EE122: Homework 1

Due Oct 2, 4:30PM

Instructions

This is the first homework for EE122. You must turn in your assignment in PDF format via your instructional account using the command `submit hw1`.

Make sure to write your name and student number at the top of your assignment. For each problem, please write your numerical answer first – bold and underlined – and then provide a description of how you arrived at your answer. The description of how you arrived at your work will allow us to assign partial credit if your answer is wrong.

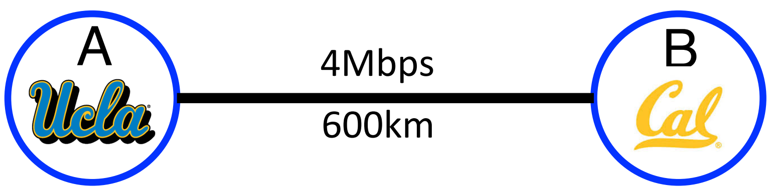
You should use the following basic stats in your calculations:

- Packets travel at the speed of light, 3×10^8 m/s
- For ease of math, you should assume 1MB = 1000 KB. 1KB = 1000B.
- 1B (byte) = 8b (bits).

Questions? Justine is the lead TA on this homework (*justine@eecs...*), email her. Better yet, post to Piazza.

1 Basic Delays

For the following questions, assume a very basic network (below) where there are no arbitrary packet drops or queueing delays. The wire is annotated with bandwidth (above the wire) and distance in kilometers (below the wire). Please report all latencies in milliseconds.



1. (5pts) There are two nodes, A and B, connected by a direct link of 600km and 4Mbps. Node A sends a 1200 byte packet to B. How long does it take for the packet to arrive at B? (*Recall: a packet arrives at B only once the very last bit of the packet reaches B!*).

2. (5pts) A wants to send a 10MB file to B. It divides the file in to 1000 byte chunks and adds a 60 byte packet header to each. It then sends the file to B in packets of (1000 + 60) byte packets.

   (a) (3pts) At what time does the complete file reach B?

   (b) (2pts) What is the 'goodput' from A to B if packets are divided in to 1000 byte payloads with 60 byte headers?

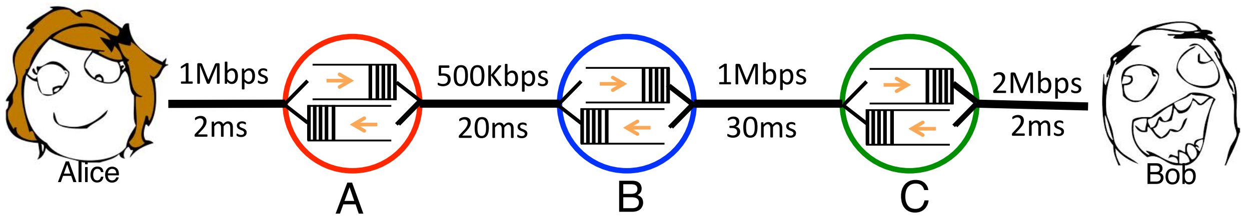
   Hint: Goodput can be calculated as the number of payload bits arriving per second. Goodput is the application level throughput, i.e. the number of useful information bits, delivered by the network to a certain destination, per unit of time. The amount of data considered excludes protocol overhead bits as well as retransmitted data packets.

3. (3pts) A sends a 1000 byte packet (no header) to B. When node B recieves the packet, it processes it for 250μs and then responds with an 80 byte 'acknowledgement' packet. When does A receive B's response?

4. (3pts) A wants to send a 10KB file to B in chunks of 1000 bytes (assume no headers). Assume that every time A sends a packet to B, it must wait until it receives an 80 byte ACK packet back from B (assume B has no processing time in this case) before sending a new packet. This is called stop-and-go. When does A finish, counted as the time that the last bit of the last ACK reaches A?

