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CONVOLUTION ERROR CONTROL CODING -A REVIEW

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Abstract- In communication system, occurrence of errors is one of the concerning factor which reduces security as well as effectiveness of system. To develop a minimal error affected system, various error controlling and detecting codes are adopted to provide a secured and effective throughput. Convolution coding is such an approach for detection and correction of errors in long distance communication. A system should be designed to detect, prevent and correct the errors. The application area includes: deep-space communication, wireless standards, voiceband modems, submarine, digital communication, satellite communication and many more.

I. INTRODUCTION:

A communication network should beable to transfer data from one end to another with acceptable accuracy. During transmission, data/message gets corrupted in channel. The channel can be microwave links, fiber optic or co axial cables which is subject to the various kind of noise, distortions and interference. Occurrence of error is random in nature, which are either due to interference in environment or due to physical defects. Such interference leads to change in the shape of the signal (original data).

Mentioned in digital communication that these changes may be of single bit or of multiple bits. Based on this change errors are classified into two groups. Firstly Single bit error, in such case only one bit is changed from 0 to 1 or from 1 to 0.So duration of noise is less.

It is least occurring in serial communication. Secondly Burst error, it is the most likely occurring in serial communication. In this case more than one bit is changed.

Length of burst is measured from first corrupted bit to last corrupted bit although there is no corrupted bit in between. Therefore duration of noise is longer as compared to single bit. Such noise is most likely occurred in long distance communication. To achieve reliable data transmission several kinds of strategies can be adopted[6,9,10,and 11]: (a) Automatic Repeat reQuest (ARQ), where any time an error is detected in an exchange of data, specified data are retransmitted by transmitter on the request of receiver.(b) Forward Error Correcting (FEC) strategies which make use of error-correcting codes that automatically correct errors detected at the receiver.FEC schemes maintain constant throughput and have bounded time delay. (c)Hybrid strategies which combine ARQ and FEC. To overcome such problems, a variety of error detection and controlling techniques are developed. For example block code, Convolutional code, Reed-Solomon code, BCH codes etc. The main idea behind detection and correction of errors is redundancy. Redundancy is those extra bits which is sent along with original message and are responsible for error correction and detection. These bits are added by sender and removed by receiver. The ratio of redundant bits to message is important in any coding scheme. As this will affect the most conserving resource of communication system i.e. power and bandwidth. In 1987 William W.WU stated that based on this coding scheme error control technique is divided into two categories: block code and convolutional codes.Constraints like cost, power, bandwidth, type of channel, allowable delay in decoding, data rate and type of information play a vital role in the selection of coding schemes[7]. This paper mainly focused on convolution codes in more prospects.

II. CONVOLUTION CODE

An alternative to block codes was introduced by Elias in 1955. Convolutional codes belong to the FEC scheme. Found it is a powerful error correcting code that have a lower code rate (usually below 0.90). Although it is more difficult to implement, it significantly applicable where bandwidth is unlimited, bit error rate is much more and retransmission is infeasible.

1. Designand Implementation

In fig.1. Convolutional encoding is the way of channel encoding. Here, redundant bits are used for error determination. BPSK or QPSK is most effectively used as modulation schemes. Wozencraft proposed sequential decoding for convolution codes. Later on further experiment arouses with Viterbi decoding in 1967 as an improved and efficient convolutional decoder.

Convolutional coding with Viterbi decoding has been the predominant forward error correction technique used in space communication, particularly in geostationary satellite communication networks, such as VSAT (very small aperture terminal) networks.

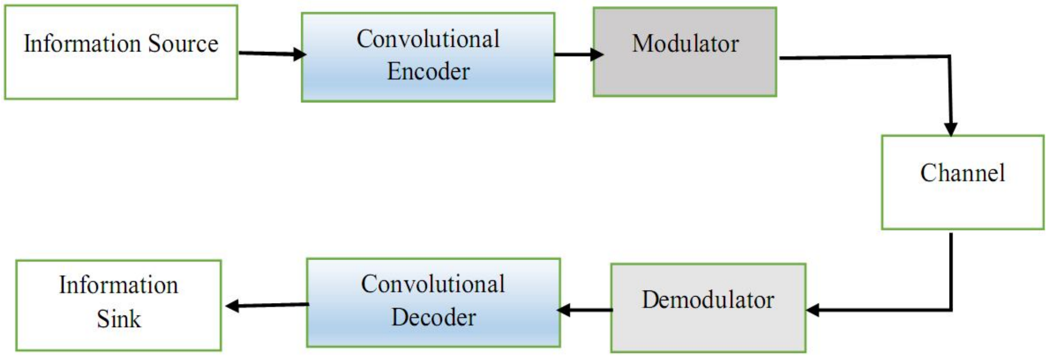

Fig.1. Convolutional encoder/decoder position in a digital communication system.

