CHAPTER 12

PRACTICE SET

Questions

Q12-1. The answer is *CSM/CD*.

- **a.** CSMA/CD is a random-access protocol.
- **b.** Polling is a controlled-access protocol.
- **c.** TDMA is a channelization protocol.

Q12-3. The answer is CDMA.

- **a.** ALOHA is a random-access protocol.
- **b.** Token-passing is a controlled-access protocol.
- **c.** CDMA is a channelization protocol.

Q12-5. The transmission rate of this network is T_{fr} = (1000 bits)/(1Mbps) = 1 ms. The vulnerable time in slotted Aloha is T_{fr} = 1ms.

Q12-7. In a slotted Aloha, the throughput at G = 1/2 is 30.2%.

- **a.** When G = 1, the throughput is increased to the maximum value of 36.8%.
- **b.** When G = 1/4, the throughput is increased to 32.1%

Q12-9. The use of K in Figure 12.13 decreases the probability that a station can immediately send when the number of failures increases. This means decreasing the probability of collision.

- **a.** After one failure (K = 1), the value of R is 0 or 1. The probability that the station gets R = 0 (send immediately) is 1/2 or 50%.
- **b.** After four failures (K = 4), the value of R is 0 to 15. The probability that the station gets R = 0 (send immediately) is 1/16 or 6.25%.

Q12-11. *Success* in an Aloha network is interpreted as receiving an acknowledgment for a frame.

Q12-13. *Success* in an CSMA/CA network is interpreted as receiving an acknowledgment for a frame.

Q12-15. The sender needs to detect the collision before the last bit of the frame is sent out. If the collision occurs near the destination, it takes $2 \times 3 = 6$ μs for the collision news to reach the sender. The sender has already sent out the whole frame; it is not listening for a collision anymore.

Q12-17. In random-access methods, there is no control over the medium access. Each station can transmit when it desires. This liberty may create collisions. In controlled-access methods, the access to the medium is controlled, either by an authority or by the priority of the station. There is no collision.

Q12-19. The last bit is 10 μs behind the first bit.

a. It takes 5 μs for the first bit to reach the destination.

b. The last bit arrives at the destination 10 μs after the first bit.

c. The network is involved with this frame for $5 + 10 = 15$ μs.

Q12-21. We can mention the following strategies:

a. It uses the combination of RTS and CTS frames to warn other stations that a new station will be using the channel.

b. It uses NAV to prevent other stations to transmit.

c. It uses acknowledgments to be sure the data has arrived and there is no need for resending the data.

Q12-23. In CSMA/CD, the lack of detecting collision before the last bit of the frame is sent out is interpreted as an acknowledgment. In CSMA/CA, the sender cannot sense collision; there is a need for explicit acknowledgments.

Problems

P12-1. In both pure and slotted Aloha networks, the average number of frames created during a frame transmission time (T_{fr}) is G.

a. For a pure Aloha network, the vulnerable time is ($2 \times T_{fr}$), which means that $\lambda = 2G$.

$$p[x] = (e^{-\lambda} \times \lambda^x) / (x!) = (e^{-2G} \times (2G)^x) / (x!)$$

b. For a slotted Aloha network, the vulnerable time is (T_{fr}), which means that $\lambda = G$.

$$p[x] = (e^{-\lambda} \times \lambda^x) / (x!) = (e^{-G} \times (G)^x) / (x!)$$

P12-3. The throughput for each network is S = G × P[success for a frame].

a. For a pure Aloha network, P[success for a frame] = e^{-2G}.

$$S = G \times P[\text{success for a frame}] = Ge^{-2G}$$

b. For a pure Aloha network, P[success for a frame] = e^{-G}.

$$S = G \times P[\text{success for a frame}] = Ge^{-G}$$

P12-5. We can find the probability for each network type separately:

a. In a pure Aloha network, a station can send a frame successfully if no other station has a frame to send during two frame transmission times (vulnerable time). The probability that a station has no frame to send is $(1 - p)$. The probability that none of the $N - 1$ stations have a frame to send is definitely $(1 - p)^{N - 1}$. The probability that none of the $N - 1$ stations have a frame to send during a vulnerable time is $(1 - p)^{2(N - 1)}$. The probability of success for a station is then

$$P[\text{success for a particular station}] = p\,(1 - p)^{2(N - 1)}$$

b. In a slotted Aloha network, a station can send a frame successfully if no other station has a frame to send during one frame transmission time (vulnerable time).

