

**ECE 465/565 Computer Networks and Protocols  
Fall 05**

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**Solutions  
Homework 1**

**Problem 3**

Consider the circuit-switched network in Figure 1.5. Recall that there are  $n$  circuits on each link.

- a) What is the maximum number of simultaneous connections that can be in progress at any one time in this network?

We can have  $n$  connections for each of the links between the four pairs of adjacent switches. This gives a maximum of  $4n$  connections.

- b) Suppose that all connections are between the switch in the upper-left-hand corner and the switch in the lower-right-hand corner. What is the maximum number of simultaneous connections that can be in progress?

We can have  $n$  connections passing through the switch in the upper-right-hand corner and another  $n$  connections passing through the switch in the lower-left-hand corner, giving a total of  $2n$  connections.

**Problem 5**

Consider sending a packet of  $F$  bits over a path of  $Q$  links. Each link transmits at  $R$  bps. The network is lightly loaded so that there are no queuing delays. Propagation delay is negligible.

- a) Suppose the network is a packet-switched virtual-circuit network. Denote the VC setup by  $t_s$  seconds. Suppose the sending layers add a total of  $h$  bits of header to the packet. How long does it take to send the file from source to destination?

The time to transmit one packet onto a link is  $(F + h)/R$ . The time to deliver the packet over  $Q$  links is  $Q(F + h)/R$ . Thus the total latency is  $t_s + Q(F + h)/R$ .

- b) Suppose the network is a packet-switched datagram network and a connectionless service is used. Now suppose each packet has  $2h$  bits of header. How long does it take to send the packet?

$$Q(F + 2h)/R$$

- c) Finally, suppose that the network is a circuit-switched network. Further suppose that the transmission rate of the circuit between source and destination is  $R$  bps. Assuming  $t_s$  setup time and  $h$  bits of header appended to the packet, how long does it take to send the packet?

Because there is no store-and-forward delays at the links, the total delay is

$$t_s + (h + F) / R.$$

**Problem 7.**

Consider sending voice from Host A to Host B over a packet-switched network. Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 48-byte packets. There is one link between Host A and B; its transmission rate is 1 Mbps and its propagation delay is 2 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 an analog signal at Host B).

Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

$$\frac{48\text{Bytes} \cdot 8\text{bits} / \text{Byte}}{64 \times 10^3 \text{bits} / \text{sec}} = 6 \text{ msec.}$$

The time required to transmit the packet is

$$\frac{48\text{Bytes} \cdot 8\text{bits} / \text{Byte}}{1 \times 10^6 \text{bits} / \text{sec}} = 384 \mu \text{ sec.}$$

Propagation delay = 2 msec.

The delay until decoding is

$$6\text{msec} + 384 \mu \text{ sec} + 2\text{msec} = 8.384\text{msec}$$

A similar analysis shows that all bits experience a delay of 8.384 msec.

**Problem 10.**

Consider the queuing delay in a route buffer (preceding an outbound link). Suppose all packets are  $L$  bits, the transmission rate is  $R$  bps, and that  $N$  packets simultaneously arrive at the buffer every  $LN / R$  seconds. Find the average queuing delay of a packet.

It takes  $LN / R$  seconds to transmit the  $N$  packets. Thus, the buffer is empty when a batch of  $N$  packets arrive.

The first of the  $N$  packets has no queuing delay. The 2nd packet has a queuing delay of  $L/R$  seconds. The  $n$ -th packet has a delay of  $(n-1)L/R$  seconds.

The average delay is:

$$\frac{1}{N} \sum_{n=1}^N (n-1)L/R = \frac{L}{R} \frac{1}{N} \sum_{n=0}^{N-1} n = \frac{L}{R} \frac{1}{N} \frac{(N-1)N}{2} = \frac{L}{R} \frac{(N-1)}{2}.$$