Chapter 1 Review Questions

1. 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.

2. Suppose Alice, an ambassador of country A wants to invite Bob, an ambassador of country B, over for dinner. Alice doesn't simply just call Bob on the phone and say, "come to our dinner table now". Instead, she calls Bob and suggests a date and time. Bob may respond by saying he's not available that particular date, but he is available another date. Alice and Bob continue to send "messages" back and forth until they agree on a date and time. Bob then shows up at the embassy on the agreed date, hopefully not more than 15 minutes before or after the agreed time. Diplomatic protocols also allow for either Alice or Bob to politely cancel the engagement if they have reasonable excuses.

3. 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.

4. 1. Dial-up modem over telephone line: residential; 2. DSL over telephone line: residential or small office; 3. Cable to HFC: residential; 4. 100 Mbps switched Etherent: company; 5. Wireless LAN: mobile; 6. Cellular mobile access (for example, WAP): mobile

5. HFC bandwidth is shared among the users. On the downstream channel, all packets emanate from a single source, namely, the head end. Thus, there are no collisions in the downstream channel.

6. Current possibilities include: dial-up; DSL; cable modem; fiber-to-the-home.

7. Ethernet LANs have transmission rates of 10 Mbps, 100 Mbps, 1 Gbps and 10 Gbps. For an X Mbps Ethernet (where X = 10, 100, 1,000 or 10,000), a user can continuously transmit at the rate X Mbps if that user is the only person sending data. If there are more than one active user, then each user cannot continuously transmit at X Mbps.

8. Ethernet most commonly runs over twisted-pair copper wire and "thin" coaxial cable. It also can run over fibers optic links and thick coaxial cable.

9. 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. FTTH: 2-10Mbps upload; 10-20 Mbps download; bandwidth is not shared.

10. There are two most popular wireless Internet access technologies today:
   a) Wireless LAN
      In a wireless LAN, wireless users transmit/receive packets to/from a base station (wireless access point) within a radius of few tens of meters. The base station is typically connected to the wired Internet and thus serves to connect wireless users to the wired network.

   b) Wide-area wireless access network
      In these systems, packets are transmitted over the same wireless infrastructure used for cellular telephony, with the base station thus being managed by a telecommunications provider. This provides wireless access to users within a radius of tens of kilometers of the base station.

11. 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.

12. 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.

13. 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 *t1*, 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 $L/R_1 + L/R_2$.

14. 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.

15. a) 2 users can be supported because each user requires half of the link bandwidth.

   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.

   c) Probability that a given user is transmitting = 0.2

   d) 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.

16. 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.

17. Java Applet

18. 10msec; d/s; no; no

19. a) 500 kbps
    b) 64 seconds
    c) 100kbps; 320 seconds

20. End system A breaks the large file into chunks. To each chunk, it adds header generating multiple packets from the file. The header in each packet includes the address of the destination: end system B. The packet switch uses the destination address to determine the outgoing link. Asking which road to take is analogous to a packet asking which outgoing link it should be forwarded on, given the packet's address.

21. Java Applet

22. Five generic tasks are error control, flow control, segmentation and reassembly, multiplexing, and connection setup. Yes, these tasks can be duplicated at different layers. For example, error control is often provided at more than one layer.

23. 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.

24. Application-layer message: data which 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.

25. Routers process layers 1 through 3. (This is a little bit of a white lie, as modern routers sometimes act as firewalls or caching components, and process layer four as well.) Link layer switches process layers 1 through 2. Hosts process all five layers.

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

b)Worms

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

c) Trojan horse

Hidden, devious part of some otherwise useful software.

27. Creation of a botnet requires an attacker to find vulnerability in some application or system (e.g. exploiting the buffer overflow vulnerability that might exist in an application). After finding the vulnerability, the attacker needs to scan for hosts that are vulnerable. The target is basically to compromise a series of systems by exploiting that particular vulnerability. Any system that is part of the botnet can automatically scan its environment and propagate by exploiting the vulnerability. An important property of such botnets is that the originator of the botnet can remotely control and issue commands to all the nodes in the botnet. Hence, it becomes possible for the attacker to issue a command to all the nodes, that target a single node (for example, all nodes in the botnet might be commanded by the attacker to send a TCP SYN message to the target, which might result in a TCP SYN flood attack at the target).

28. Trudy can pretend to be Bob to Alice (and vice-versa) and partially or completely modify the message(s) being sent from Bob to Alice. For example, she can easily change the phrase "Alice, I owe you $1000" to "Alice, I owe you $10,000". Furthermore, Trudy can even drop the packets that are being sent by Bob to Alice (and vise-versa), even if the packets from Bob to Alice are encrypted.

