

Review for Chapter 1

Review for Chapter 1

R1. What is the difference between a host and an end system? List the types of end systems. Is a Web server an end system?

Review for Chapter 1

Answer:

There is no difference. Throughout this text, the words “host” and “end system” are used interchangeably. End systems include PCs, workstations, Web servers, mail servers, Internet-connected PDAs, WebTVs, etc.

Review for Chapter 1

R3. What is a client program? what is a server program? Does a server program request and receive services from a client program?

Review for Chapter 1

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.

Review for Chapter 1

R8. Dial-up modems, HFC, and DSL are all used for residential access. For each of these access technologies, provide a range of transmission rates and comment on whether the transmission rate is shared or dedicated.

Review for Chapter 1

Answer:

Dial up modems: up to 56 Kbps, bandwidth is dedicated;

ISDN: up to 128 kbps, bandwidth is dedicated;

ADSL: downstream channel is .5-8 Mbps, upstream channel is up to 1 Mbps, bandwidth is dedicated;

HFC, downstream channel is 10-30 Mbps and upstream channel is usually less than a few Mbps, bandwidth is shared

Review for Chapter 1

R11. 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?

Review for Chapter 1

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 had the advantage in that it requires less bandwidth as it uses the same frequency.

Review for Chapter 1

R12. Suppose there is exactly one packet switch between a sending host and a receiving host. The transmission rates between the sending host and the switch and between the switch and the receiving host are R_1 and R_2 , respectively. Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L ? (ignore queuing, propagation delay, and processing delay.)

Review for Chapter 1

Answer:

At time t_0 the sending host begins to transmit. At time $t_1 = L/R_1$, the sending host completes transmission and the entire packet is received at the router (no propagation delay). Because the router has the entire packet at time t_1 , it can begin to transmit the packet to the receiving host at time t_1 . At time $t_2 = t_1 + L/R_2$, the router completes transmission and the entire packet is received at the receiving host (again, no propagation delay). Thus, the end-to-end delay is $L/R_1 + L/R_2$.

Review for Chapter 1

R13. Why is it said that packet switching employs statistical multiplexing? Contrast statistical multiplexing with the multiplexing that takes place in TDM.

Review for Chapter 1

Answer:

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

Review for Chapter 1

R15. What is the key distinguishing difference between a tier-1 ISP and a tier-2 ISP ?

Review for Chapter 1

Answer:

A tier-1 ISP connects to other tier-1 ISPs peerly; a tier-2 ISP is a customer of one or more tier-1.

Review for Chapter 1

R16. 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?

Review for Chapter 1

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.

Review for Chapter 1

R19. 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 $R_1 = 250\text{kbps}$, $R_2 = 500\text{kbps}$, and $R_3 = 1\text{Mbps}$.

a. Assuming no other traffic in the network, what is the throughput for the file transfer.

b. Suppose the file is 2 million bytes. Roughly, how long will it take to transfer the file to Host B?

c. Repeat (a) and (b), but now with R_2 reduced to 200kbps.

Review for Chapter 1

Answer:

- a) 250 kbps
- b) 64 seconds
- c) 200kbps; 80 seconds

Review for Chapter 1

R23. What are the five layers in the Internet protocol stack? What are the principal responsibilities of each of these layers?

Review for Chapter 1

Answer:

The five layers in the Internet protocol stack are – from top to bottom – the application layer, the transport layer, the network layer, the link layer, and the physical layer. The principal responsibilities are outlined in Section 1.5.1.

Review for Chapter 1

R25. What is an application-layer message? A transport-layer segment? A network-layer datagram? A link-layer frame?

Review for Chapter 1

Answer:

Application-layer message: generated by the application-layer protocol whose data is that an application wants to send and passed onto the transport layer;

transport-layer segment: generated by the transport layer and encapsulates application-layer message with transport layer header;

network-layer datagram: encapsulates transport-layer segment with a network-layer header;

link-layer frame: encapsulates network-layer datagram with a link-layer header.

Review for Chapter 1

R26. What is the difference between a virus ,a worm, and a Trojan horse?

Review for Chapter 1

Answer:

a) Virus

Requires some form of human interaction to spread. Classic example: E-mail viruses.

Review for Chapter 1

b) Worms

No user replication needed. Worm in infected host scans IP addresses and port numbers, looking for vulnerable processes to infect.

Review for Chapter 1

c) Trojan horse

Hidden, devious part of some otherwise useful software.

Problems

Problem

P2. Consider the circuit-switched network in Figure 1.8. Recall that there are n circuits on each link.

