Due Tue., Nov. 25, 2014 in class by the end of class.

**Only hand in the following problems: 4, 5, 6, 8, 12**

1. A transmitter capable of operating at 2.3 Mbps sends a frame consisting of 2200 bytes down a 500-km long communication line. How long does it take for the frame to be completely received in milliseconds (not seconds)?

2. A three-color display using 10-bits per color per pixel is to be sent at a frame-rate of 48-FPS (frames per second) and a frame size of 1920 $\times$ 1080 pixels. How large a compression would you need to send this signal down a PCM channel (capable of sending 8000 8-bit samples per second).

3. The signal-to-noise ratio achievable through a channel is 37 dB. What is the minimum channel bandwidth that I will require if I want to achieve an error-free data rate of at least 6 Mbps? Make sure to clearly indicate the units of your final answer for full marks.

4. Problem 3.32 from the Leon-Garcia/Widjaja textbook.

5. Assume I think of a *very clever* six-level pulsing scheme. Then *theoretically* how many bits per second can I send through a noiseless channel with a bandwidth of 80 MHz?

6. A modulation scheme is to achieve a data rate of 30 Mbps through a channel with a bandpass bandwidth of 7-MHz. What is the minimum integer number of constellation points needed to meet our data rate requirement?

7. Problem 3.36 from the Leon-Garcia/Widjaja textbook. Just a.) and b.) for an 8-point constellation.

8. Problem 3.39 from the Leon-Garcia/Widjaja textbook. For b) just draw the constellation.

9. Problem 3.40 from the Leon-Garcia/Widjaja textbook.

10. Problem 3.43 from the Leon-Garcia/Widjaja textbook. Just part a.)

11. Problem 3.55 from the Leon-Garcia/Widjaja textbook.

12. Problem 3.56 from the Leon-Garcia/Widjaja textbook.

13. Problem 3.57 from the Leon-Garcia/Widjaja textbook.

14. Problem 3.58 from the Leon-Garcia/Widjaja textbook.

15. Problem 3.59 from the Leon-Garcia/Widjaja textbook.

16. In Stop-and-Wait ARQ why should the receiver always send an acknowledgment message each time it receives a frame with the wrong sequence number?

17. A 1 Mbyte file is to be transmitted over a 1 Mbps communication line that has a bit error rate of $p = 10^{-6}$

    a) What is the probability that the entire file is transmitted without errors? Note for $n$ large and $p$ very small, $(1-p)^n \approx e^{-np}$.

    b) If the message is divided into 80 frames what is the probability of any one frame being in error?

    c) If the propagation delay and the processing delay are negligible and each acknowledgment is 20 bytes total how long does it take to transmit the whole file error frame using Stop & Wait ARQ if the file is split into 80 frames?

18. Suppose that a Stop-and-Wait ARQ system has a time-out value that is less than the time required to receive an acknowledgment. Sketch the sequence of frame exchanges that transpire between two stations when station A sends five frames to station B and no errors occur during transmission.

19. A telephone modem is used to connect a personal computer to a host computer. The speed of the modem is 56 kbps and the one-way propagation delay is 100 ms.

    a) Find the efficiency for Stop-and-Wait ARQ if the frame size is 256 bytes (including header and trailer). Assume a bit error rate of $10^{-4}$. Ignore (i.e. treat as zero) any information not given in the question.

    b) Find the efficiency of Go-Back-N if three-bit sequence numbering is used with frame sizes of 256 bytes. Assume a bit error rate of $10^{-4}$. Ignore (i.e. treat as zero) any information not given in the question. *Hint: Assume that the choice of the three-bit sequence number was an optimal one for GBN.*

20. Imagine a 1 Mbps system with with a propagation delay of 3 seconds and frame sizes of 500 bits including overhead which is 76 bits (i.e. this also defines the ACK size). For a bit error rate of $10^{-5}$ compare the efficiencies of GBN and SR ARQ. Ignore (i.e. treat as zero) any information not given in the question.