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New Weighted Bit-Flipping Decoding Algorithm for LDPC Codes

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***Abstract*—Several Weighted BF (WBF) algorithms are investigated in this paper, and a novel modified reliability-ratio based WBF (MRWBF) decoding algorithm for LDPC codes is proposed. WBF algorithm considers the influence of parity information on the error metric. Based on WBF, the improved WBF (IWBF) algorithm further uses the feature of message reliability on the symbol decision. The reliability-ratio based WBF (RRWBF) can eliminate the defect of requiring off-line pre-processing in IWBF. Our proposed MRWBF further removes the step of calculating normalized weighted parameters in RRWBF and achieves more reduction in decoding complexity. The results of simulations show that the proposed algorithm is feasible, effective, and can achieve good decoding performance.**

Keywords-LDPC Codes; WBF (Weighted Bit-Flipping); Message Reliability formatting

I. INTRODUCTION

The Bit-Flipping (BF) decoding algorithm, which was proposed by Gallager in 1962, and rediscovered by by Mackay and Neal in 1996 [1], is based on the hard decision of symbol. BF is simple and easy to be implemented, but has only limited decoding performance. The weighted BF decoding (WBF) algorithm uses both the check relationships and the reliability of receive message, therefore obtains a better decoding performance when compared with BF algorithm [2]. Furthermore, an improved weighted BF algorithm (IWBF) [3] was introduced by Zhang et al., which further thought over the effect of message reliability on the error metric, and thus gained better decoding performance. But the IWBF introduces a weighting factor when exploiting the credibility of symbols. IWBF's performance depends significantly on the selection of weighting factor, and the factor has to be preset with off-line process. Considering this defect, the reliability-ratio based WBF (RRWBF) was proposed to eliminate that weighting factor [4]. This paper also proposes a modified reliability-ratio based WBF (MRWBF) algorithm, which doesn't need to pre-compute any factor and removes the step of calculating normalized weighted parameters existed in RRWBF, therefore MRWBF can further reduce the computational burden.

The rest of this paper is organized as follows. We first discuss WBF, IWBF and RRWBF algorithms in Section II, then our MRWBF algorithm is introduced in Section III. Simulations are carried out in section IV, followed by conclusions in section V.

II. BF, WBF, IWBF AND RRWBF

We assume that an LDPC code is defined through a check matrix $\boldsymbol{H} = \left(h_{ij}\right)_{M \times N}$, which is sparse. $\boldsymbol{C} = \left(c_0, c_1, ..., c_{N-1}\right)$ is the coded sequence, which is modulated by BPSK and transmitted through additive white Gaussian noise. $\boldsymbol{r} = \left(r_0, r_1, ..., r_{N-1}\right)$ is the received soft-decision sequence and its hard-decision is denoted as $\boldsymbol{v} = \left(v_0, v_1, ..., v_{N-1}\right)$. Let $\mathrm{N}(m) = \{n, h_{mn} = 1\}$ be the bits connected with check node z_m, $\mathrm{M}(n) = \{m, h_{mn} = 1\}$ be the check bits connected with bit node v_n.

BF sketch is as follows:

1. Calculate $\boldsymbol{S} = \boldsymbol{H}\boldsymbol{v}^{\mathrm{T}} = \left(s_0, s_1, ..., s_{M-1}\right)^{\mathrm{T}}$. If $\boldsymbol{S} = 0$, then terminate the iteration, and declare that the decoding is successful;

2. Calculate the error metric for all message nodes,

$$\boldsymbol{T}_n = \boldsymbol{S}^{\mathrm{T}}\boldsymbol{h}_n \tag{1}$$

$$E_n = sum(\boldsymbol{T}_n) \tag{2}$$

3. Reversal the bit with highest E_k value, and go to step 1.

WBF decoding sketch is as follows:

1. Calculate $\boldsymbol{S} = \boldsymbol{H}\boldsymbol{v}^{\mathrm{T}} = \left(s_0, s_1, ..., s_{M-1}\right)^{\mathrm{T}}$. If $\boldsymbol{S} = 0$, then terminate the iteration, and declare that the decoding is successful;

2. Find out the most unreliable message node connected to each check node:

$$r_m^{\min} = \min_{\{n, n \in \mathrm{N}(m)\}} \left|r_n\right| \tag{3}$$

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

$$E_n = \sum_{m \in \mathrm{M}(n)} \left(2s_m - 1\right) r_m^{\min} \tag{4}$$

4. Turn the bit with highest E_k value, and go to step 1.

The difference between IWBF and WBF lies in step 3. The error metric in IWBF algorithm is computed as:

$$E_n = \sum_{m \in M(n)} (2s_m - 1) r_m^{\min} - a|r_n| \quad (5)$$

where a is a factor, and should be preset carefully to achieve good decoding performance.

