Chapter 1

14. The propagation delay is the time that is required for the energy of a signal to propagate from one point to another.

a. Find the propagation delay for a signal traversing the following networks at the speed of light in cable (2.3 x 10^8 meters/second):

- a circuit board 10 cm
- a room 10 m
- a building 100 m
- a metropolitan area 100 km
- a continent 5000 km
- up and down to a geostationary satellite 2 x 36000 km

Solution:

To find the propagation delay, divide distance by the speed of light in cable. Thus we have:

- a circuit board t_{prop} = 4.347 x 10^{-10} seconds
- a room t_{prop} = 4.3478 x 10^{-8} seconds
- a building t_{prop} = 4.3478 x 10^{-7} seconds
- a metropolitan area t_{prop} = 4.3478 x 10^{-4} seconds
- a continent t_{prop} = 0.02174 seconds
- up and down to a geostationary satellite t_{prop} = 0.31304 seconds

14b. How many bits are in transit during the propagation delay in the above cases, if bits are entering the above networks at the following transmission speeds: 10,000 bits/second; 1 megabit/second; 100 megabits/second; 10 gigabits/second.

Solution:

The number of bits in transit is obtained by multiplying the transmission rate *R* by the propagation delay:

Distance (m)	10 Kbps	1 Mbps	100 Mbps	10 Gbps
0.1	4.347 x 10^{-6}	4.347 x 10^{-4}	0.04347	4.3478
10	4.3478 x 10^{-4}	0.043478	4.3478	434.780
100	4.3478 x 10^{-3}	0.43478	43.478	4347.800
100 000	4.3478	434.78	43478	4.3478x10^6
5 000 000	217.4	21740	2174000	2.174x10^8
72 000 000	3130.4	313040	31304000	3.1304x10^9

15. In problem 14, how long does it take to send an L-byte file and to receive a 1-byte acknowledgment back? Let L=1, 10^3, 10^6, and 10^9 bytes.

Solution:

The total time required to send a file and receive an acknowledgment of its receipt is given by:

$t_{total} = L_{message}/R + L_{ack}/R + 2^* t_{prop} = L_{message}/R + L_{ack}/R + 2^*d/c$

where $L_{message}$ is the message length in bits, L_{ack} is the acknowledgment length in bits, R is the transmission bit rate, d is the distance traversed, and c is the speed of light. The above equation shows that there are two main factors that determine total delay:

1. Message and ACK transmission time, which depends on the message length and the transmission bit rate;

2. Propagation delay, which depends solely on distance.

When the propagation delay is small, message and ACK transmission times determine the total delay. On the other hand, when the bit rate becomes very large, the propagation delay provides a delay component that cannot be reduced no matter how fast the transmission rate becomes.

Chapter 2

11(a). Can a connection-oriented, reliable message transfer service be provided across a connectionless packet network? Explain.

Solution:

Yes. To provide a connection-oriented service, the transport layer can establish a logical connection across the connectionless packet network by setting up state information (for example, packet sequence number) at the end systems. During the connection setup, the message is broken into separate packets, and each packet is assigned a sequence number.

Using the sequence numbers, the end-system transport-layer entities can acknowledge received packets, determine and retransmit lost packets, delete duplicate packets, and rearrange out-of-order packets. The original message is reassembled as packets arrive at the receiving end.

For example, TCP provides a connection-oriented reliable transfer service over IP, a connectionless packet transfer service.

11b. Can a connectionless datagram transfer service be provided across a connection-oriented network?

Solution:

Yes. The connectionless datagram transfer service can be implemented by simply setting up a connection across the network each time a datagram needs to be transferred. Alternatively, all nodes can have permanent connections to a "connectionless server" that has the function of relaying datagrams in connectionless fashion.

17. Suppose all laptops in a large city are to communicate using radio transmissions from a high antenna tower. Is the data link layer or network layer more appropriate for this situation?

Solution:

The data link layer is concerned with the transfer of frames of information across a single hop. The network layer involves the transfer of information across a network using multiple hops per path in general. The connection from a radio antenna to the laptops is direct, and thus a data link layer protocol is more suitable for this situation.

Now suppose the city is covered by a large number of small antennas covering smaller areas. Which layer is more appropriate?

