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Optimization of Turbo Code Performance using modified Soft Output Viterbi Algorithm

Hema M, Dr. C.V. Ravishankar

***Abstract*- WiMAX (Worldwide Interoperability for Microwave Access) is a type of wireless communication technology which provides high speed service. WiMAX physical layer performance depends on number of parameters such as channel bandwidth, modulation and coding scheme. Turbo code is a concatenation of convolutional codes and it reaches the performance, which is very close to the channel capacity. Turbo code with Log-MAP (Logarithmic Maximum A Posteriori) algorithm results in computational delay, complexity and less performance but the modified Soft Output Viterbi Algorithm can overcome these problems. The objective of this project is to improve the Bit Error Rate (BER) performance of turbo code using modified Soft Output Viterbi Algorithm (SOVA). The BER vs. SNR performance of modified SOVA has been simulated in MATLAB and compared with the Log-MAP decoding algorithm. The different parameters such as iteration, frame size and code rate still improves the performance of turbo code using modified SOVA.**

***Index Terms* — AEM, BER, FEC, Log-MAP, QPSK, SOVA, WiMAX**

I. Introduction

WiMAX is a standard which describes interoperable implementations of IEEE 802.16. WiMAX works in different way compared to Wi-Fi (Wireless Fidelity). WiMAX can be used in the replacement of cable and Data subscriber line (DSL). The Institute of Electrical and Electronics Engineers Inc. is specified the WiMAX as the IEEE 802.16 standard. WiMAX can provide mobile wireless broadband connectivity without using line-of-sight at base station. The two main points to be considered to eliminate RF Interference are proper design of network and infrastructure placement. Number of information like audio, video, internet data is supported [2].

The physical layer is the lowest layer among the seven-layers of OSI model. It is represented as PHY in short. Physical layer transmits the signal in the form of bit stream through the network. Bit stream transmission is always in the mechanical and electrical level in the first layer of OSI that is PHY layer. For sending and receiving data physical layer provides media of hardware .The devices which function at the Physical layer Hubs, repeaters etc. In the same way different kind of technologies at physical layer are Ethernet cabling, token ring network, there are two more devices which are also part of physical layer are connectors and cables. Physical layer provides efficient data transmission over communications network [7]. Data is sent in the form of bits from physical layer of transmitter and received at the physical layer of receiver.

Performance of physical layer of WiMAX depends on the parameters like coding scheme, modulation and channel bandwidth etc. In Backward Error Correction (BEC), only error recognition is involved. If an error is recognized, the receiver request for transmitter to redeliver the signal. This method is effortless and needs less necessity on the code's error rectifying premises. BEC needs dual communication and results in unacceptable delay in transmission [8].

In Forward Error Correction (FEC), both error recognition and rectification are involved. There is no request from receiver to transmitter. Decoder which is in receiver part has ability to recognize and rectified errors. Hence decoder can detect the positions of errors in received information. FEC codes are attractive in wireless communication since they need simplex communication. Turbo code is a type of FEC which provides better performance compared other forward correction codes [13].

The examples of sequence estimation algorithms are viterbi algorithm, SOVA (soft output viterbi algorithm) and improved SOVA. Similarly the examples of symbol-by-symbol estimation algorithms are Maximum A Posteriori (MAP), Max-Log-MAP and the Log-MAP. Symbol-by-symbol estimation algorithm is complicated as compared sequence estimation algorithms. Excellent bit error rate can be found in symbol-by-symbol estimation algorithms. Viterbi algorithm produces hard output and its extension version SOVA produces soft output. Some modification has done in SOVA to improve its performance [9].

Log-MAP algorithm results in computational delay and complexity. SOVA can overcome these problems but performance is less as compared to Log-MAP at low SNR (Signal to Noise ratio). SOVA distinct from the viterbi algorithm, since calculation of path metric is involved to know priori probabilities of input bits and provides soft output.

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***Hema M**, Dept. of Electronics and Communication, VTU/ Sambhram Institute of Technology, Bangalore-97, India.*
***Dr. C. V. Ravishankar,** Dept. of Electronics and Communication, VTU/ Shambhram Institute of Technology, Bangalore-97, India.*

The paper structure is as follows. In section II, description of turbo code in communication system is given. Section III, gives the detailed steps involved in SOVA decoding algorithm for turbo codes. Simulation results of turbo decoder using SOVA and Log-MAP decoding in terms of BER vs. SNR graph is in section IV. Finally section V, conclude this paper.

II. Turbo Decoder

A. Turbo code is a type of error correction code whose performance is high. The performance which is provided by turbo code is close to Shannon limit. Turbo Encoder consists of two convolutional encoders which are in parallel combination and there is an interleaver between them. The input data is given to encoder1 which generates encoded data that is output1. The input data is then given to interleaver, interleaved output is given to encoder2 which produces encoded data that is output2. Hence there are two encoded sequences generated by turbo encoder.

