

Performance Analysis of Linear Block Code, Convolution code and Concatenated code to Study Their Comparative Effectiveness.

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ABSTRACT: In data communication the codes are used to for security and effectiveness which is thoroughly followed by the network. Here in LBC (linear block code), COC (convolution code), Concatenated codes (CC) are used. The work presented here is used the to make comparative effectiveness of this codes in order to make secure data analysis. Error coding is a method of detecting and correcting these errors to ensure information is transferred intact from its source to destination. Error coding uses mathematical formulas to encode data bits at the source into longer bit words for is transmission. Decoding of the code word is possible at side of receiver. The extra bits in the code word provide redundant bit, according to the coding scheme used, will allow the destination to use the decoding process to determine if the communication mediums expected error rate, signal to noise ratio and whether or not data retransmission is possible. Above coding technique implemented system can show error of exact bit in given data this error display bitwise. Faster processors and better communications technology make more complex coding schemes, with better error detecting and correcting capabilities, possible for smaller embedded systems, allowing for more robust communications.

Keywords: Concatenated code error control coding technique, Convolutional codes error control coding technique, Embedded Communication, Fault Tolerant Computing, linear block codes error control coding technique, Real-Time System, Software Reliability

I. INTRODUCTION

Environmental interference and physical defects in the communication medium can cause random bit errors during data transmission. Error coding is a method of detecting and correcting these errors to ensure information is transferred intact from its source to its destination. Error coding is used for fault tolerant computing in computer memory, magnetic and optical data storage media, satellite and deep space communications, network communications, cellular telephone networks, and almost any other form of digital data communication. Error coding uses mathematical formulas to encode data bits at the source into longer bit words for transmission. The “code word” can then be decoded at the destination to retrieve the information. The extra bits in the code word provide redundancy that, according to the coding scheme used, will allow the destination to use the decoding process to determine if the communication mediums expected error rate, and whether or not data retransmission is possible. Faster processors and better communications technology make more complex coding schemes, with better error detecting and correcting capabilities, possible for smaller embedded systems, allowing for more robust communications. During digital data transmission error will occurring this error can detect and correct this error binary signal and original signal can show bitwise. System can implemented using MATLAB. The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. CODING TECHNIQUES

1. Overview of Error Control Coding: Error-correcting codes are used to reliably transmit digital data over unreliable communication channels subject to channel noise. When a sender wants to transmit a possibly very long data stream using a block code, the sender breaks the stream up into pieces of some fixed size. Each such piece is called message and the procedure given by the block code encodes each message individually into a codeword, also called a block in the context of block codes. The sender then transmits all blocks to the receiver, who can in turn use some decoding mechanism to (hopefully) recover the original messages from the possibly

corrupted received blocks. The performance and success of the overall transmission depends on the parameters of the channel and the block code.

The theoretical contribution of Shannon's work in the area of channel coding was a useful definition of "information" and several "channel coding theorems" which gave explicit upper bounds, called the channel capacity, on the rate at which "information" could be transmitted reliably on a given. In the context of this paper, the result of primary interests the "noisy channel coding theorem for continuous channels with average power limitations." This theorem states that the capacity C of a band limited additive white Gaussian noise (AWGN) channel with bandwidth W , a channel model that approximately represents many practical digital communication and storage systems.

1.1. Linear Block Codes: Linear block codes are so named because each code word in the set is a linear combination of a set of generator code words. If the messages are k bits long, and the code words are n bits long (where $n > k$), there are k linearly independent code words of length n that form a generator matrix. To encode any message of k bits, you simply multiply the message vector u by the generator matrix to produce a code word vector v that is n bits long. Linear block codes are very easy to implement in hardware, and since they are algebraically determined, they can be decoded in constant time. They have very high code rates, usually above 0.95. They have low coding overhead, but they have limited error correction capabilities. They are very useful in situations where the BER of the channel is relatively low, bandwidth availability is limited in the transmission, and it is easy to retransmit data.

One class of linear block codes used for high-speed computer memory are SEC/DED (single-error-correcting/double-error-detecting) codes. In high speed memory, bandwidth is limited because the cost per bit is relatively high compared to low-speed memory like disks. The error rates are usually low and tend to occur by the byte so a SEC/DED coding scheme for each byte provides sufficient error protection. Error coding must be fast in this situation because high throughput is desired. SEC/DED codes are extremely simple and do not cause a high coding delay.

