AMERICAN UNIVERSITY OF BEIRUT
MAROUN SEMAAN FACULTY OF ENGINEERING & ARCHITECTURE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
EECE 350/351 - Computer Networks

Problem Set 1
Introduction

Question 1

What is a client program? What is a server program? Does a server program request and receive services from a client program?

Answer: A networking program usually has two programs, each running on a different host, communicating with each other. The program that initiates the communication is the client. Typically, the client program requests and receives services from the server program.

Question 2

List six access technologies. Classify each one as residential access, company access, or mobile access.

Answer:

- Dial-up modem over telephone line: residential
- DSL over telephone line: residential or small office
- Cable to HFC: residential
- 100 Mbps switched Ethernet: company
- Wireless LAN: mobile
- Cellular mobile access (e.g., WAP): mobile

Question 3

What are some of the physical media that Ethernet can run over?

Answer: Ethernet most commonly runs over twisted-pair copper wire and *thin* coaxial cable. It also can run over fiber optic links and thick coaxial cable.

Question 4

What advantage does a circuit-switched network have over a packet-switched network? What advantages does TDM have over FDM in a circuit-switched network?

Answer: A circuit-switched network can guarantee a certain amount of end-to-end bandwidth for the duration of a call. Most packet-switched networks today (including the Internet) cannot make any end-to-end guarantees for bandwidth. TDM requires much simpler circuitry than FDM since this multiplexing technique is limited to allocating time slots to users.

Question 5

Why is it said that packet switching employs statistical multiplexing? Contrast statistical multiplexing with the multiplexing that takes place in TDM.

Answer: In a packet-switched network, the packets from different sources flowing on a link do not follow any fixed, predefined pattern. In TDM circuit switching, each host gets the same slot in a revolving TDM frame.

Question 6

What is the key distinguishing difference between a tier-1 ISP and a tier-2 ISP?

Answer: A tier-1 ISP connects to all other tier-1 ISPs; a tier-2 ISP connects to only a few of the tier-1 ISPs. Also, a tier-2 ISP is a customer of one or more tier-1 ISPs.

Question 7

Suppose users share a 2 Mbps link. Also suppose each user requires 1 Mbps when transmitting, but each user transmits only 20 percent of the time.

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

(b) For the remainder of this problem, suppose packet switching is used. Why will there be essentially no queuing delay before the link if two or fewer users transmit at the same time? Why will there be a queuing delay if three users transmit at the same time?

(c) Find the probability that a given user is transmitting.

(d) Suppose now there are three users. Find the probability that at any given time, all three users are transmitting simultaneously. Find the fraction of time during which the queue grows.

Answer:

- 2 users can be supported because each user requires half of the link bandwidth.
- Since each user requires 1Mbps when transmitting, if two or fewer users transmit simultaneously, a maximum of 2Mbps will be required. Since the available bandwidth of the shared link is 2Mbps, there will be no queuing delay before the link. Whereas, if three users transmit simultaneously, the bandwidth required will be 3Mbps which is more than the available bandwidth of the shared link. In this case, there will be queuing delay before the link.b. Since each user requires 1Mbps when transmitting, if two or fewer users transmit simultaneously, a maximum of 2Mbps will be required. Since the available bandwidth of the shared link is 2Mbps, there will be no queuing delay before the link. Whereas, if three users transmit simultaneously, the bandwidth required will be 3Mbps which is more than the available bandwidth of the shared link. In this case, there will be queuing delay before the link.
- Probability that a given user is transmitting: 0.2.
- Probability that all three users are transmitting simultaneously = $\binom{3}{3}p^3(1-p)^{3-3} = (0.2)^3 =$ 0.008. Since the queue grows when all the users are transmitting, the fraction of time during which the queue grows (which is equal to the probability that all three users are transmitting simultaneously) is 0.008.

Question 8

Consider sending a packet from a source host to a destination host over a fixed route. List the delay components in the end-to-end delay. Which of these delays are constant and which are variable?

Answer: The delay components are processing delays, transmission delays, propagation delays, and queuing delays. All of these delays are fixed, except for the queuing delays, which are variable.

Question 9

How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5×10^8 m/s, and transmission rate 2 Mbps? More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps? Does this delay depend on packet length? Does this delay depend on transmission rate?

Answer: 10 ms; d/s; no; no.

Question 10

Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates $R_1 = 500$ kbps, $R_2 = 2$ Mbps, and $R_3 = 1$ Mbps.

(a) Assuming no other traffic in the network, what is the throughput for the file transfer?

