Computer Networks and Distributed Systems

Solutions to Q7

Context

- Lecture of 5/May: Exponential Backoff and Ethernet Switching
- Based on these two lecture presentations:
    - (Slides 126-128) http://paloalto.unileon.es/cn/ch2-2017.pdf
    - (Slides 1-39) http://paloalto.unileon.es/cn/ch3-part1-2016.pdf

1. An Ethernet interface has undergone four collisions when attempting transmission of a frame F, when will it attempt the next transmission attempt according to the *Exponential Backoff* algorithm?

   Since the interface, in the attempt to transmit frame F, has undergone 4 collisions, it will generate a random number that will be used for computing the amount of time to wait before reattempting transmission. According to the *Exponential Backoff Algorithm,* the set of possible random numbers is: {0, 1, 2, 3, … (2^k) - 1} where k is the number of collisions that occurred in attempting to transmit frame F. In the present case k = 4, therefore the set of possible cases is {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 ,13 14, 15}. The interface will randomly choose one of them, for example r = 5, then the time before attempting a new transmission is: r x 51,2µs = 5 x 51,2µs = 256 µs. The interface will check CS (Carrier Sense) 256 µs after the last collision occurred. Recall that upon CS (Carrier Sense) the interface checks whether the medium remains idle for at least 9,6µs before starting transmitting the frame F, again. If no collision occurs in this transmission attempt of frame F, the interface will clear the collision counter.

2. Network interfaces keep a counter for the total number of collisions undergone so far, do you think that this accumulated number of collisions affects the *Exponential Backoff* algorithm?

   No, the total number of collisions undergone by the interface is important because it might mean that the network technology is not scaling properly, *i.e.,* either the number of hosts is excessive or the utilization from each host is excessive or both. The total number of collisions kept by the interface is not used in the Exponential Backoff Algorithm.

3. Assume two Ethernet network interfaces, I_1 and I_2 that have just collided. Compose an example of the Channel Capture effect, which represents the lack of fairness in Ethernet's Exponential Backoff algorithm since, the interface that has undergone the least number of collisions in attempting the transmission of a frame F, is the most likely to win the next backoff. Compose an example that clearly illustrates Channel Capture, use small numbers for k.

   Assume interface I_1 has undergone k=2 collisions when attempting the transmission of frame F_1. Its ensuing *Backoff* will produce a random number from among R_1 = {0, 1, 2, 2^2-1} = {0, 1, 2, 3}.

   Assume interface I_2 has undergone k=3 collisions when attempting the transmission of frame F_2. Its ensuing *Backoff* will produce a random number from among R_2 = {0, 1, 2, 3, 4, 5, 6, 2^3-1} = {0, 1, 2, 3, 4, 5, 6, 7}.

What's the probability that I_1 win the ensuing backoff? I_1 will win every time its chosen random number is smaller than I_2's random number, this happens in the following cases where we denote the random number obtained by I_1 in the first component of each pair and where the second component is the number generated by I_2:

```
F = { (0,1) (0,2) (0,3) (0,4) (0,5) (0,6) (0,7)
            (1,2) (1,3) (1,4) (1,5) (1,6) (1,7)
                  (2,3) (2,4) (2,5) (2,6) (2,7)
                        (3,4) (3,5) (3,6) (3,7) }
```

Set F contains all cases favorable to the hypothesis that I_1 wins the backoff. Card(F) = 7 + 6 + 5 + 4 = 22

Now, we count how many cases are possible in the ensuing backoff, which set is readily calculated since it is coincident with the *Cartesian Product* $R_1 x R_2$; in fact, we need only obtain Card($R_1 x R_2$)= Card(R_1) x Card(R_2) = 4 x 8 = 32.

The probability (The *a-priori* probability) that I1 wins the backoff is the number of favorable cases divided by the number of possible cases:

Prob I_1 wins = 22/32 = 0,69. In summary, its more likely that I_1 wins the backoff (Somewhat, the right to transmit), being I1 the station that underwent the least number of collisions, we consider it unfair. This is known as the Channel Capture Effect.

4. An Ethernet interface I_1 has undergone 3 collisions with interface I_2 when attempting transmission of a frame F; I_2 has undergone 2 collisions. Compute the following probabilities:

   a. Probability that I_1 and I_2 collide again

   I_1 and I_2 will collide again when their respective chosen random numbers are equal, the following set represents the favorable cases to the hypothesis that I_1 and I_2 collide again:

   H_a = { (0,0) (1,1) (2,2) (3,3) }

   Probability of H_a = card(H_a)/card(R_1 x R_2) = 4 / 32 = 0,125

   b. Probability that I_1 wins the backoff

   We already computed this probability in question no. 3.

   c. Probability that I_2 wins the backoff

   We will proceed as in question 3 by calculating the set of cases favorable to the hypothesis that I_2 wins, *i.e.* all the cases in which the random number obtained by I_2 is less than that obtained by I_1:

```
H_c = { (1,0)
        (2,0) (2,1)
        (3,0) (3,1) (3,2) }
```

   The probability that I2 wins is: P = favorable cases/possible cases = card H_c/card(R_1 x R_2) = 6/32= 0,19

d. Probability that I_1 and I_2 will not collide in the next transmission attempt

This event is the complementary of the event from question 1, which probability is 0,125, therefore:

Probability I_1 and I_2 not collide = (1 – Probability I_1 and I_2 do collide) = 1 – 0,125 = 0,8750

e. Assume I_1 wins the backoff and that the random number it generated was 0, calculate how much time it will take until it begins transmitting F again.

