Chapter 1 Review Questions

1.

2.

3. Standards are important for protocols so that people can create networking systems and products that interoperate.

4. 1. Dial-up modem over telephone line: home; 2. DSL over telephone line: home or small office; 3. Cable to HFC: home; 4. 100 Mbps switched Ethernet: enterprise; 5. Wifi (802.11): home and enterprise: 6. 3G and 4G: wide-area wireless.

5. DSL or Digital Subscriber Line is one of the most prevalent types of broadband residential access. A residence typically obtains DSL Internet access from the same local telephone company that provides its wired local phone access

6.

7. **Ethernet LANs have transmission rates of 10 Mbps, 100 Mbps, 1 Gbps and 10 Gbps.**
8. The transmission rate of 3G is at least 1 Mbps and that of 4G is at least 10 Mbps.

9. Examples of guided media are: a fiber-optic cable, a twisted-pair copper wire, a coaxial cable etc. Examples of unguided media are: a wireless LAN, a digital satellite channel etc.

10.

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 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 $L/R_1 + L/R_2$.

12. For each attached link, the packet switch has an output queue, which stores packets that the router is about to send into that link. If an arriving packet needs to be

transmitted across a link but finds the link busy with the transmission of another packet, the arriving packet waits in the output buffer.

13. 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.

14. In FDM, a link dedicates a frequency band to each connection for the duration of the connection. For a TDM link, time is divided into frames of fixed duration, and each frame is divided into a fixed number of time slots. When the network establishes a connection across a link, the network dedicates one time slot in every frame to this connection.

15.

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.

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

19. a) 500 kbps

b) 64 seconds

c) 100kbps; 320 seconds

20.

22. A layered architecture allows us to discuss a well-defined, specific part of a large and complex system. This provides simple, logical and modular design. Further, as long as the layer provides the same service to the layer above it, and uses the same services from the layer below it, the remainder of the system remains unchanged when a layer’s implementation is changed.

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 network, link and physical layers (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 Transport layer as well.) Link layer switches process link and physical layers (layers 1 through2). Hosts process all five layers.

Chapter 1 Problems

Problem 2

a) The delay for each packet has to be multiplied by the number of packets. Hence the net delay would be PL/R.

b) When the first node sends the P-th packet to the second node, thereby incurring a net delay of PL/R, the second node sends the (P-1)-th packet to the third node. Hence an additional delay of L/R would be incurred for sending the P-th packet from the second node to the third node. Thus, the net delay would be (P+1)L/R.

c) Following the same logic as in b) above, for N links, there would be (N-1) intermediate nodes and hence the net delay would be (P+N-1)L/R.

Problem 5

Each circuit has a transmission rate of (1.536 Mbps)/12 = 128 kbps, so it takes (160,000 bits)/(128 kbps) = 1.25 seconds to transmit the file. To this, we add the circuit establishment time of 0.6 seconds, giving a total of 1.85 seconds to send the file.

Problem 6

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

$$m = \frac{L}{R}s = \frac{120}{56\times10^3}\left(2.5\times10^8\right) = 536\,\text{km}.$$

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

$$\frac{64\times8}{128\times10^3}\text{ sec = 4 msec.}$$

The time required to transmit the packet is

$$\frac{64\times8}{4\times10^6}\text{ sec }=128\mu\text{ sec.}$$

Propagation delay = 8 msec.

The delay until decoding is

$$4\text{ msec }+128\mu\text{ sec + 8 msec = 12.128 msec}$$

A similar analysis shows that all bits experience the same delay of 12.128 msec.

Problem 10

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 11

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 10, we get 6 + 20 + 16 + 4 = 46 msec.

Problem 20

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

Problem 25

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 31

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 = . $\frac{1\times10^4}{2\times10^6}\sec = 5\ m\sec$. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times 5m\sec = 10\ m\sec$

c) Time at which 1st packet is received at the destination host = $5\ m\sec\times 3\ hops = 15\ m\sec$. After this, every 5msec one packet will be received; thus time at which last (800th) packet is received = $15\ m\sec + 799 * 5m\sec = 4.01\sec$. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).