EE910: Digital Communication Systems-I

Adrish Banerjee

Department of Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur, Uttar Pradesh
India

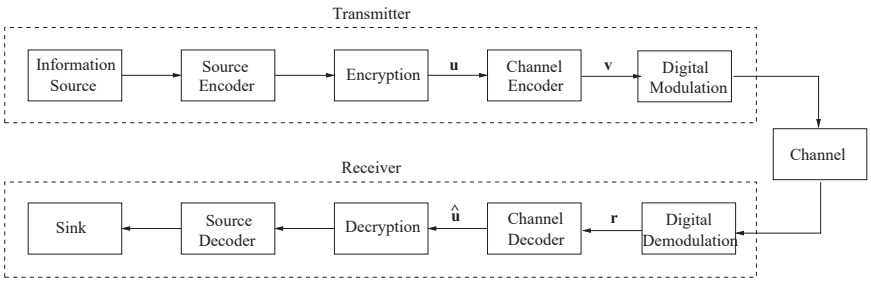
April 11, 2022

Lecture #1A: An introduction to digital communications

Books

- John G. Proakis and Masoud Salehi, "Digital Communications", 5th edition, McGraw Hill, 2008.
- Bernard Sklar and Pabitra Kumar Ray, "Digital Communications: Fundamentals and Applications", 2nd Edition, Prentice Hall
- John R. Barry, Edward A. Lee and David G. Messerschmitt, "Digital Communication", 3rd Edition, Springer.
- Michael P. Fitz, "Fundamentals of Communication Systems", 1st Edition, McGraw Hill,

Block Diagram of a Digital Communication System



Source Coding

- *Function*: To minimize the number of bits per unit time required to represent the source output.
- This process is known as *source coding* or *data compression*
- *Examples*: Huffman coding, Lempel-Ziv algorithm.
- The output of the source encoder is referred to as the *information sequence*.

Source Coding

- Use the statistical structure of a source to represent its output efficiently.
- Example: A bag contains 50% black balls, 25% red balls, 12.5% blue balls, 12.5% green balls. You are randomly picking a ball from the bag and want to convey the information about the color of the ball.
- Simple encoding (Dumb way!), black=00, red=01, blue=10, green=11. An average of 2.0 bits/color
- Smart way? black=0, red=10, blue=110, green=111. An average of 1.75 bits/color
- Can you figure out the color of the balls from the sequence 0110100111?
- Black, blue, red, black, green.
- Main principle of data compression: "Only infrmatn esentil to understnd mst b tranmitd."

Encryption

- *Function*: To make source bits transmission secure.
- This process of converting source bits (message text) into a source stream that looks like meaningless random bits of data (cipher text) is known as *encryption*.
- *Examples*: Data Encryption Standard (DES), RSA system.

Encryption

A	B	C	D	E	F	G	H	I	J	K	L	M
0	1	2	3	4	5	6	7	8	9	10	11	12
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
13	14	15	16	17	18	19	20	21	22	23	24	25

- Example Message: SEE ME IN MALL
  Take keyword as INFOSEC
  Vigenere cipher works as follows:

S	E	E	M	E	I	N	M	A	L	L
I	N	F	O	S	E	C	I	N	F	O
A	R	J	A	W	M	P	U	N	Q	Z

Channel Coding

- *Function*: To correct transmission errors introduced by the channel.
- The process of introducing some redundant bits to a sequence of information bits in a controlled manner to correct transmission errors is known as *channel coding* or *error control coding*.
- *Example*: Repetition code, Reed-Solomon codes, CRC codes.
- The encoded sequence that is the output of the channel encoder is referred to as *codeword*.

Channel Coding

- Example: Repetition codes
- Rate R=1/2 code

$$0 \rightarrow 00 \qquad 1 \rightarrow 11$$

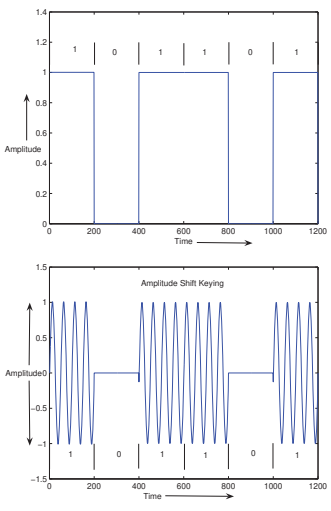
- Rate R=1/3 code

$$0 \rightarrow 000 \qquad 1 \rightarrow 111$$

Modulation

- *Function*: To map the codewords into waveforms which are then transmitted over the physical medium known as the channel.
- *Examples*: Phase shift keying (PSK), quadrature amplitude modulation (QAM).

Modulation



Channel

- The physical transmission medium; it can be wireless or wireline.
- Corrupts transmitted waveforms due to various effects such as noise, interference, fading, and multipath transmission.
- *Examples*: Binary erasure channel (BEC), Additive white Gaussian noise (AWGN) channel.

Demodulation

- *Function*: To convert received noisy waveform to a sequence of bits, which is an estimate of the transmitted data bits. This is known as *hard demodulation*.
- If the demodulator outputs are unquantized (or has more than two quantization levels), this is known as *soft demodulation*.
- Soft demodulation has significant improvement over hard demodulation.

Channel Decoding

- *Function*: To estimate the information bits $\hat{\mathbf{u}}$, and correct the transmission errors.
- If $\hat{\mathbf{u}} \neq \mathbf{u}$, decoding errors have occurred.
- The performance of the channel decoder is usually measured by the *bit error rate* (BER) or the *frame error rate* (FER) of the decoded information sequence.
- The BER is defined as the expected number of information bit decoding errors per decoded information bit.
- The coded sequences can be broken up into blocks of data *frames*. A frame error occurs if any information bit in that data frame is in error. The decoded FER is the percentage of frames in error.

Decryption

- *Function*: To recover the plain text from the cipher text with the help of key.
- It is in the key that the security of a modern cipher lies, not in the details of the cipher.

Source Decoding

- *Function*: To reconstruct the original source bits from the decoded information sequence.
- Due to channel errors, the final reconstructed signal may be distorted.