TURBO CODE RE-ANALYSIS USING DIFFERENT ALGORITHMS

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ABSTRACT

Turbo codes are a novel type of forward error correcting codes that have proved to give a performance close to the channel capacity as proposed by C. Shannon. The parallel concatenation of two identical recursive convolutional encoders that are spaced apart by an interleaver results in a turbo code encoder. The two cascaded decoding blocks used by the turbo code decoder pass along a priori knowledge generated by each block in turn. The decoding approach has the advantage of working iteratively, allowing for an increase in total performance. This study does a performance analysis of turbo codes. The performance study includes two decoding methods: the soft output Viterbi algorithm (SOVA), which uses the log-likelihood ratio to produce soft outputs, and the log maximum a posteriori probability (Log-MAP) algorithm. Both punctured and unpunctured codes are studied to determine the impact of utilizing various decoding algorithms. The performance of the two various decoding techniques is then contrasted in terms of bit error rate. MATLAB tools are utilized to perform simulations.

Keywords: Turbo Codes, Interleave, Log-likelihood Ratio, Iterative Decoding.

I. Introduction

The telecommunications industry is seeing a veritable expansion thanks to wireless technologies Satellite and cellular technologies, which were formerly used only by the military, are now commercially driven by customers who are ever more demanding and ready for seamless connection from their home to their automobile, to their business, or even for outdoor activities. Wireless communications services are in incredibly high demand. Researchers are already looking to- wards 4th generation (4G) systems, even if the adoption of 3rd generation (3G) cellular systems has been slower than initially predicted [10, 11]. In an ever-congested frequency spectrum, these systems will transmit at far higher rates than the existing 2G systems and even 3G systems. In wireless communication environments, fading and multipath delay spread reduce the signal quality. The overall performance of the systems suffers as a result. Therefore, a variety of options

are available to lessen these limitations and meet the rising demands. A growing requirement for wireless, rapid, and accurate information transmission is brought on by this rise in demand. Communications engineers have combined forward error correcting methods with high-rate transmission technology to meet this need. Turbo codes are a novel type of forward error correcting codes that have demonstrated performance nearly equal to the Shannon channel capacity [4].

II. Turbo Code Encoder

A concurrent concatenation of two or more recursive systematic convolutional codes results in a turbo code [1-3]. A generalized turbo encoder is shown in Fig.1
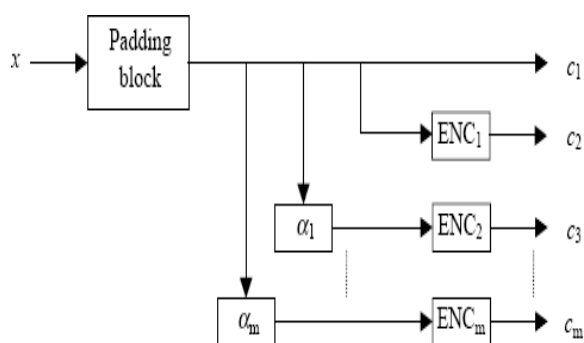

Fig. 1 turbo encoder.

The data block x with k information bits serves as the TC encoder's input. The pad-ding block adds v (memory size) tail bits to this information sequence, producing the sequence c1. Then, m parallel sets of interleavers (i) and encoders are fed with this bit stream [7]. The aim of the interleaver is to scramble the sequence c1 before feeding the output of the padding block into other constituent encoders [5].

III. Turbo Code Decoder

Turbo codes enable the construction of robust codes that make use of a rather straightforward soft-decision decoding method. The turbo decoder's two identical serial decoding blocks that share information allow for this because of their construction. The turbo code decoders frequently operate in an iterative (loop-wise) fashion by exchanging the a posteriori information obtained from the log-likelihood ratio of the previous cascaded decoder. The best decoders for the component codes that the turbo encoder uses are the constituent decoders. Fig.2 gives a visual representation of the iterative and information sharing nature of the decoding strategy.
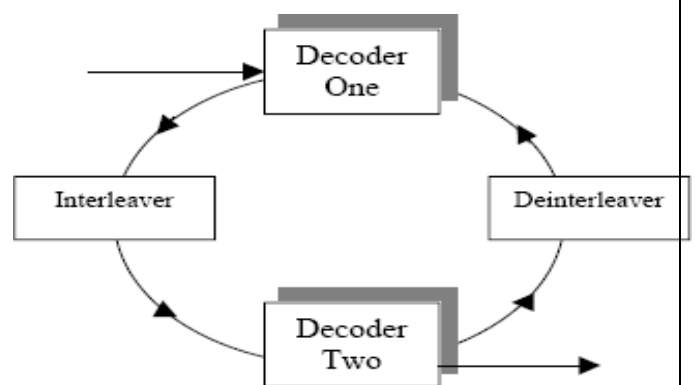

Fig. 2 Turbo decoder

The Soft Output Viterbi Technique (SOVA) and the Log-MAP decoding algorithm are suitable for turbo codes because they generate soft-bit estimations. The modified MAP decoding algorithm, known as Log-MAP, is less computationally complex than the original MAP decoding process. The MAP or the Log-MAP, which are based on the optimal decoding rule, have, nevertheless, been employed in turbo codes the most frequently because to the push for remarkably low bit error rates. In contrast, the SOVA approximates the MAP sequence decoder and will have a slightly worse bit error performance. Although SOVA's performance is compromised

compared to Log-MAP decoding rules, its complexity is greatly reduced.

