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FORWARD ERROR CORRECTION CODING TECHNIQUES FOR RELIABLE COMMUNICATION SYSTEMS

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Abstract: -

The main purpose of a communication system is to transmit information reliably over a channel. Information transmitted by the source becomes noisy when it passes through the channel whether wireless or wired. The noise causes the data to become corrupted. Therefore system requires the implementation of Forward error correction techniques to improve Bit error rate. In this paper, we provide a comprehensive review of various error-correction techniques. The fundamentals and advantages of the FEC techniques are also discussed in this paper.

Keywords: FEC, Convolutional codes (CC), Reed-Solomon codes (RS), LDPC.

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I. Introduction

The main purpose/aim of any communication system is to transmit data/information reliably over a channel. The channel can be coaxial cables, microwave links or fiber optic and is subject to various types of noise, distortion, and interference. All these may lead to errors and consequently we may require some sort/form of error control encoding to recover the information reliably. In wireless, satellite, and space communication systems, reducing error is critical. In communication system & information theory, FEC is a method of error control for data transmission in which the sender/transmitter adds systematically generated redundant data to its messages. The carefully designed redundancy in message allows the receiver to detect and correct a limited number of errors. FEC therefore provides the receiver an ability to detect and correct errors and without the need to request retransmission of data. However this requires a fixed higher forward channel bandwidth. FEC is therefore implemented in situations where retransmissions are costly or impossible like broadcasting to multiple receivers. It is accomplished by adding redundancy bits to the transmitted data using a pre-determined algorithm. The attached redundant bits may be a complex function of many data bits. The original data may or may not appear in the encoded output. The codes that include the unmodified input data in the output are systematic, whereas those that do not are non-systematic.

Error-control coding can be used for a number of different applications. Codes can be used to achieve reliable communication in presence of interference [6].

- The Internet: In a typical TCP/IP stack, error control is performed at multiple levels. Each Ethernet frame carries a CRC-32 checksum. UDP has an optional checksum covering the payload and addressing information from the UDP and IP headers. TCP provides a checksum for protecting the payload and addressing information from the TCP and IP headers.
- Deep-Space Telecommunications: Error-correction codes were tightly coupled with the history of deep-space missions due to the extreme dilution of signal power over interplanetary distances, and the limited power availability aboard space probes.
- Satellite Broadcasting: The demand for satellite transponder bandwidth continues to grow, fueled by the desire to deliver television (including new channels and High Definition TV) and IP data. Transponder availability and bandwidth constraints have limited this growth, because transponder capacity is determined by the selected modulation scheme and Forward error correction (FEC) rate. QPSK coupled with traditional Reed Solomon and Viterbi codes have been used for nearly 20 years for the delivery of digital satellite TV.
- Data Storage: Error detection and correction codes are used to improve the reliability of data storage media.
- Error-Correcting Memory: DRAM memory may provide increased protection against soft errors by relying on error correcting codes. Such error-correcting memory, known as ECC or EDAC-protected memory is particularly desirable for high fault-tolerant applications, such as servers, as well as deep-space applications due to increased radiation.
- Military Applications: In military applications error control codes are used to protect information from intentional enemy interference.
- Digital Audio Disc: It can safely be claimed that Reed-Solomon codes are the most frequently used digital error control codes in the world. This claim rests firmly on the fact that the digital audio disc, or compact disc uses Reed-Solomon codes for error correction and error concealment.

II. Convolutional Code (CC)

Convolutional code is widely used and is done by combining the fixed number of input bits. The input bits are stored in fixed length shift register and they are combined with the help of mod-2 adders. An

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input sequence and contents of shift registers perform modulo-two addition after information sequence is sent to shift registers, so that an output sequence is obtained.

