CHAPTER 12

Multiple Access

Solutions to Review Questions and Exercises

Review Questions

1. The three categories of multiple access protocols discussed in this chapter are ***random access***, ***controlled access***, and ***channelization***.
2. In ***random access*** methods, no station is superior to another station and none is assigned the control over another. Each station can transmit when it desires on the condition that it follows the predefined procedure. Three common protocols in this category are ***ALOHA***, ***CSMA/CD***, and ***CSMA/CA***.
3. In ***controlled access methods***, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations. We discuss three popular controlled-access methods: ***reservation***, ***polling***, and ***token passing***.
4. ***Channelization*** is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. The common protocols in this category are ***FDMA***, ***TDMA***, and ***CDMA***.
5. In ***random access*** methods, there is no access control (as there is in controlled access methods) and there is no predefined channels (as in channelization). Each station can transmit when it desires. This liberty may create ***collision***.
6. In a ***random access*** method, there is no control; access is based on ***contention***. In a ***controlled access*** method, either a central authority (in polling) or other stations (in reservation and token passing) control the access. Random access methods have less administration overhead. On the other hand, controlled access method are collision free.
7. In a ***random access*** method, the whole available bandwidth belongs to the station that wins the contention; the other stations needs to wait. In a ***channelization*** method, the available bandwidth is divided between the stations. If a station does not have data to send, the allocated channel remains idle.
8. In a ***controlled access*** method, the whole available bandwidth belongs to the station that is granted permission either by a central authority or by other stations. In a ***channelization*** method, the available bandwidth is divided between the stations. If a station does not have data to send the allocated channel remains idle.

9. We do not need a multiple access method in this case. The local loop provides a dedicated ***point-to-point*** connection to the telephone office.
10. We do need a multiple access, because a channel in the CATV band is normally shared between several neighboring customers. The cable company uses the ***random access*** method to share the bandwidth between neighbors.

Exercises

11. To achieve the maximum efficiency in pure ALOHA, G = 1/2. If we let ***ns*** to be the number of stations and ***nfs*** to be the number of frames a station can send per second.

$$G = \boldsymbol{ns} \times \boldsymbol{nfs} \times T_{fr} = 100 \times \boldsymbol{nfs} \times 1\ \mu s = 1/2 \quad \rightarrow \quad \boldsymbol{nfs} = \mathbf{5000\ frames/s}$$

The reader may have noticed that the T_{fr} is very small in this problem. This means that either the data rate must be very high or the frames must be very small.

12. To achieve the maximum efficiency in slotted ALOHA, G = 1. If we let ***ns*** to be the number of stations and ***nfs*** to be the number of frames a station can send per second.

$$G = \boldsymbol{ns} \times \boldsymbol{nfs} \times T_{fr} = 100 \times \boldsymbol{nfs} \times 1\ \mu s = 1 \quad \rightarrow \quad \boldsymbol{nfs} = \mathbf{10{,}000\ frames/s}$$

The reader may have noticed that the T_{fr} is very small in this problem. This means that either the data rate must be very high or the frames must be very small.

13. We can first calculate T_{fr} and G, and then the throughput.

$$T_{fr} = (1000\text{ bits}) / 1\text{ Mbps} = 1\text{ ms}$$

$$G = \boldsymbol{ns} \times \boldsymbol{nfs} \times T_{fr} = 100 \times 10 \times 1\text{ ms} = 1$$

$$\text{For } \mathbf{pure\ ALOHA} \rightarrow \quad S = G \times e^{-2G} \approx \mathbf{13.53\ percent}$$

This means that each station can successfully send only 1.35 frames per second.

14. We can first calculate T_{fr} and G, and then the throughput.

$$T_{fr} = (1000\text{ bits}) / 1\text{ Mbps} = 1\text{ ms}$$

$$G = \boldsymbol{ns} \times \boldsymbol{nfs} \times T_{fr} = 100 \times 10 \times 1\text{ ms} = 1$$

$$\text{For } \mathbf{slotted\ ALOHA} \rightarrow \quad S = G \times e^{-G} \approx \mathbf{36.7\ percent}$$

This means that each station can successfully send only 3.67 frames per second.

