15-441: Computer Networks
Homework 1

Assigned: September 12, 2006
Due: September 21, 2006

1. Consider sending a file of size $F = M * L$ bits over a path of Q links. Each link transmits at R bits/s. The network is lightly loaded so that there are no queing delays. When a form of packet switching is used, the $M * L$ bits are broken up into M packets (i.e., each packet has L bits) and all the devices in the network are store-and-forward (i.e., they must receive all of the packet before transmitting it). Assume propagation delay and processing time are negligible. [This question adapted from question 1.5 in Kurose and Ross].

   (a) Suppose the network is a packet-switched virtual circuit network. If A wants to send a message to B, it first contacts the networks, which sets up a path between A and B, the circuit, taking a certain amount of time. Once the circuit is set up, A breaks its message into packets, appends a header with the circuit identifier to each one, and sends them off into the network, where they are delivered to B. Denote the virtual circuit (VC) set-up time by t_s seconds. Suppose the sending layers add a total of h bits of header to each packet. How long does it take to send the file from source to destination?

   (b) Suppose the network is a packet-switched datagram network and a connectionless service is used. Now suppose each packet has $4h$ bits of header. How long does it take to send the file?

   (c) Repeat 1b, but assume message switching is used. That is, $4h$ bits are added to the message, and the message is not segmented–it is sent through as one massive packet.

   (d) Finally, suppose the network is a circuit-switched network like the telephone network. Further suppose that the transmission rate of the circuit between the source and destination is Rbits/s. Assuming t_s set-up time and h bits of header appended to the entire file, how long does it take to send the file?

   (e) In the previous questions, you came up with algebraic expressions for the latency of the file transfer. To get a feel for the actual wall-clock times involved, substitute in the following values which are typical of today's Internet. R=5.2Gigabits/s (an imaginary link speed, but within range), Q=10 hops (typical for a path from a CMU computer to a UPitt computer), M=1000packets and L=8000bits so F=1 million bytes (just under 1MB), h=40bits, t_s=0.1 seconds.

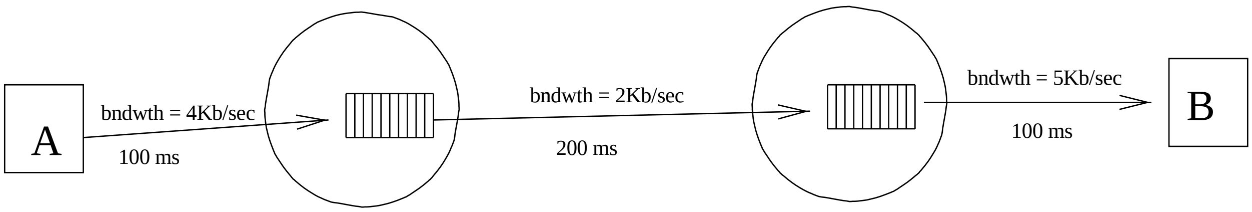
   (f) Referring to 1e, what values of M and F would give a faster transfer time over a packet switched virtual circuit network than a packet switched datagram network?

2. Calculate the total time required to transfer a 1000-KByte file in the following cases, assuming a RTT of 100ms, a packet size of 1KByte. and an initial 2RTT of handshaking before the actual data is sent.

   - The bandwidth is 1.5 Mbps and data packets can be sent continuously.
   - The bandwidth is 1.5 Mbps, but after we finish sending each data packet we must wait one RTT before sending the next

- The bandwidth is infinite, i.e., the transmit time is zero, but only up to 20 packets can be sent per RTT