This operation is equivalent to binary convolution and hence it is called convolutional coding. The ratio R=k/n is called the code rate for a convolutional code where k is the number of parallel input bits and n is the number of parallel decoded output bits, m is the symbolized number of shift registers. Shift registers store the state information of convolutional encoder, and constraint length (K) relates the number of bits upon which the output depends. A convolutional code can become very complicated with various code rates and constraint lengths.
A simple convolutional code with ½ code rate is shown in Figure 1. Here m represent the current message bit and m1,m2 represent the previous two successive message bits stored which represent the state of shift register. This is a rate (k/n) = 1/2, with constraint length K=3 convolutional encoder.
Here k is the number of input information bits and n is the number of parallel output encoded bits at one time interval. In the encoder we observe that whenever a particular message bit enters a shift register, it remains in the shift register for three shifts. And at the fourth shift the message bit is discarded or simply lost by overwriting.

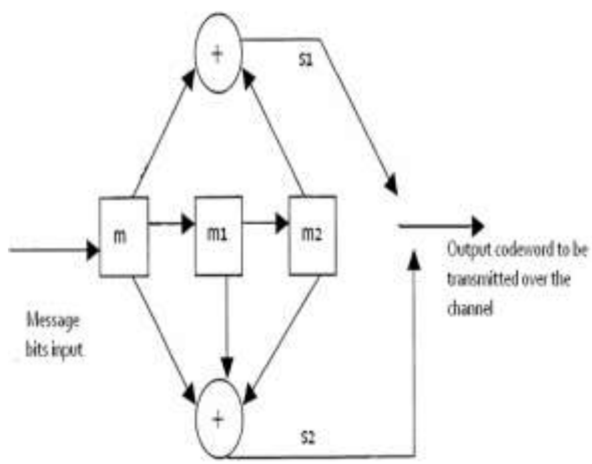

Fig. 1**:** Convolutional encoder with rate1/2, k=1, n=2, K= 4, m= 3

The constraint length, K, of the convolutional encoder is defined by K= m+1, where m is the maximum number of memories in any convolutional encoder.

Viterbi decoding algorithm is mostly applied to convolutional encoder and it uses maximum likelihood decoding technique [4]. Noisy channels cause bit errors at receiver. Viterbi algorithm estimates actual bit sequence using trellis diagram. Commonly, its decoding algorithm is used in two different forms. This difference results from the receiving form of the bits in the receiver. Decoded information is received with

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hard decision or soft decision. Decoded information is explained with ±1 on hard decision operation while soft decision decoding uses multi bit quantization [4]. Hard decision and soft decision decoding refer to the type of quantization used on the received bits.

Hard decision decoding uses 1 bit quantization on the received channel values while soft decision decoding uses multi bit quantization on the received channel values. For hard decision decoding, the symbols are quantized to one bit precision while for soft decision decoding, data bits are quantized to three or four bits of precision. The selection of quantization levels is an important design decision because of its significant effect on the performance of the link [10].

III. Reed-Solomon Codes (RS)

The RS code is one of linear block codes which were proposed in 1960 [5]. It is vulnerable to the random errors but strong to burst errors. Hence, it has good performance in fading channel which have more burst errors. In coding theory Reed–Solomon (RS) codes are cyclic error correcting codes invented by Irving S.Reed and Gustave Solomon.

They described a systematic way of building codes that could detect and correct multiple random symbol errors. By adding t check symbols to the data, an RS code can detect any combination of up to t erroneous symbols, and correct up to [t/2] symbols. As an erasure code, it can correct up to t known erasures, or it can detect and correct combinations of errors and erasures.

Furthermore, RS codes are suitable as multiple-burst bit-error correcting codes, since a sequence of b+1 consecutive bit errors can affect at most two symbols of size b. Reed-Solomon codes have found important applications from deep-space communication to consumer electronics.

They are prominently used in consumer electronics such as CDs, DVDs, Blu-ray Discs, in data transmission technologies such as DSL & WiMAX, in broadcast systems like ATSC, and in computer applications such as RAID 6 systems. The Reed-Solomon code is a [n,k,n-k+1] code, in other words, it is a linear block code of length n with dimension k and minimum Hamming distance n-k+1.