2 Queueing Delays and Drops

The following questions will involve Alice and Bob and the below packet-switched network. Each wire is annotated with bandwidth (above) and the latency in milliseconds (below) across the wire. Each switch is a store-and-forward switch, and has a five-packet queue for packets going in each direction. If the queue is full and a new packet arrives at the switch, the new packet is dropped. *Note: Once a packet begins being transmitted, it is removed from the queue. Thus, there may be at most six packets 'at' a switch at once: five in the queue and one being transmitted.*



1. (3pts) The network is 'empty' of packets and all switches are idle. Alice sends a 1500 byte packet to Bob. How long does it take to get to Bob?

2. (3pts) The network is 'empty' of packets and all switches are idle. Alice sends three 1500 byte packets to Bob, one immediately after the other. How long does it take for the last packet to reach Bob?

3. (5pts) Alice sends 20 back-to-back 1500 byte packets to Bob.

   (a) (2pts) How many packets reach Bob, and how many are dropped?

   (b) (3pts) Which packets arrive, and which packets are dropped? Assume the packets are numbered, Packet 1, Packet 2 . . . Packet 20.

4. (2pts) Bob sends a constant, infinite stream of 1500 byte packets to Alice at his maximum sending rate – 2Mbps per second. What fraction of his packets are lost?

5. (2pts) What is the *worst case end-to-end latency*...

   (a) (1pt) for Alice's 1500 byte packets to reach Bob?

   (b) (1pt) for Bob's 1500 byte packets to reach Alice?

   Hint: Not all queues will fill up.

3 Circuit Switching and Packet Switching

You have a sender and a receiver, Alice and Bob, connected by a path of Z links (and $Z-1$ switches), each with a link capacity of B bps and a propagation delay of 2ms. There are no queueing delays. The maximum packet size across this network is D bits, h of which are reserved for the header, leaving at most p for the payload ($p = D - h$). Alice wants to send an M-bit file to Bob. Assume M is evenly divisible by p.

1. (3pts) Derive an equation showing how long it takes Alice to send an M-bit file to Bob over this network, assuming the network is packet-switched with store-and-forward switches.

2. (3pts) 'Cut through routing' is an alternative to store-and-forward where a switch waits for the first h bits of a packet to arrive, and then begins transmitting the packet on the next link immediately (even if the last bits of the packet haven't arrived yet). Derive an equation showing how long it takes Alice to send an M-bit file to Bob over this network, assuming the network is packet-switched with cut-through switches.

3. (3pts) Let's assume our network uses circuit switching. When Alice wants to send a file to Bob, she first sends one 'setup' packet of exactly k bits (for $k < D$, with k total bits in the packet including both header and payload) to B (requesting as much capacity as possible) and all of the switches act like normal store-and-forward switches. After Bob receives the setup packet, a 'circuit' has been established and the switches no longer use store-and-forward: a bit coming in on a switch immediately moves to the output port at the switch. Bob sends the k bit packet back to Alice, and then Alice is free to begin transmitting her file with no headers attached. Derive an equation showing how long it takes Alice to sends an M-bit file to Bob over this network, which is circuit switched.

4. (4pts) Let k=100 bytes, Z = 8, B = 50Mbps, D = 1550 bytes, and h = 50 bytes.

   (a) (2pts) Which of the above networks will transmit a 3000 byte file fastest?

   (b) (2pts) Which of the above networks will transmit a 30MB file fastest?

4 Fun!

The ping program determines the round-trip-time (RTT) to any host in the Internet. Using a computer on campus ping the following hosts five time each to calculate an 'average RTT': cmu.edu (Pittsburgh, PA), cs.brown.edu (Providence, RI), washington.edu (Seattle, WA), ucsd.edu (San Diego, CA), uchicago.edu (Chicago, IL), columbia.edu (New York, NY), odu.edu (Norfolk, VA), stanford.edu (Palo Alto, CA). For each of these locations find the physical distance from Berkeley (You can look these up here: `http://www.geobytes.com/citydistancetool.htm`), and then compute the estimated time T for a packet to reach that location.

- (5pts) Plot a graph where the x axis represents the distance to each city, and the y axis represents the ratio between the RTT as measured by the ping program and the shortest possible time T to reach that city. (Note that the y-values are no smaller than 2 since it takes at least 2*T time for any packet to reach the destination and get back.)

- (2pts) Give (at least) two reasons why the y-values you plot are larger than 2.