Chapter 1 Problems

Problem 1

There is no single right answer to this question. Many protocols would do the trick. Here's a simple answer below:

Messages from ATM machine to Server

```
Msg name             purpose
--------             -------
HELO <userid>        Let server know that there is a card in the
                     ATM machine
                     ATM card transmits user ID to Server
PASSWD <passwd>      User enters PIN, which is sent to server
BALANCE              User requests balance
WITHDRAWL <amount>   User asks to withdraw money
BYE                  user all done
```

Messages from Server to ATM machine (display)

```
Msg name             purpose
--------             -------
PASSWD               Ask user for PIN (password)
OK                   last requested operation (PASSWD, WITHDRAWL)
                     OK
ERR                  last requested operation (PASSWD, WITHDRAWL)
                     in ERROR
AMOUNT <amt>         sent in response to BALANCE request
BYE                  user done, display welcome screen at ATM
```

Correct operation:

```
client                          server

HELO (userid)    --------------> (check if valid userid)
                 <-------------  PASSWD
PASSWD <passwd>  --------------> (check password)
                 <-------------  OK (password is OK)
BALANCE          -------------->
                 <-------------  AMOUNT <amt>
WITHDRAWL <amt>  --------------> check if enough $ to cover
                                 withdrawl
                 <-------------  OK
ATM dispenses $
BYE              -------------->
                 <-------------  BYE
```

In situation when there's not enough money:

```
HELO (userid)    --------------> (check if valid userid)
                 <-------------  PASSWD
PASSWD <passwd>  --------------> (check password)
                 <-------------  OK (password is OK)
BALANCE          -------------->
                 <-------------  AMOUNT <amt>
WITHDRAWL <amt>  --------------> check  if  enough  $  to  cover
withdrawl
                 <-------------  ERR (not enough funds)
error msg displayed
no $ given out
BYE              -------------->
                 <-------------  BYE
```

Problem 2

a) A circuit-switched network would be well suited to the application described, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session circuit with no significant waste. In addition, we need not worry greatly about the overhead costs of setting up and tearing down a circuit connection, which are amortized over the lengthy duration of a typical application session.

b) Given such generous link capacities, the network needs no congestion control mechanism. In the worst (most potentially congested) case, all the applications simultaneously transmit over one or more particular network links. However, since each link offers sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur.

Problem 3

a) We can have *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 4

Tollbooths are 75 km apart, and the cars propagate at 100km/hr. A tollbooth services a car at a rate of one car every 12 seconds.
a) There are ten cars. It takes 120 seconds, or 2 minutes, for the first tollbooth to service the 10 cars. Each of these cars has a propagation delay of 45 minutes (travel 75 km) before arriving at the second tollbooth. Thus, all the cars are lined up before the second tollbooth after 47 minutes. The whole process repeats itself for traveling between the second and third tollbooths. It also takes 2 minutes for the third tollbooth to service the 10 cars. Thus the total delay is 96 minutes.
b) Delay between tollbooths is 8*12 seconds plus 45 minutes, i.e., 46 minutes and 36 seconds. The total delay is twice this amount plus 8*12 seconds, i.e., 94 minutes and 48 seconds.

Problem 5

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

$$m = \frac{L}{R}s = \frac{120}{56 \times 10^3}\left(2.5 \times 10^8\right) = 536\,\text{km}.$$

Problem 6

Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

$$\frac{56 \cdot 8}{64 \times 10^3}\,\text{sec=7msec.}$$

The time required to transmit the packet is

$$\frac{56 \cdot 8}{2 \times 10^6}\,\text{sec}=224\mu\,\text{sec.}$$

Propagation delay = 10 msec.
The delay until decoding is

$$7\text{msec} + 224\mu\,\text{sec} + 10\text{msec} = 17.224\text{msec}$$

A similar analysis shows that all bits experience a delay of 17.224 msec.

Problem 7

a) 20 users can be supported.
b) $p = 0.1$.
c) $\binom{120}{n} p^n (1-p)^{120-n}$.
d) $1 - \sum_{n=0}^{20} \binom{120}{n} p^n (1-p)^{120-n}$.

We use the central limit theorem to approximate this probability. Let X_j be independent random variables such that $P(X_j = 1) = p$.

$$P(\text{ “21 or more users” }) = 1 - P\left(\sum_{j=1}^{120} X_j \le 21\right)$$

$$P\left(\sum_{j=1}^{120} X_j \le 21\right) = P\left(\frac{\sum_{j=1}^{120} X_j - 12}{\sqrt{120 \cdot 0.1 \cdot 0.9}} \le \frac{9}{\sqrt{120 \cdot 0.1 \cdot 0.9}}\right)$$

$$\approx P\left(Z \le \frac{9}{3.286}\right) = P(Z \le 2.74)$$
$$= 0.997$$

when Z is a standard normal r.v. Thus $P($ "21 or more users" $) \approx 0.003$.

