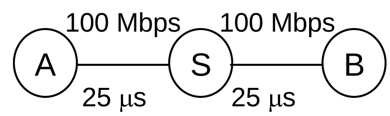
ECE 4380/6380: Computer Communications **Spring 2017**
Problem Set 1 **Due: 2:30 pm in class, Friday, January 27**

Assigned reading: Peterson and Davie, Chapter 1. Each problem carries equal weight. Most of these problems are similar to exercises found at the end of Chapter 1. Solutions to selected exercises are found in the back of the book.

1. Assume that a host can transmit at x-Mbps on a link. Calculate the time required for this host to transmit y KB. Give your answer as a function of x and y.
2. Assume hosts A and B are each connected to a switch S via 100-Mbps links. The propagation delay on each link is 25 μs. The switch S is a store-and-forward device and it requires a delay of 35 μs to process a packet after is has received the last bit in the packet. Calculate the total time required to transmit 40,000 bits from A to B in the following scenarios. (The total time is measured from the start of the transmission of the first bit at A, until the last bit is received at B. We always assume that links are bi-directional with the same transmission rate and propagation delay in each direction unless specifically instructed otherwise.)



   (a) The bits are framed into a single packet
   (b) The bits are framed as two 20,000 bit packets. As soon as A completes transmission of the last bit of the first packet it begins transmission of the first bit of the second packet (so that there is no delay at A between transmission of the two packets).
3. Assume hosts A and B are each connected to a switch S. The link between A and S has a transmission rate of 15-Mbps, and the propagation delay is 25 μs. The link between S and B has a transmission rate of 60-Mbps, and the propagation delay is 50 μs. The switch S is a store-and-forward device and it requires a delay of 25 μs to process a packet after is has received the last bit in the packet. Assume that A has an infinite supply of packets, and each of A's packet consists of a 150 bit header and 10,000 bits of information. After each packet A transmits, it must wait to receive an acknowledgment packet from B in reply before it can transmit the next packet. When B receives a packet it immediately generates an acknowledgment packet for A, and assume that the acknowledgement packet is 150 bits. Assume that there are no other delays.
   (a) Find the throughput (i.e., the average number of information bits per second) that A is able to achieve to B.
   (b) Find the total round trip time (RTT), that is, the time from when A starts to transmit the first bit of a packet until the last bit of the ACK is received at A. How big is the "pipe" when considering the direction from host A to host B? (See section 1.5.2 in Peterson and Davie for discussion of a network as a pipe, and here we are interested in the RTT scenario and not the size of the pipe using only the one-way latency.)
   (c) Now consider the pipe in the direction from host B to host A. One might argue that the pipe in this direction should be four times bigger than in the direction from A to B because host B can transmit four times more quickly than host A. (Of course, the RTT is the same for both pipes.) If, instead, B has an infinite supply of packets for A, what is the throughput that B is able to achieve to A? Why should we consider the size of the pipe from B to A to be the same as the size of the pipe from A to B, instead of four times larger?
4. Suppose that a certain communications protocol includes a 100 byte header in each packet. Consider a session in which 1 million bytes of data is sent from a source to a destination. During the course of this session one of the packets is corrupted and this packet is discarded at the destination. The protocol ensures that this packet is retransmitted so that all the data is correctly delivered to the destination. What is the *total* number of bytes that are sent from the source to the destination using four different sizes for the packets: 1,000, 5,000, 10,000, and 20,000 bytes? (Note if the packet size is

1,000 bytes, then it contains 100 bytes of overhead and 900 bytes of data.) Which size packet is optimal in this scenario?

