# Hamming code included Manchester Line Coding implementation using Shannon's Model

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***Abstract*— The communication system has been constantly evolving to advance the interaction in both wired and wireless medium. One of the remarkable milestones in the initial development of the communication system was laid by the research findings from Shannon. The most common challenge of any communication system is the transmission of a message from source to destination without any error. This is a research paper to demonstrate the Line coding process (using Manchester encoding and decoding Scheme) of a message using the structure of the communication system proposed by Shannon. The two imperative features of this encoding and decoding processes include the transmission of the signal through a noisy channel and correction of the errors using a Forward Error Correction (FEC) approach i.e., Hamming Code implementation. The error detection and correction application are partially rectified and resolved by this FEC enforcement in the noisy transmission channel of a signal.**

## I. INTRODUCTION

The communication model proposed by Shannon has introduced the concepts that were never considered until 1948. Some of the identifications in the model of a general communication system are noise in the channel, influential factors during a signal transmission from source to the destination, their limitations etc. are the significant outcomes in his research paper. According to his paper, the main components of the communication system are determined in the following figure: [1]

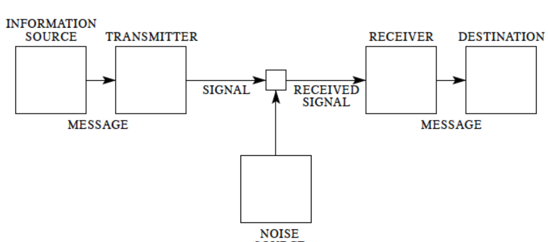


Fig. 1. Shannon's Communication model [1]

**Information source:** It is the message generation point or technically the initial source for the message storage in the system. The message is further transmitted to the next components to reach the destination.

**Transmitter:** This is responsible for modulating a message into a signal and this converted signal is transmitted to the next phase.

**Channel:** It is the medium of communication or the connector to transmit the signal from transmitter to receiver.

**Receiver:** This is accountable for the conversion of a signal to its original message format. It is also called the demodulator and helps in deriving the message from a modulated signal.

**Information Destination:** It is the destination where the information has to be reached for a person or machine.

**Noise source:** A source that generates unwanted information which makes modifications to the original information in the transmitting signal is a noise source. Any data that is exposed to noise would result in obscured data.

Line Coding is a process of understanding the transmission of information from one part to another part of the communication system. It is one of the forms of Coding Theory, which is a system of rules that converts information from one form to another. In the line coding process, the main steps are encoding and decoding. Encoding is a phase where the data is converted from one system to another system in the form of codes. And decoding is the phase that does the opposite of encoding process and retrieves the original data that was been in a different format. In simpler terms, according to the mathematical model of Communication by Shannon, the message produced at the information source is modulated/ encoded by the transmitter and transmits the signal along a noisy channel. It is collected over the receiver, which does the demodulation/decoding process to regain the original message for the information destination.

Noise is the most usual type of barriers in any communication system. Noise is immaterial information that is generated in the components of the communication system to affect the flow of information transmission. Sometimes, in other models of communication, there is a scope of noise generation in the segments like the transmitter or the receiver rather than only in the channel. This causes issues like random or continuous disturbances in the message and change the meaning or lucidity of the original message that was transmitted by the information source. To avoid this, there are multiple Forward Error Correction (FEC) mechanisms developed that strive for effective and error-prone communication between the information source and destination.

## II. MODEL DESIGN

According to the mathematical model of communication proposed by Shannon, a simulated version of the communication system was implemented using the Manchester Line coding application. The fundamental idea of the line coding process is to convert the analog data into a digital signal and transmit it from the source to the final receiver. In other words, the Manchester line coding process involves a series of steps to encode a message into signal and decode a signal into the original message using an additional clock signal. Clock signals are measured in cycles and the length of one complete cycle is called a bit period. It is also the duration required for a signal to start and stop within a single bit propagation in asynchronous signalling systems [2].

