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 explore the relationship between switches processing time and propagation time

What you need to do:

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

[1] See **Appendix** about what an obvious and clear link is.

Exercise 1 (100 points)

This exercise explores of the impact of the switching time (time spent on routers, switches or other intermediary networking devices) and the propagation time (distance).

A factor in the delay of a store-and-forward packet-switching system is how long it takes to store and forward a packet through a switch (router (L3 switch) or L2 switch). The objective of this exercise is to investigate the impact of the switch time on the overall delivery delay of a packet. The switch time is about 10 μse per device: we assume (oversimplification) that ***each*** *device adds this switching time to the packet delay in order to process (routing...) the packet. Consider a packet P sent from Auburn University (AU) to the department of computer science at Texas A&M University (CS TAMU at cs.tamu.edu) (about 1250 kms) over a copper line. Assume the propagation speed in copper to be 2/3 the speed of light.*

a) (32 points) What is the propagation time from the packet P to reach the destination? Ping `cs.tamu.edu`. Provide a screenshot of your ping collecting at least 20 ping packets. Report here the minimum, average, and maximum round trip time provided by Ping. Recall that the one way transit can be estimated as half the round trip time. Check/discuss whether your calculations (to determine the one way propagation time from source to destination) match the ping measurements. If the calculations do not match the ping measurement, propose possible explanations.

$$Propagation\ Delay\ (t_{pd}) = \frac{distance\ (d)}{propagation\ speed\ (c_p)} \tag{1}$$

$$d = 1,250\ [kms] * 10^3\ [m] = 1,250,000\ [m] \tag{2}$$

$$c_p = \frac{2}{3} \cdot 3 \times 10^8\ [\frac{m}{s}] = 2 \times 10^8\ [\frac{m}{s}] \tag{3}$$

$$t_{pd} = \frac{d}{c_p} = 0.00625\ [s] * 1000 = 6.25\ [ms] \tag{4}$$

```
mto0006@tux061:~$ ping cs.tamu.edu
PING cs.tamu.edu (13.249.48.30) 56(84) bytes of data.
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=1 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=2 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=3 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=4 ttl=237 time=19.1 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=5 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=6 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=7 ttl=237 time=19.5 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=8 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=9 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=10 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=11 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=12 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=13 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=14 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=15 ttl=237 time=19.1 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=16 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=17 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=18 ttl=237 time=19.2 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=19 ttl=237 time=19.3 ms
64 bytes from server-13-249-48-30.iah50.r.cloudfront.net (13.249.48.30): icmp_seq=20 ttl=237 time=19.3 ms
^C
--- cs.tamu.edu ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19027ms
rtt min/avg/max/mdev = 19.130/19.303/19.521/0.112 ms
```

b) (16 points) Provide the approximate number of switches (routers) between a computer at Auburn University and a computer at the destination. Provide the answer and do not forget to write how you found the answer. (You can use the command `traceroute` on Unix machines or `tracert` on Windows: let us know if you encounter difficulties.). Note that these commands do not reveal L2-switches. Provide a screenshot.

```
mto0006@tux061:~$ traceroute cs.tamu.edu
traceroute to cs.tamu.edu (13.249.48.116), 30 hops max, 60 byte packets
 1  131.204.14.2 (131.204.14.2)  0.556 ms  0.579 ms  0.699 ms
 2  10.0.255.160 (10.0.255.160)  0.481 ms  0.638 ms  0.719 ms
 3  10.0.252.9 (10.0.252.9)  0.891 ms  0.871 ms  0.848 ms
 4  131.204.254.53 (131.204.254.53)  1.709 ms 131.204.254.100 (131.204.254.100)  1.281 ms 131.204.254.53 (131.204.254.53)  1.7
 5  131.204.254.53 (131.204.254.53)  1.351 ms 131.204.254.22 (131.204.254.22)  5.593 ms  5.614 ms
 6  52.46.254.4 (52.46.254.4)  5.591 ms 131.204.254.22 (131.204.254.22)  5.521 ms  5.555 ms
 7  54.239.105.158 (54.239.105.158)  6.431 ms 54.239.105.146 (54.239.105.146)  6.353 ms 150.222.66.91 (150.222.66.91)  6.897 m
 8  150.222.66.103 (150.222.66.103)  5.957 ms 150.222.66.101 (150.222.66.101)  6.236 ms 54.239.105.166 (54.239.105.166)  6.199
 9  54.239.104.35 (54.239.104.35)  5.895 ms 15.230.56.58 (15.230.56.58)  5.791 ms 15.230.56.32 (15.230.56.32)  5.719 ms
10  52.93.64.108 (52.93.64.108)  20.743 ms 150.222.250.87 (150.222.250.87)  19.526 ms 52.93.64.124 (52.93.64.124)  21.032 ms
11  52.93.64.158 (52.93.64.158)  20.047 ms 52.93.64.47 (52.93.64.47)  22.966 ms 52.93.64.128 (52.93.64.128)  21.505 ms
12  * * 52.93.64.45 (52.93.64.45)  19.676 ms
13  * * *
14  * * *
15  * * *
16  * * *
17  * * server-13-249-48-116.iah50.r.cloudfront.net (13.249.48.116)  19.301 ms
```

