Fall Term 2006
TelCom 2310
Computer Networks
Monday 3:00 pm - 5:50 pm
Sennott Square 6110
http://www.cs.pitt.edu/∼znati/tel2310.html

Homework 1 Solution

Problem 1

1. The number of hops is one less than the number of nodes visited.

   - For a star topology, the fixed number of hops is 2.
   - For a loop topology, the furthest distance from a source node is situated at $\frac{N}{2}$ hops if the number of nodes in the loop is even, and at $\frac{N-1}{2}$ hops if the number of nodes in the loop is odd.
     - **Even Case:** Notice that there are 2 nodes located at i hops from the source, for $1 <= \ i \ <= \frac{N}{2} - 1$, and only one node, the furthest from the source, located at $\frac{N}{2}$ hops from the source. Therefore, the average number of hops = $\frac{2}{N-1} \sum_{i=1}^{\frac{N}{2}-1} i \ + \ \frac{N}{2} \ = \ \frac{N^2}{4(N-1)}$.
     - **Odd Case:** In this case, there are exactly 2 nodes located at i hops from the source, for $1 <= i <= \frac{N-1}{2}$. Therefore, the average number of hops = $\frac{2}{N-1} \sum_{i=1}^{\frac{N-1}{2}} i \ = \ \frac{N+1}{4}$.
   - For a fully connected topology, each node is directly connected to all other nodes. Therefore, the number of hops is simply 1.
   - Since a tree is defined to be any geometry which interconnects all nodes so that there is a single path between any two nodes but not loops or circuits, a tree can be formed from any ring configuration by deleting one link. Thus, for any ring configuration, a tree configuration with shorter total length can be found and the minimum possible total length of any tree must be shorter than the minimum possible total length of any ring.

Problem 2

(a) Assume that the program can be decomposed into k modules where the size of each module N/k lines. The cost of writing these modules is:

$$C(k) = k\left(a^2 + \left(\frac{N}{k}\right)^2\right) = ka^2 + \frac{N^2}{k} \tag{1}$$

(b) Note that the function $C(k)$ increases to infinity for k going to zero and for k going to infinity. Thus, we expect that there is a minimum value. To find the value of k that corresponds to that minimum, we calculate the derivative of $C(k)$ with respect to k and we set it to zero. This gives:

$$\frac{dC(k)}{dk} = a^2 - \frac{N^2}{k^2} = 0, \ i.e., \ k = \frac{N}{a} \tag{2}$$

We can find the values of N such as $C^* \ < \ N^2$ ($i.e$, it is preferable to decompose the program into modules). This is the case when $2Na < N^2$, $i.e.$, $N > 2a$.

Problem 3

Define the following parameters for a communication network:

- N = number of hops between two given end systems,
- L = message length in bits,
- B = data rate, in bits per second (bps), on all links,
- P = packet size
- H = overhead (header) bits per packet, and
- S = call setup time (circuit switching or virtual, and
- D = propagation delay.

Assume that $N = 4$, $L = 3200$, $B = 9600$, $P = 1024$, $H = 16$, $S = 0.2$, and $D = 0.001$ and that the queueing delay and processing overhead are ignored.

(a) The end-to-end delay for circuit switching is:

$$T = C_1 \ + \ C_2, \text{ where} \tag{3}$$

- C_1 = Call setup time,
- C_2 = Message delivery time.
- C_1 = S = 0 sec.
- C_2 = Propagation Delay + Transmission Time. Therefore, C_2 = $N \times D + \frac{L}{B}$ = $4 \times 0.001 + \frac{3200}{9600} = 0.337$ sec.
- $T = 0.2 \ + \ 0.337$ = 0.537 sec.

(b) The end-to-end delay for packet switching is:

$$T = D_1 \ + \ D_2 \ + D_3 \ + D_4, \text{ where} \tag{4}$$

- D_1 = Time to transmit and deliver all packets through the first hop,
- D_2 = Time to deliver the last packet acros the second hop,
- D_3 = Time to deliver the last packet across the third hop, and
- D_4 = Time to deliver the last packet across the forth hop.