I_1 will probe CS idle for 0 x 51,2 µs + IFG = 0s + 9,6µs = 9,6 µs. After the backoff time elapses (0µs), I_1 must probe CS idle for a time length of IFG (Inter Frame Gap) or 9,6µs.

5. What does the term "Store and Forward device" mean? What network equipment do you know that belong to the Store/Forward (S/F) class of equipment?

The term *store-and-forward* refers to a kind of networking equipment that, when it receives a new data unit, it stores that data unit in a buffer and then, it proceeds to analyze its contents and decide where it will forward the data unit to.

6. A network is comprised of shared medium Ethernet segments S_1-S_4, each connected to one port of a 4-port switch. Respond to the following questions:

a. Host H in segment S_1 sends a frame which destination MAC is that of broadcast, explain which hosts will receive that frame

The arrangement of LAN segments and the Ethernet switch constitutes a single Extended LAN, *i.e.*, a single network, then, all the hosts comprising the Extended LAN will receive the frame because the switch floods every Ethernet frame addressed to the broadcast address

b. How many broadcast domains there exist in the network?

A single Extended LAN constitutes a single *broadcast domain*

c. How many collision domains there exist in the network?

According to the problem statement, the Extended LAN contains four collision domains

7. What is a broadcast storm? Why are broadcast storms to be avoided?

A broadcast storm consists of the *continuous* proliferation of a broadcast frame due to a loop present in an Ethernet switched LAN.

By all means, broadcast storms should be avoided because frame proliferation consumes a vast proportion of the available network bandwidth (Aggregated throughput) thereby virtually preventing any other traffic from being transmitted through the network

8. Thoroughly review the bridge learning/switching algorithm in slide no. 9 of the 2nd presentation above, then, solve the following textbook exercises:

a. Ch.2: 43.a and 43.b

Exercise 43.a is solved in exam 2 contained into the following *exam solution document:*
http://paloalto.unileon.es/cn/CN-ExRefSol2013.pdf

Exercise 43.b. Give the probability that A wins this third backoff:
A has undergone 1 collision in its attempt to transmit frame A_4, therefore, in the next backoff race it will choose a random number from $\{0, 2^1 - 1\} = \{0, 1\}$

B has undergone 3 collisions in attempting to transmit B_1, therefore, it will choose a random number from $R_B = \{0, 1, 2, \ldots, 2^3 - 1\} = \{0, 1, 2, 3, 4, 5, 6, 7\}$

A wins this backoff in the following cases, where the pair (r_a, r_b) represents the *random numbers* drawn by A and by B, respectively in the current backoff race:

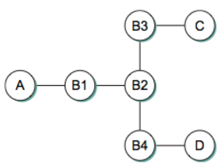
```
H = { (0,1) (0,2) (0,3) (0,4) (0,5) (0,6) (0,7)
            (1,2) (1,3) (1,4) (1,5) (1,6) (1,7) }
```

The probability that A wins is:

P = favorable cases/possible cases = card H/card(R_A x R_B) = 13/16 = 0,812

b. Ch3: 15, 16 and 17

Exercise 15.



A sends to C: *Since the forwarding tables are empty now, B1 will flood the frame sent by A, therefore all switches learn A.*

C sends to A: *B3 learns C and, since it knows A, it will forward the frame to B2, which will forward it to B1, from which will be eventually delivered to A. Switches B3, B2 and B1 learn C.*

D sends to C: *B4 learns D, and since B4 has not learned C so far, B4 will flood this frame which will cause all switches to learn D*

Forwarding tables (Host, Port)

Switch B1: (A, Left port where A is connected)
(C, Right port where B2 is connected)

Switch B2: (A, Left port)
(C, Upper port)
(D, Lower port)

Switch B3: (A, Lower port)
(C, Right port)
(D, Lower port)

Switch B4: (A, Upper port)

```
(D, Right port)
```

Exercise 16. *This exercise is solved in the textbook (p. 805)*

Exercise 17. *This exercise is solved in the following exam solution of CN/2013:*
http://paloalto.unileon.es/cn/CN-ExRefSol2013.pdf *(Page 8, exam exercise 2).*