Computer Networks — Assignment #1

September 10, 2025

Assignment #1
Total: **8 points**
Due date: **September 25th**

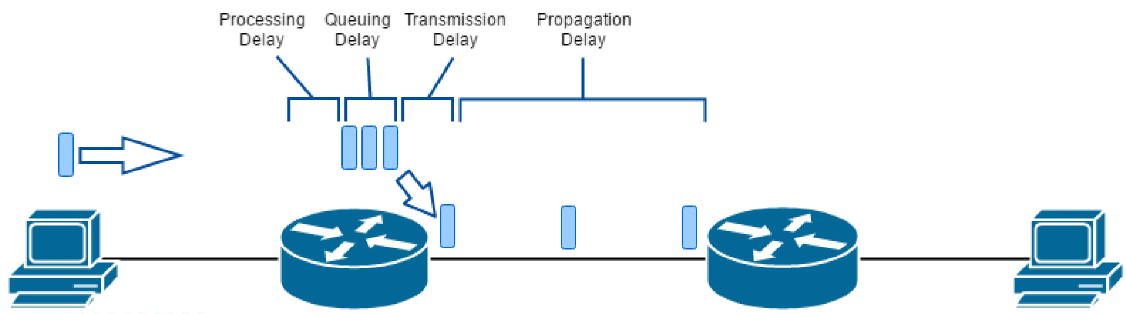
This assignment must be completed ***individually****.*

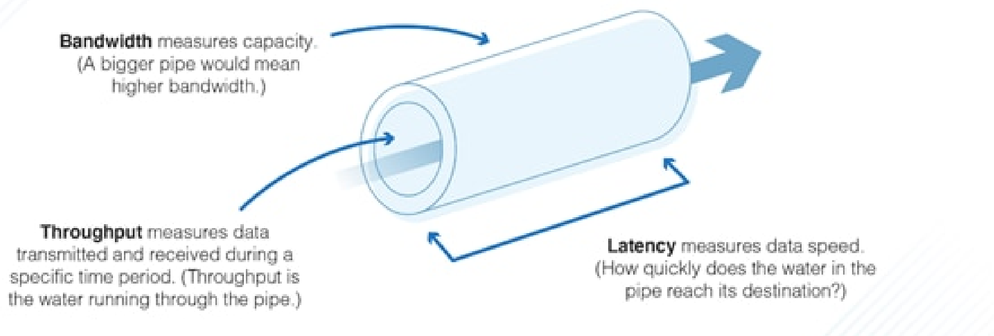
I.e. you should work alone without any help or collaboration from others.

Please provide detailed answers to the following questions.

Submit a PDF document containing detailed answers and explanation to the questions in the assignment. You can either create a digital document for answering the questions OR write them down in a paper and take photos or scan them – please be sure that the quality of the document is readable.

For Problem #9, upload your codes and documentation files in a separated tarball, zip or GZ file.





Problem 1 [0.5 pt.] Let's consider the general case of sending one packet from source to destination over a path consisting of N links each of rate R (thus, there are $N - 1$ routers between source and destination).

a) Calculate the *end-to-end* delay for a packet of length L in this case?

b) Generalize the previous equation for sending P such packets back-to-back over the N links.

Problem 2 [1 pt.] Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.

a) Express the propagation delay, d_{prop}, in terms of m and s.

b) Determine the transmission time of the packet, d_{trans}, in terms of L and R.

c) Ignoring processing and queuing delays, obtain an expression for the *end-to-end* delay.

d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?

e) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

f) Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

g) Suppose $s = 2.5 \times 10^8$ m/sec, $L = 120$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

Problem 3 [1 pt.] Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time.

a) When *circuit switching* is used, how many users can be supported?

b) For the remainder of this problem, suppose *packet switching* is used. Find the probability that a given user is transmitting.

c) Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution.)

d) Find the probability that there are 21 or more users transmitting simultaneously.