Scrambling of bits provides two purposes in interleaver. When interleaved input is given to the second encoder, the encoded output of the second encoder is completely distinct from output of the first encoder. If one of the encoded outputs has low weight, the other has more weight. As mentioned above larger weight improves the performance of the decoder. The divide-and-conquer strategy can be selected to decode as turbo encoder is parallel combination of two codes. If the second decoder input is scrambled, then its output will be distinct compared to first encoder output.

The process which is usually used in communication system to enhance the performance of forward error correcting codes is interleaving. When the number of errors in the code word is more than the error-correcting capability of respective code then it is not possible to get the proper, error free data at the receiver. This problem can overcome by Interleaving. Hence interleaving is used usually in error correction process.

Phase-shift keying (PSK) is type of digital modulation which modifies the phase of carrier signal according to modulating. QPSK uses four different phases to modulate the transmitting signal hence it is a 4 level modulation and each two bits are linked and profiled to any one of four phases of radio frequency signal. There are four marks on the constellation sketch of QPSK, equidistant over a circle. It uses two bits per symbol to reduce the BER. This modulation gives one to one relation between symbol rate and bit rate after modulation and before demodulated signal.

QPSK modulation gives high data rate. Hence turbo encoded output is modulated by QPSK modulator. Modulated data is passed through the channel where noise may get added. Demodulation performs the process which is exactly opposite to that of modulation. This demodulated output is given to turbo decoder.

Modified algorithm is used in the turbo decoder. Turbo decoder comprise of two decoders. There are two output sequences coming from two encoders. In the beginning of decoding, one of the two encoded sequences is given to first decoder. The output of first decoder will be considered as a reference signal for priori knowledge in the second decoder. Second encoded sequence is decoded in second decoder. Finally turbo decoder provides original information.

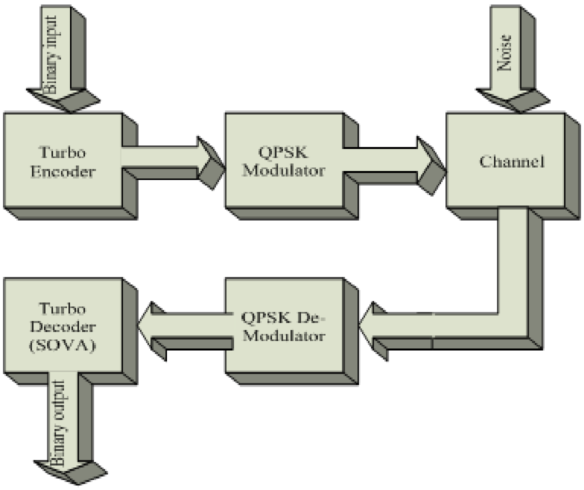

Fig. 1- Block diagram of Turbo Code based Communication System.

III. Soft Output Viterbi Algorithm

The steps involved in encoding and decoding process based on trellis diagram are

1) Generate the data by using random generator which results in binary digits. For understanding purpose, let us assume the input sequence as

0	0	1	0	0	1	1	1

Table 1- Input sequence.

Input has to be encoded by encoder which consists of two flip flops, single input and double outputs. For each input bit encoder generates two output bits, those resultant bits called as channel symbol. Since there are two flip flops, number of states is four.

2) Encoded sequence from Trellis diagram is

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

Table 2- Encoded sequence.

Add noise to the transmitted channel symbols which result in received channel symbols.

3) When encoded sequence is transmitted through channel, there is a chance of occurring an error. So in this case, we assume errors at two different places to show, how original input bits get back when soft output viterbi algorithm is applied. Assumed received sequence is,

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

Table 3- Received sequence.

4) Calculation of the branch metric by comparing received channel symbol with possible channel symbols. Decoding starts from this step onwards only. The trellis diagram which we used in encoding is also used in decoding. Received symbol consists of two bits at each time. So it is necessary to determine the distance between received and all possible channel symbols we could have received.

The Hamming distance is nothing but how many bits are different between the received channel symbol and the possible channel symbol. The distance can be zero, one, or two. Now, we have to use the metric as the Hamming distance and save the result as accumulated error metric values for the first time instant. The Accumulated Error Metric (AEM) will be determined by adding the previous Accumulated Error Metric to the current branch metric for further time instants. If no bits are matched metric is 2, If 1 bit is matched metric is 1 and if both bits are matched metric is 0. Finally after decoding trellis diagram is as shown below.