Problem 8

a) 10,000

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

Problem 9

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 connecting the first and the second link requires L/R_2 to transmit the packet onto the second link; the packet propagates over the second link in d_2/s_2. Similarly, we can find the delay caused by the second switch and the third link: L/R_3, d_{proc}, and d_3/s_3.
Adding these five delays gives

$$d_{end\text{-}end} = L/R_1 + L/R_2 + L/R_3 + d_1/s_1 + d_2/s_2 + d_3/s_3 + d_{proc} + d_{proc}$$

To answer the second question, we simply plug the values into the equation to get 6 + 6 + 6 + 20+16 + 4 + 3 + 3 = 64 msec.

Problem 10

Because bits are immediately transmitted, the packet switch does not introduce any delay; in particular, it does not introduce a transmission delay. Thus,

$$d_{end\text{-}end} = L/R + d_1/s_1 + d_2/s_2 + d_3/s_3$$

For the values in Problem 9, we get 6 + 20 + 16 + 4 = 46 msec.

Problem 11

The arriving packet must first wait for the link to transmit 6,750 bytes or 54,000 bits. Since these bits are transmitted at 2 Mbps, the queuing delay is 27 msec. Generally, the queuing delay is (nL + (L - x))/R.

Problem 12

The queuing delay is 0 for the first transmitted packet, *L/R* for the second transmitted packet, and generally, *(n-1)L/R* for the n^{th} transmitted packet. Thus, the average delay for the *N* packets is

(L/R + 2L/R + ... + (N-1)L/R)/N
*= L/(RN) * (1 + 2 + ... + (N-1))*
*= L/(RN) * N(N-1)/2*
= LN(N-1)/(2RN)
= (N-1)L/(2R)

Note that here we used the well-known fact that

1 + 2 + ... + N = N(N+1)/2

Problem 13

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 14

a) The transmission delay is L/R. The total delay is

$$\frac{IL}{R(1-I)} + \frac{L}{R} = \frac{L/R}{1-I}$$

b) Let $x = L/R$.

$$\text{Total delay} = \frac{x}{1-ax}$$

Problem 15

$$\text{Total delay } = \frac{L/R}{1-I} = \frac{L/R}{1-aL/R} = \frac{1/\mu}{1-a/\mu} = \frac{1}{\mu-a}.$$

Problem 16

The total number of packets in the system includes those in the buffer and the pack is being transmitted. So, N=10+1.
Because $N = a \cdot d$, so (10+1)=a*(queuing delay + transmission delay). That is, 11=a*(0.01+1/100)=a*(0.01+0.01), thus, a=550 packets/sec.

Problem 17

a) There are Q nodes (the source host and the $Q-1$ routers). Let d_{proc}^{q} denote the processing delay at the qth node. Let R^{q} be the transmission rate of the qth link and let $d_{trans}^{q} = L / R^{q}$. Let d_{prop}^{q} be the propagation delay across the qth link. Then

$$d_{end-to-end} = \sum_{q=1}^{Q} \left[d_{proc}^{q} + d_{trans}^{q} + d_{prop}^{q} \right].$$

b) Let d_{queue}^{q} denote the average queuing delay at node q. Then

$$d_{end-to-end} = \sum_{q=1}^{Q} \left[d_{proc}^{q} + d_{trans}^{q} + d_{prop}^{q} + d_{queue}^{q} \right].$$

Problem 18

The command:

```
traceroute -q 20 www.eurecom.fr
```

will get 20 delay measurements from the issuing host to the host, www.eurecom.fr. The average and standard deviation of these 20 measurements can then be collected. Do you see any differences in your answers as a function of time of day?

Problem 19

Throughput = $min\{R_s, R_c, R/M\}$

Problem 20

If only use one path, the max throughput is given by
$\max\{\min\{R_1^1, R_2^1, \ldots, R_N^1\}, \min\{R_1^2, R_2^2, \ldots, R_N^2\}, \ldots, \min\{R_1^M, R_2^M, \ldots, R_N^M\}\}$.

If use all paths, the max throughput is given by $\sum_{k=1}^{M} \min\{R_1^k, R_2^k, \ldots, R_N^k\}$.