### A. Manchester Encoding

This is a serial data signalling system which uses a clock signal along with the original data to transmit a Manchester wave [3]. There are 3 main stages associated in the encoding process of an original message between the information source and the channel. Let's say, a word is propagated from the information source and sent to the transmitter for encoding purpose. In the transmitter, initially, the message that we are considering to encode has to be converted into the binary (bits) format. Secondly, we need to create a clock variable for double the length of the message in binary format (A series of 1's and 0's till the data length). The binary data of the message will undergo the XOR operation with clock bits to derive the Manchester square wave bits/ signal [4].

One of the main assumptions here to be identified is that the clock cycle is complete for every data bit transmission. This is because we have to double the data bits in the transmitter to perform XOR operation with clock bits and achieve the Manchester square wave signals.

### B. Manchester Decoding

There are multiple ways to accomplish the Manchester Decoding process. Of all the complex techniques, a simpler reverse mechanism to the encoding process is applied to derive the originally transmitted message at the receiver end. This decoding process involves 4 key steps between the channel and the destination. Firstly, the obtained Manchester encoded signal is identified at the receiver and create a clock variable for the length of the signal. The clock bits and the Manchester signal bits will undergo XOR logic operation to yield the original data bits in duplicated format. Eliminate the duplicates bits (that are sequencing after every bit) from the binary data. And lastly, convert the binary data to a string/ASCII format to attain the original information.

### C. Generation of Noise

Noise is produced from the noise source into the channel and gets meddled with the signal bits that are in transmission. It is a form of energy that are randomly spread from low to the highest value of frequency bits. Before the implementation of FEC on the line coding process, the noise bits were randomly added into the Manchester signal bits and are passed on to the receiver. Also, it was added in such a way that the maximum frequency of the noise added Manchester signal is not greater than double the amplitude value of the pure Manchester data signal. But later to prove the effectiveness of the Hamming Code FEC implementation, a limited level of noise has been added with the original Manchester signal. To be precise, only single bits are modified in every character's binary bits sequence present in the original message.

### D. Hamming Code FEC

The process of rectifying the errors occurred in data transmission in an uncertain communication channel is called Forward Error Correction. Hamming code is a type of forwarding Error Correction (FEC) method, which was invented by Richard W. Hamming at Bell Labs in 1950 [5]. It helps in the correction of single-bit errors and also in the detection of two-bit errors. Hamming code is generated by adding the redundant bits (parity) to the original codes on the transmitter side. When the signal that is inclusive of hamming code is received at the receiver end, the error bits are identified by calculation of syndrome with the parity bits and the resultant bits. The errors can be rectified by interchanging the 0 bits with 1 and vice versa.

Hamming code implementation has the power of detecting and correcting the single-bit errors in a message and its reliable only to a particular extent of noises in the signal. Although there are other FEC techniques to correct multiple errors in a message, the main aim of this paper is to illustrate the working and proposition of hamming code with (8,12) variant, where an 8-bit data is encoded as 12-bit data in the encoding transmission.

## III. EVALUATION OF MODEL

In this section, the validity of the model that is generated on decoding the message with and without the implemented of FEC are discussed. Visualization of the resultants is the key to evaluate the encoding and decoding processes of the Manchester line coding with active noise inclusion in the system.

### A. Without FEC

There are two notable points in the Manchester signal, before the implementation of any FEC in this line coding process.

1) Random addition of noise bits to the signal bits. As this model includes noise in a random proportion, the resultant information at the receiver may not be guaranteed to match with the original message transmission from the information source.
2) A sequence of 8 bits is achieved during the conversion of ASCII to binary in the encoding process, to restore the ASCII format, sequences of 8-bits are captured to convert them into single characters, one after the other in the decoding methodology.

The following figure shows the signal transmission for a string message 'ke'. Here the green line represents the clock bits transmission, red for the original data in binary bits format, blue for the noiseless Manchester signal and black for the noise added Manchester signal respectively.

