Problems for Lecture 1

19 August 2022

Preparation

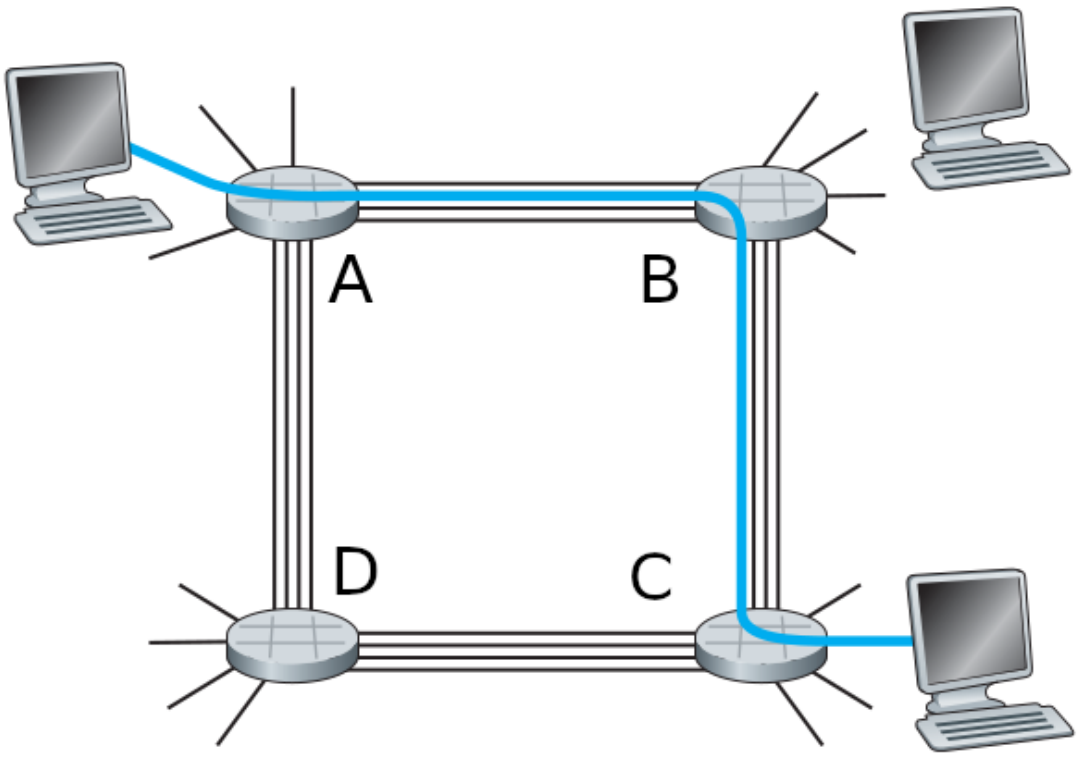
Try to answer these exercises:

1. The equation

$$d_{end-to-end} = N\frac{L}{R}$$

   gives a formula for end-to-end delay of sending one packet of length L over N links of transmission rate R. Generalize this formula for sending P such packets back-to-back over the N links.

2. Consider the circuit-switched network in this figure



   Assume there are 4 circuits on each link.

   a. What is the maximum number of simultaneous conections that can be in progress at the same time in this network?

   b. Suppose that all connections are between switches A and C. What is the maximum number of simultaneous conections that can be in progress?

   c. Suppose we want to make four connections between switches A and C, and another four connections between B and D. Can we route these calls through the four links to accomodate all eight connections?

3. This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. 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 $s = 2.5 \cdot 10^8$, *L* = 120 bits, and *R* = 56 kbps. Find the distance *m* so that d_{prop} equals d_{trans}.

4. 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*.
    a. 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?
5. Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of R = 2 Mbps. Suppose the propagation speed over the link is $s = 2.5 \cdot 10^8$ meters/sec.
    a. Calculate the bandwidth-delay product, $R \cdot d_{prop}$.
    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? (100m)
    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. Suppose there is a 10 Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of $s = 2.4 \cdot 10^8$ meters/sec.
    a. What is the propagation delay of the link?
    b. What is the bandwidth-delay product, $R \cdot d_{prop}$?
    c. Let *x* denote the size of the photo. What is the minimum value of *x* for the microwave link to be continuously transmitting?

In Class

Suppose you would like to urgently deliver 300 terabytes of data from Boston to Los Angeles. You have available a 1 Gbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? **Explain your answer.**