Research on LDPC Coding Cooperative System Based on Intelligent Joint Iterative Decoding

Yifeng He\textsuperscript{1,2,*}, Guozhi Rong\textsuperscript{1}, Zhemin Duan\textsuperscript{2}, Xin Li\textsuperscript{1}

\textsuperscript{1}Xi’an Institute of Space Radio Technology, Xi’an 710100 China

\textsuperscript{2}Electronic Information College, North western Polytechnical University, Xi’an 710072 China

Abstract. Gain of multi-relay coding cooperation. As the number of joint iterations increases, the bit error rate performance increases rapidly, which is significantly better than the coding non-cooperative system under the same conditions. The source output should be represented with as few binary digits as possible. Various noises and interferences in the channel are the main causes of bit errors in digital communication system receivers. Collaborative technology can improve the performance of the system without significantly increasing the system bandwidth or increasing the transmit power, and has attracted more and more attention in the academic and engineering fields.

1. Introduction

Traditional wireless communication systems generally improve channel capacity and reliability by increasing system bandwidth or transmitting power. However, with the rapid development of wireless communication technology, the available spectrum bandwidth has been highly saturated [1]. Cooperative communication technology is an important means to improve the performance of wireless communication systems, and coding cooperation is one of the enhanced cooperative protocols. The basic idea is to combine cooperative diversity technology with channel coding technology. The core of collaboration technology is to make use of the cooperation among multiple nodes in communication network to realize path sharing [2]. The channel capacity of the entire communication network is increased, so that a single antenna terminal in a multi-hop wireless communication network can effectively resist channel fading [3]. The function of the source is to transmit the message carrying the information, and the output can be an analog signal, such as an audio or video signal. The signal is discrete in time and has a finite number of output characters. Collaborative technology can improve the performance of the system without significantly increasing the system bandwidth or increasing the transmit power, and is receiving more and more attention in the academic and engineering fields [4].

The basic idea of cooperative communication is to form a virtual multi-input and multi-output system through mutual cooperation between single-antenna users to achieve diversity gain, thereby improving the performance of the entire communication system [5]. Different portions of the encoded codeword are transmitted by mutually independent cooperative channels such that the entire cooperative communication system can benefit from both cooperative diversity and coding gain [6]. The message generated by the source is converted to a sequence of binary digits by the source encoder. In theory, the source output should be represented with as few binary digits as possible. Various noises and interferences in the channel are the main causes of error in the receiver of digital communication systems [7]. Contrary to the decorrelation effect of source coder, channel coder adds redundancy to the discrete information sequence output by source coder appropriately. We need to find an effective representation...
of source output so that it can produce little or no redundancy. Considering the power, the cooperative performance gain can reduce the transmission power of the nodes and the inter-user interference [8]. Relay cooperation can expand the coverage of existing cellular networks and other structures, and reduce the blind spots in communication.

2. Intelligent Multi-Relay Coding Cooperative System

In the joint iteration of the RS code and the LDPC code, the BP algorithm of the LDPC code is a soft-in soft-out decoding method, which can directly provide soft information to the outer code decoder. Different users transmit different parts of the codeword through mutually independent channels, combining efficient channel coding techniques with cooperative techniques to obtain both coding gain and diversity gain. Discrete memoryless channels can be considered as a more generalized discrete input, a special case of discrete output channels. The interference of various noises in the channel makes it difficult to make reliable communication. Channel coding is a means to improve the reliability of information transmission. It can detect and correct errors on the receiving end itself after an error occurs in the transmission process [9]. At the receiving end, the decoding results are output after the iteration decoding of the inner and outer codes, and in each iteration of the inner and outer codes.

In order to reduce the decoding complexity of external codes, the internal LDPC codes iterate several times before the output is used as the input of the external RS decoding. When the codeword arrives at the receiving end, it can be judged whether it meets the coding rules or not. Packet data units are introduced into the original system to provide data services on wireless systems. The blocking rate is shown in Figure 1 when the error correction code is 1. The blocking rate of error-correcting coding is 4 as shown in Figure 2.

![Fig. 1 Error correction code 1 time blocking rate](image1)

![Fig. 2 Error correction code 4 blocking rate](image2)

In order to make a codeword have the ability of error detection or correction, it is necessary to add extra symbols to the original codeword to expand the difference between codewords. That is to say, the original codeword is transformed into redundant codeword according to some rules, and the bits of each codeword are related to each other. In order to highlight the advantages of cooperative relay coding system, and the distance between relay node and destination node is shorter than that between source
node and destination node. Therefore, it is assumed that the channel SNR from relay to destination node is higher than that from source to destination node. In the LDPC code coding cooperative communication system, the destination point decoder performs independent iterative decoding on the two received signals from the source node and the relay point respectively by using the traditional cooperative system decoding method. Then use one decoding result to assist the other way to decode. The joint iterative detection decoding process consists of two inner and outer iterations, where the internal iteration is to provide a priori information for the next external iteration. When it is not met, determine the location of the error and correct it according to certain rules. The process of correcting and restoring the original codeword is called decoding.