1.2. Convolutional Codes: Convolutional codes are generally more complicated than linear block codes, more difficult to implement, and have lower code rates (usually below 0.90), but have powerful error correcting capabilities. They are popular in satellite and deep space communications, where bandwidth is essentially unlimited, but the BER is much higher and retransmissions are infeasible. Convolutional codes are more difficult to decode because they are encoded using finite state machines that have branching paths for encoding each bit in the data sequence. A well-known process for decoding convolutional codes quickly is the Viterbi Algorithm. The Viterbi algorithm is a maximum likelihood decoder, meaning that the output code word from decoding a transmission is always the one with the highest probability of being the correct word transmitted from the source.

The main difference between block codes and the Convolutional codes (or recurrent) codes is the following: In block code, a block of n digits generated by the encoder in a particular time unit depends only on block of k input message digits generated by the encoder in a time unit depends on not only the block of k message digits within that time unit, but also on the preceding $(N-1)$ blocks of message digits ($N > 1$). Usually the values of k and n will be small.

1.3. Concatenated codes: The field of channel coding is concerned with sending a stream of data at the highest possible rate over a given communications channel, and then decoding the original data reliably at the receiver, using encoding and decoding algorithms that are feasible to implement in a given technology.

Shannon's channel coding theorem shows that over many common channels there exist channel coding schemes that are able to transmit data reliably at all rates R less than a certain threshold C , called the channel capacity of the given channel. In fact, the probability of decoding error can be made to decrease exponentially as the block length N of the coding scheme goes to infinity. However, the complexity of a naive optimum decoding scheme that simply computes the likelihood of every possible transmitted codeword increases exponentially with N , so such an optimum decoder rapidly becomes infeasible.

Dave Forney showed that concatenated codes could be used to achieve exponentially decreasing error probabilities at all data rates less than capacity, with decoding complexity that increases only polynomially with the code block length.

III. INDENTATIONS AND EQUATIONS

1. Linear block code:

Theorem 1: Let a linear block code C have a parity check matrix H . The minimum distance of C is equal to the smallest positive number of columns of H which are linearly dependent.

This concept should be distinguished from that of rank, which is the largest number of columns of H which are linearly independent.

Proof:

Let the columns of H be designated as $d_0; d_1; \dots; d_{n-1}$. Then since $cH^T = 0$ for any codeword c , we have

$$0 = c_0d_0 + c_1d_1 + \dots + c_{n-1}d_{n-1}$$

Let c be the codeword of smallest weight, $w = w(c) = d_{min}$. Then the columns of H corresponding to the elements of c are linearly dependent. 2 Based on this, we can determine a bound on the distance of a code:

$$d_{min} = n - k + 1: \text{The Singleton bound}$$

This follows since H has $n - k$ linearly independent rows. (The row rank = the column rank.) So any combination of $n - k + 1$ columns of H must be linearly dependent.

For a received vector r , the syndrome is

$$s = rH^T$$

Obviously, for a codeword the syndrome is equal to zero. We can determine if a received vector is a codeword. Furthermore, the syndrome is independent of the transmitted codeword. If $r = c + e$,

$$\begin{aligned} s &= (c + e)H^T \\ &= eH^T \end{aligned}$$

Furthermore, if two error vectors e and e' have the same syndrome, then the error

vectors must differ by a nonzero codeword. That is, if

$$\begin{aligned} eH^T &= e'H^T \text{ then} \\ (e - e')H^T &= 0 \end{aligned}$$

This means they must be a codeword.

2. Convolutional Code:

2.1 Coding and decoding with Convolutional Codes: Convolutional codes are commonly specified by three parameters; (n, k, m) .

n = number of output bits

k = number of input bits

m = number of memory registers

The quantity k/n called the code rate is a measure of the efficiency of the code. Commonly k and n parameters range from 1 to 8, m from 2 to 10 and the code rate from $1/8$ to $7/8$ except for deep space applications where code rates as low as $1/100$ or even longer have been employed. Often the manufacturers of Convolutional code chips specify the code by parameters (n, k, L) , the quantity L is called the constraint length of the code and is defined by

$$\text{Constraint Length, } L = k(m-1)$$

The constraint length L represents the number of bits in the encoder memory that affect the generation of the n output bits. The constraint length L is also referred to by the capital letter K , which can be confusing with the lower case k , which represents the number of input bits. Sometimes K is defined as equal to product of k and m . Often in commercial spec, the codes are specified by (r, K) , where r = the code rate k/n and K is the constraint length. The constraint length K however is equal to $L - 1$.