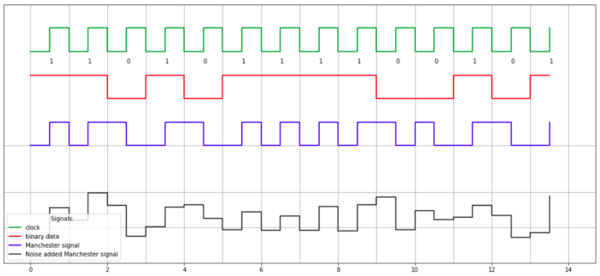


Fig. 2. Transmission of different bits on the transmitter end without the application of FEC [6]

### B. With FEC

The Hamming (12,8) a variant of hamming codes is executed in this research work. Invoking this FEC technique in the line coding process will encode an 8-bit message (because the ASCII format of a character has 8-bit length data) into the 12-bit transmission that consists of additional 4 parity bits with the original data. The usage of parity bits is the key to identify the single-bit errors in different variants of Hamming code. The main steps executed under the encoding and decoding processes of Hamming FEC are:

Encoding steps:

- Generate the parity check matrix
- Creation of the Code generator matrix from the combination of a data identity matrix and the parity matrix.
- Multiply the generator matrix with the original message to bring a linear hamming code.

Decoding steps:

- Multiply the received message with the previously created parity check matrix. The resultant here is the syndrome vector-matrix
- If the syndrome is natural, then there is no error in the message, else it is the value of the error position in the hamming code received.

Two significant factors have to be considered with the implementation of Hamming (8,12) codes in this Manchester line coding process.

1) Controlled addition of noise to each character in the message. It means that out of 8 binary bits, and an only single bit is modified.
2) Unlike the previous model, a sequence of 12 bits is captured in the decoding process to convert them into a single character.

The following figure shows the signal transmission for a string message ‘ke’. Here the green line represents the clock bits transmission, red for the original data encoded with the Hamming (8,12) FEC technique in binary bits format, blue for the noise added Manchester signal respectively.

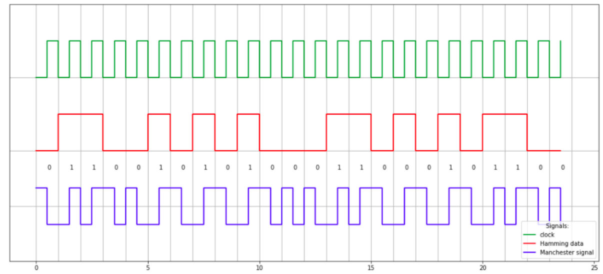


Fig. 3. Transmission of different bits on the transmitter end with the application of FEC [7]

## IV. DISCUSSION

In this section, the results of the models that are generated on decoding the message with and without the implemented of Hamming codes FEC are discussed. The best way to evaluate the Hamming code FEC model is by comparing the Signal to Noise Ratio (SNR) percentage values before and after the FEC application. SNR is the measure that compares a signal frequency power to its noise frequency power.

### A. Results Accuracy

The SNR percentages before the FEC implementation were always greater than 80%. As the random noise bits addition rate is higher to the signal bits, the error percentage was mostly around 80-90% and sometimes even 100

The below figure shows the plot of SNR distribution of the message received at destination before the Hamming FEC code.

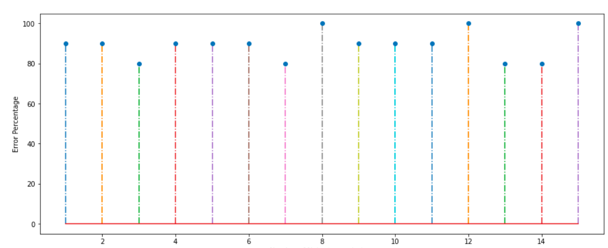


Fig. 4. Plot distribution of SNR percentages before Hamming code - FEC.

