Written Assignment 1

Total Points: 100
Due Date: 2025/03/23, 21:00
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Homework Policy

1. Please do not plagiarize. Any suspected plagiarism will be investigated by the TA. You will receive zero points if plagiarism is confirmed.

2. It is okay to discuss homework in general terms with your classmates. However, all the content is expected to be your own work. Please avoid using AI tools to generate any answers.

3. Contact the TA for any questions. Use the subject **[2025ICN] WA1** as the email title.

4. Professor Liao and the TA retain the authority to modify the rules and grades.

Submission Policy

1. Submit your assignment in `[student_id]_WA1.pdf` to NTU Cool.

2. Late submission: $\frac{1}{3}$ deduction from your original score for one-day late submission. $\frac{2}{3}$ score deduction from your original score between one day and two days. No credit will be given for the submission that is more than two days late.

1. Consider an application that transmits data at a steady rate (for example, 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 by briefly justifying your answer.

   a) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why? (10%)

   b) Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as 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? (10%)

2. 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. (2%)

   b) Determine the transmission time of the packet, d_{trans}, in terms of L and R. (2%)

   c) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay. (2%)

   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? (3%)

   e) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet? (3%)

   f) Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet? (3%)

   g) Suppose $s = 2.5 \cdot 10^8$, $L = 120$ bits, $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}. (5%)

3. Consider Figure 1. Assume that we know the bottleneck link along the path from the server to the client is the first link with rate R_s bits/sec. Suppose we send a pair of packets back-to-back from the server to the client, and there is no other traffic on this path. Assume each packet of size L bits, and both links have the same propagation delay d_{drop}.

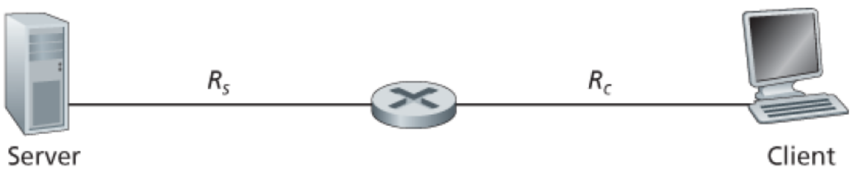

Figure 1: Throughput for a file transfer from server to client.

a) What is the packet inter-arrival time at the destination? That is, how much time elapses from when the last bit of the first packet arrives until the last bit of the second packet arrives? (6%)

b) Now assume that the second link is the bottleneck link (i.e., $R_c < R_s$). Is it possible that the second packet queues at the input queue of the second link? Explain. (7%)

c) Now suppose that the server sends the second packet T seconds after sending the first packet. How large must T be to ensure no queuing before the second link? Explain. (7%)

4. 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 2.5×10^8 meters/sec.

   a) Calculate the bandwidth-delay product, $R \cdot d_{prop}$. (4%)

   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? (4%)

   c) Provide an interpretation of the bandwidth-delay product. (4%)

   d) What is the width (in meters) of a bit in the link? (4%)

   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 D. (4%)

5. In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. Figure 2 illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is $8 \cdot 10^6$ bits long that is to be sent from source to destination in Figure 2. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

   a) Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host? (4%)

   b) Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch? (4%)

   c) How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment. (4%)

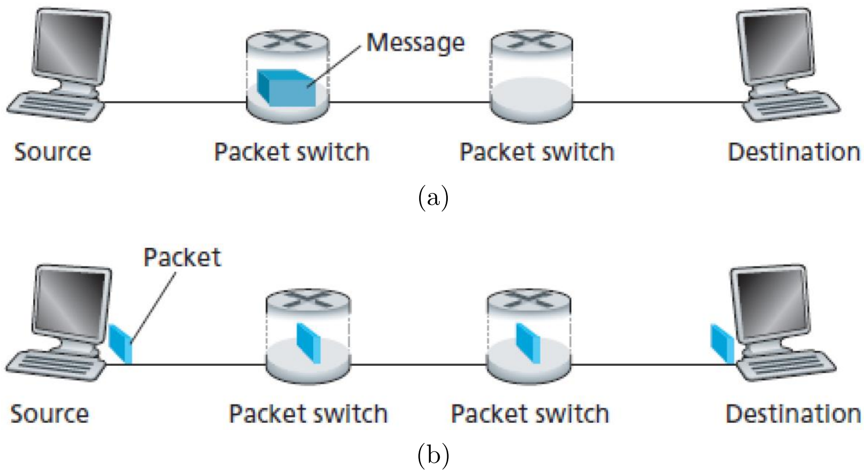

Figure 2: End-to-end message transport: (a) without message segmentation; (b) with message segmentation.

d) In addition to reducing delay, what are reasons to use message segmentation? (4%)

e) Discuss the drawbacks of message segmentation. (4%)