CS118 Homework 1 Solutions

1. What are network protocols? Please write down the definition of network protocols.

10 Protocols define the format and the order of messages exchanged among communication entities, as well as the actions taken on the transmission and/or receipt of a message or other event.

2. Tell the following statements true or false.

(T) End systems are just hosts. There are no differences between the two terms.

15 (F) In packet switching transmissions, bandwidth is divided into pieces and each packet uses one or several pieces of bandwidth.

(F) Full buffer is the only reason that causes packet loss.

3. Consider an application that transmits data at a steady rate (e.g., the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answers:

20 (a) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

(b)Suppose that a packet-switched network is used and the only traffic in this network comes from such applications described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

a) A circuit-switched network would be well suited to the application described, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session circuit with no significant waste. In addition, we need not worry greatly about the overhead costs of setting up and tearing down a circuit connection, which are amortized over the lengthy duration of a typical application session.

b) Given such generous link capacities, the network needs no congestion control mechanism. In the worst (most potentially congested) case, all the applications simultaneously transmit over one or more particular network links. However, since each link offers sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur.

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. What is the average queuing delay for the N packets?

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The queuing delay is 0 for the first transmitted packet, L/R for the second transmitted packet, and generally, $(n-1)L/R$ for the n^{th} transmitted packet. Thus, the average delay for the N packets is:

$(L/R + 2L/R + \ldots\ldots + (N-1)L/R)/N$

$= L/(RN) * (1 + 2 + ... + (N-1))$
$= L/(RN) * N(N-1)/2$
$= LN(N-1)/(2RN)$
$= (N-1)L/(2R)$

Note that here we used the well-known fact that

$$1 + 2 + ... + N = N(N+1)/2$$

5. Suppose users share a 1 Mbps link. Also suppose each user requires 100kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of statistical multiplexing in Section 1.3.)

(a) When circuit switching is used, how many users can be supported?

(b) For the remainder of the problem, suppose packets switching is used. Find the probability that a given user is transmitting.

(c) Suppose there are 40 users. Find the probability that at any given time, exactly *n* users are transmitting simultaneously. (Hint: Use the binomial distribution.)

(d) Find the probability that there are 11 or more users transmitting simultaneously.

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a) 10 users can be supported.

10 b) Probability that a given user is transmitting = 0.1

c) Probability that exactly n users are transmitting simultaneously = $\binom{40}{n} p^n (1-p)^{40-n}$

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10 d) $1 - \sum_{n=0}^{10} \binom{40}{n} p^n (1-p)^{40-n}$.

We use the central limit theorem to approximate this probability. Let X_j be independent random variables such that $P(X_j = 1) = p$.

$$P(\text{“11 or more users”}) = 1 - P\left(\sum_{j=1}^{40} X_j \le 11\right)$$

$$P\left(\sum_{j=1}^{40} X_j \le 11\right) = P\left(\frac{\sum_{j=1}^{40} X_j - 4}{\sqrt{40 \cdot 0.1 \cdot 0.9}} \le \frac{7}{\sqrt{40 \cdot 0.1 \cdot 0.9}}\right)$$

$$\approx P(Z \le 3.69)$$

$$= 0.998$$

when Z is a standard normal r.v. P(11 or more users) ≈ 0.002