IV. MAP Algorithm

An elementary comprehension of the MAP algorithm is required before comprehending the decoding of turbo codes. A posteriori probability for the states and transitions of a Markov sequence sent across a discrete memoryless channel were to be estimated. This research produced an algorithm that attempts to decode block and trellis codes while minimising symbol error rates. The MAP algorithm's goal is to reduce the symbol error rate when decoding block and trellis codes. Therefore, the decoder's task is to identify the most likely input bits (original/uncoded information sequence), based on the received symbols, after receiving the information across the channel. It is customary to calculate a log-likelihood ratio (LLR) and base the bit estimations on comparisons based on the magnitude of the likelihood ratio to a threshold because the input spans the entire binary alphabet. The definition of the log-likelihood ratio for the input symbol index at

time t is

$$\Lambda(x_t) = \ln \frac{P(x_t = 1 \mid r)}{P(x_t = 0 \mid r)}$$

In this expression, $P(x_t \square i \mid r)$ is the a posteriori probability of the information bit, $x_t \square\square i$, where i {0,1}, when the knowledge of the received data r is given. Based on the values of the log-likelihood ratio, the decoder generates estimations of the information bits. The magnitude of the log-likelihood ratio is defined as the soft output or soft value which can be passed after pro-

cessing to the other decoder as a priori information. The estimator follows the following rule

$$x_t = \begin{cases} 1 & if\ \Lambda(x_t) \geq 0 \\ 0 & otherwise \end{cases}$$

(A) Log-MAP Decoding

With the advantage of simplifying the computation by doing away with multiplicative operations and the requirement to store small values for the probabilities, the Log-MAP decoding algorithm is used, which is based on the same principle as the MAP decoding algorithm [6,9]. In terms of a microprocessor's processing speed, the multiplicative operation is computationally more expensive than the addition operator. The computation of the log-likelihood ratio requires a huge amount of memory, which makes the implementation of this technique challenging. After defining all the entities required in the decoding process the complete decoder structure for Log-MAP algorithm as shown in Fig. 3
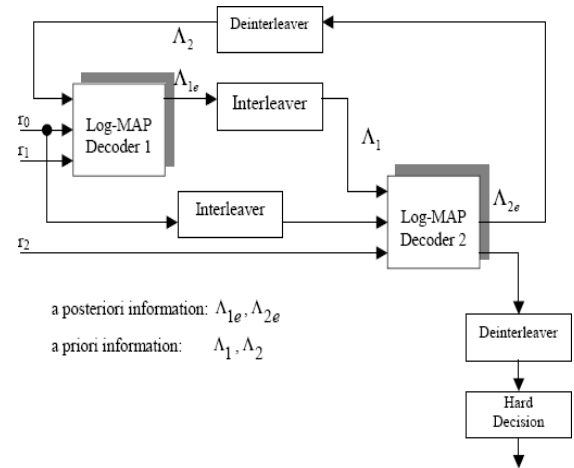

a posteriori information: $\Lambda_{1e}, \Lambda_{2e}$

a priori information: Λ_1, Λ_2

Fig. 3 Log-MAP algorithm

(B) SOVA Decoding

In the form of the LLR, the SOVA decoder additionally calculates the soft output information for each transmitted symbol. The algorithm relies on the validity of the maximum likelihood (ML)

selected path to calculate this LLR [9]. The reliability of the decision is determined at each node in the trellis by the absolute difference between the competing paths and the surviving paths. The more distinct the competing path is from the survivor path, the more trustworthy the survivor path is. For the purposes of this reliability calculation, it is assumed that the accumulated metric for the survivor path is always superior to the accumulated metric for the competing path. Furthermore, since the other survivor paths will be ignored, only the ML survivor path requires the reliability values to be calculated in order to reduce complexity Figure 4 illustrates the SOVA decoding algorithm's structure.
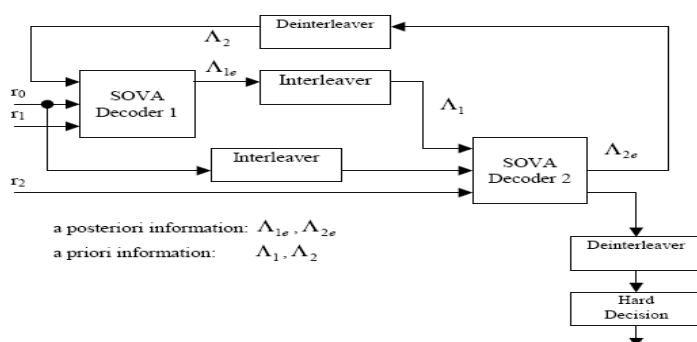

