# Homework Problems and Discussion Questions

# Chapter 1

## Review Questions

*Sections 1.1-1.4*

1) What are the two types of services that the Internet provides to its applications? What are some of characteristics of each of these services?

2) It has been said that flow control and congestion control are equivalent. Is this true for the Internet's connection-oriented service? Are the objectives of flow control and congestion control the same?

3) Briefly describe how the Internet's connection-oriented service provides reliable transport.

4) What advantage does a circuit-switched network have over a packet-switched network?

4) What advantages does TDM have over FDM in a circuit-switched network?

5) Suppose that between a sending host and a receiving host there is exactly one packet switch. 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 router uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length $L$. (Ignore queuing and propagation delay.)

6) What are some of the networking technologies that use virtual circuits? Find good URLs that discuss and explain these technologies.

7) What is meant by connection state information in a virtual-circuit network?

8) Suppose you are developing a standard for a new type of network. You need to decide whether your network will use VCs or datagram routing. What are the pros and cons for using VCs?

*Sections 1.5-1.7*

9) Is HFC bandwidth dedicated or shared among users? Are collisions possible in a downstream HFC channel? Why or why not?

10) What are the transmission rate of Ethernet LANs? For a given transmission rate, can each user on the LAN continuously transmit at that rate?

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

12) Dail-up modems, ISDN, HFC and ADSL are all used for residential access. For each of these access technologies, provide a range of transmission rates and comment on whether the bandwidth is shared or dedicated.

13) Consider sending a series of packets from a sending host to a receiving host over a fixed route. List the delay components in the end-to-end delay for a single packet. Which of these delays are constant and which are fixed?

14) Review the car-caravan analogy in Section 1.6. Again assume a propagation speed of 100km/hour.

> a) Suppose the caravan travels 200 km, beginning in front of one toll booth, passing through a second toll booth, and finishing just before a third toll booth. What is the end-to-end delay?
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> b) Repeat (a), now assuming that there are 7 cars in the caravan instead of 10.

15) List five tasks that a layer can perform. It is possible that one (or more) of these tasks could be performed by two (or more) layers?

16) What are the five layers in the Internet protocol stack? What are the principle responsibilities for each of these layers?

17) Which layers in the Internet protocol stack does a router process?

**Problems**

1) Design and describe an application-level protocol to be used between an Automatic Teller Machine, and a bank's centralized computer. Your protocol should allow a user's card and password to be verified, the account balance (which is maintained at the centralized computer) to be queried, and an account withdrawal (i.e., when money is given to the user) to be made. Your protocol entities should be able to handle the all-too-common case in which there is not enough money in the account to cover the withdrawal. Specify your protocol by listing the messages exchanged, and the action taken by the Automatic Teller Machine or the bank's centralized computer on transmission and receipt of messages. Sketch the operation of your protocol for the case of a simple withdrawl with no errors, using a diagram similar to that in Figure 1.2-1. Explicity state the assumptions made by your protocol about the underlying end-to-end transport service.

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

- Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?
- Suppose that a packet-switching 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 that the capacities of each and every link. Is some form of congestion control needed? Why?

3) Consider sending a file of $F = M * L$ bits over a path of $Q$ links. Each link transmits at $R$ bps. The network is lightly loaded so that there are no queueing delays. When a form of packet switching is used, the $M * L$ bits are broken up into $M$ packets, each packet with $L$ bits. Propagation delay is negligible.

a) Suppose the network is a packet-switched virtual-circuit network. Denote the VC set-up time by $t_s$ seconds. Suppose to each packet the sending layers add a total of $h$ bits of header. How long does it take to send the file from source to destination?

b) Suppose the network is a packet-switched datagram network, and a connectionless service is used. Now suppose each packet has $2h$ bits of header. How long does it take to send the file?

c) Repeat (b), but assume message switching is used (i.e., $2h$ bits are added to the message, and the message is not segmented).

d) Finally, suppose that the network is a circuit switched network. Further suppose that the transmission rate of the circuit between source and destination is $R$ bps. Assuming $t_s$ set-up time and $h$ bits of header appended to the entire file, how long does it take to send the file?

4) Experiment with the message-switching Java applet in this chapter. Do the delays in the applet correspond to the delays in the previous question? How do link propagation delays effect the the overall end-to-end delay for packet switching and for message switching?

5) 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 (i.e., no queueing 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 packet from Host A to Host B. Neglect propagation delay.

6) This elementary problem begins to explore propagation delay and transmission delay, two central

concepts in data networking. Consider two hosts, Hosts A and B, connected by a single link of rate *R* bps. Suppose that the two hosts are separted 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*.
> b) Determine the transmission time of the packet, $d_{trans}$ in terms of *L*and *R*.
> c) Ignoring processing and queing 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 $t=d_{trans}$, 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 $s=2.5*10^8$, $L=100$bits and $R=28$ kbps. Find the distance *m*so that $d_{prop}$equals $d_{trans}$.