$$P[\text{success for a particular station}] = p\,(1 - p)^{(N - 1)}$$

P12-7. To find the value of p that maximizes the throughput, we need to find the derivative of S with respect to p, dS/dp, and set the derivative to zero. Note that for large N, we can say $N - 1 \approx N$.

a. The following shows that, in a pure Aloha network, for a maximum throughput $p = 1/(2N)$ and the value of the maximum throughput for a large N is $S_{max} = e^{-1}/ 2$, as we found using the Poisson distribution:

$$S = Np\,(1-p)^{2(N-1)} \;\rightarrow\; dS/dp = N\,(1-p)^{2(N-1)} - 2Np(N - 1)(1-p)^{2(N-1) - 1}$$

$$dS/dp = 0 \;\rightarrow\; (1-p) - 2(N - 1)p = 0 \;\rightarrow\; p = 1 / (2N - 1) \approx 1 / (2N)$$

$$S_{max} = N[1/(2N)]\,[1 - 1/(2N)]^{2N} = (1/2)\,[1 - 1/(2N)]^{2N} = (1/2)\,e^{-1}$$

b. The following shows that, in a slotted Aloha network, for a maximum throughput $p = 1/N$ and the value of the maximum throughput for a large N is $S_{max} = e^{-1}$, as we found using the Poisson distribution:

$$S = Np\,(1-p)^{(N-1)} \;\rightarrow\; dS/dp = N\,(1-p)^{(N-1)} - Np(N - 1)(1-p)^{(N-1) - 1}$$

$$dS/dp = 0 \;\rightarrow\; (1-p) - (N-1)p = 0 \;\rightarrow\; p = 1/N.$$

$$S_{max} = N[1/(N)]\,[1 - 1/(N)]^N = [1 - 1/(N)]^N = e^{-1}$$

P12-9. We first find the probability of success for each station in any slot (P_{SA}, P_{SB}, and P_{SC}). A station is successful in sending a frame in any slot if it has a frame to send and the other stations do not.

$$P_{SA} = (p_A)\,(1 - p_B)\,(1 - p_C) = (0.2)\,(1 - 0.3)\,(1 - 0.4) = 0.084$$

$$P_{SB} = (p_B)\,(1 - p_A)\,(1 - p_C) = (0.3)\,(1 - 0.2)\,(1 - 0.4) = 0.144$$

$$P_{SC} = (p_C)\,(1 - p_A)\,(1 - p_B) = (0.4)\,(1 - 0.2)\,(1 - 0.3) = 0.224$$

We then find the probability of failure for each station in any slot (P_{FA}, P_{FB}, and P_{FC}).

$$P_{FA} = (1 - P_{SA}) = 1 - 0.084 = 0.916$$

$$P_{FB} = (1 - P_{SB}) = 1 - 0.144 = 0.856$$

$$P_{FC} = (1 - P_{SC}) = 1 - 0.224 = 0.776$$

a. Probability of success for any frame in any slot is the sum of probabilities of success.

$$P[\text{success in first slot}] = P_{SA} + P_{SB} + P_{SC} = (0.084) + (0.144) + (0.224) \approx 0.452$$

b. Probability of success for the first time in the second slot is the product of failure in the first and success in the second.

$$P[\text{success in second slot for A}] = P_{FA} \times P_{SA} = (0.916) \times (0.084) \approx 0.077$$

c. Probability of success for the first time in the third slot is the product of failure in two slots and success in the third.

$$P[\text{success in third slot for C}] = P_{FC} \times P_{FC} \times P_{SC} = (0.776)^2 \times (0.224) \approx 0.135$$

