CS 655: Introduction to Computer Networks
Fall 2020
Homework 1

To be completed individually. Please review the academic conduct rules mentioned in the syllabus.

Answer all questions. Submit on Gradescope.

1. What is a network protocol? What is a network service? What is the difference between a service interface and implementation of a service? Discuss these concepts in the context of layered network architecture.

2. Consider the problem of sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 15 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

3. (a) Suppose N packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length L and the link has transmission rate R. What is the average queuing delay for the N packets?

   (b) Now suppose that N such packets arrive to the link every LN/R seconds. What is the average queuing delay of a packet?

4. Perform a Traceroute between source and destination on the same continent at three different hours of the day. (*Hint:* type 'man traceroute' on Linux.)

   a) Find the average and standard deviation of the round-trip delays at each of the three hours.

   b) Find the number of routers in the path at each of the three hours. Did the paths change during any of the hours?

   c) Try to identify the number of ISP networks that the Traceroute packets pass through from source to destination. Routers with similar names and/or similar IP addresses should be considered as part of the same ISP. In your experiments, do the largest delays occur at the peering interfaces between adjacent ISPs?

   d) Repeat the above for a source and destination on different continents. Compare the intra-continent and inter-continent results.

5. Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of R = 4 Mbps. Suppose the propagation speed over the link is 2.5×10^8 meters/sec.

    a) Calculate the bandwidth-delay product, R x d_{prop}. (*Hint:* d_{prop} here represents the *one-way propagation delay* from A to B.)

    b) Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?

    c) Provide an interpretation of the bandwidth-delay product.

    d) What is the width (in meters) of a bit in the link? Is it longer than a football field? (*Hint:* the length of a football (not soccer!) field is 100 yards, which is 91.44 meters.)

    e) Derive a general expression for the width of a bit in terms of the propagation speed s, the transmission rate R, and the length of the link m.

6. In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as message segmentation. The figure below illustrates the end-to-end transport of a message (a) without and (b) with message segmentation. Consider a message that is 8×10^6 bits long that is to be sent from source to destination in the figure below. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays. Also ignore the transmission of header bits in your calculations.

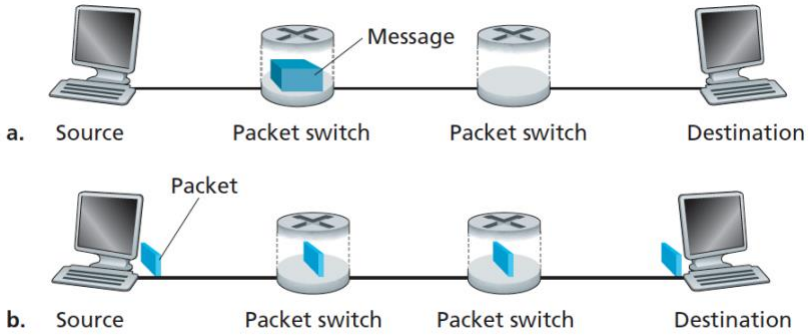
    a. Consider sending the message from source to destination without message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

    b. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

    c. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

    d. In addition to reducing delay, what are reasons to use message segmentation?

    e. Discuss the drawbacks of message segmentation.



7. Suppose that a certain communications protocol involves a per-packet overhead of 120 bytes for headers. We send 1 million bytes of data using this protocol; however, when one data byte is corrupted, the entire packet containing it is lost. Give the total number of overhead + loss bytes for packet data sizes (i.e. the size of only the data portion of the packet) of 1000, 5000, 10000, and 20000 bytes, assuming a) the connection loses a single byte of data, and b) the sender does not retransmit lost packets. Which of these sizes is optimal?