ECE 4380/6380: Computer Communications **Spring 2017**
Problem Set 4 **Due: 2:30 pm in class, Wednesday, March 1**

Assigned reading: Peterson and Davie, Chapter 2. Each problem is worth 10 points

1. Binary exponential backoff

Assume that four hosts connected to an Ethernet have been involved in a number of collisions, and in addition at time *T* all of them have detected a new collision. The table below lists the number of successive collisions that each host has been involved in including the current collision. Let the slot time be 1 time unit, and assume that the collision occurred in slot 0. Treat collisions as taking one time slot. Assume that host A decides to make its retransmission attempt in slot 1. What is the probability that A's transmission in slot 1 is successful? (Notice that host A is transmitting in slot 1. If host A transmits in a different slot the problem is more complicated because it depends on which nodes transmitted in earlier slots and if they were successful or not).

Host	Collision count
A	5
B	2
C	3
D	4

2. Ethernet timing and access protocol

Assume that the Ethernet collision protocol operates as follows. If a host detects a transmission while it is transmitting a frame, then: (i) if the host has already transmitted the 64 bit preamble, the host stops transmitting the frame and sends a 32 bit jamming sequence; (ii) else the host finishes transmitting the 64 bit preamble and then sends a 32 bit jamming sequence. For simplicity, assume a collision is detected as soon as an interfering signal first begins to reach a host. Suppose the frames are 512 bits long, that is, a node transmits a 64-bit preamble followed by the 512-bit frame and followed by a 8-bit postamble. For this problem we will ignore the 9.6 μsec waiting period that a host must wait after it transmitted a successful frame.

Hosts *A* and *B* are the only active hosts on a 10 Mbps Ethernet and the propagation time between them is 25 μsec, or 250 bit durations. Suppose *A* begins transmitting a frame at time $t = 0$, and just before the beginning of the frame reaches *B*, *B* begins sending a frame, and then almost immediately *B* detects a collision.

(a) Does *A* finish transmitting its frame before it detects that there was a collision? Explain why this is important
(b) What time does *A* finish sending its jamming signal? What time does *B* finish sending its jamming signal?
(c) What time does *A* first hear an idle channel again? What time does *B* first hear an idle channel again?
(d) Suppose each host next decides wait one slot before the retransmission (i.e., 51.2 μsec), and then retransmits immediately after hearing the channel idle (assume a host can instantaneously detect when the channel is idle). After the resulting (second) collision: when does *A* next hear the channel idle? When does *B* next hear the channel idle?
(e) Suppose after the second collision, *B* decides to wait one more slot to retransmit and *A* decides to retransmit immediately after hearing the channel idle. Is the transmission of *A* successful?

3. Ethernet collisions

Assume that the Ethernet collision protocol operates as follows. If a host detects a transmission while it is transmitting a frame, then: (i) if the host has already transmitted the 64 bit preamble, the host stops transmitting the frame and sends a 32 bit jamming sequence; (ii) else the host finishes transmitting the 64 bit preamble and then sends a 32 bit jamming sequence. For simplicity, assume a collision is detected as soon as an interfering signal first begins to reach a host. Suppose the frames are 512 bits long, that is, a node transmits a 64-bit preamble followed by the 512-bit frame and followed by a 8-bit postamble. For this problem we will ignore the 9.6 μsec waiting period that a host must wait after it transmitted a successful frame.

Three hosts, A, B, and C, are the only active hosts on a 10 Mbps Ethernet. The propagation time between A and B is 5 μsec and between B and C is 15 μsec, and host B is located between hosts A and C. Suppose A begins transmitting its frame at time t= 0, B begins transmitting its frame at time t=5 μsec, and C begins transmitting its frame at time t=20 μsec (note that B and C detect collisions at the instant they start transmitting their frames). Each host will detect a collision and assume this is the first collision that any of the hosts have detected. Consider the behavior of a host after it has begun its transmission.

(a) At what time does host A first detect the channel idle?
(b) At what time does host B first detect the channel idle?
(c) At what time does host C first detect the channel idle?
(d) Suppose that host A selects slot 0 for its retransmission (that is, there is no delay before beginning its retransmission after detecting the channel idle) and hosts B and C both select slot 1 (that is, wait for 51.2 μsec after detecting the channel is idle before attempting a retransmission). Is host A's retransmission attempt successful? Explain why or why not.

4. Medium access control.

Consider the medium access control for a new cable-based network that employs carrier sense multiple access with collision detection (CSMA/CD). For purposes of this problem, assume the system is the same as for the original Ethernet design, but that the nodes can transmit at y bits per second, the minimum number of bits in a frame is x bits (assume this design does not need a preamble or postamble), and the propagation speed is c meters per second. Assume that when there is a collision present at a host it can detect it instantly, and all delays other than due to propagation can be ignored.