A number of areas each covered by small antennas can be interconnected using the "bridging" approach of problem 16, which remains in the data link layer. However, the network layer may be more appropriate because it provides for the transfer of data in the form of packets across the communication network. A key aspect of this transfer is the routing of the packets from the source machine to the destination machine, typically traversing a number of transmission link and network nodes where routing is carried out.

19. Suppose an application layer entity wants to send an L-byte message to its peer process, using an existing TCP connection. The TCP segment consists of the message plus 20 bytes of header. The segment is encapsulated into an IP packet that has an additional 20 bytes of header. The IP packet in turn goes inside an Ethernet frame that has 18 bytes of header and trailer. What percentage of the transmitted bits in the physical layer correspond to message information, if $L = 100$ bytes, 500 bytes, 1000 bytes?

Solution:

TCP/IP over Ethernet allows data frames with a payload size up to 1460 bytes. Therefore, $L = 100$, 500 and 1000 bytes are within this limit.

The message overhead includes:

- TCP: 20 bytes of header
- IP: 20 bytes of header
- Ethernet: total 18 bytes of header and trailer.

Therefore

$L = 100$ bytes, 100/158 = 63% efficiency.

$L = 500$ bytes, 500/558 = 90% efficiency.

$L = 1000$ bytes, 1000/1058 = 95% efficiency.

20. Suppose that the TCP entity receives a 1.5 megabyte file from the application layer and that the IP layer is willing to carry blocks of maximum size 1500 bytes. Calculate the amount of overhead incurred from segmenting the file into packet-sized units.

Solution:

1500 - 20 -20 = 1460 bytes

1.5 Mbyte / 1460 byte = 1027.4, therefore 1028 blocks are needed to transfer the file.

Overhead = ((1028 x 1500 - 1.5M)/1.5M) x 100 = 2.8%

Chapter 6

4. Suppose that the ALOHA protocol is used to share a 56 kbps satellite channel. Suppose that frames are 1000 bits long. Find the maximum throughput of the system in frames/second.

Solution:

Maximum throughput for ALOHA = 0.184
Maximum throughput in frames/sec = (56000 bits/sec) x (1 frame/1000 bits) x 0.184 = 10.304
The maximum throughput is approximately 10 frames/sec.

5. Let G be the total rate at which frames are transmitted in a slotted ALOHA system. What proportion of slots goes empty in this system? What proportion of slots go empty when the system is operating at its maximum throughput? Can observations about channel activity be used to determine when stations should transmit?

Solution:

Proportion of empty slots = P[0 transmission] = $[G^0/0!]e^{-G} = e^{-G}$

Maximum throughput = 0.368; $G_{mt} = 1$
Proportion of empty slots at maximum throughput = e^{-1} = 0.368

Any attempt to decrease the proportion of empty slots below e^{-1} is counterproductive as this action will push the throughput below its maximum value.

9. In a LAN, which MAC protocol has a higher efficiency: ALOHA or CSMA-CD? What about in a WAN?

Solution:

The maximum efficiency achieved by the Slotted ALOHA is 0.368. The efficiency of CSMA-CD is given by $1/(1 + 6.4a)$, and is sensitive to $a = t_{prop}R/L$, the ratio between delay-bandwidth product and frame length.

In a LAN environment, the end-to-end distance is around 100m and the transmission rates are typically 10Mbps, 100Mbps and 1Gbps (See Table 6.1). An Ethernet frame has a maximum length of 1500 bytes = 12,000 bits.

The table shows the efficiency of CSMA-CD at various transmission rate. Assume L = 12,000 bits and propagation speed of 3×10^8.

	a	Efficiency
10 Mbps	3×10^{-4}	0.998
100 Mbps	3×10^{-3}	0.981
1 Gbps	3×10^{-2}	0.839

Note however that if shorter frame sizes predominate, e.g. 64 byte frames, then a increases by a factor of about 20. According to the above formula the efficiency of CSMA-CD at 1 Gbps then drops to about 0.7. The situation however is worse in that the minimum frame size at 1 Gbps needs to be extended to 512 bytes, as discussed in page 436 of the text.

In a WAN environment d is larger. Assuming 100 Km, a is larger by a factor of 10^3 resulting in an efficiency of 0.36, 0.05, and 0.005 respectively for 10 Mbps, 100 Mbps, and 1 Gbps transmission rates. In the case of 10 Mbps transmission rate the efficiency of CSMA-CD is close to the efficiency of ALOHA but in the other two cases it is much less than ALOHA.