

**ECEN4533 Final Exam 4 May 2009**

1) You are a staff engineer at MegaMoron Communications, Inc., working on MoronChat, a new Instant Messaging (IM) protocol. A small wireless device with keyboard will be surgically implanted in the forearm of customers.

1a) [15] A cellular telephone RF channel with a bandwidth of 30 KHz and SNR of 1000 is to be used to move the text messages. How many bits/second can such a channel theoretically support? [Answer = 299,017 bps]

1b) [10] Suppose each letter typed is mapped to an 8 bit code word, stuck into a fixed size 53 byte cell (this includes the letter & all overhead) and immediately transmitted. If an average *active* user types 30 words a minute, with an average IM size of 4.1 letters per word, what physical layer bit rate will be generated by each *active* customer? [Each active customer will generate an average of 869.2 bps]

1c) [15] Assuming the system can be modeled as an M/D/1 queue if there are multiple users, theoretically how many *active* users can be supported over each RF channel? [343]

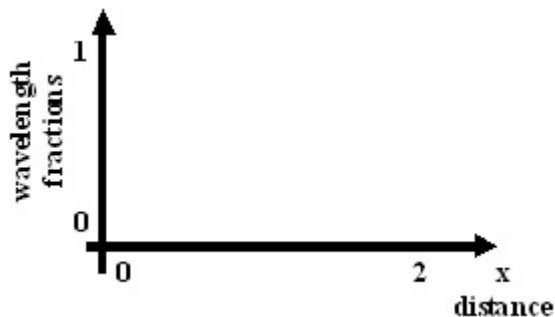
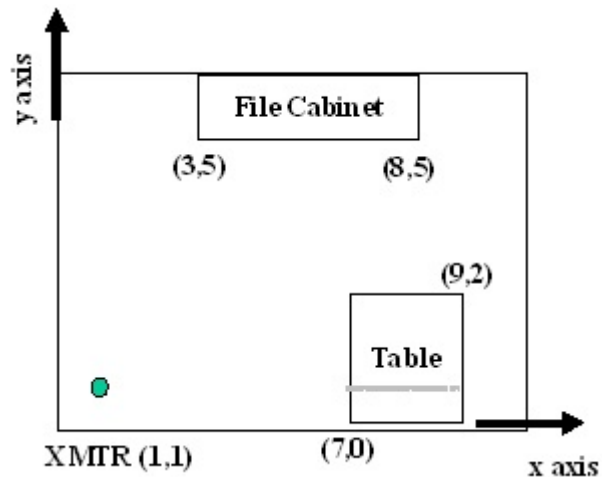
2) [15] During some peak time period it's observed that 78,000 packets/second arrive and there are typically 360 packets in a router. **Compute** the average length of time each packet spends in the router. [4.615 msec]

3) [20] A wireless LAN transmitter operating at a center frequency of 240 MHz is located at coordinates (1,1) in a room. The front of a metal file cabinet is located from coordinates (3,5) to (8,5). All units are in meters. The transmitting and receiving antenna are exactly the same height off the floor. Note that the reflection off the file cabinet will result in an immediate 180 degree phase shift. This means that the reflected path is, from an RF perspective, half a wavelength longer than the actual physical distance of the path.

The wavelength  $\lambda$  of the RF signal is 1.25 m.

3a) [3] Compute the distance, in wavelengths, from the transmitter to the table edge directly to the right at (7,1). [4.8 wavelengths]

3b) [3] Compute the distance, in wavelengths, from the transmitter to the table edge at (9,1). [6.4 wavelengths]



3c) [4] Compute the distance, in wavelengths, from transmitter → file cabinet → table edge (7,1). [8.5 wavelengths]

3d) [4] Compute the distance, in wavelengths, from transmitter → file cabinet → table edge (9,1). [9.552 wavelengths]

3e) [6] On the table, somewhere along the line between (7,1) and (9,1), will the direct and reflected

signal arrive in phase? Explain. [For the signals to arrive in phase, the number of *fractions* of a wavelength cycle must be identical at some point. For the example, if the direct line distance from the transmitter to the center of the table, in wavelengths, is 2.6, and the reflected distance (including the phase shift) to the same point is 3.6 wavelengths, the two signals will arrive in phase. The first signal will completely oscillate twice and complete 0.6 tenths (216 degrees) of a third cycle, while the reflected wave will effectively oscillate three times and 0.6 tenths (216 degrees) of a fourth cycle. On a scope the peaks and valleys of these two signals would line up, indicating they're in phase.