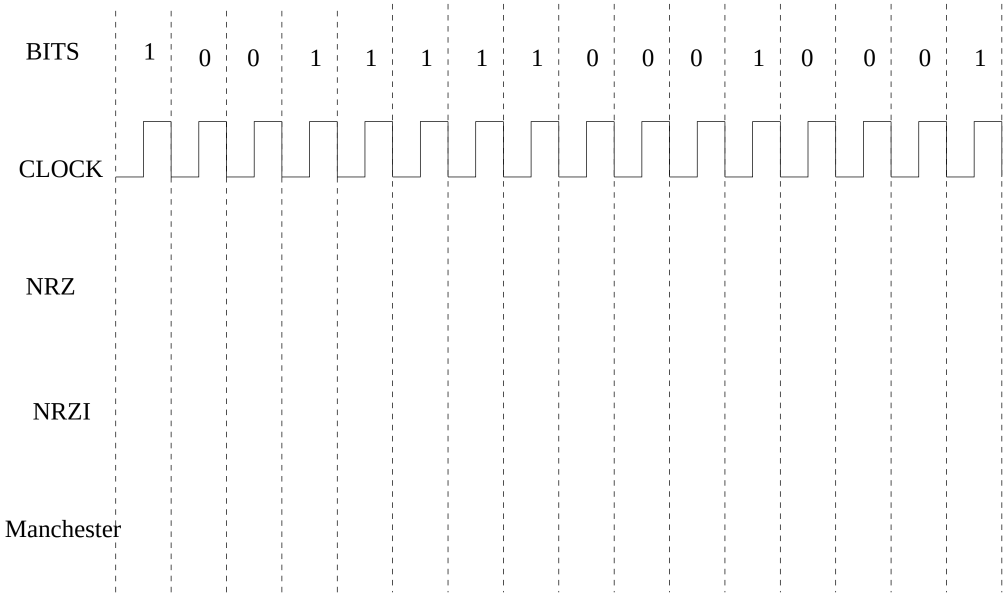
3. Consider the network below. Every router is a first-come-first-serve (FCFS) router. Each router has one buffer of size 10 packets. On each link we denote two numbers: The top number is the bandwidth on the link. The bottom number is the time it takes for light to travel from one end of the link to the other. Assume that all packets are of size 1Kbit and all rates are in Kbits/second.



   Provide an upper bound and a lower bound on the end-to-end delay for a packet passing from A to B. (Assume that packets lost are not counted in the upper/lower bound. Assume that all times not specified in the figure are so close to zero as to not be important).

4. For each of the following operations on a remote file server, discuss whether they are more likely to be delay senstive or bandwidth sensitive (q17 Chapter1 Peterson and Davie). Your answer should not be longer than 1-3 sentences.
   (a) Open a file
   (b) Read the contents of a file
   (c) List the contents of a directory
   (d) Display the attributes of a file

5. Show the NRZ, Manchester, and NRZI encodings for the bit pattern shown in the figure below. Assume that the NRZI signal starts out low (Exercise 1, Chapter 2, Peterson and Davie)



Charles, an ex-441 student, is given the task of building a new network link technology. Unfortunately, many of his beta-testers complain that their packets get corrupted when using his technology! He tracks the problem down to time synchronization problems between the sender and receiver on the link. Perhaps you can help Charles solve his problems by telling him a little about different encoding methods. Identify the problem and give a 1-2 sentence explanation about why this occurs.

For each of these sub-parts, identify whether the encoding can have problems with:

A. Long strings of 0s

B. Long strings of 1s

C. Both long strings of 1s or long strings of 0s

D. None of the above

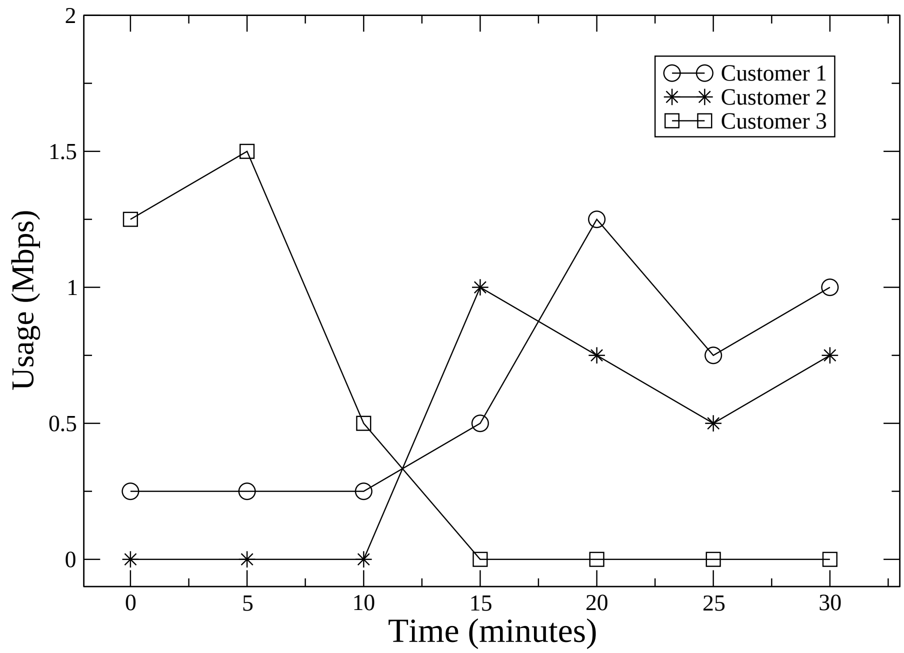
(a) Manchester encoding

(b) NRZ

(c) NRZI

6. Statistical multiplexing refers to the efficiency gain from having multiple users share link capacity. You have recently graduated and are working for a small ISP that has 3 customers. These customers already have lines to your local office, and you must purchase upstream connectivity to a large ISP to connect your customers to the Internet.

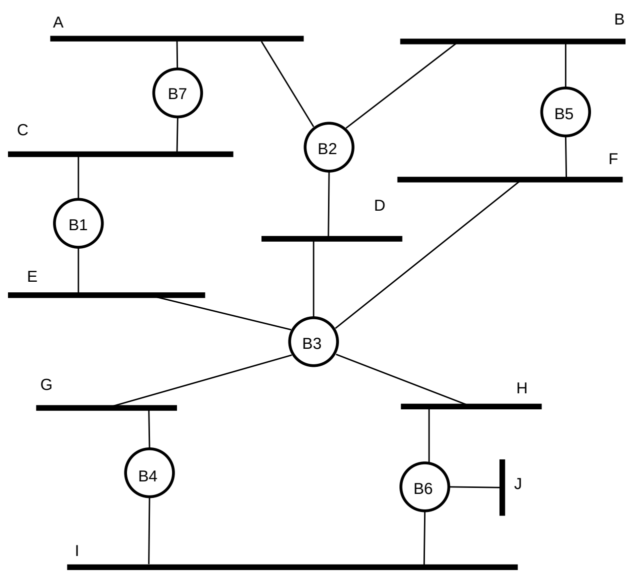
   Nominally, you sell each customer a 2 Mbps service, but having noticed that customers tend to use varying amounts of bandwidth, your boss is curious about how much you could cut costs. He provides you with a chart showing average usage for each customer over a 30 minute interval.



(a) Based on this sample, what is the minimum upstream capacity your ISP could have purchased without your customers noticing performance issues? What would the stat mux gain be using this much bandwidth compared to buying 2 Mbps per customer?

(b) Customer 2 runs an e-commerce site and wants to make sure its customers always receive quick page loads. It asks for a "service level agreement" (SLA) that provides a strict guarantee of 2 Mbps at any time, or your ISP will have to pay a stiff penalty. Now how much upstream bandwidth would you suggest purchasing based purely on past usage? What is the new stat mux gain?

7. Given the extended LAN shown in the figure below, indicate which ports are not selected by the spanning tree algorithm. The LAN's in the figure are labeled A-J and the bridges in the figure are labeled B1-B7. Hub Bi has an ID of i which is used as the tie breaker. (q13 Chapter 3 Peterson and Davie).



8. Ethernet has a minimum packet size to guarantee that collisions are detected. This problem considers an Ethernet-like medium to explore how the minimum packet size is chosen.
   (a) How does a minimum packet size help detect collisions?
   (b) Assume the speed of propagation through copper Ethernet wire is $2 * 10^8$ m/s . If the maximum size of your network is 500 m, and you transmit data at 100 Mbits/s what is the minimum packet size needed to detect collisions?
   (c) Being a brilliant CMU graduate, you figure out how to create a Ethernet wire that carries data at the speed of light ($3 * 10^8$ m/s). What is the new minimum packet size for your network?
   (d) Your boss wants you to upgrade the network from 100 Mbits/s to Gigabit (1000 Mbits/s). What are the two ways that you can change the network to handle this new speed.
   (e) (optional bonus question) Why did the original 3Mbit/s Ethernet not have a minimum packet size specified?