Interleaved Processing of Bit-Flipping Decoding
For LDPC Codes

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Abstract

The BF decoding algorithm for LDPC codes is simple. However, if the number of burst errors is bigger than which BF algorithm can process, the decoding may fail. Interleaving technology is a kind of effective techniques to handle burst errors. Under this technology, consecutive errors in one codeword can be dispersed into multiple code words, therefore the number of errors in each codeword may be lower and in the range of processing ability of BF algorithm. Thence the interleaving technology in decoding can reduce the probability of correction failing and improve the transmission performance. In this paper, a class of burst channel has been studied and the interleaving is applied for data transmission. Simulation results show that the use of interleaving techniques can effectively reduce error rate.

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1. Introduction

The family of Low-Density Parity-Check (LDPC) codes proposed Gallager in 1962 has attracted substantial research interest. The Bit-Flipping (BF) decoding algorithm is based on the symbol hard decision and can achieve only limited decoding performance [1]. To bridge the performance gap between

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BF decoding and BP decoding [2], weighted BF decoding (WBF) and its variants algorithms were proposed. WBF considers both the receive message reliability and the check relationship among those messages [3]. Based on WBF, Zhang et al. proposed an improved weighted BF algorithm (IWBF) [4], which further considered the influence of message reliability on the error metric, and achieved more better decoding performance. However, the IWBF needs a weighting factor and the performance of algorithm depends significantly on the weighting factor.

Those algorithms are simple, however, if the number of burst errors is bigger than which BF algorithm can process, the decoding may fail. Interleaving technology is a kind of effective techniques to handle burst errors. Under this technology, consecutive errors in one codeword can be dispersed into multiple code words, therefore the number of errors in each codeword may be lower and in the range of processing ability of BF algorithm. Thence the interleaving technology in decoding can reduce the probability of correction failing and improve the transmission performance.

In this paper, a class of burst channel has been studied and the interleaving technology is applied for data transmission. Simulation results show that the use of interleaving techniques can effectively reduce error rate.

The remainder of this paper is organized as follows. We begin by discussing the BF, WBF, and IWBF algorithms. In Section 3, we present the interleaving scheme for BF decoding algorithm. Simulation results are presented in section 4, followed by conclusions.

2. BF, WBF and IWBF

LDPC codes are defined by a sparse check matrix $H = h_{ij}^{M \times N}$. Assume code word $C = c_0, c_1, \ldots, c_N$ is transmitted with BPSK modulation, through a noisy channel. Let $r = r_0, r_1, \ldots, r_N$ be the soft-decision received sequence and $v = v_0, v_1, \ldots, v_N$ be the hard-decision sequence. Let $m, n, h_{mn}$ be the set of bits connected with the check node $z_m$, $n, m, h_{mn}$ be the set of checks connected with the bit node $v_n$.

The decoding process of BF is as follow:
1. Compute the syndrome $S = Hv^T$. If $S = 0$, then the iteration is terminated and the decoding is declare successful. If not, go to the second step;
2. For each message node, compute the error metric:
   $E_n = \text{sum}(S^T h_n)$
3. Turn the bit with highest $E_n$ value, and go to step 1.

The decoding process of WBF is as follow:
1. Compute the syndrome $S = Hv^T$. If $S = 0$, then the iteration is terminated and the decoding is declare successful. If not, go to the second step;
2. Find the most unreliable message node associated with each check node:
   
   $r_{mn}^{\min} = \min_{n,m} |r_n|$

(2)
3. For each message node, compute the error metric:

\[ E_{m,n} = 2s_m r_m^{\min} \]  

(3)

The IWBF algorithm is different to WBF algorithm at the step 3. The error metric is replaced as:

\[ E_{m,n} = 2s_m r_m^{\min} |r_s| \]  

(4)

where the factor should be selected carefully to achieve better decoding performance.

3. BURST CHANNEL AND INTERLEAVING

Meteor burst communications (MBC), also referred to as meteor scatter communications, is a radio propagation mode that exploits the ionized trails of meteors during atmospheric entry to establish brief communications paths between radio stations up to 2250 kilometers (1400 miles) apart. Meteor trail channel is a typical wireless intermittent NLOS channel. For the design of meteor burst communication systems, using simulated channel for analysis and comparison is both simple and economic.

Interleaving technology is an effective technique to improve transmission performance under burst channel. We consider the block interleaver in this paper, which processes the \( m \cdot n \) bits.

The scheme is as followed: In sender, the data is coded by a linear encoder, processed by an interleaver, modulated, transported through a burst channel. In receiver, received signal is processed by hard decision, deinterleaved, and then decoding by BF algorithm.

4. SIMULATIONS

The LDPC code selected in this article is a (1008,504,3,6) regular LDPC code given in [5]. Simulations use the following criteria: meteor burst channel, BPSK modulation. The maximum number of iterations in BF algorithm is fixed at 30.

From Fig.1 and Fig.2, we can see that the performance of proposed interleaving scheme is better than that of BF. The interleaving scheme achieves 1.1dB processing gain at BER=10^{-5}, and 1.6dB processing gain at FER=10^{-4}.
5. CONCLUSIONS

Combined with interleaving technology and the BF decoding algorithm, this paper proposes an improved coding scheme for data transmission under burst channel. This scheme considers the case of consecutive errors merged in one code word for the reason of burst interference. The interleaving scheme can divided those consecutive errors into a few code words, and the decoding ability of BF algorithm can solve the reduced errors in one codeword. Simulation results show that interleaving scheme is feasible, effective.

References