5. A token-ring network uses a single cable that has the ends of the cable attached to make a single loop. Assume that the transmission rate of the hosts connected to the cable is 100 Mbps and the propagation speed on the cable is 2×10^8 m/s. Determine the circumference of the loop to exactly contain one 300-byte packet, assuming that the hosts do not introduce any delay. Next, repeat the calculation of the circumference but now assume that there is a host every 100 m, and each host introduces 10 bits of delay. (see also problem 24 in chapter 1)
6. Consider *N* hosts connected to a switch. The hosts forward packets to the switch, and assume that all packets must forwarded by one outgoing port on the switch. Recall that synchronous time-division multiplexing assigns each host one slot in an *N* slot frame. Consider the same type of system but a different mechanism, called *round-robin*, for determining which packet to transmit in a slot. For the round-robin protocol, the switch considers each host in a cyclical order and if there is a packet from the selected host it is forwarded, otherwise the host is skipped and the test is repeated for the next host until a packet is found. For example, if in slot $t - 1$, the switch forwarded a packet from host i (where i is an integer between 1 and N), then in slot t, the switch looks for a packet from host $i + 1$ (or 1 if $i = N$). If there is not a packet from host $i + 1$, the next host is considered until a packet is found to forward in slot t.
   (a) How does this forwarding protocol differ from STDM and from statistical multiplexing?
   (b) Which forwarding protocol do you expect will maintain the highest utilization of the outgoing link? Which one is likely to have the lowest utilization?
7. **Transfer Times**. Calculate the total time required to transfer a 1500-KB file in the following cases. To simplify the problem, assume that the one-way propagation delay through the network is 75 ms, a packet size of 1 KB data, and that the size of the acknowledgement packets is so small that we can ignore the transmission time for the acknowledgment packets (but not the propagation delay). Assume that a TCP-like connection is established before the file transfer begins, and that we can model this as an initial $2 \times$ RTT of "handshaking" before data is sent (i.e., the handshaking takes 300 ms and we can ignore the transmission time of the packets used for the handshakes). Define the transfer to be completed when the last acknowledgment packet indicating that all data bits have been received at the destination is received at the source host. So, the transfer time is from the start of the initial handshake until the last acknowledgement is received at the source host. (Note this problem is similar to problems 3 and 4 in the book, and the solution for problem 4 is in the back of the book. However, notice that Peterson and Davie have a different definition of transfer time)
   (a) The bandwidth is 2.5 Mbps, and data packets can be sent continuously.
   (b) The bandwidth is 2.5 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next.
   (c) The bandwidth is "infinite," meaning that we take the transmit time to be zero, and up to 30 packets can be sent per RTT.
   (d) The bandwidth is infinite, and during the first RTT we can send one packet (2^{1-1}), during the second RTT we can send two packets (2^{2-1}), during the third we can send four (2^{3-1}), and so on. (A justification for such an exponential increase will be given in Chapter 6.)
8. Networking utilities
   (a) The Unix utility `ping` can be used to find the RTT to various Internet hosts. Read the man page for `ping` and look for the –s option to see how you can control the time between ping packet transmissions. When the `ping` command is interrupted the minimum, average, and maximum RTT will be displayed. There is an equivalent program available on Windows (open a DOS window by running "cmd.exe", then type "ping /?"). Unfortunately, ping packets have been misused for denial-of-service attacks in the internet, and may firewalls now block ping packets. If you have a connection that will allow ping packets, what are the average round trip times to

ucsd.edu, google.com, and uni-heidelberg.de? If your encounter a firewall, when you are on campus try to ping clemson.edu.

(b) tracert (Windows)/traceroute (Unix): tracert effectively performs a ping to every hop from your laptop to the destination address you specify; thus, it not only can be used to measure end-to-end and per-hop delays, it also helps you see the network topology. On Unix systems an alternative program to traceroute is tracepath (use tracepath if traceroute is not installed).
   (i) tracert www.clemson.edu, what does the output tell you?
   (ii) tracert ucsd.edu, other than the Clemson network, what other backbone network providers will you need to go through to reach UCSD? (Hint, see the network domain names, such as Clemson.edu. Most have a form like yyy.xxx.net. Striping off the first part of the name, and opening xxx.net in a browser often tells you which provider it belongs to).

(c) While end hosts, such as web servers, often block ping packets, most routers in the backbone networks still allow ping packets. One web site that collects data from ping traces is http://www.internettrafficreport.com/main.htm. From the web site, find the average response time for North America. Also, from the list of routers for North America find the minimum response time that is greater than zero, and the maximum response time.