2.2 Code Parameters and the Structure of the Convolutional code: The Convolutional code structure is easy to draw from its parameters. First draw m boxes representing the m memory register. Then draw n modulo-2 adders to represent the n output bits. Now connect the memory registers to the adders using the generator polynomial.

This is a rate 1/3 code. Each input bit is coded into 3 output bits. The constraint length of the code is 2. The 3 output bits are produced by the 3 modulo-2 adders by adding up certain bits in the memory registers. The selection of which bits are to be added to produce the output bit is called the generator polynomial (g) for that output bit. For example, the first output bit has a generator polynomial of (1, 1, 1). The output bit 2 has a generator polynomial of (0, 1, 1) and the third output bit has a polynomial of (1, 0, 1). The output bits just the sum of these bits.

$$v_1 = \text{mod}2 (u_1 + u_0 + u_{-1})$$

$$v_2 = \text{mod}2 (u_0 + u_{-1})$$

$$v_3 = \text{mod}2 (u_1 + u_{-1})$$

from fig.(1)

The polynomials give the code its unique error protection quality. One (3,1,4) code can have completely different properties from an another one depending on the polynomials chosen.

3. Concatenated Codes: Let C_{in} be a $[n, k, d]$ code, that is, a block code of length n , dimension k , minimum Hamming distance d , and rate $r = n/k$, over an alphabet A :

$$C_{in} : A^k \rightarrow A^n$$

Let C_{out} is a $[N, K, D]$ code over an alphabet B with $|B| = |A|^k$ symbols:

$$C_{out} : B^K \rightarrow B^N$$

The inner code C_{in} takes one of $|A|^k = |B|$ possible inputs, encodes into an n -tuple over A , transmits, and decodes into one of $|B|$ possible outputs. We regard this as a (super) channel which can transmit one symbol from the alphabet B . We use these channel N times to transmit each of the N symbols in a codeword of C_{out} . The concatenation of C_{out} (as outer code) with C_{in} (as inner code), denoted $C_{out} \circ C_{in}$, is thus a code of length Nn over the alphabet A .^[1]

$$C_{out} \circ C_{in} : A^{kK} \rightarrow A^{nN}$$

It maps each input message $m = (m_1, m_2, \dots, m_K)$ to a codeword $(C_{in}(m'_1), C_{in}(m'_2), \dots, C_{in}(m'_N))$, where $(m'_1, m'_2, \dots, m'_N) = C_{out}(m_1, m_2, \dots, m_K)$.

The key insight in this approach is that if C_{in} is decoded using a maximum-likelihood approach (thus showing an exponentially decreasing error probability with increasing length), and C_{out} is a code with length $N = 2^{nr}$ that can be decoded in polynomial time of N , then the concatenated code can be decoded in polynomial time of its combined length $n2^{nr} = O(N \cdot \log(N))$ and shows an exponentially decreasing error probability, even if C_{in} has exponential decoding complexity.^[1] This is discussed in more detail in section decoding concatenated codes.

In a generalization of above concatenation, there are N possible inner codes $C_{in,i}$ and the i -th symbol in a codeword of C_{out} is transmitted across the inner channel using the i -th inner code. The Justesen codes are examples of generalized concatenated codes, where the outer code is a Reed-Solomon code

3.1. Theorem: The distance of the concatenated code $C_{out} \circ C_{in}$ is at least dD , that is, it is a $[nN, kK, D']$ code with $D' \geq dD$.

Proof: Consider two different messages $m^1 \neq m^2 \in B^K$. Let Δ denote the distance between two codewords. Then

$$\Delta(C_{out}(m^1), C_{out}(m^2)) \geq D.$$

Thus, there are at least D positions in which the sequence of N symbols of the codewords $C_{out}(m^1)$ and $C_{out}(m^2)$ differ. For these positions, denoted i , we have

$$\Delta(C_{in}(C_{out}(m^1)_i), C_{in}(C_{out}(m^2)_i)) \geq d.$$

Consequently, there are at least $d \cdot D$ positions in the sequence of $n \cdot N$ symbols taken from the alphabet A in which the two codewords differ, and hence

$$\Delta(C_{in}(C_{out}(m^1)), C_{in}(C_{out}(m^2))) \geq dD.$$

2. If C_{out} and C_{in} are linear block codes, then $C_{out}C_{in}$ is also a linear block code.

This property can be easily shown based on the idea of defining a generator matrix for the concatenated code in terms of the generator matrices of C_{out} and C_{in} .