15. Let us find the relationship between the minimum frame size and the data rate. We know that

$$T_{fr} = (\text{frame size}) / (\text{data rate}) = 2 \times T_p = 2 \times \text{distance} / (\text{propagation speed})$$

or

$$(\text{frame size}) = [2 \times (\text{distance}) / (\text{propagation speed})] \times (\text{data rate})]$$

or

$$\mathbf{(frame\ size) = K \times (data\ rate)}$$

This means that minimum frame size is proportional to the data rate (K is a constant). When the data rate is increased, the frame size must be increased in a network with a fixed length to continue the proper operation of the CSMA/CD. In Example 12.5, we mentioned that the minimum frame size for a data rate of 10 Mbps is 512 bits. We calculate the minimum frame size based on the above proportionality relationship

Data rate =	10 Mbps	→	minimum frame size = **512 bits**
Data rate =	100 Mbps	→	minimum frame size = **5120 bits**
Data rate =	1 Gbps	→	minimum frame size = **51,200 bits**
Data rate =	10 Gbps	→	minimum frame size = **512,000 bits**

16. Let us find the relationship between the collision domain (maximum length of the network) and the data rate. We know that

$$T_{fr} = \text{(frame size) / (data rate)} = 2 \times T_p = 2 \times \text{distance / (propagation speed)}$$

or

$$\text{distance} = [\text{(frame size) (propagation speed)}] / [2 \times \text{(data rate)}]$$

or

$$\textbf{distance = K / (data rate)}$$

This means that distance is inversely proportional to the data rate (K is a constant). When the data rate is increased, the distance or maximum length of network or collision domain is decreased proportionally. In Example 12.5, we mentioned that the maximum distance for a data rate of 10 Mbps is 2500 meters. We calculate the maximum distance based on the above proportionality relationship.

Data rate =	10 Mbps	→	maximum distance = **2500 m**
Data rate =	100 Mbps	→	maximum distance = **250 m**
Data rate =	1 Gbps	→	maximum distance = **25 m**
Data rate =	10 Gbps	→	maximum distance = **2.5 m**

This means that when the data rate is very high, it is almost impossible to have a network using CSMA/CD.

17. We have $t_1 = 0$ and $t_2 = 3\ \mu s$
   a. $t_3 - t_1 = (2000\text{ m}) / (2 \times 10^8\text{ m/s}) = 10\ \mu s \rightarrow t_3 = 10\ \mu s + t_1 =$ **$10\ \mu s$**
   b. $t_4 - t_2 = (2000\text{ m}) / (2 \times 10^8\text{ m/s}) = 10\ \mu s \rightarrow t_4 = 10\ \mu s + t_2 =$ **$13\ \mu s$**
   c. $T_{fr(A)} = t_4 - t_1 = 13 - 0 = 13\ \mu s \rightarrow Bits_A = 10\text{ Mbps} \times 13\ \mu s =$ **130 bits**
   d. $T_{fr(C)} = t_3 - t_2 = 10 - 3 = 07 \mu s \rightarrow Bits_C = 10\text{ Mbps} \times 07\ \mu s =$ **70 bits**
18. We have $t_1 = 0$ and $t_2 = 3\ \mu s$
   a. $t_3 - t_1 = (2000\text{ m}) / (2 \times 10^8\text{ m/s}) = 10\ \mu s \rightarrow t_3 = 10\ \mu s + t_1 =$ **$10\ \mu s$**
   b. $t_4 - t_2 = (2000\text{ m}) / (2 \times 10^8\text{ m/s}) = 10\ \mu s \rightarrow t_4 = 10\ \mu s + t_2 =$ **$13\ \mu s$**
   c. $T_{fr(A)} = t_4 - t_1 = 13 - 0 = 13\ \mu s \rightarrow Bits_A = 100\text{ Mbps} \times 13\ \mu s =$ **1300 bits**
   d. $T_{fr(C)} = t_3 - t_2 = 10 - 3 = 07\ \mu s \rightarrow Bits_C = 100\text{ Mbps} \times 07\ \mu s =$ **700 bits**