About 4 of the 12 gateway hops (17 is the final destination) are "missing". The execution shows that over 30 maximum hops, 12 "destinations" were reached.

c) (20 points) Assuming that there are about 20 switches between AU and the destination, what is the ratio of the total switch time to the propagation time? Is the switching time a major component in the total delivery time? Discuss.

$$Total\ Switch\ Time = Number\ of\ switches \times Switch\ time\ per\ device \quad (1)$$

$$Total\ Switch\ Time = 20\ [switches] * 10 \times 10^{-6}\ [s] = 2 \times 10^{-4}\ [s] \quad (2)$$

$$Ratio_{TST} = \frac{2 \times 10^{-4}}{2 \times 10^{-2}} = \frac{1}{100} \quad (3)$$

The switching time definitely impacts the total delivery time and is of much smaller quantity in comparison to the propagation delay.

d) (32 points) How many switches should there be between AU and the destination such that the switch time is equal to the propagation time? Discuss the impact of propagation time and the processing/switching times on the intermediary nodes. Which parameter impacts more delay on networks, propagation time or switching time?

$$\#\ of\ switches = \frac{2 \times 10^{-4}}{6.25} \quad (1)$$

$$\#\ of\ switches \approx 31250 \quad (2)$$

Switching time occurs after the data packets have been processed. Thus if a network were exposed to any errors during transmission, this could result in large queues of data packets not be received.

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%).
- Calculation mistakes will be minimally penalized (2 to 5% of full credit) while errors on units will be more heavily penalized.

- 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?

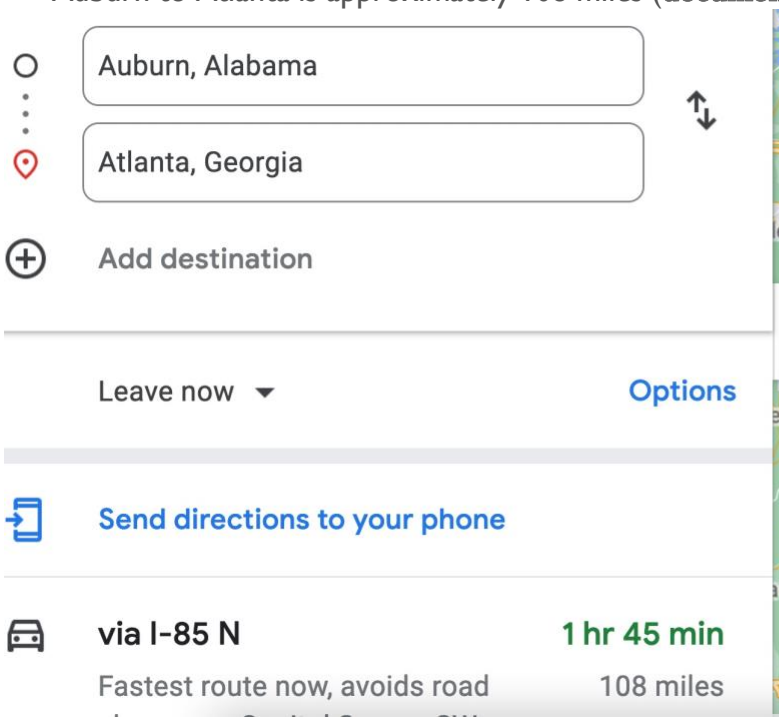
Here is an example to explain what an **obvious and clear** link is and how we grade your work.

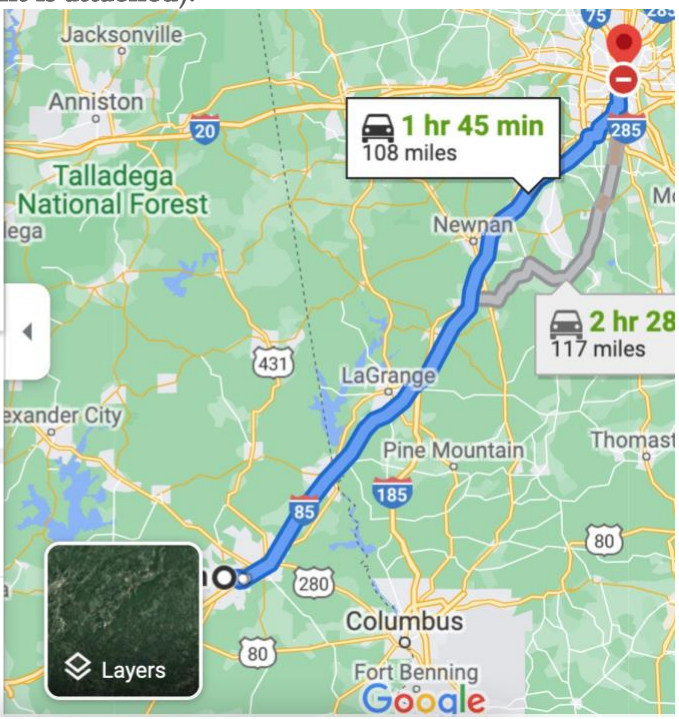
Consider the following problem:

"(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".