Assignment 6
EE6143: Advanced Topics in Communications

Due: 11:59 PM, 15 May 2021

1 Problem Statement

This assignment extends the work you did in Programming Assignment 2 (Assignment 3). You will simulate a bits to bits OFDM system in which data is transmitted through an AWGN channel. You will use LDPC coding to increase the reliability of your transmission. The goal is to study the variation of bit error rate (BER) with $\frac{E_b}{N_0}$ for different constellations- 16 QAM and 64 QAM for different code rates. Upon completing the assignment you will develop a better understanding of the following

- LDPC encoding and decoding in 5G
- Effect of code rate on performance

In this assignment, you will adhere to the 5G NR specifications as in Assignment 3 for time domain and frequency domain structure. These will be detailed for you in Sections 2 and 3.

This assignment can either be done individually or in a group of two. Details regarding collaboration can be found in Section 5.

2 Setup

As mentioned in Section 1, you will stick to the 5G standards while implementing this assignment.

2.1 5G NR specific constraints

Consider the following constraints

1. You are to transmit 42000 bits of information at a carrier frequency of 3.5 GHz with a subcarrier spacing of 30 kHz at different code rates and using different constellations.
2. You are allocated 50 resource blocks per OFDM symbol to transmit data.
3. Data can be transmitted in each symbol of the slot. All the resource elements (REs) starting from the first RE can be used for transmission.

2.2 System to be implemented

This assignment is based on the steps described in Section 7.2, TS 38.212. Figure 1 provides a schematic of the system you need to implement. Please note that Figure 1 has been provided only as a tentative schematic. Make any suitable modifications as needed.

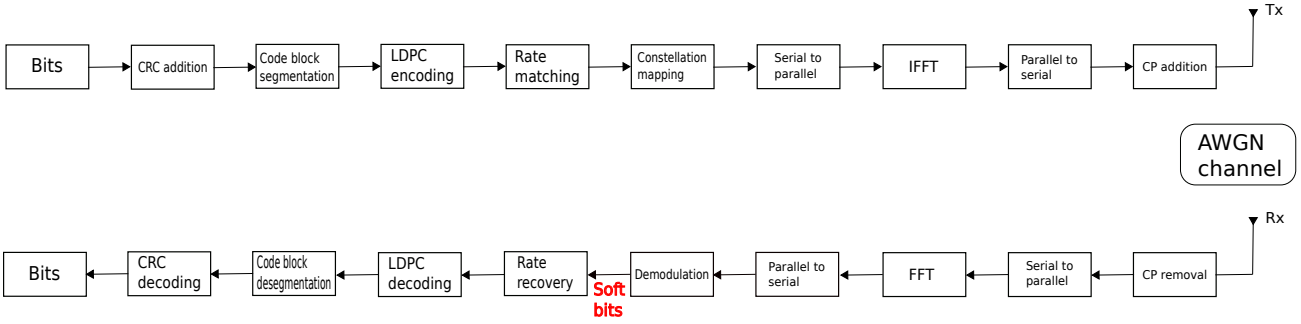

Figure 1: A schematic of the OFDM chain with LDPC- note that for this exercise, you will provide soft bits as the input to the rate recovery module

Please refer to the following source to complete the assignment-

https://in.mathworks.com/help/5g/gs/ldpc-processing-chain-for-dl-sch.html

Make use of the inbuilt MATLAB functions used in the above example! The following steps describe one possible way of realising the system depicted in Figure 1-

1. Generate 42000 random bits such that each bit is equally likely.
2. For each constellation
   (a) Select a range of suitable of $\frac{E_b}{N_0}$/SNR values so that a BER of 10^{-3} can be seen for all code rates.
   (b) For each code rate,
      i. Perform CRC addition, code block segmentation, LDPC encoding and rate matching as shown in Figure 1. Use functions from the MATLAB 5G toolbox for this as done in the link provided above.

ii. Determine how many QAM symbols you will obtain from the coded bits. You are allowed to transmit using 50 PRBs in every OFDM symbol. However, you may use how many ever OFDM symbols necessary to transmit the data. If the REs corresponding to the last necessary OFDM symbol are partially filled, generate zero bits, modulate and transmit them to fill up the empty REs. Exclude these symbols used to fill up the remaining REs during the computation of BER.

iii. Pass the coded bits through the OFDM system as you did in Assignment 3 for various values of SNR. Convert between $\frac{E_b}{N_0}$ and SNR appropriately. Transmit data only through an AWGN channel.

iv. At the receiver, demodulate the QAM symbols to obtain soft bits upon which rate recovery, LDPC decoding, Code block desegmentation and CRC removal can be performed.

v. Compute the BER.

You will modify the above setup as described in Section 3 to obtain the results desired in this simulation. You will find details regarding the values of parameters such as FFT/IFFT size, cyclic prefix length and so forth in Section 3.

3 Simulation

3.1 Parameters

Use the parameter values specified below to obtain the results required for your evaluation. However, feel free to play around with these values and record anything interesting you might observe in your report!

