BER Performance Comparison of HOVA and SOVA in AWGN Channel

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ABSTRACT: Classical Viterbi algorithm (HOVA) and Soft Output Viterbi Algorithms (SOVA) are used for error correction in many applications. Among FEC schemes, convolutional encoding and Viterbi decoding are the most popular because of their powerful coding-gain performances. In this paper the performance analysis of Convolutional encoder and hard decision Viterbi algorithm and SOVA Bit Error Rate (BER) have been analyzed as well as compared considering different constraint lengths, generator polynomials. The rate considered is ½ rate for both the algorithms.

KEYWORDS: FEC, Viterbi Decoder, SOVA, Generator polynomial, Trellis diagram

I. INTRODUCTION

Encoding the information sequence prior to transmission implies adding extra redundancy to it, which is then used at the receiver end to reconstruct the original sequence, effectively reducing the probability of errors induced by a noisy channel. Different structures of codes have developed since, which are known as channel coding. Convolutional codes [1] are a type of Error Correcting Codes (ECC) widely used in channel coding since the late 1960's [2]. They are preferred for their powerful correcting capability with high speed at low cost compared with their competing block codes [3]. Other types include error detecting codes, which only detect errors and request for retransmission; however, these types are more complex and expensive, as they require a two-way transmission system.

There have been a few convolutional decoding methods such as sequential and Viterbi decoding, of which the most commonly employed technique is the Viterbi Algorithm (VA) [4, 5]. Viterbi decoding was developed by Andrew, J, Viterbi, the founder of Qualcomm Corporation [6].

Evaluation process of convolutional encoder and decoder (CODEC), for the various constraint lengths and for different generator polynomials is discussed considering only few bytes of data [7]. The performance is analysed for the burst errors and distributed errors. Impact of constrain length for the different input images for SOVA algorithm is presented in [8]. A high performance generic soft input hard output Viterbi decoder is presented [9] and prototyped on an FPGA board. The presented Viterbi decoder is intended to be used in a complete wireless LAN transceiver prototype.

Viterbi decoding method uses the Maximum Likelihood Decoding (MLD) algorithm, this method find a most likely pattern from the received data, and is known as the most optimum decoding method. In the proposed work the code rate ½ is used. The performance of Viterbi decoders are analysed for the different constraint lengths (CL) as well as for different generator polynomials.

II. RELATED WORK

Error recovery capability of convolutional CODEC is discussed in [10]. FPGA implementation of Viterbi decoder is discussed in [11], paper concludes that the use of error-correcting codes have proven to be an effective way to overcome data corruption in digital communication channels. Analysis of constrain length and generator polynomials choice impact on the performance of convolutional CODEC in AWGN channel for image applications is presented in [8]. The performance of Soft Output Viterbi decoding Algorithm (SOVA) has been discussed with the simulation results in [13]. SOVA for the various constraint lengths and for different generator polynomials are simulated and discussed. Performance of SOVA for burst and random errors are also tested in [13]. A high performance generic soft input hard output Viterbi decoder is presented in [14] and prototyped on an FPGA board. In this paper the performance comparison of SOVA and HOVA is done.

III. PROPOSED ALGORITHM

The model considered for the simulation is shown in Fig.1. The channel considered is AWGN channel. At the receiver side two types of Viterbi algorithm methods; hard decision decoder and SOVA are simulated. The different generator polynomials, different constraint lengths are considered for convolutional coding and as well as for decoding.
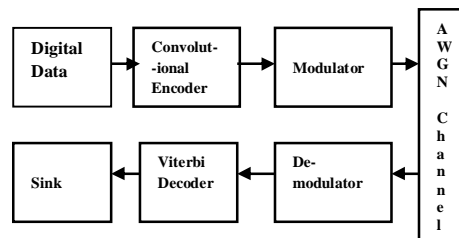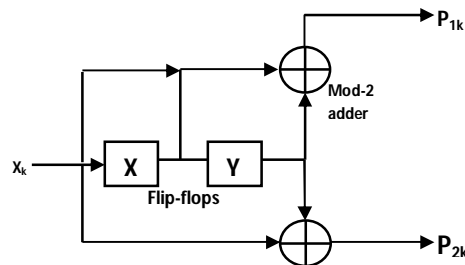

Fig. 1 Proposed system diagram

Fig. 2 Convolutional encoder

The performance measure parameter used is BER for different SNRs. Performance analysis is done in terms of BER for different constraint lengths, generator polynomials and comparison is also shown.

