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Performance of Coded Cooperation using Log-Map and SOVA Decoder

K.Vijayalakshmi, S.Joy Vincy Praba

SKP Engineering college,
Thiruvannamalai

Abstract: **The user cooperation technique called, coded cooperation, where cooperation is achieved through channel coding method using turbo decoder. Coded cooperation achieves imposing gains compared to a non-cooperative system while maintaining the same information rate, transmit power and bandwidth. In this paper we have analyzed the performance of the Log-Map (log-maximum a posteriori probability) and Modified SOVA (Soft Output Viterbi Algorithm) for the Turbo Decoder. The performance of Log-Map and Modified SOVA over the AWGN channel is obtained. The BER and SNR performances are compared. It has been verified by the simulation results that the proposed adaption to the fixed scaling factor method gives enhanced results of the performance of Log-Map and Modified SOVA. Simulations of this work will be in MATLAB.**

Keywords: **Turbo-code, Decoder, Log-Map, SOVA, AWGN**

I. INTRODUCTION

Cooperation between pairs of wireless communication achieves [1, 2, 3, 4, 5], diversity by a signaling plot that allows two single-antenna mobiles (users) to send their information using both of their antennas. The basic approach to the cooperation has been for a mobile to "listen" to a partner's transmission, and in a diverse time or frequency slot to retransmit either an amplified version of the received signal (amplify-and-forward) or a decoded version of the received signal decode-and-forward [7].The user might simply forward the analog signal received from its partner, a technique known as amplify-and-forward. As an alternative the user may retransmit estimate of the received symbols, obtained via hard detection this system is generally as decode- and-forward. This paper presents a user cooperation methodology called coded cooperation **[**8], where cooperative signaling is included with channel coding method using turbo decoder.

Instead of repeating some form of the received information, the user decodes the partner's transmission and transmits additional parity symbols according to some overall coding scheme. This method maintains the same information rate, code rate, bandwidth, and transmit power as a comparable non-cooperative system. As a consequence of this, coded cooperation exhibits a graceful degradation behavior such that in the nastiest case it always performs at least as well as a analogous non-cooperative system. This is a considerable development over the previous methods. Through these analyses, we differentiate the performance of coded cooperation, and exhibit the impressive gains it provides relative to a comparable non-cooperative system.

A.Cooperative Communication

In cooperative wireless communication [4,7], we are concerned with a wireless network, of the cellular or ad hoc variety, where the wireless agents, which we call *users*, may increase their effective quality of service via cooperation. In a cooperative communication system, each wireless user is assumed to transmit data as well as act as a cooperative agent for another user (Fig1.1).

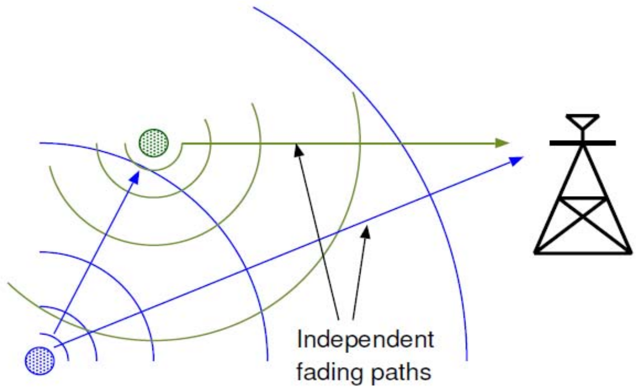

Fig 1.1 Co-operative Communication

For an explanation of the ideas behind cooperative communication, we refer the reader to Figure1 which shows two mobile users communicating with a destination. Each user has only one antenna and thus cannot individually generate transmit diversity. However, due to the inherently broadcast nature of wireless communication, it may be possible for one user to receive the other, in which case it can forward some version of the received information, along with its own data. The mobile wireless channel suffers from multi-path fading, which causes the signal attenuation to vary significantly over the course of a given transmission.

Co-operation leads to interesting trade-offs in code rates and transmit power. In the case off power, one may argue on one hand that more power is needed because each user, when in cooperative mode is transmitting for both users. On the other hand, the baseline transmits power for both users will be reduced because of diversity. In the face of this trade-off, one hopes for a net reduction of transmit power, given everything else being constant. In cooperative communication,each user transmits both its own bits as well as some information for its partner, so it may appear that each user requires more bandwidth. Even amplify-forward and decode-forward techniques were already shown to be significant, there has not been an equivalent study on coded cooperation using turbo decoder. In this work we use coded cooperation using turbo decoder to obtain better performance. Using MATLAB the performance of Log-

Map and SOVA techniques are compared with various signaling methods.