The two meter long line on the table begins at 4.8 wavelengths from the transmitter and ends at a distance of 6.4 wavelengths, a total of 1.6 wavelengths. If the wavelength *fractions* are plotted on the graph above, a line will start at (0,0.8), run diagonally to the top of the graph, start at (0.25,0) on the bottom and again run diagonally to the top, and finally start at (1.5,0) on the bottom and run to (2,0.4). The reflected path distance in wavelengths varies from 8.5 to 9.55. If this is plotted on the same graph another line would start at (0,0.5) and increase by 1.05 wavelengths over the two meter distance (meaning it too will hit the top of the graph and reappear at the bottom, but only once). These two sets of lines do not cross, indicating that *nowhere on the line from (7,1) to (9,1) are the two signals in phase.*]

5) A corporate computer server accepts 6, 7, or 8 symbol passwords. A typical keyboard is known to have 94 possible symbols.

5a) [15] How many possible passwords are there assuming there no restrictions as to the symbol combinations that can be used? [Note: For comparison purposes, there are 171,476 words in the 2nd edition of the **Oxford English Dictionary**.] [ $6.161 * 10^{15}$  passwords]

5b) [20] A hacker has access to this server via a system with an average available bandwidth of 8 Mbps and an average one-way propagation delay of 41 msec. Estimate the time it will take a hacker to break into this system assuming all passwords are equally likely. Assume the hacker must use the equivalent of STOP & WAIT for each password submission to the server; i.e. the hacker submits a password which is inserted in one packet, and then must wait for an ACK packet from the server. The ACK packet will alert the hacker as to whether or not the password was correct. Only after the ACK is received can another password be submitted. You'll need to make several assumptions to solve this problem. Write them down! So long as they are reasonable the instructor will accept them. [Assumptions (others are possible): (1) Hacker has an automated program that will spit out passwords with negligible processing time. (2) Ethernet packets with 66 bytes of overhead used. Most passwords have 8 symbols = 8 bytes, meaning 74 B packets. (3) ACK packets assumed to be 67 B (Ethernet + 1 B yes or no). (4) Server doesn't block access after a few tries. (4) On average, the correct password will be found once 1/2 of them are tried. (5) Blatantly obvious passwords aren't used. Answer then = 8.026 million years.]

4) TCP logical connections have just been opened between a web server and your office PC. The PC grants (and will continue to grant) a window of 64,000 bytes to the server. Assume all packets are successfully transmitted each way *except ACK #1*, which gets corrupted and discarded by the server's NIC. Assume further that...

- \*There is no other traffic on the network.
  - \*The propagation delay and average time to inject a packet into the system,  $E[T_s]$  both = 1 msec.
  - \*The time to inject an ACK into the system,  $T_{ack}$ , = 0.1 msec
  - \*The server is using TCP's Slow Start.
  - \*Standard TCP ACK's are being used and are issued immediately upon complete receipt of a packet.
  - \*The server's Retransmission Time Out value = 3 seconds & commences when leading edge of packet #1 is transmitted.
  - \*Selective Repeat is being used.
  - \*The server is using Fast Retransmit & Fast Recovery.
  - \*Server & PC processing time is negligible.
- [40] Complete the time distance diagram shown & estimate the time it will take the web server to successfully transmit a 10 packet web page to your office PC. Time starts when the web server transmits the leading edge of packet #1 and stops when your PC receives the trailing edge of packet #10. [3.0133 seconds]

