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DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
EECE350 COMPUTER NETWORKS

PROBLEM SET 1

Important Notes:
- 1 B (Byte) = 8 b (bits)
- 1 KB = 1024 bytes, 1 MB = 1024 KB, 1 GB = 1024 MB
- 1 Kbps = 1000 bps; 1 Mbps = 10^6 bps; 1 Gbps = 10^9 bps

Problem 1: Short questions

A. Name one key advantage of packet switching.

Packet switching allows more efficient usage of network resources (e.g., bandwidth) for bursty data applications, by taking advantage of statistical multiplexing of resources.

B. Using one or two sentences, define what is a protocol.

A protocol defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or reception of a message or other events.

C. Using one or two sentences, describe what is transmission delay?

The transmission delay is the amount of time required to push (that is, transmit) all of the bits in a packet onto the link. This can be calculated by dividing the length of the packet (L bits) by the transmission rate (R) of the link.

D. Using one or two sentences, describe what is propagation delay?

The amount of time required for the bits to propagate down the link is propagation delay

E. What is the latest RFC for TCP? Who is (are) the author(s) of it? When was it published? What RFCs does it obsolete? Explain the TCP header fields (indicate the size and meaning of each).

Problem 2

If host A wants to send a packet of size 80 KB to host B. Consider that A and B are 1000 m apart, the link bandwidth is 5 Mbps, and the signal propagation speed in the line is 2×10^8 m/s.

a. What will be the packet transmission delay?

Packet Transmission Delay = d_{trans} = L/R = 80*1024*8 bits / (5 * 10^6 bps) = 131.072 ms

b. What will be the propagation delay?

Propagation delay = distance/propagation speed = 1000 / 2×10^8 = 5 µs

Problem 3

A 4 Mbps circuit-switched link uses TDM to support 150 simultaneous users. Suppose that the time to establish an end-to-end circuit between any two users is 0.5 sec. Consider a time when there are ONLY 45 active hosts on the network, and Host A wants to send a 500-Byte message to host B. What will be the total time for host B to receive the message?

- X does not matter because it is circuit switching
- bandwidth for each user = $(4x10^6)/150$ = 26667 bits
- transmission time = message size/bandwidth = (500x8)/26667 = 0.1499 = 0.15 s
- propagation time = RTT/2 = 0.5/2 = 0.25 s (assuming a symmetrical link)
- total time = setup time + transmission time + propagation time = 0.5 + 0.15 + 0.25 = 0.9 s

Problem 4

If we have a link whose full capacity is 150 Mbps. Each user in this network is independently active 10% of the time and requires a bandwidth of exactly 4 Mbps.

a. If we are using circuit switching, what is the maximum number of users that can be supported.

When circuit switching is used, each user is allocated 4 Mbps all the time (irrespective of probability of transmission). Therefore 150 Mbps / 4 Mbps = 37.5 → a maximum of 37 users can be supported.

b. Suppose there are 26 users. Find the probability that at any given time, exactly N users are transmitting simultaneously.

probability of active = p = 0.1;

probability of inactive = 1 – p = 0.9

$$P(X = N) = \binom{26}{N} 0.1^N 0.9^{26-N}$$

c. What is the probability that at any given time, not more than half of the users are active at the same time?

$$P(X \leq 13) = \sum_{k=0}^{13} \binom{26}{k} 0.1^k 0.9^{26-k}$$

Problem 5

Beirut and Tripoli are two end hosts on the Internet. Consider the following topology, link capacity and other specifications:

- Tripoli, the destination host, is 4 hops away from Beirut, the source, i.e., there are 3 intermediate routers: Beirut – R1 – R2 – R3 – Tripoli.
- The distance between any two adjacent nodes is 20 kilometers (km).
- The signal propagation speed is 2×10^5 km per second.
- The message size is 50 MB.
- The maximum packet size is 1500 Bytes. The header size is 40 Bytes. Note for packet switching the message should be divided into packets, each of which cannot exceed the maximum packet size.
- The transmission speed of each link is 100 Mbps.
- The circuit setup time is 0.5 seconds for the circuit switching case.
- The processing time for routing & forwarding decision at each node can be ignored.
- Neglect all other delays.

Answer the following questions – make sure to illustrate your calculations clearly.

a. If circuit switching is used, what is the end-to-end delay to deliver the message from Beirut to Tripoli? For circuit switching, assume that the message is sent all together (without any headers) and without any waiting delays in the routers (No stop-and-wait).

   Transmission delay = message size/transmission speed = $(50*8*2^{20}) / (100 * 10^6) = 4.2$ sec
   Propagation delay = 4* (distance/propagation speed) = $4* 20 / (2*10^5) = 4*10^{-4}$ sec
   End to end delay = Transmission delay + Propagation delay + circuit setup time
   $= 4.2 + 4*10^{-4} + 0.5 = 4.7004$ sec

b. Now consider the packet switching case, as described above.
   i. What is the time for one packet to be received from Beirut to Tripoli?

      Packet size in bits = 1500 * 8 = 12,000 bits
      Propagation delay per hop = $20 / (2*10^5) = 10^{-4}$ sec
      Transmission delay per hop = $(12{,}000) / (100 * 10^6) = 1.2*10^{-4}$ sec
      Total time = $4* (10^{-4} + 1.2*10^{-4}) = 880 *10^{-6}$ sec

   ii. Calculate the end-to-end delay to deliver the message from Beirut to Tripoli.

   Since the message size is 50 MB and the maximum packet size is 1500 bytes there will be a total of (a +1) packets where a= floor[$50*2^{20}/1460$] = 35,910;
   - each packet contains 1500B = 1460B data and 40B header,
   - and the last packet contains W = ($50*2^{20}$ – a*1460B) + 40B packets = 240 B

Total delay = Total delay of one [largest] packet from source to destination + transmission delay of remaining packets from one [slowest] hop

➔ Total delay = 4 * $(trans + prop)_{\text{largest packet}}$ + (a-1)*trans + $tran_{last}$

- total delay of largest packet = 880 *10^{-6} sec
- transmission delay of (a-1) full packets = (35,910-1) * 1.2*10^{-4} sec
- transmission delay of last packet = 240 B / (100 * 10^{6}) = 19.2*10^{-6} sec

Total delay = 880 *10^{-6} sec + 4,309,080 *10^{-6} sec + 19.2*10^{-6} sec = 4,309,979.2*10^{-6} sec = 4.31 sec

c. If the host at Tripoli is sending the same exact message to the host at Beirut, i.e. the question is reversed. How will the total end-to-end delays calculated in a. and b. change? Justify your answer.

If the source and destination are reversed there is no difference as the path and delays are symmetrical.