Problem 4 [1 pt.] Calculate the total time required to transfer a 1.5-MB file in the following cases, assuming an RTT of 80 ms, a packet size of 1 KB data, and an initial $2 \times$ RTT of "handshaking" before data is sent:

a) The bandwidth is 10 Mbps, and data packets can be sent continuously.

b) The bandwidth is 10 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next.

c) The link allows infinitely fast transmit, but limits bandwidth such that only 20 packets can be sent per RTT.

d) Zero transmit time as in *(c)*, but during the first RTT we can send one packet, during the second RTT we can send two packets, during the third we can send four $= (2^{3-1})$, etc.

Problem 5 [0.5 pt.] Consider a point-to-point link 50 km in length. At what bandwidth would propagation delay (at a speed of 2×10^8m/sec) equal transmit delay for 100-byte packets? What about 512-byte packets?

Problem 6 [1 pt.] Suppose a 128-kbps point-to-point link is setup between the Earth and a rover on Mars. The distance from the Earth to Mars (when they are closest together) is approximately 55 Gm, and data travels over the link at the speed of light $3 \times 10^8 m/s$.

a) Calculate the minimum RTT for the link.

b) Calculate the delay $\times$ bandwidth product for the link.

c) A camera on the rover takes pictures of its surroundings and sends these to Earth. How quickly after a picture is taken can it reach Mission Control on Earth? Assume that each image is 5 MB in size.

Problem 7 [1 pt.] Calculate the latency (from first bit sent to last bit received) for:

a) 1-Gbps Ethernet with a single store-and-forward switch in the path and a packet size of 5000 bits. Assume that each link introduces a propagation delay of $10\mu s$ and that the switch begins retransmitting immediately after it has finished receiving the packet.

b) Same as *(a)* but with three switches.

c) Same as *(b)*, but assume the switch implements "cut-through" switching; it is able to begin retransmitting the packet after the first 128 bits have been received.

Problem 8 [0.5 pt] Consider the queuing delay in a router buffer. Let I denote traffic intensity; that is, $I = La/R$, where L represents the packet lenght, a is the average rate of received packets, and R is the link's transmission rate. Suppose that the queuing delay takes the form $IL/R(1 - I)$ for $I < 1$.

a) Provide a formula for the total delay, that is, the queuing delay plus the transmission delay.

b) Plot the total delay as a function of L/R.

Problem 9 [1.5 pt.] Consider the code presented during the *socket tutorial.*

1. Modify this program, so that each time the client sends a line to the server, the server sends the original line back to the client plus the date and time of when it was received on the server side.
2. The server will keep the connection "alive" until the word/command `>>> Ciao-Ciao` is entered by the client.

- **Be sure to test your implementation in the lab machines as the code will tested in that environment!**
  Code that does NOT compile or run in the lab. machines will receive a zero!
- Add comments explaining the logic and main elements in the code.
- Include a README explaining: how to compile your code, how to run it and any special needs in order to make the code work as expected.

Brain Teasers & Further Readings

- How long does it take an electromagnetic (EM) signal to travel from my laptop (during lecture) to the closest router in IC-220 and in AI-2040?
  How long would it take the same EM signal to reach a satellite in *geostationary[1] orbit*?
- The speed at which the light, travels in vacuum is 300,000 km/s; however in many books, problems, exercises, etc. we use a value that can range from 180,000 to 240,000 (most of the times something around 200,000 km/s). Why? and why does the *speed of light* matter in networks communications?
- What is a *Farady cage*? What role does it play in networks communications?
- Which are the different *performance* indicators we have discussed in the context of networks? Why are these useful/important?
- Consider the command line tool `traceroute`, what is it useful for?
- What type of considerations we need to give to *units* in performance quantities and why? Can you give an exampple?
- "40 maps that explain the internet," by Timothy B. Lee (June 2, 2014) – https://www.vox.com/a/internet-maps

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[1] https://en.wikipedia.org/wiki/Geostationary_orbit