IV. SIMULATION MODEL

Convolutional codes are commonly specified by three parameters; (n, k, m). Where 'n' is the number of output bits, 'k' is the number of input bits considered at a time and 'm' is the number of memory registers. The quantity k/n called the code rate is a measure of the efficiency of the code. Convolutional encoder consists of a shift register with 'm' memory registers, and 'n' modulo-2 adders interconnected.

A. Convolutional Encoder

Convolutional encoding is accomplished using a combination of simple shift register and modulo-2 adders. In systematic style of encoding the input bits are included in the output stream along with the parity bits generated. Fig. 2 shows a ½ rate non-systematic convolutional encoder with constraint length 3. It makes use of two generator polynomials (g_1, g_2) for calculating two output bits (P_{1k}, P_{2k}) for every input bit (X_k) considered. Inputs to the mod-2 adder (which generates P_{1k}, P_{2k}) are decided by g_1 and g_2

B. Viterbi Decoder

Using the next-state table and output table a trellis for HOVA may be drawn as shown in Fig. 3. The Viterbi decoder makes use of this trellis diagram to calculate most probable input sequence. The zero input is represented by dotted line and one input is represented by the solid line in the Fig 3. There are two branches leaving and entering each

state. Each branch is labelled with the corresponding outputs. In general case of (n, k, m) code and an information sequence of length kL, there are 2^k branches leaving and entering each state, and 2^{kL} distinct paths through the trellis corresponding to the 2^{kL} code words. The decoder must produce the estimate of code word $\hat{V}$ of the code word v based on the received sequence r. A MLD for a discrete memory less channel (DMC) chooses $\hat{V}$ as the code word v which maximizes the log-likelihood function log P(r|v). Since for a DMC

$$Log\ P(r|v) = \sum_{i=0}^{L+m-1} \log P(ri\ |vi) \qquad (1)$$

Where P (ri|vi) is a channel transition probability. The log-likelihood function log P (r|v) is called the metric associated with the path v, and is denoted M(r|v). The terms log P(ri|vi) in the sum (1) is called branch metrics and denoted by M(ri|vi). The Viterbi decoder algorithm works as follows:

1.   Compute the partial metric for the single path entering each state in the Fig. 3 up to stage b.

2.   Compute the partial metric for all the paths entering a state by adding the branch metric entering that state to the metric of the connecting survivors at the preceding time unit. For each state store the path with the largest metric (the survivor), together with its metric, and eliminate all other paths.

3.   Repeat the step 2 for all L+m stages. Stop

There are 2^k survivors from time unit m through time unit 'L', one for each of the 2^k states. After time unit 'L' there are fewer survivors, since there are fewer states while the encoder is returning to the all-zero state. Finally, at time unit L+m, there is only one state, the all-zero state and hence only one survivor, and the algorithm terminates. After trellis construction is performed for the complete block of encoded data, trace back is performed for determining the decoded output sequence. The basic idea is to start from a specific state (pre-defined or having the smallest path metric) and trace the path leading to this state backwards in time to reconstruct the encoder input is a trace back length.

In concatenated decoding systems (series or parallel) it is common for one decoder to pass the reliability (confidence) information about its decoded outputs so called soft outputs to a second decoder. The SOVA is a variation of the Viterbi algorithm. This algorithm has two modifications over the classical Viterbi algorithm. First, the path metrics used to select the maximum likelihood path through the trellis are modified to take account of a-priori information. Second, the algorithm is modified to provide a soft output for each decoded bit.
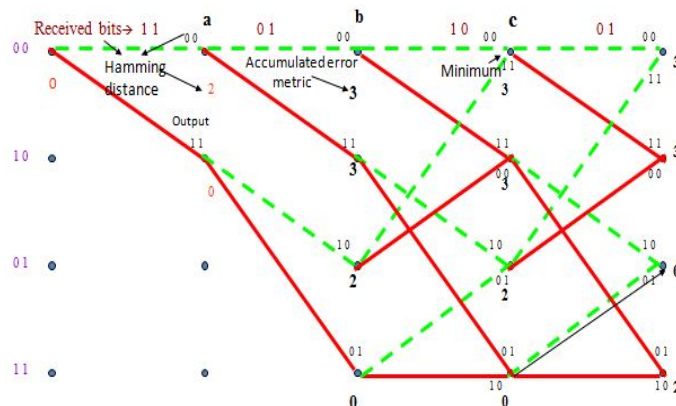