Assume the following

1. FFT size : 4096
2. CP length for first OFDM symbol in a slot : 352
3. CP length for remaining 2^{nd} to 14^{th} OFDM symbol : 288
4. SCS : 30 kHz
5. Number of bits to be transmitted : 42000
6. Number of resource blocks : 50
7. QAM constellations : 16, 64

8. Code rates for 16 QAM: [434/1024, 616/1024]

9. Code rates for 64 QAM: [466/1024, 873/1024]

Note that unlike in Programming Assignment 2, you have not been asked to transmit one slot of information. Instead, your goal is to transmit 42000 bits of information- the number of OFDM symbols you will be using will depend on the code rates and modulation order. However, in each OFDM symbol, you can only transmit 50 PRBs worth of data.

Implementing CFO and timing offset are not necessary. You may make use of the solutions provided for Programming Assignment 2 or reuse your code from the same as you see fit.

3.2 Transmission through an AWGN channel

In this simulation, you will complete the setup described in Section 2. Following this, you will obtain the BER vs $\frac{E_b}{N_0}$ curves for each code rate of each modulation order. Use the code rate values specified in Section 3.1 for each constellation. These values have been obtained from Table 5.1.3.1-2 of TS 38.214. In all, you will produce two separate plots-

1. BER vs $\frac{E_b}{N_0}$ for 16 QAM for the code rates specified in Section 3.1 for 16 QAM. Also plot the theoretical AWGN BER curve for 16 QAM on the same graph.

2. BER vs $\frac{E_b}{N_0}$ for 64 QAM for the code rates specified in Section 3.1 for 64 QAM. Also plot the theoretical AWGN BER curve for 64 QAM on the same graph.

Compare the empirical curves with the theoretical uncoded curves and note down your observations in your report.

4 Submission

The assignment is due by **11:59 PM, 15 May 2021**. **Late submissions will be penalized heavily.**

Adhere to the following guidelines when submitting your assignments

1. Submit a single .zip file with your submission in it. Compress all the files into one .zip file with the name "Assignment6_[your_roll_no].zip". If you are not a student at IITM then name the file as "Assignment6_[your_first_name_your_last_name].zip" and submit it.
   For instance, if you are a student at IITM with the roll number EE16B025, then your

submission will be Assignment6_EE16B025.zip
If you are a participant from DoT and your name is (say) Milind Kumar, then your submission will be Assignment6_Milind_Kumar.zip

2. Each submission file must contain the following

   (a) OFDM_LDPC.m

   (b) Report_[your_roll_no].pdf (for IITM students) or
   Report_[your_first_name_your_last_name].pdf (for DoT participants). This report is optional for DoT participants.

   Descriptions of each file are given below. Further, also include any associated functions that you may have written or files that complete your code.

4.1 OFDM_LDPC.m

When run, this file should perform the simulations described in Section 3.2.

The following variables should be present (**with the exact same name!**) at the top of this script-

1. **QAMorder** : the modulation order for which the simulation should be run. Upon setting this value to one of 16 or 64 and running the code, the plot corresponding to the specified modulation order, as described in Section 3.2 should be produced. Set this value to 16 at the time of submission.

When run, the following should be the output-

1. A plot of both empirical (at different code rates) and theoretical BER vs $\frac{E_b}{N_0}$ curves for the specified constellation.

No other outputs should be generated. Further, make sure nothing else is printed onto the console.

4.2 Report_[identity].pdf

A LaTeXreport is mandatory for IITM students. DoT personnel are **very strongly encouraged** to submit a report- made using LaTeX or even MS Word/Google Docs. However, the report is not mandatory for DoT personnel.

The report must contain the following-

1. Results, details and observations for the simulation described in Section 3.
2. Some elementary theory about LDPC coding, rate matching and the need for them in a communication system.

Feel free to add any theoretical insights or observations you might have made during the completion of the assignment. Further, the report must have a Table of Contents, a List of Figures and a References Section. Refer to the Appendix for details regarding plotting, collaboration and the code.

5 Evaluation

This assignment will be evaluated for 100 points with the following split-

1. Code documentation: 5 points
2. Code functioning: 20 points
3. Simulation results: 60 points
   (a) Results for 16 QAM: 30 points
   (b) Results for 64 QAM: 30 points
4. Report: 15 points
   (a) Presentation: 5 points
   (b) Theory, results and analysis: 10 points

Appendices

A Plotting guidelines

Ensure the following when preparing scientific plots

- All plots must have a grid.
- All plots must have a legend.
- All plots must have a title.
- The X and Y axes must be labelled in all the plots.
- All figures must have captions in the report.

B Coding guidelines

- Provide detailed documentation for the code in form of comments and Docstrings.
- Remove all debug statements (such as print statements) from the code before you submit.

C Collaboration guidelines

- You can either work individually or in a group of two.
- Do not plaigiarise or copy either the code or the report! If you have discussed with someone else or some other team, make sure to mention their names in the code and report.