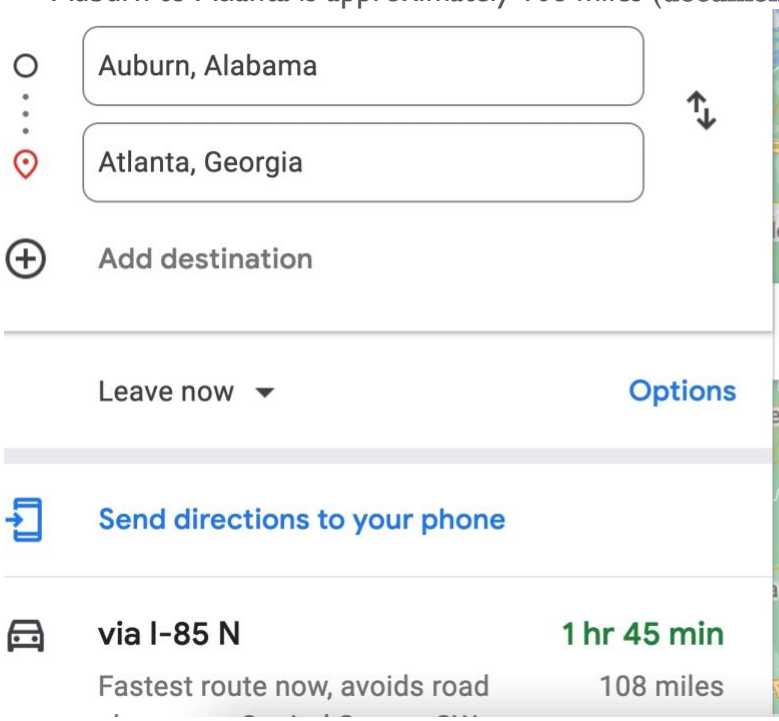
Here is an example to explain what an **obvious and clear** link is and how we grade your work.

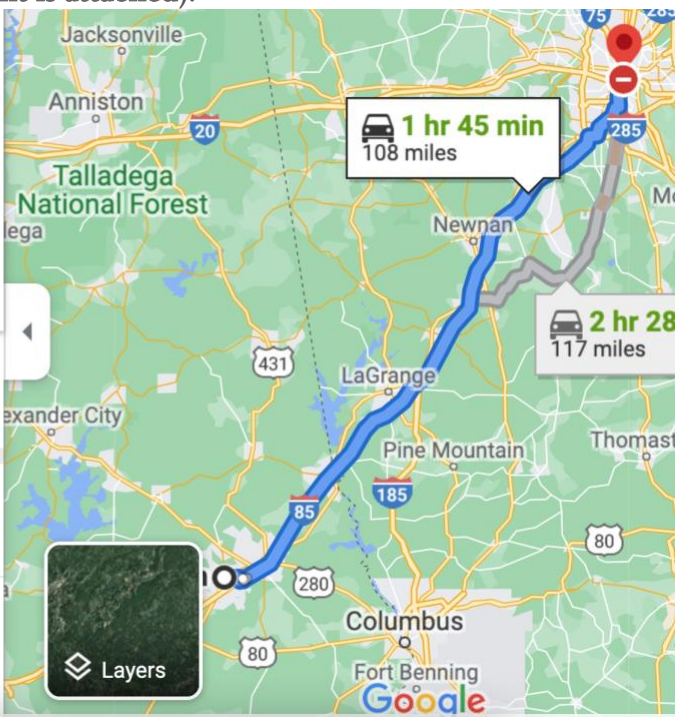
Consider the following problem:

"(100 points) John travels from Auburn to Atlanta in his car at a speed of 60 mph. Leaving at 8am, at what time will John reach Atlanta".

Here are the answers of three students and their scores:

- Student 1 answers: "9:48am". Student 1 will get 25 points.
- Student 2 answers : "John will reach Atlanta at 9:48am". Student 2 will get 25+15 = 40 points
- Student 3 answers: "The time t to travel a distance d at speed v is equal to d/v = d/60mph. The problem does not provide the distance d from Auburn to Atlanta. Based on GoogleMaps, the distance from Auburn to Atlanta is approximately 108 miles (document is attached).





Therefore, the time t = 108 miles/60mph * 60 minutes/hour= 108 minutes. Since John left at 8am, he will then reach Atlanta at 8am + 108 minutes = 8 am + 60 minutes + 48 minutes = 9:48".

Student 3 will get 25 + 15 + 60 = 100 points

Do you see the direct link going from the data provided in the question to the final answer, using general knowledge/formula and documents?.... Can you now solve the following problem and get 100 points?

"(100 points) Alice travels from Auburn to Atlanta in her car at a speed of 60 mph. Leaving at 8am, at what time will Alice reach Atlanta assuming that she had a flat tire that delayed her 30 minutes".