Lab 4: Channel Coding: Making Communication Reliable

Report Due: 21:00, 5/31, 2019

1 Overview

In computing and telecommunication, an error correction code (ECC) is used for controlling errors in data over unreliable or noisy communication channels. The central idea is that the sender encodes the message with redundancy in the form of an ECC.

2 Experiments

In this section, first we calculate the SER and BER of the system, and derive the theoretical curves. Next, we will implement convolutional code, including encoder and decoder. In the end, I want you to simulate the entire communication system.

1. **SER & BER:** In digital communication, the number of symbol errors (bit errors) is the number of received symbols (bits) that have been altered due to noise, interference, etc.

   (a) Generate a sequence of $n = 1000$ bits and simulate transmitting the sequence over a 16-QAM communication system with different E_b/N_0.

   Repeat the experiment R times. Each experiment randomly generates a sequence of bits. Plot the average SER vs. E_b/N_0 and average BER vs. E_b/N_0 curves with $R = \{10, 100, 1000\}$. Observe the changes among the curves.

   (b) (Handwriting) Please derive the theoretical SER of 16-QAM, and the upper/lower bound for SER of 16-QAM.

   (c) Show simulated SER, theoretical SER, and upper/lower bound for SER in one figure.

2. **Convolutional Code:** A convolutional code is a type of error correction code, and can be described by an finite-state-machine. Next, we will go through some convolutional code and Viterbi decoding algorithm exercises.

   (a) (Handwriting) A convolutional encoder has two finite impulse response (FIR),

   $$\mathbf{h}^{(1)} = [1\ 1\ 1\ 1],\ \mathbf{h}^{(2)} = [1\ 1\ 0\ 1].$$

   Please calculate the code rate, and plot shift register structure, state transition diagram, and trellis diagram.

   (b) (Handwriting) Following (a), trace the path through the trellis diagram corresponding to the message sequence $\{10111\}$.

(c) Write a Matlab function to implement a convolutional encoder. The function should have the following arguments:

```
encoded_data = convolutional_enc(binary_data, impulse_response)
```

(d) (Handwriting) Following (a), the received data is {1000101101011000}. Using the Viterbi algorithm, compute the decoded data.

Please see pp.28-39 in Comm_Lab_Week_11_ver_20190501.pdf, construct the trellis diagram, and write the cost and the previous state on the trellis diagram.

(e) Write a Matlab function to implement a convolutional decoder. The function has the following arguments:

```
decoded_data = convolutional_dec(binary_data, impulse_response)
```

3. **Communication System:** After four Labs, now you have gone through the entire communication system. Combine all processing blocks in each Lab, and simulate transmitting a audio file (`handel.ogg`) to the communication system. Discuss the influence of the parameters (e.g., the number of levels in the quantizer, the constellation, Huffman coding, error correction code, SNR, and so on) on the quality of the received signal.

3 Lab Report

There is no format requirements for your lab report. In the report, you should address the results of the exercises mentioned above. You should also include your simulation program in the appendix of the report. Include whatever discussions about the new findings during the lab exercise, or the problems encountered and how are those solved. Do not limit yourself to the exercises specified here. You are highly encouraged to play around with your simulation program on self-initiated extra lab exercises/discussions. For example, you can record your own voice or search for sound clips with no copyright at Freesound.org (`https://freesound.org/`).