- a. What is the maximum number of simultaneous connections that can be in progress at any one time in this network?
- b. Suppose that all connections are between the switch in the upper-left-hand corner and the switch in the lower-right-hand corner. What is the maximum number of simultaneous connections that can be in progress?

Problem

Answer:

- a) We can n connections between each of the four pairs of adjacent switches. This gives a maximum of $4n$ connections.
- b) We can n connections passing through the switch in the upper-right-hand corner and another n connections passing through the switch in the lower-left-hand corner, giving a total of $2n$ connections.

Problem

P5. 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 meter/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 .
- b. Determine the transmission time of the packet, d_{trans} , in terms of L and R .

Problem

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

d. Suppose Host A begins to transmit the packet at time $t=0$. At time d_{trans} , where is the last bit of the packet?

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

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

g. Suppose $s=2.5 \cdot 10^8$, $L=100\text{bits}$, and $R=28\text{KBPS}$. Find the distance m so that d_{prop} equals d_{trans}

Problem

Answer:

a) $d_{prop} = m/s$ seconds.

b) $d_{trans} = L/R$ seconds.

c) $d_{end-to-end} = (m/s + L/R)$ seconds.

d) The bit is just leaving Host A.

Problem

e) The first bit is in the link and has not reached Host B.

f) The first bit has reached Host B.

g) Want

$$m = \frac{L}{R} s = \frac{100}{28 \times 10^3} (2.5 \times 10^8) = 893 km$$

Problem

P7. 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. (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 this problem, suppose packet switching is used. Find the probability that a given user is transmitting.

Problem

- 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.

Problem

Answer:

a) 10 users can be supported because each user requires one tenth of the bandwidth.

b) $p = 0.1$.

c) $\binom{40}{n} p^n (1-p)^{40-n}$.

d) $1 - \sum_{n=0}^9 \binom{40}{n} p^n (1-p)^{40-n}$.

Problem

We use the central limit theorem to approximate this probability. Let X be independent random variables such that $P(X = x) = \binom{40}{x} p^x (1-p)^{40-x}$

Thus $P(\text{more than 10 users}) = 1 - P(X \leq 10)$

$$\begin{aligned} P(X \leq 10) &= P\left(\frac{X - 4}{\sqrt{40 * 0.1 * 0.9}} \leq \frac{6}{\sqrt{40 * 0.1 * 0.9}}\right) \\ &= P\left(Z \leq \frac{6}{\sqrt{3.6}}\right) = P(Z \leq 3.16) \approx 0.999 \end{aligned}$$

when Z is a standard normal r.v. Thus $P(\text{"10 or more users"}) \approx 0.001$.

Problem

P8. Consider the discussion in section 1.3 of statistical multiplexing in which an example is provided with a 1 Mbps link. Users are generating data at a rate of 100 kbps when busy, but are busy generating data only with probability $p=0.1$. Suppose that the 1 Mbps link is replaced by a 1 Gbps link.

Problem

- a. What is N , the maximum number of users that can be supported simultaneously under circuit switching?
- b. Now consider packet switching and a user population of M users. Give a formula (in terms of p, M, N) for the probability that more than N users are sending data.

Problem

Answer:

(a) 10,000

(b)
$$\sum_{n=N+1}^M \binom{M}{n} p^n (1-p)^{M-n}$$

Problem

P9. 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 destination end system. Let d_i , s_i , and R_i denote the length, propagation speed, and the transmission rate of link i , for $i=1,2$. The packet switch delays each packet by d_{proc} .

Problem

Assuming no queuing delays, in terms of d_i, s_i, R_i ($i=1,2, \dots, L$), and L , what is the total end-to-end delay for the packet? Suppose now the packet length is 1,000 bytes, the propagation speed on both links is $2.5 \cdot 10^8 \text{ m/s}$, the transmission rates of both links is 1 Mbps, the packet switch processing delay is 2 msec, the length of the first link is 6,000 km, and the length of the last link is 3,000 km. For these values, what is the end-to-end delay?

Problem

Answer:

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

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

To answer the second question, we simply plug the values into the equation to get $8 + 8 + 24 + 12 + 2 = 54$ msec.

Problem

P12. A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and three other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 1,250 bytes and the link rate is 1 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length L , the transmission rate is R , x bits of the currently-being-transmitted packet have been transmitted, and n packets are already in the queue?

Problem

Answer:

The arriving packet must first wait for the link to transmit $3.5 \cdot (1250 \cdot 8 / 10^6) \text{s} = 35 \text{ms}$

Generally, the queuing delay is $[nL + (L - x)]/R$.