Figures and Tables:

1. Convolutional code:

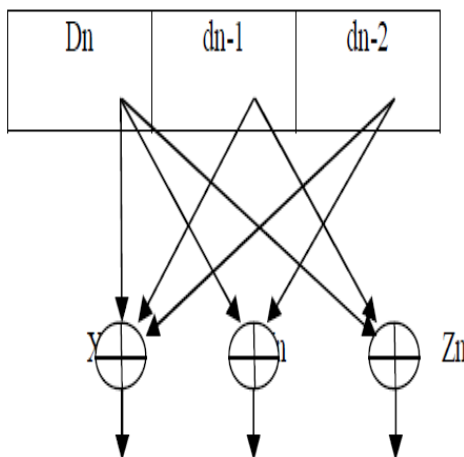


Fig.1 Sequential Statement

1.1. polynomials are selected for given table:

Constraint Length	G1	G2
3	1 1 0	1 1 1
4	1 1 0 1	1 1 1 0
5	1 1 0 1 0	1 1 1 0 1
6	1 1 0 1 0 1	1 1 1 0 1 1
7	1 1 0 1 0 1	1 1 0 1 0 1
8	1 1 0 1 1 1	1 1 1 0 0 1 1

9	1 1 0 1 1 1	1 1 1 0 0 1 1 0 1
10	1 1 0 1 1 1 0 0 1	1 1 1 0 0 1 1 0 0 1

1.2. Convolutional code resulted binary message and bitwise graph

```

Original_Signal =

Columns 1 through 13

0 0 1 1 0 1 1 0 0 1 0 0 0

Columns 14 through 16

1 0 1

Error_Signal =

Columns 1 through 13

0 0 1 1 0 1 0 0 0 1 0 0 0

Columns 14 through 16

1 0 1

Recovered_Signal =

Columns 1 through 13

0 0 1 1 0 1 1 0 0 1 0 0 0

Columns 14 through 16

1 0 1
    
```

Fig.2 Binary message of convolutional code

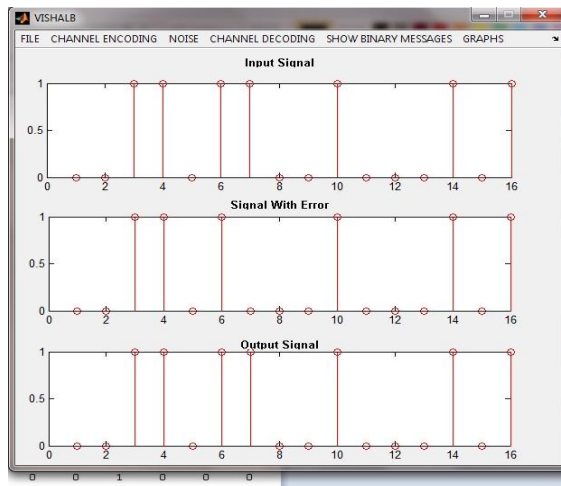


Fig.3 Bitwise graph of convolutional code

2. Linear block code resulted binary message and bitwise graph

```
Original_Signal =
    0   1   1   0   1   1   0   0   0

Error_Signal =
    0   1   1   0   1   1   1   0   0

Recovered_Signal =
    0   1   1   0   1   1   0   0   0
```