Fig. 3 Trellis diagram for Viterbi decoding algorithm

V. RESULTS AND DISCUSSIONS

The performance of Viterbi decoders is analyzed by varying the constraint lengths, Generator polynomials.
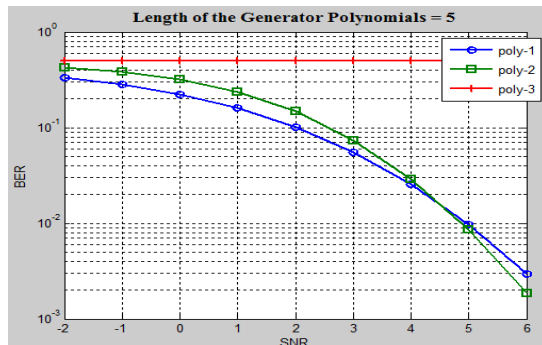

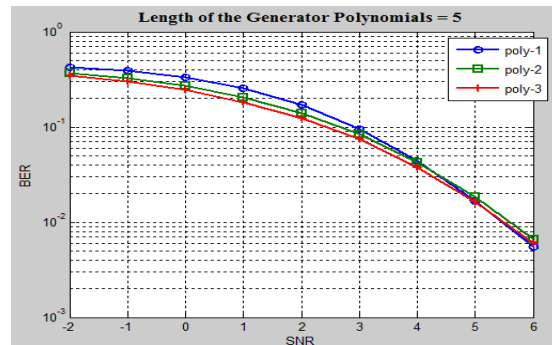Fig. 4a Performance Analysis of HOVA for CL of 5

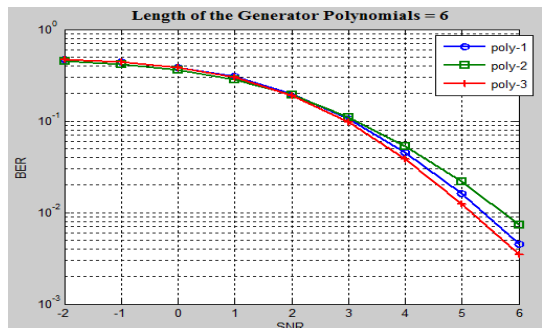Fig. 4b Performance Analysis of HOVA for CL of 5

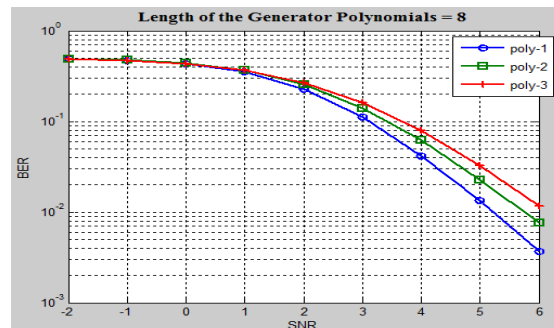Fig. 5 Performance Analysis of HOVA for CL of 6

Fig. 6 Performance Analysis of HOVA for CL of 8

Fig. 4a and Fig. 4b shows the BER performance of VD for the constraint length of five. Fig. 4a also shows the performance for catastrophic polynomial. A decoder is said to exhibit catastrophic error-propagation when a finite number of channel errors results in infinitely many decoding mistakes. Three different generator polynomials with the constraint length of 5 are considered. The same set of inputs is considered for the three different polynomials simulation. From these results it may be concluded that as the polynomial changes the BER performance also changes. BER performance for the constraint length of six and eight are shown in Fig.5 and Fig.6 respectively. While choosing the generator polynomial care should be taken to ensure that polynomial is not exhibiting catastrophic property.

From the simulation shown from Fig.4 to Fig.6 it may be concluded that the BER performance changes as the length of generator polynomial changes it also changes from polynomial to polynomial. It is also observed that the decoding time increases as the length of the generator polynomial increases. The simulations are also carried out for the SOVA for different constraint lengths.

Fig. 7a shows the BER performance of HOVA and SOVA for a same generator polynomial of constraint length of 3. In the Fig.7b the average BER performance for three different generator polynomials for SOVA and HOVA are depicted. Fig.8 and Fig.9 shows the BER performance comparison between the two algorithms for the constraint length of 4 and 6 are shown. It may be observed that the SOVA BER performance is optimal compared to the HOVA in all the cases.
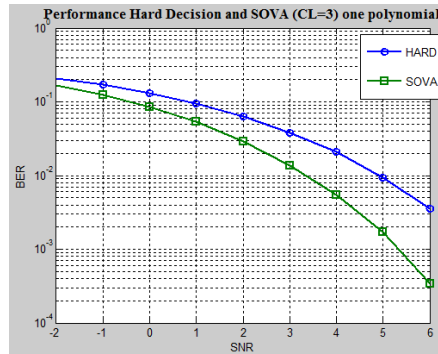
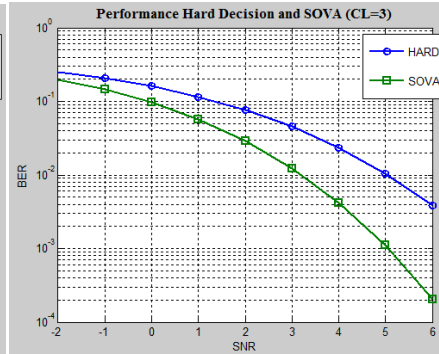Fig.7a Performance Analysis of HOVA and SOVA for CL of 3