Note that in this case, both stations have already sent more bits than the minimum number of bits required for detection of collision. The reason is that with the 100 Mbps, the minimum number of bits requirement is feasible only when the maximum distance between stations is less than or equal to 250 meters as we will see in Chapter 13.

19. See Figure 12.1.

Figure 12.1 *Solution to Exercise 19*

$$W_8 = \begin{bmatrix} +1 & +1 & +1 & +1 & +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 & +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 & +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 & +1 & -1 & -1 & +1 \\ +1 & +1 & +1 & +1 & -1 & -1 & -1 & -1 \\ +1 & -1 & +1 & -1 & -1 & +1 & -1 & +1 \\ +1 & +1 & -1 & -1 & -1 & -1 & +1 & +1 \\ +1 & -1 & -1 & +1 & -1 & +1 & +1 & -1 \end{bmatrix}$$

20. See Figure 12.2.

Figure 12.2 *Solution to Exercise 20*

$$W_1 = \begin{bmatrix} -1 \end{bmatrix} \qquad W_2 = \begin{bmatrix} -1 & -1 \\ -1 & +1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} -1 & -1 & -1 & -1 \\ -1 & +1 & -1 & +1 \\ -1 & -1 & +1 & +1 \\ -1 & +1 & +1 & -1 \end{bmatrix}$$

21.

Third Property: we calculate the inner product of each row with itself:

Row 1 • Row 1	[+1 +1 +1 +1]	•	[+1 +1 +1 +1]	= +1 + 1 + 1 + 1 = **4**
Row 2 • Row 2	[+1 −1 +1 −1]	•	[+1 −1 +1 −1]	= +1 + 1 + 1 + 1 = **4**
Row 3 • Row 1	[+1 +1 −1 −1]	•	[+1 +1 −1 −1]	= +1 + 1 + 1 + 1 = **4**
Row 4 • Row 4	[+1 −1 −1 +1]	•	[+1 −1 −1 +1]	= +1 + 1 + 1 + 1 = **4**

Fourth Property: we need to prove 6 relations:

Row 1 • Row 2	[+1 +1 +1 +1]	•	[+1 −1 +1 −1]	= +1 − 1 + 1 − 1 = **0**
Row 1 • Row 3	[+1 +1 +1 +1]	•	[+1 +1 −1 −1]	= +1 + 1 − 1 − 1 = **0**
Row 1 • Row 4	[+1 +1 +1 +1]	•	[+1 −1 −1 +1]	= +1 − 1 − 1 + 1 = **0**
Row 2 • Row 3	[+1 −1 +1 −1]	•	[+1 +1 −1 −1]	= +1 − 1 − 1 + 1 = **0**
Row 2 • Row 4	[+1 −1 +1 −1]	•	[+1 −1 −1 +1]	= +1 + 1 − 1 − 1 = **0**
Row 3 • Row 4	[+1 +1 −1 −1]	•	[+1 −1 −1 +1]	= +1 − 1 + 1 − 1 = **0**

22.