Problem 21

Probability of successfully receiving a packet is:
$p_s = (1-p)^N$.
The number of transmissions needs to be performed until the packet is successfully received by the client is a geometric random variable with success probability p_s.
Thus, the average number of transmissions needed is given by: $1/p_s$
Then, the average number of re-transmissions needed is given by: $1/p_s - 1$.

Problem 22

Lets call the first packet A and call the second packet B.
a). If the bottleneck link is the first link, then, packet B is queued at the first link waiting for the transmission of packet A. So, the packet inter-arrival time at the destination is simply L/R_s.

b). If the second link is the bottleneck link and since both packets are sent back to back, it must be true that the second packet arrives at the input queue of the second link before the second link finishes the transmission of the first packet. That is,
$L/R_s + L/R_s + d_{prop} < L/R_s + d_{prop} + L/R_c$ (1)
The left hand side of the above inequality represents the time needed by the second packet to *arrive at* the input queue of the second link (the second link has not started transmitting the second packet yet).
The right hand side represents the time needed by the first packet to finish its transmission onto the second link.

We know that (1) is possible as $R_c < R_s$. And it is clear that (1) shows that the second packet must have queuing delay at the input queue of the second link.
If we send the second packet *T* seconds later, then we can ensure the there is no queuing delay for the second packet at the second link if we have,
$L/R_s + L/R_s + d_{prop} + T >= L/R_s + d_{prop} + L/R_c$
Thus, T must be $L/R_c - L/R_s$.

Problem 23

40 terabytes = $40 * 10^{12} * 8$ bits.
So, if using the dedicated link, it will take $40 * 10^{12} * 8 / (100 * 10^6) = 3200000$ seconds = 37 days.

But with FedEx overnight delivery, you can guarantee the data arrives in one day, and it only costs you no more than $100.

Problem 24

a) 160,000 bits
b) 160,000 bits
c) The bandwidth-delay product of a link is the maximum number of bits that can be in the link.
d) the width of a bit = length of link / bandwidth-delay product, so 1 bit is 125 meters long, which is longer than a football field
e) *s/R*

Problem 25

s/R=20000km, then R=s/20000km= $2.5*10^8/(2*10^7)$= 12.5 bps

Problem 26

a) 80,000,000 bits
b) 800,000 bits, this is because that the maximum number of bits that will be in the link at any given time = min(bandwidth delay product, packet size) = 800,000 bits.
c) .25 meters

Problem 27

a) $t_{trans} + t_{prop}$ = 400 msec + 80 msec = 480 msec
b) 20 * (t_{trans} + 2 t_{prop}) = 20*(20 msec + 80 msec) = 2 sec

Problem 28

Recall geostationary satellite is 36,000 kilometers away from earth surface.
a) 150 msec
b) 1,500,000 bits
c) 600,000,000 bits

Problem 29

Let's suppose the passenger and his/her bags correspond to the data unit arriving to the top of the protocol stack. When the passenger checks in, his/her bags are checked, and a tag is attached to the bags and ticket. This is additional information added in the Baggage layer if Figure 1.20 that allows the Baggage layer to implement the service or separating the passengers and baggage on the sending side, and then reuniting them (hopefully!) on the destination side. When a passenger then passes through security, and additional stamp is often added to his/her ticket, indicating that the passenger has passed through a security check. This information is used to ensure (e.g., by later checks for the security information) secure transfer of people.

Problem 30

a) Time to send message from source host to first packet switch = $\frac{8\times10^6}{2\times10^6}\sec = 4\sec$. With store-and-forward switching, the total time to move message from source host to destination host = $4\sec\times 3\ hops = 12\sec$

b) Time to send 1st packet from source host to first packet switch = . $\frac{2\times10^3}{2\times10^6}\sec = 1\ m\sec$. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times1\ m\sec = 2\ m\sec$

c) Time at which 1st packet is received at the destination host = . $1\ m\sec\times 3\ hops = 3\ m\sec$. After this, every 1msec one packet will be received; thus time at which last (4000th) packet is received = $3\ m\sec + 3999 * 1m\sec = 4.002\sec$. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).

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 31

Java Applet

Problem 32

Time at which the 1st packet is received at the destination = $\frac{S+80}{R}\times 3$ sec. After this, one packet is received at destination every $\frac{S+80}{R}$ sec. Thus delay in sending the whole file =

$$delay = \frac{S+80}{R}\times 3 + (\frac{F}{S}-1)\times(\frac{S+80}{R}) = \frac{S+80}{R}\times(\frac{F}{S}+2)$$

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

$$\frac{d}{dS}delay = 0 \Rightarrow S = \sqrt{40F}$$