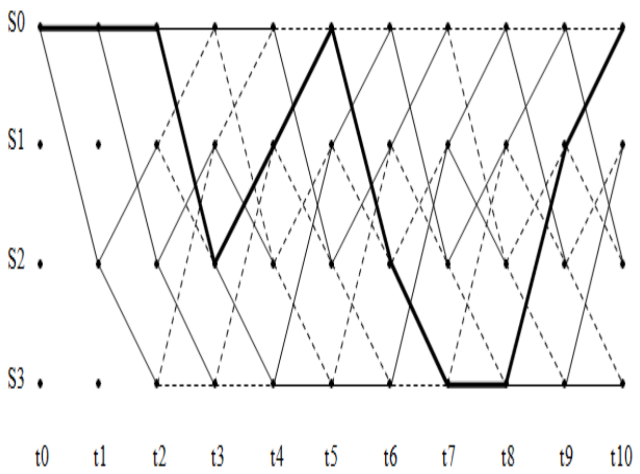

Fig. 2- Trellis Diagram

4) The following table shows the accumulated error metric values for all four states from t_0 to t_{10}.

	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
S_0		0	0	2	2	1	2	2	3	4	2
S_1			3	3	1	2	3	3	3	2	3
S_2		2	2	0	3	2	1	3	4	4	3
S_3			3	3	1	2	3	1	1	2	3

Table 4- Accumulated error metric values

5) After reaching the end of trellis diagram, we have to trace back with the help of predecessor state table. First we must select the best state for trace back. Here state S_0 is taken at t_{10} and the predecessor state table is shown below.

	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
S_0	0	0	0	0	0	1	1	0	1	1	1
S_1	0	0	2	2	2	3	2	3	2	3	3
S_2	0	0	0	0	1	0	0	0	1	0	0
S_3	0	0	2	2	2	3	3	2	3	3	3

Table 5 – Predecessor states

6) The number of states which we select and save while working backward through predecessor state table is shown in below table.

	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}
S	0	0	0	2	1	0	2	3	3	1	0

Table 6– Selected states

7) Now we have to decide the original bits with the help of saved states. Finally decoded bits are shown below

0	0	1	0	0	1	1	1

Table 7- Output sequence

IV. Results

The simulation has been done for turbo code using two algorithms Soft Output Viterbi Algorithm (SOVA) and logarithmic Maximum A posteriori (Log-MAP). Simulation has done with system parameters like modulation-digital modulation, phase shift keying-Quadrature Phase Shift Keying. Code rate of turbo decoder is 1/2, decoding algorithm- soft output viterbi algorithm and logarithmic Maximum A posteriori. The Fig. 3 shows the BER vs. SNR performance of turbo codes using SOVA and Log-MAP. As SNR increases BER reduces for both the algorithms and SOVA has less BER at any SNR compared to Log-MAP.

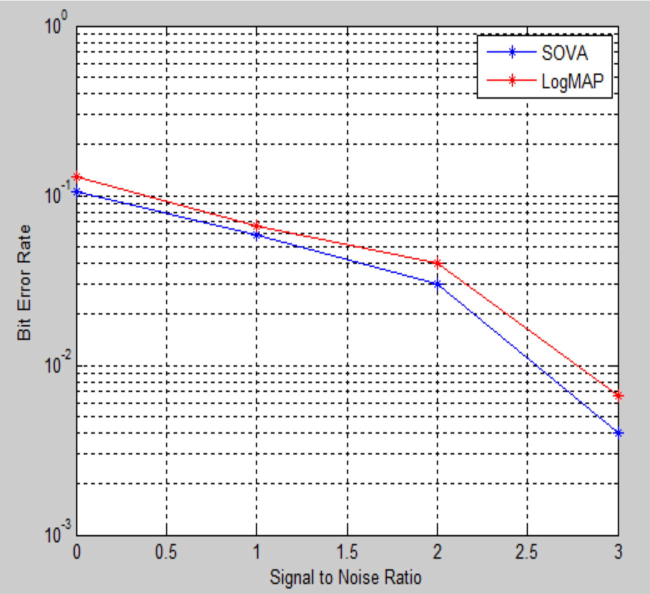

Fig. 3- The BER vs. SNR performance of turbo codes using SOVA and Log-MAP.

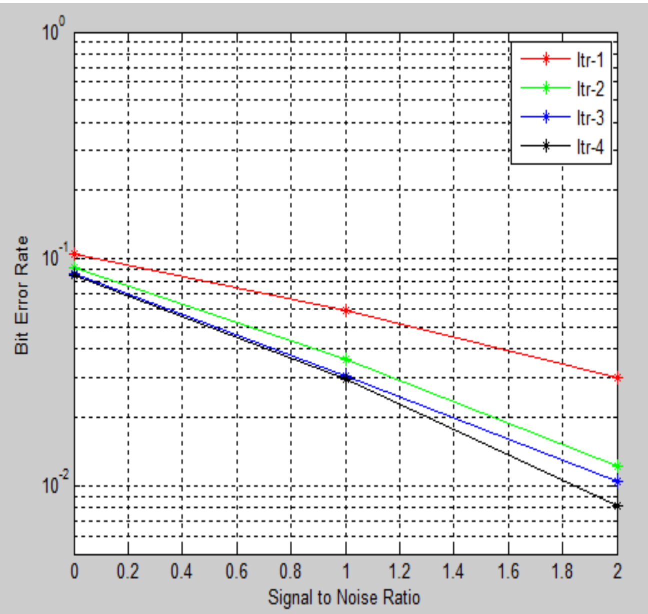

Fig. 4- Performance of SOVA for different iterations.