Fig. 4 SOVA decoding

V. Simulation Results

The simulation results for the additive white Gaussian noise channel using the SOVA and Log-MAP decoding schemes are presented. By simulating the punctured scheme with odd-even interleaving, the impact of puncturing is also investigated. To enable a fair comparison, the results for codes with and without punctures are obtained by simulating the schemes under the same parameters [8].
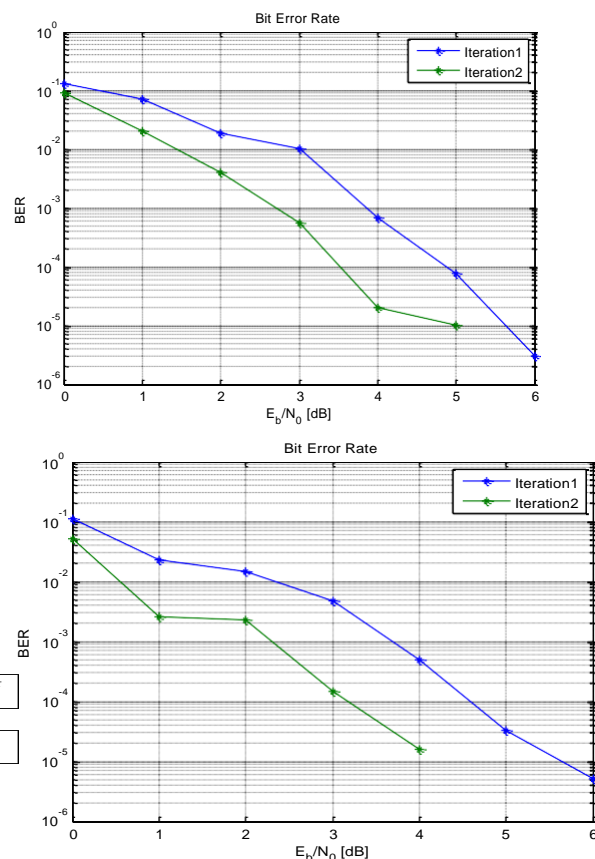

Fig. 5 BER plot for log-map decoder: Punctured

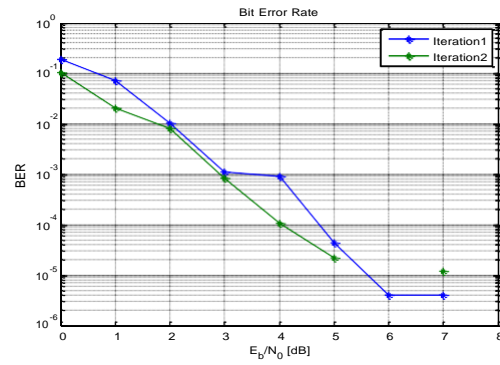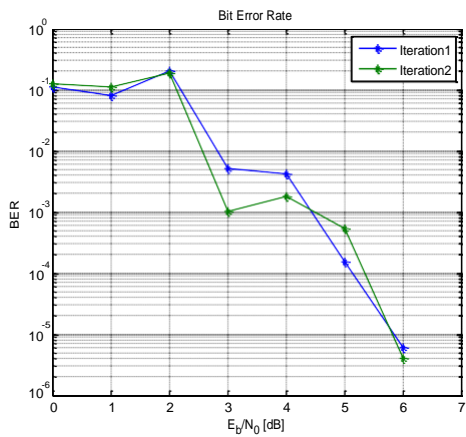Fig. 6 BER plot for log-map decoder: Unpunctured

Fig. 7 BER plot for SOVA decoder: Punctured

Fig. 8 BER plot for SOVA decoder:

Unpunctured

It is evident from Figs. 5 and 6 that punctured code affects the decoder's performance in comparison to unpunctured code for the log Map decoder. The performance of the SOVA decoder is clearly affected by punctured code when compared to unpunctured code, as shown in Figs. 7 and 8. According to the simulation results, the performance of the decoder for a fixed turbo encoder increases with the size of the data frame. This indicates that the data frame size plays a significant role in the performance of turbo codes and that as frame size increases, performance of the code improves, which is contrary to the typical Viterbi decoder. Similar to how unpunctured code performs better, punctured code results in a decrease in decoder performance.

VI. Conclusion

By concatenating two recursive non-systematic convolutional codes in parallel, the turbo code, a very potent error-correcting coding scheme, is presented. The simulation results clearly show that the code may, with more iterations, achieve very low bit error rates at even low signal to noise ratios. The iterative procedure aims to further minimise bit mistakes. However, determining how many iterations are required to achieve the best results has proven to be a challenging task. Since the SOVA decoder approximates the MAP decoding method and as a result experiences performance deterioration, it is not surprising that it performs less well than the Log-MAP algorithm. Although SOVA suffers from performance degradation, it has an advantage over Log-MAP algorithm in terms of hardware implementation because it does not need a lot of memory to store numbers. This is because Log-MAP algorithm is prone to memory overflows despite having better performance.

VII. References

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