This paper is summarized as follows. Section 2 describes the various cooperative signaling methods such as amplify-forward, decode-forward and coded co-operation. Section 3 elaborates the turbo decoder and its algorithm. The result and conclusion will be analysed in section 4 and section 5 respectively.

II. Co-Operative Signaling Methods

A.Amplify-and-Forward

Amplify-and-forward is conceptually the most simple of the cooperative signaling methods. Each user in this method receives a noisy version of the signal transmitted by its partner. As the name implies, the user then amplifies and retransmits this noisy signal. The destination will combine the information sent by the user and partner and will make a final decision on the transmitted symbol. Although the noise of the partner is amplified in this scheme, the destination still receives two independently-faded versions of the signal and is thus able to make better decisions for the transmitted symbols. Nevertheless, amplify-and-forward is a simple method that lends itself to analysis, and therefore has been very useful in furthering the understanding of cooperative communication systems [3].Laneman and Wornell first proposed amplify-and-forward as a cooperative signaling scheme. In this work, they compute the bit error rate (BER) for un coded symbol-wise amplify-and-forward, and show that, despite the noise propagation from the partner, amplify-and-forward performs significantly better than non-cooperative transmission. They demonstrate that amplify-and-forward signaling achieves diversity order two for two cooperating users.

B. Decode-and-Forward Method

In decode-and-forward, a user attempts to detect the partner's symbols, and then retransmits an estimate of the detected symbols. The first work proposing a detect-and-forward protocol for user cooperation was by Sendonaris, Erkip, and Aazhang. This was actually the first work in the area of cooperative communication and has inspired much of the current activity in this area [2, 3].

Laneman, Wornell, and Tse consider the outage probability of a basic detect-and-forward protocol, for which an outage event occurs if the channel between the user and partner is in outage. In other words, an outage is assumed if a user does not successfully detect the partner’s symbols. It is shown that this protocol achieves diversity order one, the same as non-cooperative transmission, and actually performs worse than non-cooperative transmission for a wide range of conditions. This is due to the fact that a user may often relay erroneous estimates of the partner's symbols.

To avoid the problem of error propagation by the partner, Laneman,Wornell,and Tse propose a hybrid detect-and-forward method where, at times when the channel between the users has high instantaneous SNR, users detect and forward their partner's data, but when the channel has low SNR, the users revert to a non cooperative mode. In particular, if the channel between the users is in outage, each user chooses not to cooperate, but simply to repeat its own symbols for that period. Laneman, Wornell, and Tse show that this hybrid detect-and-forward protocol does achieve diversity two, and provides gains over non-cooperative transmission similar to those of their amplify-and-forward scheme discussed above. Cooperative diversity is achieved by having a user repeat in some form the symbols received from the partner.

C. Coded Cooperation

The user cooperation framework, called coded cooperation, in which cooperative signaling is integrated with channel coding. The basic idea behind coded cooperation is that each user tries to transmit incremental redundancy for its partner. The key to the efficiency of coded cooperation is that all this is managed automatically through code design and there is no need for feedback between users. This method has two key characteristics. First, cooperation occurs through partitioning a user's code word such that part of the code word is transmitted by the user itself, while the remainder is transmitted by the partner through partial or complete decoding. Second, we employ error detection at the partner to avoid error propagation. Many of the previous methods either admit forwarding of erroneous estimates of the partner's symbols, or include propagation of the partner's noise. Error propagation diminishes the performance, particularly when the channel between partners is poor.

It is possible to implement these characteristics in a natural and simple manner by a method that uses common error control codes, as explained in the sequel. Furthermore, the incorporation of cooperation with channel coding allows a great degree of exibility, since by varying the associated code rate, the coupling between the cooperating users can be controlled and adapted to channel conditions. Performance results show that coded cooperation achieves impressive gains for a variety of channel conditions. The users divide their source data into blocks that are augmented with cyclic redundancy check (CRC) code. In coded cooperation, each of the users’ data is encoded into a codeword that is partitioned into two segments, containing $N1$ bits and $N2$ bits, respectively. In general, various channel coding methods can be used within this coded cooperation method. The code bits for the two frames may be selected through puncturing, product codes, or other forms of concatenation. To obtain the concert results, we utilize a simple but effective implementation using rate-compatible punctured convolutional (RCPC) codes [6, 8]. In this implementation the code word for the first frame is obtained by puncturing a code word of length N bits to obtain $N1$ code bits. The additional code bits transmitted in the second frame are those punctured to form the first frame code word. The user’s act separately in the second frame, with no knowledge of whether their own first frame was correctly decoded. As a result, there are four possible cooperative cases for the transmission of the second frame: both users cooperate, neither user cooperates, user 1 cooperates and user 2 does not, and vice versa. The coded cooperation framework is very flexible and can be used with virtually any channel coding scenario. The coded cooperation will develop the performance of the partner with the poor uplink SNR at the expense of the partner with the better uplink SNR. The code bits for the two frames may be selected through puncturing, product codes, or other forms of concatenation.