Fig.4 shows the performance of SOVA for different iterations. Bit error rate reduces as number of iterations increases. Fig. 4 clearly shows iteration 4 has less BER compared to other iterations. In Fig. 5, we can clearly observe the performance of SOVA for different frame sizes. Like iterations, as frame size increases bit error rate reduces. We have simulated SOVA for frame sizes 100, 300 and 500. As clearly shown in figure 5, the frame size 500 gives better performance with less BER compared to other frame sizes. The bit error rate performance of SOVA for different code rates is shown in below figure 6. Fig. 6 clearly shows that code rate 1/3 provides less BER compared to code rate 1/2.

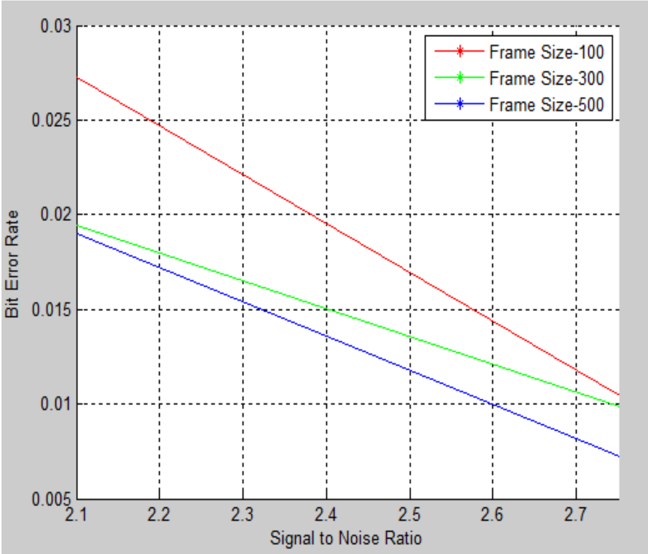

Fig. 5- Performance of SOVA for different frame sizes.

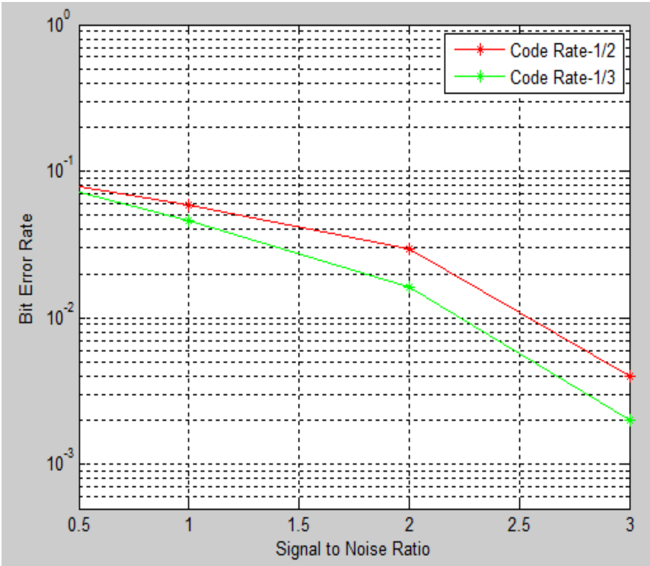

Fig. 6- Performance of SOVA for different code rates.

II. Conclusion

The turbo decoder is a type of FEC which offers better performance compared to any other FEC and it is implemented with modified soft output viterbi algorithm to improve the WiMAX service performance. The modified Soft output viterbi decoding algorithm provides minimum system complexity and decoding delay than logarithmic Maximum A posteriori. The performance of turbo decoder with modified soft output viterbi algorithm and logarithmic maximum a posteriori has been analyzed with the simulation result. It is observed that performance of turbo decoder improves further with the increase in iteration and frame size parameters. With the reduction in code rate, turbo code performance considerably enhances. The choosing of optimum values of these parameters optimizes the performance of Turbo decoder.

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First Author

Hema M
Student, Dept. of Electronics and Communication,
Sambhram Institute of Technology,
Bangalore, India.

Second Author

Dr. C. V. Ravishankar
Professor & HOD
Dept. of Electronics and Communication,
Sambhram Institute of Technology,
Bangalore, India.