The difference between RRWBF and WBF is at the second and third step in the iterative process. Instead of finding the unreliable message nodes, RRWBF algorithm tries to find the most reliable message nodes associated with each check node.

$$r_m^{\max} = \max_{\{n, n \in N(m)\}} |r_n| \quad (6)$$

and compute the error metric by:

$$E_n = \sum_{m \in M(n)} (2s_m - 1) b \frac{r_m^{\max}}{|r_n|} \quad (7)$$

where the variable b is a normalization factor.

III. MRWBF

MRWBF is similar to RRWBF, but no longer need any weighting or normalization factor. MRWBF is conducted directly from WBF and IWBF, and the process is similar to that of WBF, but the Equation (4) is modified as follows:

$$E_n = \sum_{m \in M(n)} (2s_m - 1) r_m^{\min} / |r_n| \quad (8)$$

MRWBF is also similar to IWBF in that their message reliabilities all have a subtraction, which are showed in Equation (5) and (8) respectively. MRWBF is also similar to RRWBF in that they all have a division as showed in Equation (7) and (8). Both the subtraction and the division in MRWBF can reduce the error metric for the symbols with more message reliability.

IV. SIMULATIONS

The LDPC code selected in simulations is a (504, 252, 3, 6) regular LDPC code [5]. We use BPSK modulation with AWGN channel in all simulations, and the maximum number of iterations is set to 30 for all weighted BF algorithms. The factor is set to $a = 0.4$ in IWBF, which can guarantee IWBF a better performance. That is confirmed by simulations.

Fig.1 and Fig.2 show that the proposed MRWBF outperforms IWBF and RRWBF in the case of that the signal to noise ratio(SNR) is greater than 7, and has better performance than IWBF, but slightly worse performance than RRWBF in the case of SNR lower than 7.

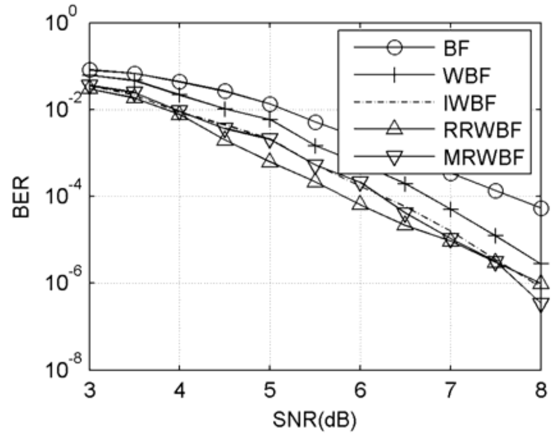

Figure 1. BER performance of (504,252,3,6) regular LDPC codes

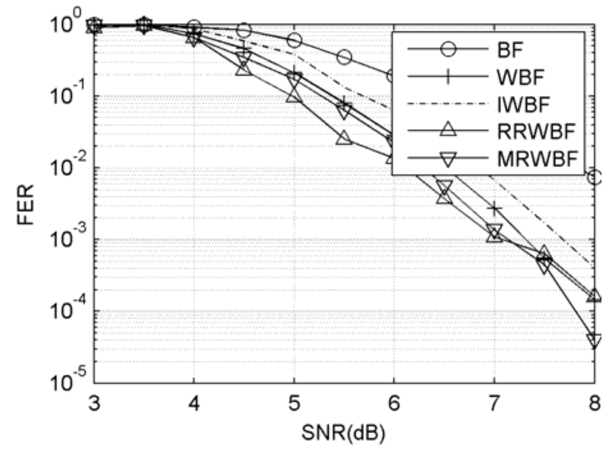

Figure 2. FER performance of (504,252,3,6) regular LDPC codes

V. CONCLUSION

Using both the reliability of received symbols and the parity information, this paper introduced an improved weighted bit flipping decoding algorithm-MRWBF. This algorithm did not require the off-line pre-processing as needed in the IWBF algorithm, and did not need to calculate the normalization factor needed in the RRWBF, therefore the computational complexity of our proposed algorithm was lower than that of IWBF and RRWB. Simulation results showed that the decoding performance of MRWBF was same or better than that of IWBF and RRWBF. Therefore, the proposed MRWBF algorithm is feasible, effective and practical.

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