3. Basic Channel Model for Point-to-Point Transmission

3.1. Joint Iterative Detection Decoder Model

An important parameter of linear block codes is the weight of the codeword, that is, the number of non-zero elements contained in the codeword. The weight distribution of the code is formed by the weight of all codewords in the code. The performance of iterative decoding algorithms such as parallel concatenated codes, serial concatenated codes, low density parity check codes and repetitive cumulative codes can be predicted by external information transfer. LDPC codes are used in cooperative communication with relay channels. Two coding modes of LDPC coded cooperative communication system are proposed. In addition to describing the encoding process of convolutional codes with state diagrams and lattice diagrams, tree diagrams can also be used to describe the encoding process of convolutional codes \[10\]. In the trellis diagram, the minimum distance between the output codeword and the all-zero codeword is described as the deviation from the all-zero path starting from a node and returning to the all-zero path at a later time.

It is assumed that each component channel in the dual relay coding cooperative system is subjected to path loss, Rayleigh fading, and complex Gaussian white noise, and the receiver has received channel state information. The information to be transmitted is grouped, and supervised symbols are added after each set of binary information symbols. Then add the information symbols and the supervised symbols. In general, the parity condition is:

\[
d_i = \sqrt{(T_{ai} - x)^2 + (T_{bi} - y)^2 + (T_{ci} - z)^2}
\]  

(1)

If the received codewords have the following symbols:

\[
\hat{x} = T_h(A, t) = \begin{cases} 
A & |A| \geq t \\
0 & |A| < t
\end{cases}
\]

(2)

Then the decoder calculates its sum as:

\[
K_{s,d} = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} \frac{|W_{t,d}(m, n) - \mu_{s,d}|^4}{\sigma_{s,d}^4}
\]

(3)

3.2. Joint Iterative Detection Decoding Algorithms

The Tanner graph representation of the LDPC code has two sets of nodes, one called a variable node and the other called a check node. Since the subcode obtained by the decomposition has a simple structure, its code rate and minimum distance are more easily obtained. When using hard decision decoding, the output of the demodulator is the branch metric of the path can be expressed as:

\[
D(V_t, V') = \sqrt{\sum_{i=1}^{L} \left( \frac{V_{ni} - V'_{ni}}{V_{ni} + V'_{ni}} \right)^2}
\]

(4)

The relative metrics for these two paths are:
\[ p(x; \alpha, \beta) = \frac{\beta \eta(\alpha, \beta)}{2 \Gamma(1/\beta)} \exp\{-\eta(\alpha, \beta)|x|^\beta\} \]  

Among them:
\[ P_n = \frac{\sum_{i=1}^{k} \sigma_i^2}{\sum_{i=1}^{n} \sigma_i^2} \]  

The available error correction coding can then be introduced, and the probability of group call in the system is:
\[ U_y = \frac{H_{y_i}}{\sqrt{\sum_{i=1}^{k} H_i^2}}, i = 1, \ldots, n, j = 1, \ldots, k \]  

As the number of internal iterations increases, the bit error rate of the system decreases rapidly, which is attributed to the joint MS decoding algorithm based on multi-layer Tanner graph. The subcode representation of the LDPC code is used to facilitate the decomposition and simplification of some complex relationships in the computational process. A number of candidate codewords are generated based on different trial sequences using a hard decision decoder. They are then compared to the received sequence to select a candidate codeword that has the closest soft distance to the received sequence as the output codeword of the decoder. The user detects and estimates the received information sent by the cooperative partner which is disturbed by noise, recovers the original information, and then forwards it to the target user. After full iteration, the value of external and internal information in the joint MS iterative decoder has been stabilized. Continuing to increase the number of internal iterations can not provide more external information.

4. Conclusion
Because of the coding randomness of LDPC codes, no interleaver is used in the concatenated scheme, and the internal and external codes exchange information with each other to improve the coding gain. Theoretical analysis and numerical simulation show that the performance of the ideal LDPC coded cooperative system using the new efficient joint iterative decoding algorithm is significantly better than that of the coded non-cooperative system. LDPC coding is carried out at the transmitter of the communication system, and the corresponding decoding is needed at the receiver so as to realize the error correction of the coding. The simulation results show that the S-R channel characteristics from the source node to the relay point in LDPC coded cooperative system have a significant impact on the performance of the whole cooperative system. Theoretical analysis and numerical simulations show that the performance of multi-relay RA coding cooperative system using efficient joint iterative detection and decoding algorithm is significantly better than that of coding non-cooperative system. The simulation results confirm the rationality of the multi-relay coding cooperation model and the effectiveness of the joint iterative detection decoding algorithm. Through collaboration, system performance has been greatly improved, fully embodying the advantages of collaborative communication and joint iterative decoding. The overall code rate and the strength of joint iterative decoding are improved compared to a cooperative communication scheme based on a regular LDPC code.

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