Problem

P13. Consider the queuing delay in router buffer (preceding an outbound link). Suppose all packets are L bits, the transmission rate is R bps, and that N packets simultaneously arrive at the buffer every LN/R seconds. Find the average queuing delay of a packet. (*Hint:* The queuing delay for the first packet is zero; for the second packet L/R ; for the third packet $2L/R$. The M th packet has already been transmitted when the second batch of packets arrives.)

Problem

Answer:

It takes LN / R seconds to transmit the N packets. Thus, the buffer is empty when a batch of N packets arrive.

The first of the N packets has no queuing delay. The 2nd packet has a queuing delay of L/R seconds. The n^{th} packet has a delay of $(n-1)L/R$ seconds.

The average delay is

$$\frac{1}{N} \sum_{n=1}^N (n-1)L/R = \frac{L}{R} \frac{1}{N} \sum_{n=0}^{N-1} n = \frac{L}{R} \frac{1}{N} \frac{(N-1)N}{2} = \frac{L}{R} \frac{(N-1)}{2}.$$

Problem

P22. Suppose there is a 10 Mbps microwave link between a geostationary satellite and its base station on Earth. Every minute the satellite takes a digital photo and sends it to the base station. Assume a propagation speed of $2 \cdot 10^8$ meters/sec.

Problem

- a. What is the propagation delay of the link?
- b. What is the bandwidth-delay product, $R \cdot d_{prop}$?
- c. Let χ denote the size of the photo. What is the minimum value of χ for the microwave link to be continuously transmitting.

Problem

Answer:

a) $3.6 \cdot 10^7 / 2 \cdot 10^8 = 180 \text{ msec}$

b) $R \cdot d_{\text{prop}} = 10 \text{ Mbps} \cdot 180 \text{ msec} = 1.8 \cdot 10^6 \text{ bits}$

c) continuously transmitting means $d_{\text{trans}} = d_{\text{prop}}$

thus we have

$$x / 10 \text{ Mbps} = 180 \text{ msec} \Rightarrow x = 1.8 \cdot 10^6 \text{ bits}$$

Problem

P24. 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 1.24 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 Figure 1.24. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

