Computer Networking: A Top-Down Approach Featuring the Internet, 5th Edition

Solutions to Review Questions and Problems

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Chapter 1 Review Questions

1. 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.

2. 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.

3. 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

4. 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.

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

6. 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.

7. 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.

8. 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.

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.

10. 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.

11. 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 $L/R_1 + L/R_2$.

12. 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.

13. 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.

14. 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.

15. 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.

16. Java Applet

17. 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.

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

19. Java Applet

20. 10msec; d/s; no; no

21. 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.

22. 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.

23. 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.

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. 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.

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.

e) Trojan horse
Hidden, devious part of some otherwise useful software.

27. 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.

28. 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).

Chapter 1 Problems

Problem 1

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 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

Tollbooths are 100 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 two minutes, for the first tollbooth to service the 10 cars. Each of these cars has a propagation delay of 60 minutes before arriving at the second tollbooth. Thus, all the cars are lined up before the second tollbooth after 62 minutes. The whole process repeats itself for traveling between the second and third tollbooths. Thus the total delay is 124 minutes.

b) Delay between tollbooths is 7*12 seconds plus 60 minutes, i.e., 61 minutes and 24 seconds. The total delay is twice this amount, i.e., 122 minutes and 48 seconds.

Problem 4

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 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

$$m = \frac{L}{R} S = \frac{100}{28 \times 10^3}\left(2.5 \times 10^8\right) = 893\,\text{km}.$$

Problem 6

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

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

$$P(\text{ "11 or more users" }) = 1 - P\left(\sum_{j=1}^{40} X_j \le 10\right)$$

$$P\left(\sum_{j=1}^{40} X_j \le 10\right) = P\left(\frac{\sum_{j=1}^{40} X_j - 4}{\sqrt{40 \cdot 0.1 \cdot 0.9}} \le \frac{6}{\sqrt{40 \cdot 0.1 \cdot 0.9}}\right)$$

$$\approx P\left(Z \le \frac{6}{\sqrt{3.6}}\right) = P(Z \le 3.16)$$

$$= 0.999$$

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

Problem 7

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

$$\frac{48 \cdot 8}{64 \times 10^3}\ \text{sec=6msec.}$$

The time required to transmit the packet is

$$\frac{48 \cdot 8}{1 \times 10^6}\,\text{sec} = 384\mu\,\text{sec}.$$

Propagation delay = 2 msec.
The delay until decoding is

$$6\text{msec} + 384\mu\,\text{sec} + 2\text{msec} = 8.384\text{msec}$$

A similar analysis shows that all bits experience a delay of 8.384 msec.

Problem 8

a) 10,000

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

Problem 9

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

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

For the values in Problem 9, we get 8 + 16 + 4 = 28 msec.

Problem 10

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 11

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

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

Note that here we used the well-known fact that

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

Problem 12

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

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

To answer the second question, we simply plug the values into the equation to get 8 + 8 + 16 + 4 + 1 = 37 msec.

Problem 13

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

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

Let $x = L/R$.

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

Problem 14

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

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

b) Let d^q_{queue} denote the average queueing delay at node q. Then

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

Problem 15

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 16

The arriving packet must first wait for the link to transmit 3,500 bytes or 28,000 bits. Since these bits are transmitted at 1 Mbps, the queuing delay is 28 msec. Generally, the queuing delay is $[nL + (L - x)]/R$.

Problem 17

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

Problem 18

a) .25 meters
b) 40,000,000 bits
c) 400,000 bits

Problem 19

25 bps

Problem 20

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 21

a) $10 * (t_{trans} + 2\, t_{prop}) = 10*(40 \text{ msec} + 80 \text{ msec}) = 1.2 \text{ sec}$
b) $t_{trans} + t_{prop} = 400 \text{ msec} + 40 \text{ msec} = 440 \text{ msec}$

c) It takes a longer time to send the file if it is broken up into packets and each packet has to be acked before the next one can be sent out.

Problem 22

a) 150 msec
b) 1,500,000 bits
c) 600,000,000 bits

Problem 23

a) 40,000 bits
b) 40,000 bits
c) The bandwidth-delay product of a link is the maximum number of bits that can be in the link
d) 1 bit is 250 meters long, which is longer than a football field
e) *s/R*

Problem 24

a) Time to send message from source host to first packet switch = $\frac{7.5\times10^6}{1.5\times10^6}\sec = 5\sec$. With store-and-forward switching, the total time to move message from source host to destination host = $5\sec\times 3\ hops = 15\sec$
b) Time to send 1st packet from source host to first packet switch = . $\frac{1.5\times10^3}{1.5\times10^6}\sec = 1\ m\sec$. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times 1\ m\sec = 2\ m\sec$
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 (5000th) packet is received = $3\ m\sec + 4999 * 1 m\sec = 5.002\sec$. 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 25

Time at which the 1st packet is received at the destination = $\frac{S+40}{R}\times 2$ sec. After this, one packet is received at destination every $\frac{S+40}{R}$ sec. Thus delay in sending the whole file =

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

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

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

Problem 26

Java Applet