P12-11. The data rate (R) defines how many bits are generated in one second and the propagation speed (V) defines how many meters each bit is moving per second. Therefore, the number of bits in each meter $n_{b/m} = R / V$. In this case,

$$n_{b/m} = R / V = (100 \times 10^6 \text{ bits/s}) / (2 \times 10^8 \text{ m/s}) = 1/2 \text{ bits/m}.$$

P12-13. Let L_m be the length of the medium in meters, V the propagation speed, R the data rate, and $n_{b/m}$ the number of bits that can fit in each meter of the medium (defined in the previous problems). We can then proceed as follows:

$$a = (T_p) / (T_{fr}) = (L_m / V) / (F_b / R) = (L_m / F_b) \times (R / V)$$

We have $(R / V) = n_{b/m} \rightarrow a = (L_m / F_b) \times (n_{b/m})$

Since $L_b = L_m \times n_{b/m} \rightarrow a = (L_b / F_b)$

P12-15. The propagation delay for this network is $T_p = (2000 \text{ m}) / (2 \times 10^8 \text{ m/s}) = 10$ μs. The first bit of station A's frame reaches station B at (t_1 + 10 μs).

a. Station B has not received the first bit of A's frame at (t_1 + 10 μs). It senses the medium and finds it free. It starts sending its frame, which results in a collision.

b. At time (t_1 + 11 μs), station B has already received the first bit of station A's frame. It knows that the medium is busy and refrains from sending.

P12-17. The first bit of each frame needs at least 25 μs to reach its destination.

a. The frames collide because 2 μs before the first bit of A's frame reaches the destination, station B starts sending its frame. The collision of the first bit occurs at t = 24 μs.

b. The collision news reaches station A at time t = 24 μs + 24 μs = 48 μs. Station A has finished transmission at t = 0 + 40 = 40 μs, which means that the collision news reaches station A 8 μs after the whole frame is sent and station A has stopped listening to the channel for collision. Station A cannot detect the collision because $T_{fr} < 2 \times Tp$.

c. The collision news reaches station B at time t = 24 + 1 = 25 μs, just two μs after it has started sending its frame. Station B can detect the collision.

P12-19. We calculate the probability in each case:

a. After the first collision (k = 1), R has the range (0, 1). There are four possibilities (00, 01, 10, and 11), in which 00 means that both station have come up with R = 0, and so on. In two of these four possibilities (00 or 11), a collision may occur. Therefore the probability of collision is 2/4 or 50 percent.

b. After the second collision (k = 2), R has the range (0, 1, 2, 3). There are sixteen possibilities (00, 01, 02, 03, 10, 11, …, 33). In four of these sixteen possibilities (00, 11, 22, 33), a collision may occur. Therefore the probability of collision is 4/16 or 25 percent.

P12-21. We use the definition to find the throughput as $S = 1 / (1 + 6.4a)$.

$S = (T_{fr}) / (\text{channel is occupied for a frame})$

$S = (T_{fr}) / (k \times 2 \times T_p + T_{fr} + T_p)$

$S = 1 / [2e (T_p) / (T_{fr}) + (T_{fr}) / (T_{fr}) + T_p / (T_{fr})]$

$S = 1 / [2ea + 1 + a] = 1 / [1 + (2e + 1)a] = 1 / (1 + 6.4a)$

P12-23. We need to check three properties: the number of sequences (N) in each chip should be a power of 2, the dot product of any pair of chips should be 0, and the dot product of each chip with itself should be N.

a. The number of sequences, $N = 2$, is a power of 2.

b. $[+1, +1] \bullet [+1, -1] = (+1) + (-1) = 0$

c. $[+1, +1] \bullet [+1, +1] = (+1) + (+1) = 2 = N$
$[+1, -1] \bullet [+1, -1] = (+1) + (+1) = 2 = N$

The code passes the text for the three properties; it is orthogonal.

P12-25. Alice sends the code $(0110)_2$ and Bob sends the code $(1011)_2$. A 0 bit is changed to −1 and a 1 bit is changed to +1. In other words, Alice is sending $d_A = (-1, +1, +1, -1)$ and Bob is sending $d_B = (+1, -1, +1, +1)$. Each data item is multiplied by the corresponding code. The signal generated by Alice and Bob is shown below.