There are $P - H = 1024 - 16 = 1088$ data bits per packet. A message of 3200 bits require four packets. Therefore:

- D_1 = $4 \times t$ + p, where
  - t = transmission time for one packet,
  - p = propagation delay for one hop.
- D_1 = $4 \times \frac{P}{B} + D$ = $4 \times \frac{1024}{9600} + 0.001 = 0.428$ sec.
- D_2 = D_3 = D_4 = $t + p$ = $\frac{P}{B} \ + \ D = 0.108$ sec.
- T = 0.752 sec.

Notice that the above solution assumes that the last packet is padded to a full size packet. If padding of the last packet is not allowed, the transmission of the unpadded packet takes only 0.2363, and the total transmission T = 0.667.

Problem 4

The objective of this homework is to derive the maximum packet size for a given transmission network.

(a) The total number of bits, N_{bits}, that must be transmitted to send the message is :

$$N_{bits} = M \; + \; \lceil \frac{M}{(K_{max} - n_h)} \rceil \times n_h, \tag{5}$$

with $\lceil x \rceil$ the smallest integer greater than or equal to x.

(b) Ignoring the queueing and processing delays at the intermediate packet switching nodes, the total time, T, required to transmit a message of size M over j is the time it takes for the first packet to travel over the first $j-1$ links plus the time it takes the entire message to travel over the final link. If R represents the transmission rate in bits per second (bps), T is given by:

$$T = \frac{(j-1)K_{max} \; + \; M \; + \; \lceil \frac{M}{(K_{max} - n_h)} \rceil \times n_h}{R} \tag{6}$$

Problem 5

Consider a network to connect 100 people. Each link in the network provides for communication between two people.

1. To connect N people, we need $M = \frac{N \times (N-1)}{2}$ lin ks. For $N = 100$, $M = 4950$. If the mean distance between two people is 1 km, we need 4950 kms of wires.

2. To achieve a more efficient resource utilization the solution depicted in Figure 1 can be used:

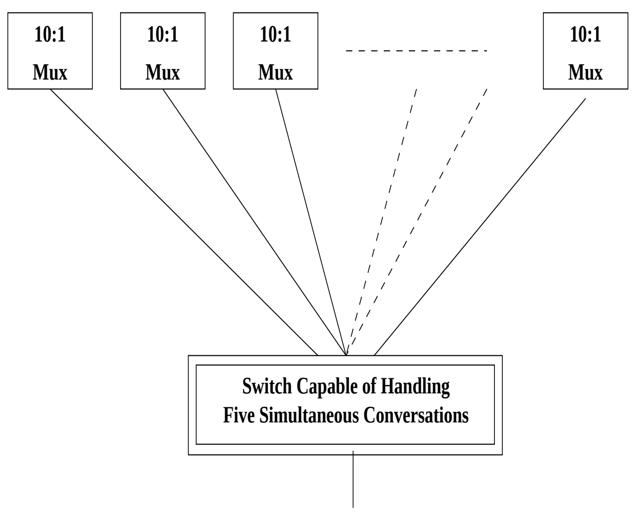

Figure 1: Network Configuration

Problem 6

Assume that the program is composed of 3 files, each file containing in average 250,000 characters. Each character is 8 bits. Furthermore assume that you can ride your bike at 18km/hr from your house to the professor's office.

1. The total number of bits to be transmitted is $250000 \times 3 \times 8$. The time, in seconds, it takes to transmit these bits is $\frac{250000 \times 3 \times 8}{300} = 20000$ sec. Over this time, the student, riding at 18km/hr, can travel a distance d, in kilometers:

$$d = \frac{(18 \times 20000)}{3600} = 100\text{km} \tag{7}$$

Therefore, unless the professor lives more than 100 km away from the student, it is faster to deliver the homework directly.