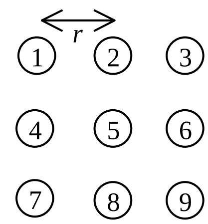
(a) What is the maximum distance of the cable so that a node can always detect a collision?
(b) Note that a frame can be longer than x bits, and once a node has transmitted x bits without a collision, it should not detect a collision before completing the transmission. If a collision were detected it would be called a *late collision*. In the next two parts we argue that if a late collision occurs it must be due to an improper configuration of the network. The timing of the late collision can be used to bound the location of the interfering node. Let d meters be the answer found in part (a). Assume that more than d meters of cable have been installed for this network. Assume that a node starts to transmit a frame that is g bits (where $g > x$) and after transmitting $x + e$ bits it detects a collision. Assume e is a positive integer and that $e < g - x$. What is the minimum distance in meters between this node and the node that has caused the collision?
(c) Assume that a node continuously transmits a long sequence of frames, and that each frame is g bits. After completing the transmission of one frame, the node must wait s seconds before it can transmit the next frame. Assume that a node has transmitted an arbitrarily long sequence of frames with out collision, and that the node detects a collision after transmitting $x + e$ bits in the current frame. (As above $g > x$ and $e < g - x$.) The minimum distance found in part (b) is based on the implied assumption that the interfering node waits to begin its transmission until the

moment before the other frame arrives. What is the minimum distance between the nodes if the interfering node begins to transmit as soon as the channel becomes idle from the previous frame?

5. 802.11 access points

For a wireless network based on the IEEE 802.11 standard it is desirable that there is some overlap in the area that is covered by each of the access points (AP's). Consider two AP's that are configured to use the same frequency channel, and are located close enough to each other so as to be within communication range of each other. Explain why this configuration of AP's is undesirable.

6. 802.11 MAC



Consider an 802.11 ad hoc wireless network, and assume that nine wireless nodes are arranged in a uniform grid as shown in the figure to the right. For example, *r* meters separate nodes 1 and 2. Assume that each node has the same signal coverage and a circular shape represents the coverage (e.g., if the signal coverage is *r* meters then nodes 1 and 2 can transmit to each other but nodes 1 and 5 cannot). Assume that node 1 transmitted an RTS to node 2, node 2 transmitted a CTS to node 1, and node 1 is currently transmitting a data packet to node 2. At this instant, which nodes are permitted to transmit an RTS?

7. Hidden terminal problem

Consider an ad hoc wireless network, and assume that nine wireless nodes are arranged in a uniform grid as shown in the figure for the previous problem. Assume that each node has the same signal coverage and a circular shape represents the coverage (e.g., if the signal coverage is *r* meters then nodes 1 and 2 can transmit to each other but only if no other node is transmitting that is within *r* meters of the receiver). What is the minimum signal coverage so that none of the nodes suffer from the hidden terminal problem?

8. Communication range versus carrier sense range

Define the maximum *communication range*, R, to be the maximum distance between two radios such that they can exchange RTS, CTS, data, and ACK frames if there is no interference. In many wireless systems, a receiver can detect that another radio is transmitting even if the receiver is unable to acquire or decode the transmission because its distance from the transmitter is greater than R. The receiver can sense the presence of the transmitter by detecting its carrier. Define the *carrier sensing range*, R_S as the maximum distance at which a receiver can detect the presence of a transmitter. Define the *interference range* to be R_I. A receiver that is within communication range of a transmitter can receive a frame if there are no other transmissions within range R_I of the receiver. A common assumption, and the one used in our textbook, is that the communication, sensing, and interference ranges are equal. However, the carrier sensing range can be tuned. For this problem set the carrier sensing range to be equal to $2R$. The interference range is more complex to model. Consider two simplistic cases for modeling the interference range, and determine if the hidden terminal problem occurs or not. Assume there are no obstacles.

a. Let $R_I = R$. (This might apply to modulation techniques that are robust to interference like direct-sequence spread spectrum.)

b. Let $R_I = 2R$. (High rate modulation techniques like OFDM are more sensitive to interference.)

9. Ethernet capture effect. (Required for 638 students only)

Let Ash and Beech be two stations attempting to transmit on an Ethernet. Each has a steady queue of frames ready to send: Ash's frames will be numbered A_1, A_2, and so on, and Beech's similarly. Let $T = 51.2$ μs be the exponential backoff base unit.

Suppose Ash and Beech simultaneously attempt to send frame 1, collide, and happen to choose backoff times of $0\times T$ and $1\times T$, respectively, meaning Ash wins the race and transmits A_1 while Beech waits. At the end of this transmission, Beech will attempt to retransmit B_1 while A will attempt to transmit A_2. These first attempts will collide, but now A backs off for either $0\times T$ or $1\times T$, while Beech backs off for time equal to one of $0\times T$, $1\times T$, $2\times T$ or $3\times T$.
Note that you should not consider any inter-frame delay for this problem.

(a) Give the probability that Ash wins this second backoff race immediately after this first collision; that is, Ash's first choice of backoff time $k \times 51.2$ μs is less than Beech's.

(b) Suppose Ash wins this second backoff race. Ash transmits A_3, and when it is finished, Ash and Beech collide again as Ash tries to transmit A_4 and Beech tries once more to transmit B_1. Give the probability that Ash wins this third backoff race immediately after the first collision.

(c) For this part, assume that Beech does not limit the range of values it uses for backoff after its 10^{th} collision. Also, assume that Ash and Beech continue this process indefinitely (i.e., Ash continues to win each race and Beech keeps trying). Calculate the probability that Ash wins the *i*-th backoff race given than it has won all the previous races. Note you have already calculated the probability that Ash wins the second race in part (a) and the third race in part (b).

(d) Using the result from part (c) give the probability that Ash wins all the remaining races given that it has won the 1^{st}, 2^{nd}, and 3^{rd}. It is not necessary to find a closed form solution. Also, using a spread sheet or simple program give an approximate numerical answer.