Fig.4 Binary message of linear block code

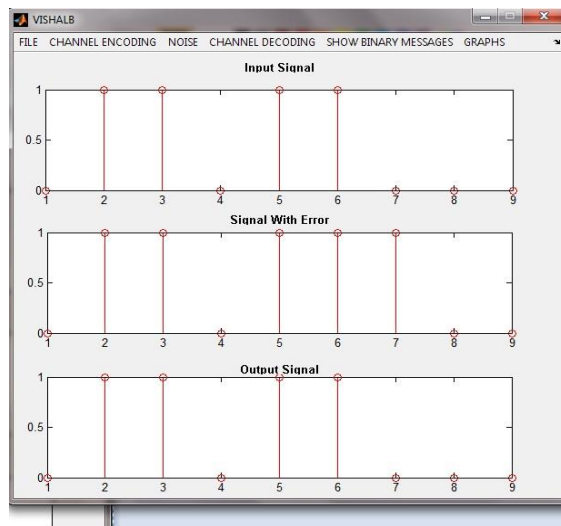


Fig.5 Bitwise graph of linear block code

3. Concatenated code resulted bitwise graph

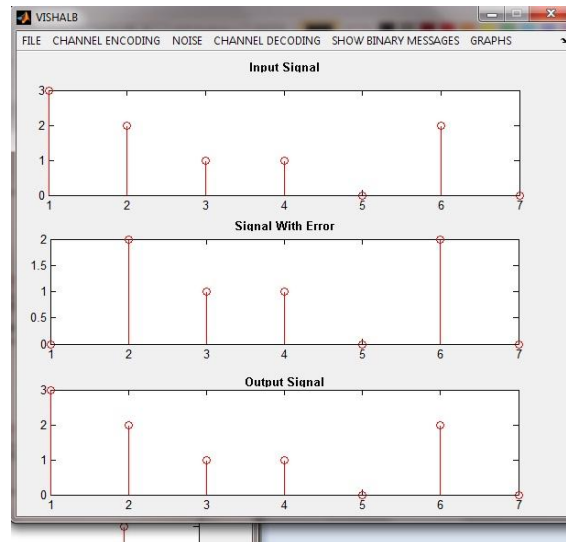


Fig.6 Concatenated code resulted graph bitwise.

4. BER to Eb/No graph

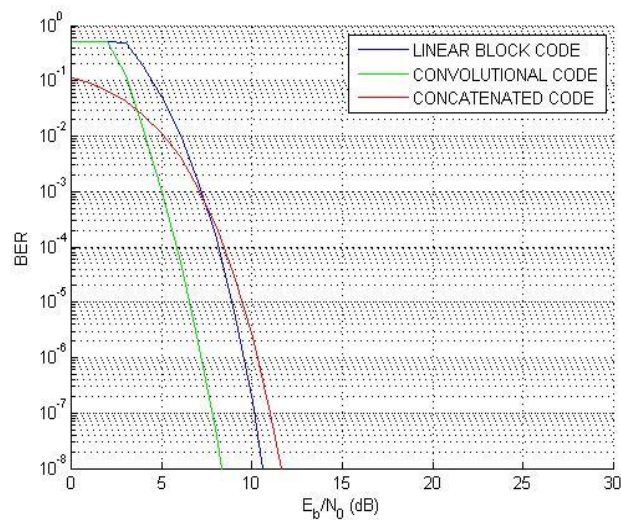


Fig.7 BER to Eb/No

IV. CONCLUSION

- 1 Show in the BER to E_b/N_0 graph the convolutional code is very good capability of error correction then linear block code.
- 2 Convolutional code is very difficult to implementation then linear block code.
- 3 Concatenated code is both binary and non binary data can be send through encoder most useful for error correction capability.
- 4 Convolutional code is better than linear block code and concatenated code.

- 5 Important reasons to use coding are achieving dependable data storage in the face of minor data corruption/loss mid gaining the ability to provide high precision I/O even on noisy transmission lines such as cellular phones (error coding decouples message precision from analog noise level).
- 6 Most use full in real time system can show error bitwise exact bit is show in result.
- 7 Error signal can easily display on screen command window of matlab.
- 8 The error coding technique for an application should be picked based on The types of errors expected on the channel (e.g., burst errors or random bit error)
- 9 Whether or not it is possible to retransmit the information (codes for error detection only or error "detection and correction)
- 10 Expected error tale on the communication channel (high or low)
- 11 There are several tradeoffs between channel efficiency and the amount of coding/decoding logic implemented

FUTURE APPLICATION AND DEVELOPMENT

- 1 Fault tolerant computing in computer memory
- 2 Magnetic and optical data storage media
- 3 Satellite and deep space communications
- 4 Network communications
- 5 Cellular telephone networks
- 6 Almost any other form of digital data communication

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