CS/ECE 438: Communication Networks for Computers   Spring 2018
Problem Set 2   Due: start of class, Wednesday, February 14th

All problems carry equal weight. To receive full credit, show all of your work.

Physical Layer

1. **Noisy Channel Data Rates**
The decibel is a measure of the ratio between two signal levels: $N_{db} = 10 \log_{10}(P_2/P_1)$, where N_{db} = the number of decibels, P_1 = the input power level and P_2 = the output power level.
    a. A telephone line is known to have a loss of 20db. The input signal power is measured as 0.25 watt and the output noise is measured as 10 μwatt. Using this information, calculate the output signal-to-noise ratio in dB.
    b. What is the capacity of this phone line with a frequency range of 300 Hz – 4800 Hz?
    c. If the attenuation rate of this phone line is 8 dB/km, and the minimum output signal is 0.005 watt, given the input signal from part a), how long can the phone line be before it requires a repeater?

2. **Encoding**
    a. **Bit and baud rates**. Suppose, it is possible to send 128 different types of signals on a link, and that there is no noise. How many bits per second (bps) can such a link achieve at 4000 baud?
    b. **SNR**. What signal-to-noise ratio (in dB) is needed to put a 7 Gbps carrier on a 500-MHz line? (Note: for line speeds in networking, giga-, mega-, kilo- indicate powers of 1000, not 1024.)

3. **Encoding and Channel Capacity**
    a. Show the NRZ, Manchester, NRZI and 4B/5B encoding signals (the resulting NRZI signal for 4B/5B), using a diagram similar to that in the class slides, for the data bit sequence 1111 0001 1011. To be definite, suppose the NRZI signals begin at low voltage.
    b. In 1962, Bell Labs introduced the first version of their Transmission System 1 (T-1). Subsequent specifications carried multiples of the basic T1 data rates. What signal-to-noise ratio is needed to put a T3, 672channel, carrier on a 75-MHz line?

4. **Modulation**
    a. A modem constellation diagram has data points at the following coordinates: (1, 1), (1, -1), (-1, 1), (-1, -1), (2, 2), (2, -2), (-2, 2), (-2, -2), (3, 3), (3, -3), (-3, 3), (-3, -3), (4, 4), (4, -4), (-4, 4), and (-4, -4). How many bps can a modem with these parameters achieve at 1600 baud?
    b. A modem constellation diagram has data points at (-12, 4) and (-48, -16). Does the modem use phase modulation and/or amplitude modulation? Explain your answer.

5. **Framing**
Consider the data bit sequence 0000 1010 1111 1111 0101 0000 0110 0000 1111 1111 0000 1110. In this problem, you will frame these bits in three ways.
    a. First, frame the bits with byte stuffing as used in the BISYNC protocol. You need show only the body (including stuffed bytes) and the sentinel bits. DLE is ASCII character 16 (decimal), STX is 2, and ETX is 3.
    b. Second, frame the bits using bit stuffing as defined by the HDLC protocol. Again, you need show only the (stuffed) data bits and the sentinel bits.
    c. Third, frame the bits into 8-bit RS-232 characters. Use "0" to represent start bits and "1" to represent stop bits.
    d. Now, counting only the bits that you wrote, calculate the efficiency (as a percentage of real data per bit sent) of your answers to (a), (b), and (c).

6. Error Detection

a. A CRC is constructed to generate a 4-bit checksum for an 11-bit message. The generator polynomial is $x^4 + x^3 + 1$. Encode the data bit sequence **10000110100**. Now assume that bit 4 (counting from the most significant bit) in the code word is in error and show how the error is detected.

b. The bit sequence **10010110011** corresponds to the polynomial $x^{10}+x^7+x^5+x^4+x+1$. Divide this polynomial by the CRC generator polynomial x^3+1 and report the remainder as a polynomial. Is the bit sequence correctly encoded with the given generator (i.e., is the remainder 0)?

c. Suppose a 4 bit CRC is appended to an n bit message according to the CRC polynomial $x^4 + x + 1$. The encoded message thus has $n + 4$ bits. What is the largest value of n such that any double bit error can be detected? (Hint: any error sequence corresponds to a polynomial that is the product of C(x) and some other polynomial.)

7. Networking Utilities

a. The Unix utility `ping` can be used to find the round trip time (RTT) to various Internet hosts. See the man page for `ping` to see how to use it and the -s option with other options to see how you can control the time between ICMP packet transmissions, and to display the resulting round trip times. Upon interrupting execution of `ping`, the min, average and maximum RTT will also be displayed. Report the average (average over ten pings) round trip times for pings to the following domains:
   i. cs.illinois.edu
   ii. www.illinois.edu
   iii. www.nps.gov
   iv. www.cambridge.uk
   v. sydney.edu.au

b. The Unix utility `traceroute` is like ping, but it sends packets that are limited to go one hop, then two hops, then three hops, and so on, towards a given destination, and the intermediate routers are reported. Read the man page for `traceroute` and experiment with it. Try `traceroute` on the servers that you just pinged. Report the number of routers that are encountered along the way. Answer these questions: what is the relation between this number and the RTT? Is the number of hops the only factor affecting the RTT?