As there is a limitation of noise addition in this encoding process, the resultant signal will have the only single error for each character, and they can be resolved by the Hamming Codes decoding process. Even if the SNR percentage is calculated before doing the error correction, the ratio value would be around 4-10% depending on the length of the message. So, every time a message is passed through this line coding, it comes out as an original message after doing the error correction. Therefore, the message would be accurate by 100 per cent and the SNR percentage by zero.

### B. Advantages of the scheme

The basic Manchester encoding and decoding scheme has the potential to rectify the noise with the addition of FEC - Hamming code approach. This latest code can detect the error in the bits and can also correct them on the receiver

```
1  output = decode(ManchesterSignal)
2
3  output

The position of errors is both codewords are  0  and  5  respectively
The final message after doing error correction:
'ke'
```

Fig. 5. Screenshot of the message from the decoding method in implementation [7]

end. The time taken for the error detection and correction process computations takes less than a second. Guaranteed transmission of an original message at the receiver end without any need of retransmission at any given stage. Apart from the implementation of the FEC in this scheme, it has given a greater understanding in the logical and digital conversions of a signal message from a noisy channel into a perfect linear signal that can be error-free.

### C. Disadvantages of the scheme

The biggest limitations of executing Hamming code forward error correction in the encoding scheme are: Ability to correct only the single-bit errors, detect up to two errors (only if they are consequent) and cannot do any more than that. (It also means that hamming codes are inefficient in extreme noisy channels). Thus, the constraint of adding noise to a message, like only in the ratio of 1:12 makes it successful else deficient. The Manchester line coding needs a clock and duplicated data bits to transmit and receive signals. On the other hand, the hamming code conversions from 8-bit to 12 bits in encoding and 12 bits to 8-bit in decoding mechanisms are lengthy approaches and intricated. The complexity of the entire process increases with the increase in the transmission of data bits/ original message. This further causes in the increased usage of resources like memory space (both in the transmitter and the receiver), bandwidth in the signal transmissions in the communication systems. If any error occurs in the parity bits that are computed from the hamming technique itself, then there is no chance of receiving an error-free message at the receiver. Typical coding implementation of this whole process in python includes plenty of data formats and conversions to achieve the desired output.

### D. Shortcomings

On reading multiple ways of Manchester decoding techniques, most of them additional timer signals to decode the synchronized signal into the string format of the message. It means that the decoding process needs more memory space than the bits needed for encoding transmission. In some cases, as the number of data bits increases, there are more errors received on the receiver end and alterations in the original message. All these shortcomings and previously mentioned drawbacks prove that this is not an optimal FEC approach.

## V. FUTURE WORK

To improve this research work, longer data messages can be considered and make it compatible with lengthy messages or texts. Alongside, the drawbacks and shortcomings mentioned in the above sections can be undertaken to enhance the Hamming included Manchester line coding. As hamming codes correction is limited to single-bit errors, the implementation of other FEC's like convolutional codes, Reed – Solomon codes can be explored. This scheme can be tested against the influencing factors of the communication system and identify the areas of improvisation.

## VI. CONCLUSION

In this paper, a basic communication system was simulated using the Manchester line coding from the foundations of Shannon communication model. A study on the error producing communication system was improved with the application of Hamming codes forward error correction technique. To organize the ASCII data in different stages of communication model, hamming (8,12) variant codes are adopted. It is a single-bit error correction technique, that helps in identifying the error position and correcting it into actual, without the need of re-transmission. The Hamming code FEC is highly suitable in systems that are least prone to errors or noise transmissions.


## ACKNOWLEDGMENT

Professor of Information Technology, Doctor Trevor Michael Tomesh delivered a proficient level of knowledge and understanding that extremely supported in this project work and research. I like to show my grace and gratitude to Professor Doctor Trevor for his guidance and assistance in gaining this work achievable.


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