Question 1 (20 points):

Consider two nodes, A and B, that use the slotted ALOHA protocol to contend for a channel. Suppose node A has more data to transmit than node B, and node A’s retransmission probability $p_A$ is greater than node B’s retransmission probability, $p_B$.

A. Provide a formula for node A’s average throughput. What is the total efficiency of the protocol with these two nodes?

B. If $p_A = 2p_B$, is node A’s average throughput twice as large as that of node B? Why or why not? If not, how can you choose $p_A$ and $p_B$ to make that happen?

C. In general, suppose there are $N$ nodes, among which node A has retransmission probability $2p$ and all other nodes have retransmission probability $p$. Provide expressions to compute the average throughputs of node A and of any other node.

Question 2 (10 points):

Recall that with the CSMA/CD protocol, the adapter waits $K \times 512$ bit times after a collision, where $K$ is drawn randomly. For $K = 100$, how long does the adapter wait until returning to Step 2 for a 10 Mbps broadcast channel? For a 100 Mbps broadcast channel?
Question 3 (20 points):

In this problem, you will put together much of what you have learned about Internet protocols. Suppose you walk into a room, connect to Ethernet, and want to download a Web page. What are all the protocol steps that take place, starting from powering on your PC to getting the Web page? Assume there is nothing in our DNS or browser caches when you power on your PC. (Hint: the steps include the use of Ethernet, DHCP, ARP, DNS, TCP, and HTTP protocols.) Explicitly indicate in your steps how you obtain the IP and MAC addresses of a gateway router.

Question 4 (10 points):

Consider the single-sender CDMA example in the following figure. What would be the sender’s output (for the 2 data bits shown) if the sender’s CDMA code were (1, −1, 1, −1, 1, −1, 1, −1)?

![CDMA Example Diagram](image)

Question 5 (10 points):

Suppose there are two ISPs providing WiFi access in a particular café, with each ISP operating its own AP and having its own IP address block.

A. Further suppose that by accident, each ISP has configured it's AP to operate over channel 11. Will the 802.11 protocol completely break down in this situation? Discuss what happens when two stations, each associated with a different ISP, attempt to transmit at the same time.
B. Now suppose that one AP operates over channel 1 and the other over channel 11. How do your answers change?

Question 6 (10 points):
Suppose an 802.11b station is configured to always reserve the channel with the RTS/CTS sequence. Suppose this station suddenly wants to transmit 1,000 bytes of data, and all other stations are idle at this time. As a function of SIFS and DIFS, and ignoring propagation delay and assuming no bit errors, calculate the time required to transmit the frame and receive the acknowledgment.

Question 7 (10 points):
Consider two mobile nodes in a foreign network having a foreign agent. Is it possible for the two mobile nodes to use the same care-of address in mobile IP? Explain your answer.

Question 8 (10 points):
Recall the simple model for HTTP streaming shown in the following figure. Recall that $B$ denotes the size of the client’s application buffer, and $Q$ denotes the number of bits that must be buffered before the client application begins playout. Also $r$ denotes the video consumption rate. Assume that the server sends bits at a constant rate $x$ whenever the client buffer is not full.

A. Suppose that $x < r$. As discussed in the text, in this case playout will alternate between periods of continuous playout and periods of freezing. Determine the length of each continuous playout and freezing period as a function of $Q$, $r$, and $x$.

B. Now suppose that $x > r$. At what time $t = t_f$ does the client application buffer become full?
Let's assume that the server sends bits at a constant rate \( x \) whenever the client buffer is not full. (This is a gross simplification, since TCP's send rate varies due to congestion control; we'll examine more realistic time-dependent rates \( (t) \) in the problems at the end of this chapter.) Suppose at time \( t = 0 \), the application buffer is empty and video begins arriving to the client application buffer. We now ask at what time does playout begin? And while we are at it, at what time does the client application buffer become full?

First, let's determine \( Q \), the time when \( Q \) bits have entered the application buffer and playout begins. Recall that bits arrive to the client application buffer at rate \( x \) and no bits are removed from this buffer before playout begins. Thus, the amount of time required to build up \( Q \) bits (the initial buffering delay) is \( Q / x \).

Now let's determine \( t_f \), the point in time when the client application buffer becomes full. We first observe that if \( x < r \) (that is, if the server send rate is less than the video consumption rate), then the client buffer will never become full! Indeed, starting at time \( t_p \), the buffer will be depleted at rate \( r \) and will only be filled at rate \( x < r \). Eventually the client buffer will empty out entirely, at which time the video will freeze on the screen while the client buffer waits another \( Q \) seconds to build up \( Q \) bits of video.

Thus, when the available rate in the network is less than the video rate, playout will alternate between periods of continuous playout and periods of freezing. In a homework problem, you will be asked to determine the length of each continuous playout and freezing period as a function of \( Q \), \( r \), and \( x \). Now let's determine \( t_p \) for when \( x > r \). In this case, starting at time \( t_p \), the buffer increases from \( Q \) to \( B \) at rate \( xr \) since bits are being depleted at rate \( r \) but are arriving at rate \( x \), as shown in Figure 7.3. Given these hints, you will be asked in a homework problem to determine \( t_p \), the time the client buffer becomes full. Note that when the available rate in the network is more than the video rate, after the initial buffering delay, the user will enjoy continuous playout until the video ends.

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**Figure 7.3**

Analysis of client-side buffering for video streaming

- **Video server**
- **Internet**
- **Client application buffer**

**Labels:**
- Fill rate = \( x \)
- Depletion rate = \( r \)