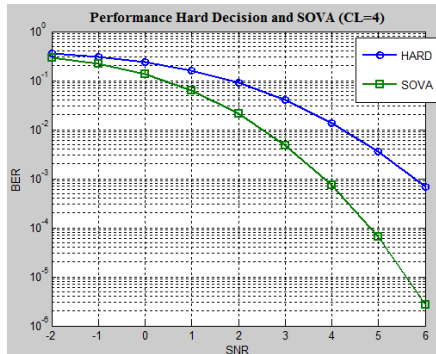Fig.7b Performance Analysis of HOVA and SOVA for CL of 3

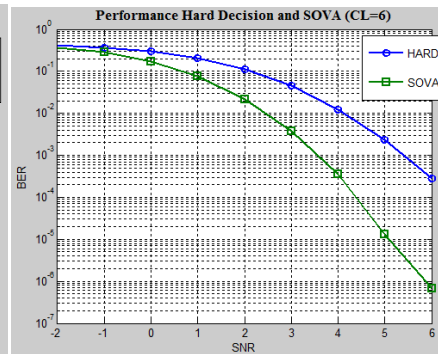Fig.8 Performance Analysis of HOVA and SOVA for CL of 4

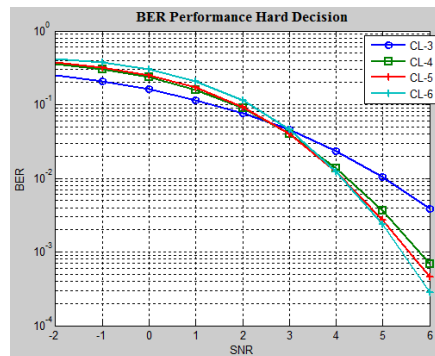Fig.9 Performance Analysis of HOVA and SOVA for CL of 6

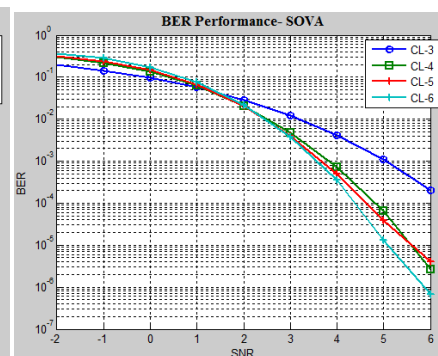Fig.10 Performance comparison of HOVA for a different CLs

Fig.11 Performance comparison of SOVA for a different CLs

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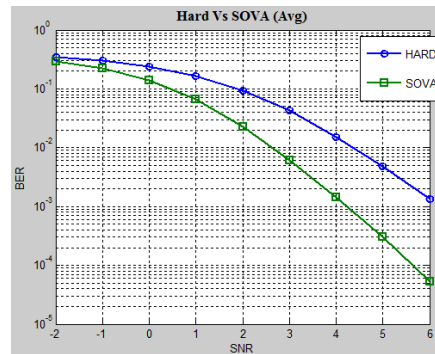**Vol. 2, Issue 2, February 2014**

Fig.12 Performance Analysis of HOVA and SOVA for CL of 6

The BER performance of HOVA for the different constraint lengths is plotted in the Fig. 10. For every constraint length average BER performance of three different generator polynomials are considered. It may be observed that for the low SNRs (Less than 2.7); lower constraint lengths are giving better results for higher SNR higher constraint lengths are giving optimal performance. Similarly SOVA BER performances for different constraint lengths are plotted in Fig.11. It may be observed that for the SNR more than one higher constraint length polynomials are giving optimal results. Average BER shown in Fig.10 and Fig.11 are plotted in Fig.12. From the figure it may be concluded that BER performance of SOVA is better compared to HOVA for any constraint lengths and for any generator polynomials.

VI. CONCLUSION

In this paper, the effects of selection of constraint lengths, generator polynomials, on the performance of a HOVA and SOVA have been investigated. By the simulation results it may be concluded that BER performances of Viterbi decoders changes as the constraint length and generator polynomials changes. It is observed that the performance varies with change in generator polynomial even for the same constrained lengths. So a good performing generator polynomial for the given circumstances should be selected before proceeding. From the results it may be concluded that the performance of SOVA is optimal compared to that of HOVA.

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