Problem

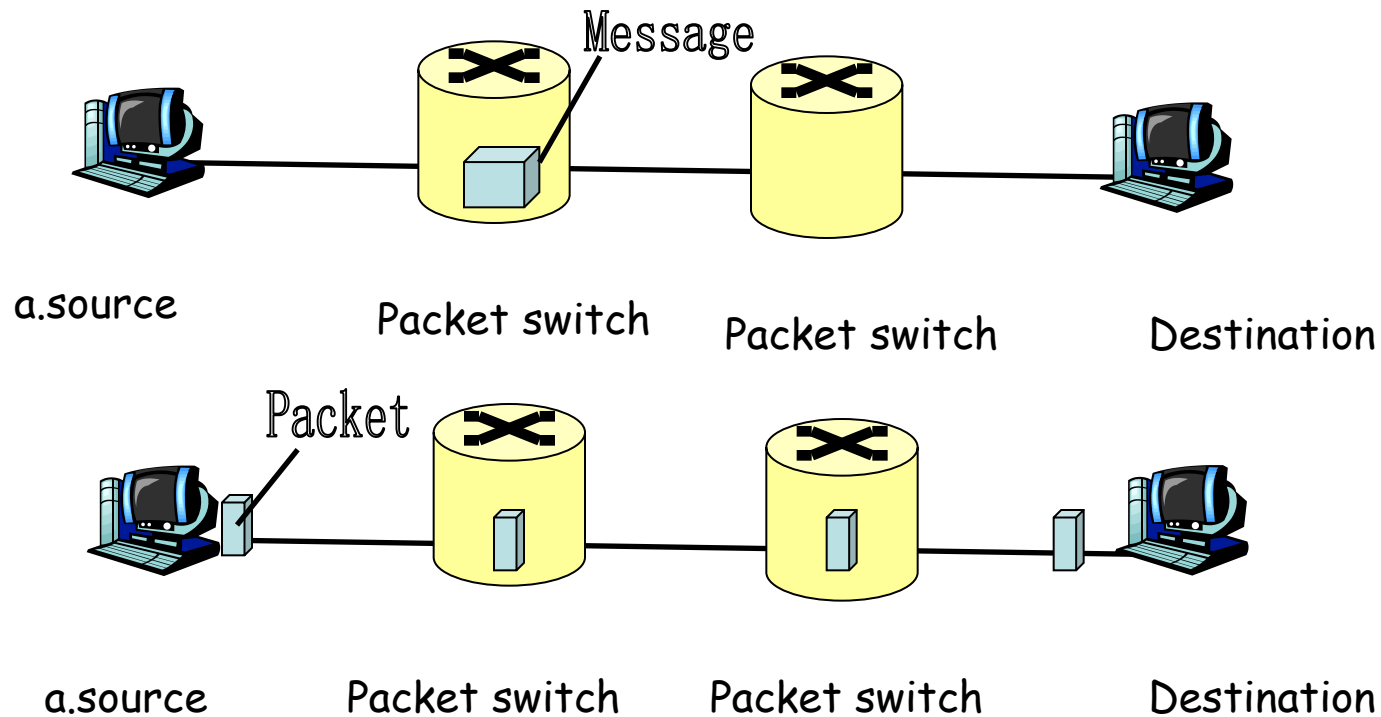


Figure 1.24 End-to-end message transport (a) without message segmentation; (b) with message segmentation.

Problem

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?

Problem

b. Now suppose that the message is segmented into 4,000 packets, with each packet being 2,000 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?

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.

Problem

Answer:

a) Time to send message from source host to first

packet switch is $8 \times 10^6 \text{ bits} / 2 \text{ Mbps} = 4 \text{ s}$

With store-and-forward switching, the total time to move message from source host to destination host $= 3 \times 4 \text{ s} = 12 \text{ s}$

Problem

b) Time to send 1st packet from source host to first

packet switch = $2000\text{bits} / 2\text{Mbps} = 1\text{ms}$

Time at which 2nd packet is received at the first switch
= time at which 1st packet is received at the second
switch = $2 \times 1\text{ msec} = 2\text{ msec}$

Problem

c. Time at which 1st packet is received at the destination host = $1 \text{ msec} \times 3 \text{ hops} = 3 \text{ msec}$.

After this, every 1msec one packet will be received; thus time at which last 4000th packet is received = 4.002s. It can be seen that delay in using message segmentation is significantly less

Problem

d) Drawbacks:

- i. Packets have to be put in sequence at the destination.
- ii. 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.

Problem

P26. Consider sending a large file of F bits from Host A to Host B. There are two links (and one switch) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of S bits each and adds 40 bits of header to each segment, forming packets of $L=40+S$ bits. Each link has a transmission rate of R bps. Find the value of S that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

Problem

Time at which the 1st packet is received at the

destination = $\frac{S + 40}{R} \times 2 \text{ sec.}$ After this, one packet is

received at destination every $\frac{S + 40}{R} \text{ sec.}$ Thus delay

in sending the whole file =

$$\text{delay} = \frac{S + 40}{R} \times 2 + \left(\frac{F}{S} - 1\right) \times \left(\frac{S + 40}{R}\right) = \frac{S + 40}{R} \times \left(\frac{F}{S} + 1\right)$$

To calculate the value of S which leads to the minimum delay,

$$\frac{d}{dS} \text{delay} = 0 \Rightarrow \frac{F}{R} \left(\frac{1}{S} - \frac{40 + S}{S^2}\right) + \frac{1}{R} = 0 \Rightarrow S = \sqrt{40F}$$

Problem

The time to transmit one packet onto a link is $(40 + S)/R$

total latency is $((40+S)/R)(F/S+1)$

Simplified: $(40F/S+F+40+S)/R$

However, We have to consider the situation where F/S is not an integer.

Under the situation above the latency is

$$\frac{40 + S}{R} \left(\left\lfloor \frac{F}{S} \right\rfloor + 1 \right) + \frac{F - \left\lfloor \frac{F}{S} \right\rfloor S + 40}{R}$$

Simplified:

$$\frac{F + S + 40 + 40 * \left(\left\lfloor \frac{F}{S} \right\rfloor + 1 \right)}{R}$$

Problem

We have the latency is
$$\frac{\mathbf{F} + \mathbf{S} + 40 + 40 * \left(\left\lceil \frac{\mathbf{F}}{\mathbf{S}} \right\rceil \right)}{\mathbf{R}}$$

The question is converted to find the value of S that minimizes

$$\mathbf{S} + 40 \left\lceil \frac{\mathbf{F}}{\mathbf{S}} \right\rceil$$

When we simplified $\lceil F/S \rceil$ as F/S , we have the answer

$$\mathbf{S} = \sqrt{40\mathbf{F}}$$