(b) Suppose the file is 4 million bytes. How long will it take to transfer the file to Host B?

(c) Repeat (a) and (b), but now with R_2 reduced to 100 kbps.

Answer:

- 500 kbps; 64 seconds.
- 100 kbps; 320 seconds.

Problem 1

Suppose users share a 1 Mbps link. Also suppose each user requires 100 kbps when transmitting, but each user transmits only 10 percent of the time.

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

(b) For the remainder of this problem, suppose packet 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.

Solution:

- 10 users can be supported because each user requires one-tenth of the bandwidth.
- $p = 0.1$.
- $\binom{40}{n} p^n (1-p)^{40-n}$.
- $1 - \sum_{n=0}^{10} \binom{40}{n} p^n (1-p)^{40-n}$.

Problem 2

Consider a packet of length L which begins at end system A, travels over one link to a packet switch, and travels from the packet switch over a second link to a destination end system. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link $i = 1, 2$. The packet switch delays each packet by d_{proc}. Assuming no queuing delays, in terms of d_i, s_i, R_i, ($i = 1, 2$), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,000 bytes, the propagation speed on both links is 2.5×10^8 m/s, the transmission rates of both links is 1 Mbps, the packet switch processing delay is 1 ms, the length of the first link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

Solution: The first end system requires L/R_1 to transmit the packet onto the first link; the packet propagates over the first link in d_1/s_1; the packet switch adds a processing delay of d_{proc}; after receiving the entire packet, the packet switch requires L/R_2 to transmit the packet onto the second link; the packet propagates over the second link in d_2/s_2. Adding these five delays gives:

$$d_{\text{end-end}} = \frac{L}{R_1} + \frac{L}{R_2} + \frac{d_1}{s_1} + \frac{d_2}{s_2} + d_{\text{proc}}$$

To answer the second question, we simply plug the values into the equation to get:

$$8 + 8 + 16 + 4 + 1 = 37 \text{ ms}.$$

Problem 3

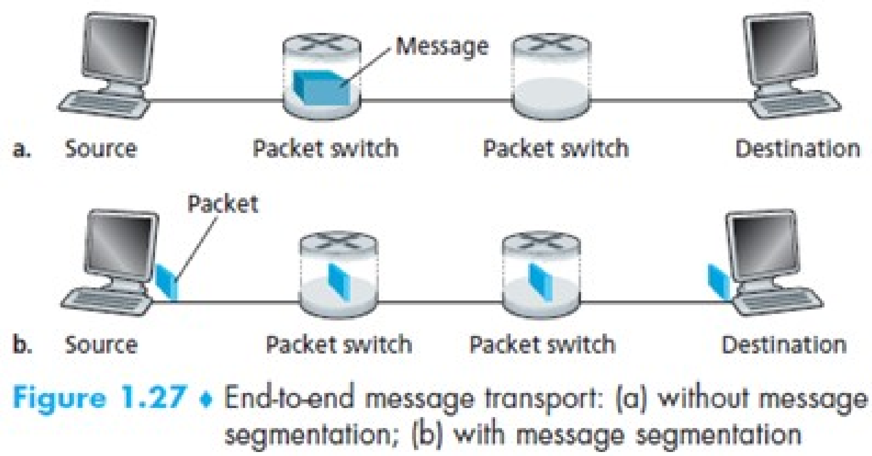

Figure 1: Illustration for Problem 3

In modern packet-switched networks, 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 1 illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 7.5×10^6 bits long that is to be sent from source to destination in Figure 1. Suppose each link in the figure is 1.5 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?

(b) Now suppose that the message is segmented into 5,000 packets, with each packet being 1,500 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?

(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.

(d) Discuss the drawbacks of message segmentation.

Solution:

- Time to send message from source host to first packet switch = $\frac{7.5\times10^6}{1.5\times10^6} = 5$ seconds. With store-and-forward switching, the total time to move message from source host to destination host = $5 \times 3 = 15$ seconds.
- Time to send 1st packet from source host to first packet switch = $\frac{1500}{1.5\times10^6} = 1$ ms. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $1 + 1 = 2$ ms.
- Time at which 1st packet is received at the destination host = 3 ms. After this, every 1 ms, one packet will be received; thus, the time at which the last (5000th) packet is received = $3 + 4999 \times 1 = 5002$ ms = 5.002 seconds. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).
- Drawbacks:
  - Packets have to be put in sequence at the destination.
  - Message segmentation results in many smaller packets. Since header size is usually the same for all packets regardless of their size, with message segmentation the total amount of header bytes is more.