ESD5 – Fall 2024
Problem Set 6

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October 21, 2024

Problem 1 – Computing Rates

In this exercise, you will learn how encoding can influence the rate of a channel.

(a) Consider the simple encoding scheme where we send an 8-bit message using the channel six times and decode it by taking the majority vote. What is the rate of this encoding scheme?

(b) Consider a BFSK transmitter that sends information at a rate of 10 kbps using a space frequency of 500 kHz and a mark frequency of 700 kHz. How much bandwidth is needed for the transmission?

Problem 2 – Digital Modulation

In this exercise, you will learn a digital modulation scheme and define its main properties. Consider the signal constellation shown in Fig. 1. Answer the following.

(a) What type of modulation is represented?

(b) How many symbols are represented?

(c) How many bits does each symbol represent?

(d) What is the bit rate if the baud rate is 10000 symbols/second?

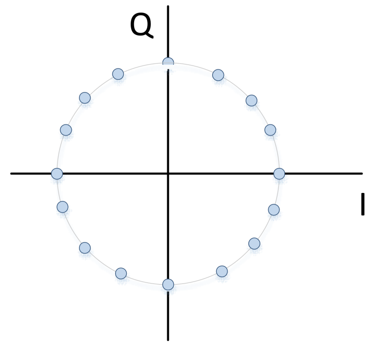

Figure 1: Example of a signal constellation.

Problem 3 – Yet Another Digital Modulation Technique

Consider a communication system that transmits a bit stream using 16-QAM.

(a) How many bits are transmitted per symbol?

(b) Suppose four different phases and four different amplitudes are used. Sketch a constellation diagram for the 16-QAM modulation. Label/Indicate the symbols. Is the order important to label them? Are there other ways to label them?

Plus: For the interested, you can play with 16-QAM on MATLAB and try to draw the constellation from there by using: `https://se.mathworks.com/help/comm/gs/examine-16-qam-using-matlab.html`

Problem 4 – An Error Detection Scheme

In this exercise, you will learn an error detection mechanism. In particular, we consider Error detection with Cyclic Redundancy Check (CRC). The message 11011 will be transmitted using CRC polynomial $x^3 + x + 1$ to protect it from errors.

(a) How many bits are required to apply the CRC?

(b) Describe the CRC generation process and compute the message that should be transmitted.

(c) Consider that the transmission is damaged, so the receiver receives 11010001. Will this error be detected?

Hint : Please see, for example, `https://ecomputernotes.com/computernetworkingnotes/communication-networks/cyclic-redundancy-check` to better understand CRC.

Problem 5 – Maximum Ratio Combinining and Incremental Retransmission

In this exercise, you will see how we can combine baseband bits to improve our communication. Then, you grasp the role of retransmission and how we can make it more efficiency through a thought exercise about incremental redundancy.

(a) Let $\mathbf{s} = (s_1, s_2, \dots s_u)$ represent the packet sent by Xia to Yoshi through the respective baseband symbols. Yoshi does not receive the first packet transmission correctly, Xia does not receive an ACK, and she retransmits the same $\mathbf{s}$. Let us look at the same received symbol from both packet transmissions:

$$y_{i,1} = hs_1 + n_{i,1}, \tag{1}$$

$$y_{i,2} = hs_2 + n_{i,2}, \tag{2}$$

where the index j stands for the jth packet transmission; $y_{i,j}$ is the ith symbol received by Yoshi and $n_{i,j}$ is the ith noise sample. It is assumed that the channel h stays constant during the transmission and the retransmission.

1. Using Chase combining or maximum ratio combining (MRC), what is the message that Yoshi creates? How do the signal-to-noise ratio (SNR) and nominal throughput change in this case?
2. The idea of partial retransmission is that instead of retransmitting the same $\mathbf{S}_{1,1} = \mathbf{S}_{1,2} = \mathbf{S}_{1,3} = \mathbf{s}$, Xia can retransmit another set of symbols $\mathbf{R}_{1,2}$ for the first retransmission, $\mathbf{R}_{1,3}$ for the second retransmission, etc. The redundancy of $\mathbf{R}_{1,2}, \mathbf{R}_{1,3}, \dots$ is not introduced in the first transmission but upon feedback from the receiver. This is why this retransmission method is called *incremental redundancy*. Describe a simple protocol that uses incremental redundancy to show that this approach can improve the throughput without decreasing the reliability.

Extra Problem – Hamming Code with Syndrome Decoding

Based on the file "`extra_hamming_code.m`", write the code for an encoder that uses the $(7, 4)$ Hamming code and a decoder that uses the syndrome decoding algorithm. The decoder must return the decoded message and print the number of erroneous bits detected in the received codeword.