7) In this problem we consider sending voice from Host A to Host B over a packet-switched network (e. g., Internet phone). Host A converts on-the-fly analog voice to a digital 64 kbps bit stream. Host A then groups the bits into 48-byte packets. There is one link between host A and B; its transmission rate is 1 Mbps and its propagation delay is 2 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it coverts the packet's bits to an analog signal. How much time elapses from when a bit is created (from the original analog signal at A) until a bit is decoded (as part of the analog signal at B)?

8) Suppose users share a 1 Mbps link. Also suppose each user requires 100 Kbps when transmitting, but each user only transmits 10% of the time. (See the discussion on "Packet Switching versus Circuit Switching" in Section 1.4.1.)

> a) When circuit-switching is used, how many users can be supported?
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> b) For the remainder of this problem, suppose packet-switching is used. Find the probability that a given user is transmitting.
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> c) Suppose there are 40 users. Find the probability that at any given time, *n* users are transmitting simultaneously.
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> d) Find the probability that there are 10 or more users transmitting simultaneously.

9) Consider the queueing delay in a router buffer (preceding an outbound link). Suppose all packets are *L* bits, the transmission rate is *R* bps and that *N* packets arrive to the buffer every *L/RN* seconds. Find the average queueing delay of a packet.

10) Consider the queueing delay in a router buffer. Let I denote traffic intensity, that is, I = La/R. Suppose that the queueing delay takes the form LR/(1-I) for I < 1. (a) Provide a formula for the "total

delay," that is, the queueing delay plus the transmission delay. (b) Plot the transmission delay as a function of L/R.

11) (a) Generalize the end-to-end delay formula in Section 1.6 for heterogeneous processing rates, transmission rates, and propagation delays. (b) Repeat (a), but now also suppose that there is an average queuing delay of $d_{queue}$ at each node.

12) Consider an application that transmits data at a steady rate (e.g., the sender generates one packet of *N* bits every *k* time units, where *k* is small and fixed). Also, when such an application starts, it will stay on for relatively long period of time.

> 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 as described above. Furthermore, assume that the sum of the application data rates is less that the capacities of each and every link. Is some form of congestion control needed? Why or why not?

13) Perform a traceroute between source and destination on the same continent at three different hours of the day. Find the average and standard deviation of the delays. Do the same for a source and destination on different continents.

14) Recall that ATM uses 53 byte packets consisting of 5 header bytes and 48 payload bytes. Fifty-three bytes is unusually small for fixed-length packets; most networking protocols (IP, Ethernet, frame relay, etc.) use packets that are, on average, significantly larger. One of the drawbacks of a small packet size is that a large fraction of link bandwidth is consumed by overhead bytes; in the case of ATM, almost ten percent of the bandwidth is "wasted" by the ATM header. In this problem we investigate why such a small packet size was chosen. To this end, suppose that the ATM cell consists of *P* bytes (possible different from 48) and 5 bytes of header.

> a) Consider sending a digitally encoded voice source directly over ATM. Suppose the source is encoded at a constant rate of 64 kbps. Assume each cell is entirely filled before the source sends the cell into the network. The time required to fill a cell is the **packetization delay.** In terms of *L*, determine the packetization delay in milliseconds.
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> b) Packetization delays greater than *20* msecs can cause noticeable and unpleasant echo. Determine the packetization delay for $L = 1{,}500$ bytes (roughly corresponding to a maximum-size Ethernet packet) and for $L = 48$ (corresponding to an ATM cell).
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> c) Calculate the store-and-forward delay at a single ATM switch for a link rate of R = 155 Mbps (a popular link speed for ATM) for $L = 1500$ bytes and $L = 48$ bytes.

d) Comment on the advantages of using a small cell size.

## Discussion Questions

1) Write a one-paragraph description for each of three major projects currently under way at the W3C.

2) What is Internet phone? Describe some of the existing products for Internet phone. Find some of the Web sites of companies that are in the Internet phone business.

3) What is Internet audio-on-demand? Describe some of the existing products for Internet audio-on-demand. Find some of the Web sites of companies that are in the Internet audio-on-demand business. Find some Web sites which provide audio-on-demand content.

4) What is Internet video conferencing? Describe some of the existing products for Internet video conferencing. Find some of the Web sites of companies that are in the Internet video-conferencing business.

5) Surf the Web to find a company that is offering HFC Internet access. What transmission rate of the cable modem? Is this rate always guaranteed for each user on the network?

6) Discussion question: Suppose you are developing an application for the Internet.Would you have your application run over TCP or UDP? Elaborate. (We will explore this question in some detail in subsequent chapters. For now appeal to your intuition to answer the question.)

7) Discussion question: What are some of the current activities of the The World Wide Web Consortium (W3C)? What are some of the current activities of the National Laboratory for Applied Network Research or NLANR?

8) Discussion question: What does the current topological structure of the Internet (i.e., backbone ISPs, regional ISPs, and local ISPs) have in common with the topological structure of the telephone networks in the USA? How is pricing in the Internet the same as or different from pricing in the phone system.

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