Third Property: we calculate the inner product of each row with itself:

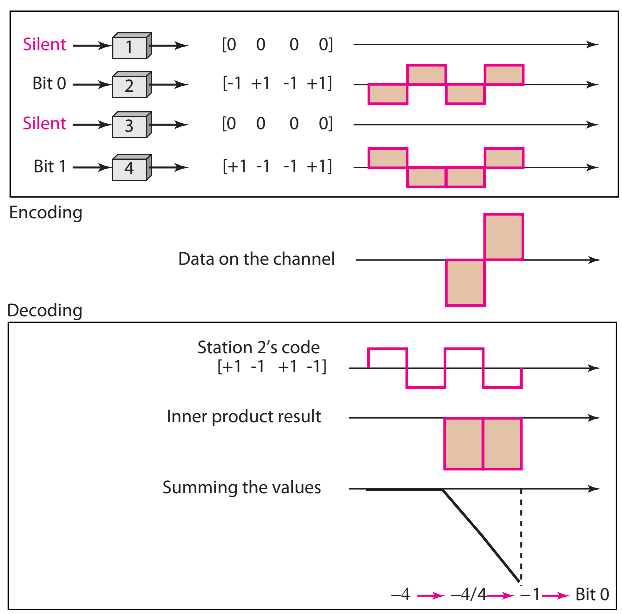
Row 1 • Row 1	[−1 −1 −1 −1]	•	[−1 −1 −1 −1]	= +1 + 1 + 1 + 1 = **4**
Row 2 • Row 2	[−1 +1 −1 +1]	•	[−1 +1 −1 +1]	= +1 + 1 + 1 + 1 = **4**
Row 3 • Row 1	[−1 −1 +1 +1]	•	[−1 −1 +1 +1]	= +1 + 1 + 1 + 1 = **4**
Row 4 • Row 4	[−1 +1 +1 −1]	•	[−1 +1 +1 −1]	= +1 + 1 + 1 + 1 = **4**

Fourth Property: we neede to prove 6 relations:

Row 1 • Row 2	[−1 −1 −1 −1]	•	[−1 +1 −1 +1]	= +1 − 1 + 1 − 1 = **0**
Row 1 • Row 3	[−1 −1 −1 −1]	•	[−1 −1 +1 +1]	= +1 + 1 − 1 − 1 = **0**
Row 1 • Row 4	[−1 −1 −1 −1]	•	[−1 +1 +1 −1]	= +1 − 1 − 1 + 1 = **0**
Row 2 • Row 3	[−1 +1 −1 +1]	•	[−1 −1 +1 +1]	= +1 − 1 − 1 + 1 = **0**
Row 2 • Row 4	[−1 +1 −1 +1]	•	[−1 +1 +1 −1]	= +1 + 1 − 1 − 1 = **0**
Row 3 • Row 4	[−1 −1 +1 +1]	•	[−1 +1 +1 −1]	= +1 − 1 + 1 − 1 = **0**

23. Figure 12.3 shows the encoding, the data on the channel, and the decoding.

Figure 12.3 *Solution to Exercise 23*



24. We can say:

Polling and Data Transfer
Station 1: [poll + 5 × (frame + ACK)]
Station 2: [poll + 5 × (frame + ACK)]
Station 3: [poll + 5 × (frame + ACK)]
Station 4: [poll + 5 × (frame + ACK)]
Polling and Sending NAKs
Station 1: [poll + NAK]
Station 2: [poll + NAK]
Station 3: [poll + NAK]
Station 4: [poll + NAK]
Total Activity:
8 polls + 20 frames + 20 ACKs + 4 NAKs = **21024 bytes**
We have 1024 bytes of overhead.

25. We can say:

Polling and Data Transfer
Frame 1 for all four stations: 4 × [poll + frame + ACK)]
Frame 2 for all four stations: 4 × [poll + frame + ACK)]
Frame 3 for all four stations: 4 × [poll + frame + ACK)]
Frame 4 for all four stations: 4 × [poll + frame + ACK)]
Frame 5 for all four stations: 4 × [poll + frame + ACK)]
Polling and Sending NAKs
Station 1: [poll + NAK]
Station 2: [poll + NAK]
Station 3: [poll + NAK]
Station 4: [poll + NAK]
Total Activity:
24 polls + 20 frames + 20 ACKs + 4 NAKs = **21536 bytes**
We have 1536 bytes of overhead which is 512 bytes more than the case in Exercise 23. The reason is that we need to send 16 extra polls.