The Reed-Solomon code is optimal in the sense that the minimum distance has the maximum value possible for a linear code of size (n, k), this is known as the Singleton bound. Such a code is also called a maximum distance separable code. The error-correcting ability of a Reed–Solomon code is determined by its minimum distance, or equivalently, by n−k, the measure of redundancy in the block. If the locations of the error symbols are not known in advance, then a Reed–Solomon code can correct up to $(n - k) / 2$ erroneous symbols, i.e., it can correct half as many errors as there are redundant symbols added to the block.

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A Reed–Solomon code is able to correct twice as many erasures as errors, and any combination of errors and erasures can be corrected as long as the relation $2Er + S \leq n - k$ is satisfied, where Er is the number of errors and S is the number of erasures in the block. For practical uses of Reed–Solomon codes, it is common to use a finite field F with 2^m elements. In this case, each symbol can be represented as an m-bit value.

The sender sends the data points as encoded blocks, and the number of symbols in the encoded block is $n = 2^m - 1$. Thus a Reed–Solomon code operating on 8-bit symbols has $n = 2^8 - 1 = 255$ symbols per block. The number k, with $k < n$, of data symbols in the block is a design parameter [12].

IV. Results

We developed, implemented and tested the codes. Performance of the developed model is evaluated for different code rates by taking random data stream of defined length for each of the coding techniques..

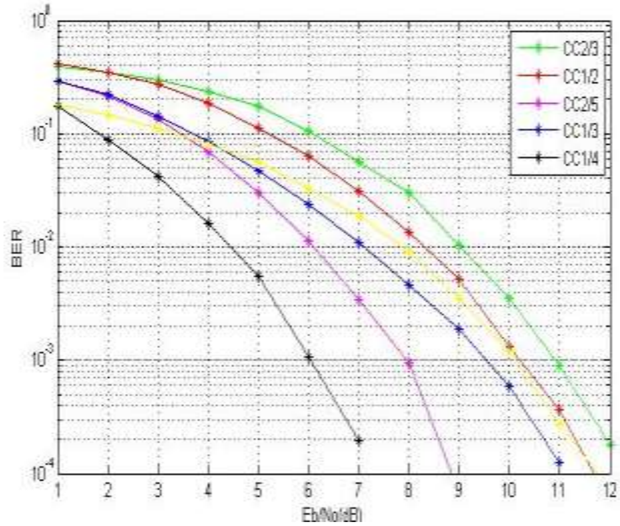

Figure 2: BER of CC code with varying code rate

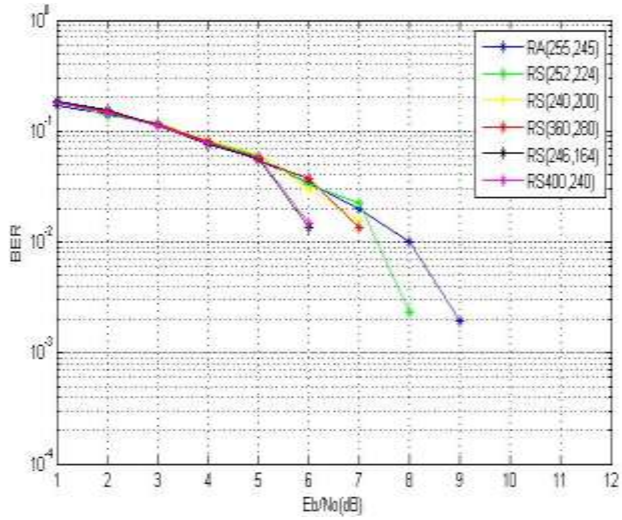

Figure 3: BER of RS code with varying code rate

V. Conclusion

We evaluate and compare the performance in terms of BER of different Forward Error Correction codes. We evaluate BER of convolutional and RS codes at different code rates. The less the code rate better is the result.

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