1.1Convolutional Encoder

In convolutional codes message bits sequence is passed through a linear finite state shift register in addition with a combinational logic of modulo-two addition. This code is well-known as (n, k, m) codes, where n,k,m are encoder parameter. A (n,k,m) convolutional codes can be implemented with k-inputs, n-output linear sequential circuit with input memory m.typically k<n and m must be kept larger to achieve low error probability. The quantity k / n called the code rate is a measure of the bandwidth efficiency of the code. Generally, the value of k and n ranges from 1 to 8, m from 2 to 10 and code rate from 1/8 to 7/8 with an exception for deep space communication where code rate is as low as 1/100 or even longer can be employed. The Codes are applied in a frame structure. Zero bits are appended in the message, for resetting the shift registers. Code rate may fall below k/n because of these added bits do not carry any information along with them.

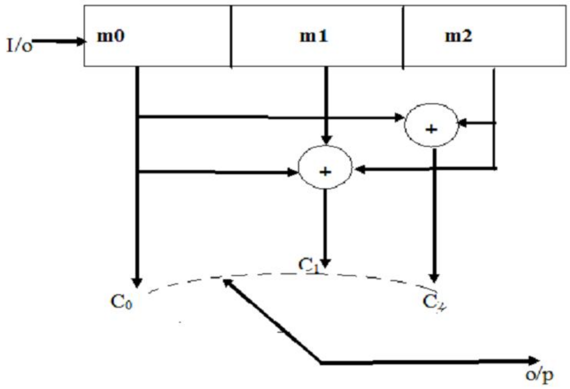

Fig.2 Convolutional Encoder with code rate 1/3

From fig.2. With n=1 k=3 and L=2 the mentioned encoder is designed.The three check bits are C_0,C_1,and C2. As C_0=m0, C_1 =m0+m1+m2 and C_2=m0+m2 (+ represents XOR operation).The operations of convolutional codes are defined by their polynomials,state diagram and trellis diagram.Implementation and design of convolutional codes with effective throughput can be analyzed in various research papers and concluded that data rate up to 6.61Gbits/s have been achieved on 32 bit parallel implementations of convolutional encoders.

1.2Decoders.

The performance of convolutional code depends on the decoding algorithm employed and the distance properties of the code. For decoding of convolutional codes,for relatively small values of k, the Viterbi algorithm is universally used. VITERBI decoder is one of the most widely used components in digital communications and storage devices. Although its VLSI implementation is studied in depth over the last decades, still everynew design starts with design space exploration.. Viterbi decodercan be either hard or soft decision. Hard decision and soft decision viterbi decoding refer to the type of quantization usedon the received bits. Hard decisiondecoding uses 1 bit quantization on the received channelvalues while soft decision decoding uses multi bit quantization on the received channel values.

Here a summarized introduction of convolutional decoder is focused. The decoding algorithm uses two metrics: Thebranch metric(BM), it is a measure of the "distance" between transmitted and received signals, BMU is typically the smallest unit of Viterbi decoder. Its complexity increases exponentially with reciprocal of the coding rate. In hard decision decoding, where we are given a sequence of digitized parity bits, the branch metric is the hamming distance between the expected parity bits and the received ones.

The Path Metric(PM),for hard decision decoding, it corresponds to the Hamming distance over the most likely path from the initial state to the current state in the trellis. By "most likely", mean the path with smallest Hamming distance between the initial state and the current state, measured over all possible paths between the two states.

The path with the smallest Hamming distance minimizes the total number of bit errors, and is most likely when the BER is low.