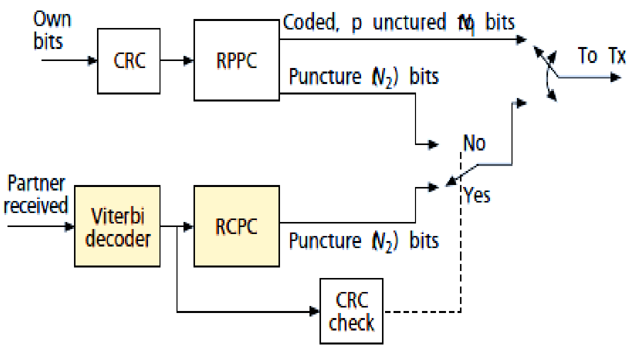

Fig.2.1 Coded Cooperation

III. Proposed Method

A. Coded Cooperation-Turbo Decoder

In our system a user cooperation technique called coded-cooperation using turbo-decoder**.** Each codeword is transmitted from the user's and partner's antenna respectively.

Coded cooperation has a graceful degradation compared to non co-operative system. Generally it performs superior than other cooperative methods for moderate to high signal-to-noise ratio. Coded Cooperation achieves impressive gain which maintaining the same information rate, transmission power and bandwidth. Turbo coding has been adopted as a channel coding scheme for several 3rd generation mobile systems, in particular 3GPP (third generation partnership project) for high data rates.

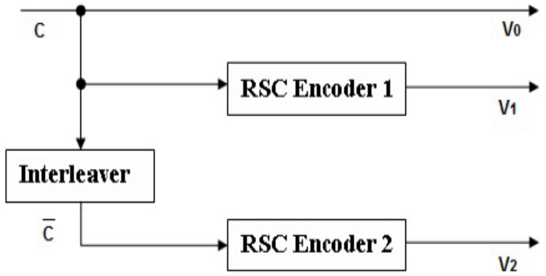

Fig. 3.1 Turbo Decoder

The fundamental Turbo decoder is built with two identical recursive systematic convolutional (RSC) codes with analogous concatenation. These two component decoders are alienated by an interleaver.The interleaver changes the input sequence with a certain rule. Only one of the systematic outputs from the two component decoders is used because the systematic output from the other component decoder is just a permuted version of the chosen systematic output. Figure shows the fundamental Turbo code decoder. The first RSC decoder outputs the systematic V0 and recursive convolutional V1 sequences while the second RSC decoder rejects its systematic sequence and only outputs the recursive convolutional V2 sequence.

C. Decoding Algorithm

The trellis based estimation algorithms are classified into two types

The trellis based estimation algorithms are classified into two types.They are sequence estimation algorithms and symbol-by-symbol estimation algorithms [9, 10,11]. The Viterbi algorithm, SOVA (soft output Viterbi algorithm) and Modified SOVA are classified as sequence estimation algorithms. Whereas the MAP algorithm, Max-Log-Map and the Log-Map algorithm are classified as symbol-by-symbol estimation algorithms. In general the symbol -by-symbol estimation algorithms are more complex than the sequence estimation algorithms but their BER performance is much enhanced than the sequence estimation algorithms. In this we have analyzed the performance of the Log-Map (log-maximum a posteriori probability) and Modified SOVA (Soft Output Viterbi Algorithm) for the Turbo Decoder. The Log-MAP gives high performance and Modified SOVA is less complex. These algorithms share common operations.

