CS 372: Introduction to Computer Networks

Homework #5 - Partial Solution

(based on Chapters 5 and 6 of *Kurose & Ross, 6th Ed.*)

REVIEW QUESTIONS

Answer the following review questions from Chapter 5 of the textbook:

- R2 [5 pts]

  Even if all of the Internet's links provided a reliable delivery service, TCP's reliable transport would not be redundant. First of all, TCP provides the service of *in-order delivery* as part of its reliable transport, and just having reliable links would not be a sufficient substitute for this service. Additionally, links are not the only place that packet losses can occur; for example, IP datagrams can be lost if a routing loop is encountered (eventual TTL expiration).

- R4 [5 pts]

  If two nodes begin transmitting at the same time, and the propagation delay between these two nodes (d_{prop}) is less than the transmission delay of each node's packet ($d_{trans} = L/R$), then the two nodes will start receiving each other's transmissions before their own transmission is complete. Therefore, yes, a collision will occur in this scenario.

- R11 [10 pts]

  An ARP query is sent in a broadcast frame (with destination address FF:FF:FF:FF:FF:FF) because the host making the query doesn't know which interface on the LAN corresponds to the IP address in question. The ARP response can be sent directly back to the original host because that host's MAC address is known (it was included in the source address field of the original ARP query.

PROBLEMS

Answer the following homework problems from Chapter 5 of the textbook:

- P8 [20 pts]

  a. To find the value of p that maximizes slotted ALOHA's efficiency $E(p)$, we begin by taking the derivative of the efficiency with respect to p, and then setting it equal to 0 to find the value of p that maximizes the efficiency:

  $$\begin{aligned}\frac{d\,(E(p))}{dp} &= \frac{d\left(Np(1-p)^{N-1}\right)}{dp} \\ &= (Np)(N-1)(1-p)^{N-2}(-1) + (N)(1-p)^{N-1} \\ 0 &= N(1-p)^{N-2} \cdot [(1-p) - p(N-1)]\end{aligned}$$

  At this point, we can see by inspection that setting $p = 1$ is one way to make the entire expression equal to 0 (via the $N(1-p)^{N-2}$ term). If $p = 1$, however, then all N nodes will always transmit in every slot; this must mean that $p = 1$ actually *minimizes* the efficiency. The other value of p that can make the entire derivative equal to 0 can be found by examining the $[(1-p) - p(N-1)]$ term:

  $$\begin{aligned}0 &= (1-p) - p(N-1) \\ p(N-1) &= 1-p \\ pN - p &= 1-p \\ p &= 1/N\end{aligned}$$

  The value of p that maximizes slotted ALOHA's efficiency is therefore $1/N$.

b. Next, we can find the long-run efficiency by taking the limit as described in the problem:

$$\begin{aligned}
\text{Long-run efficiency} &= \lim_{N\to\infty} E(1/N) \\
&= \lim_{N\to\infty} N \cdot (1/N) \cdot (1 - 1/N)^{N-1} \\
&= \lim_{N\to\infty} (1 - 1/N)^{N-1} \\
&= \lim_{N\to\infty} (1 - 1/N)^{N} \cdot (1 - 1/N)^{-1} \\
&= \lim_{N\to\infty} \frac{(1 - 1/N)^{N}}{(1 - 1/N)} \\
\text{Long-run efficiency} &= \frac{(1/e)}{1} = 1/e
\end{aligned}$$

ADDITIONAL QUESTIONS

From Chapter 6:

- [20 pts] Consider the two-sender CDMA example shown in Figure 6.6 of the textbook.

a. What is Sender 2's output to the channel, before it is added to the signal from Sender 1? In other words, what is $Z^2_{i,m}$?

  - The first part of Sender 2's output, $Z^2_{0,m}$, is defined as: $d^2_0 \cdot c^2_m$. This is simply $(1) \cdot (1, -1, 1, 1, 1, -1, 1, 1) = (1, -1, 1, 1, 1, -1, 1, 1)$
  - The second part of Sender 2's output, $Z^2_{1,m}$, is defined as: $d^2_1 \cdot c^2_m$. This is simply $(1) \cdot (1, -1, 1, 1, 1, -1, 1, 1) = (1, -1, 1, 1, 1, -1, 1, 1)$

b. Suppose that a second receiver (Receiver 2) wants to receive the data sent by Sender 2. Show (by calculation) that the receiver is able to recover Sender 2's data from the combined signal ($Z^*_{i,m}$) by using Sender 2's code. The first part of the combined signal, $Z^*_{0,m}$, is $(2, 0, 2, 0, 2, -2, 0, 0)$. We can recover Sender 2's data from the combined signal by using the following equation:

$$d^2_0 = \frac{\sum_{m=1}^{8} Z^*_{0,m} \cdot c^2_m}{8} = \frac{(1 \cdot 2) + (-1 \cdot 0) + (1 \cdot 2) + (1 \cdot 0) + (1 \cdot 2) + (-1 \cdot -2) + (1 \cdot 0) + (1 \cdot 0)}{8} = 1$$

The second part of the combined signal, $Z^*_{1,m}$, is $(0, -2, 0, 2, 0, 0, 2, 2)$. We can recover Sender 2's data from the combined signal by using the following equation:

$$d^2_1 = \frac{\sum_{m=1}^{8} Z^*_{1,m} \cdot c^2_m}{8} = \frac{(1 \cdot 0) + (-1 \cdot -2) + (1 \cdot 0) + (1 \cdot 2) + (1 \cdot 0) + (-1 \cdot 0) + (1 \cdot 2) + (1 \cdot 2)}{8} = 1$$