Another decoding is Sequential decodingis mainly used is as an approximate decoding algorithm for long constraint-length convolutional codes. Sequential decoding is characterized as sequential search for the shortest path through a trellis. The purpose using of sequential decoding is to reduce cost and memory requirements.

III. PERFORMANCE OF CONVOLUTION CODE

Convolutional code error correction capability in AWGN channel is shown in graph fig. 3, BER to E_b/N_b(dB), which is good as compared to Block code and without coding. Parameters for the following plot are N=7,K=3, d_{min}=5 for block code and convolutional coding using trellis method for state estimation. Performance metrics of convolutional code include some issues. Firstly, how much better soft decision decoding in compared to hard decision decoding. As soft decoding is algorithm based decision whereas hard decision is based on circuit implementation like integrated and dump circuit. The explanation to this issue is shown in plot below fig.3which shows performance results for same set of codes having same code rate. Secondly, the reduction in the bit error rate, and comparison with other codes.The explanation depends on the amount of noise,the constraint length(larger K has better error correction)and thenumber of generators (larger this number, the lower the rate, and the better the error correction). Third issue is about the time of decoding which is related with the value of K we need to process (2^K) transitions each bit time, so thetime complexity is exponential in K and the last but not least issue include the need of measure of state and space for encoders. Number of state and space of encoder depends on the amount of space is linear in K, the constraint length,and the encoder is much easier to implement than the Viterbi decoder.

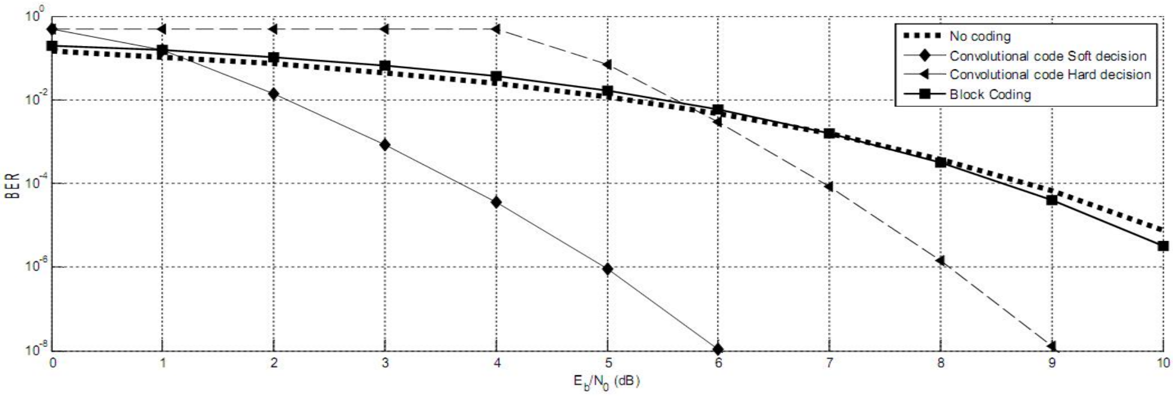

Fig.3. BER v/s E_b/N_b(dB) plot

IV. APPLICATIONS OF CONVOLUTION CODES

A wide scenario of application of convolution codes has come into the picture from various research papers, out of which few remarkable application areas is mentioned in this paper. Convolutional codes are often used to improve the performance of digital radio, mobile phones, satellite links, and Bluetooth implementations. Convolutional codes are very popular over both wired and wireless links, in deep space missions to achieve reliable data transfer, including digital video, radio, mobile communication and satellite communication. The first large-scale application includes a rate-1/2 convolutional code with constraint length 20 for the Pioneer 1968 mission. The receiver used 3-bit soft decisions and sequential decoding implemented on a general-purpose 16-bit minicomputer with a 1 MHz clock rate. Recently, In Mars Exploration, use a k of 15 and a rate of 1/6 will also use convolution codes.

CONCLUSION

After reviewing various research papers, it is revealed that the performance parameter like amount of state and space of an encoder, delay in decoding process, reduction in BER and soft decoding and hard decoding for coder and decoder has improved. But there is still a trade-offs between channel efficiency and the amount of coding/decoding logic implemented. Also we can analysis convolution coding techniques with respect to other coding techniques. The performance of convolution coding with various modulation techniques can also enhance its area of application with minimal error.

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