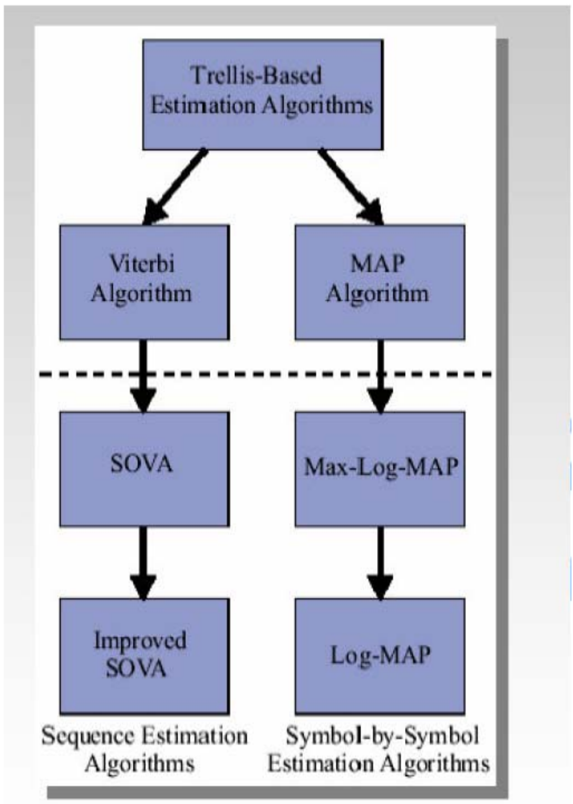

Fig 3.2 Decoding algorithms for turbo decoder

IV. Results

The performance of log-map and Modified SOVA over the AWGN channel is obtained. The BER and SNR performances are compared. It has been verified by the simulation results that the proposed modification to the fixed scaling factor method gives improved results of the performance of Log-Map and Modified SOVA. Simulations of this work will be in MATLAB .The simulation result is shown below.

The figure 4.1 shows the performance of Log-Map and the figure 4.2 shows the comparable graph of Modified SOVA, SOVA, Log-Map and various cooperative signaling methods. Here we analyzed the performance of Log-Map and Modified SOVA over the AWGN channel. This simulation compares the BER and SNR performance.

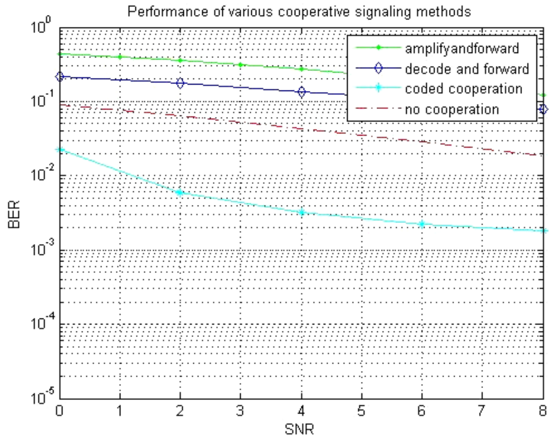

Fig. 4.1 comparisons of Log-Map and various cooperative signaling methods

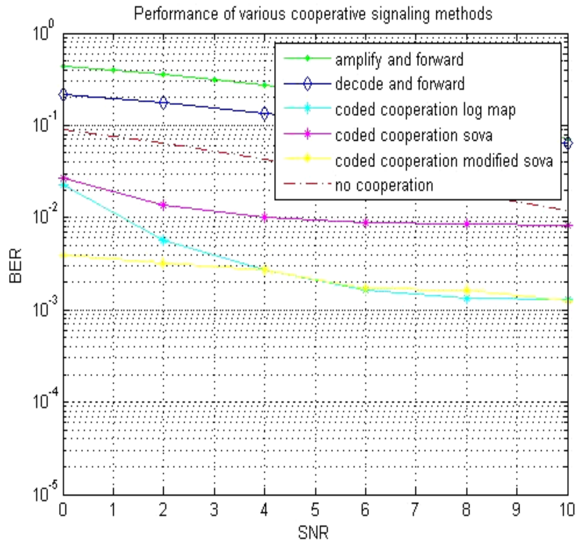

Fig 4.2 Comparing the performance of Modified SOVA and various cooperative signaling methods

It has been verified by the simulation results that the proposed modification to the fixed scaling factor method gives improved results of the performance of Log-Map and Modified SOVA. Using coded cooperation method it shows better performance than previous method like amplify-and-forward & decode-and-forward.

V. CONCLUSION

In this system the co-operation is achieved through channel coding using turbo decoder by the method of coded co-operation. The performance of the Log-Map and Modified SOVA algorithm for the turbo decoder is analyzed and found that the Log-Map gives high performance and Modified SOVA is less complex when compared with other decoding algorithmic techniques. The various decoding algorithms are available for decoding of turbo codes. The performance of Log-Map and Modified SOVA over the AWGN channel is obtained. This result shows that the performances of BER and SNR are improved. Using coded cooperation method gives superior performance than existing method like amplify-and-forward, decode-and-forward.

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