On Using Redundant Parity Check Equation for LDPCA decoding in Distributed Video Coding

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Abstract

In the video coding, the most significant problem is the encoding complexity. It is the distributed video coding (DVC) that the encoding complexity is decreased but the decoding complexity is increased. In the DVC, the encoding complexity is decreased by using the channel coding. Especially, LDPC(A) codes are widely used. In this paper, we introduce a new decoding method for LDPC(A) code improving the error correcting capability for both the AWGN and the DVC channels.

Keywords: LDPC code, LDPCA code, DVC, Absorbing set, RPCE

1. Introduction

The study of DVC is based on the Slepian-Wolf (SW) Theorem (1973) [1]. This Theorem was presented only for lossless compression. But since the advent of Wyner-Ziv (WZ) coding scheme that can be applied for lossy compression through the quantization of the original information, SW theorem is utilized in lossy video compression paradigm known as Distributed Video Coding (DVC) [2]. DVC has been widely studied by Stanford University [3], Berkeley University [4] and Europe's joint research group [5]. DVC encoder performs only simple operation like error correction encoding. DVC decoder, however, has to carry out most of the complex operations including error correction decoding and motion estimation and compensation which were components of the encoder in other conventional video coding methods.

LDPC and Turbo codes are widely used. Recently, the LDPC Accumulate (LDPCA) code was tested [6]. In general, LDPCA code's original rate (message length /codeword length) is 1/2.

The parity-check matrix of a (n,k) linear code can be loosely defined as any matrix of rank n-k whose null space is the code. But, in this case, there may exist some rows that are linearly dependent to the remaining rows in the parity-check matrix. These rows can be called redundant parity-check equations (RPCEs). These can be often observed in the parity-check matrices of LDPC codes. The existence of redundant parity-check equations does not affect the performance of the algebraic decoder, but on the other hand, it affects the performance of iterative decoder using a belief propagation (BP) algorithm [7, 8]. It is observed that adding redundant rows may improve the performance, but unfortunately, the RPCEs do not always give good effects. There must be some clever way to select RPCEs to be added.

In order to prevent performance degradation due to added RPCEs, RPCEs is added only when decoding fails. In [9], by removing an Absorbing set using RPCEs, the performance improved in error floor. The method of [9] can be applied to any LDPC codes, but it can be used only in Hard Decision Decoding (HDD). So in [10], we have proposed the algorithm

which can be applied to Soft Decision Decoding (SDD) based on [9]. In this paper, we propose the expanded algorithm based on [10].

The paper is organized as follows. In Section 2, a new decoding algorithm using RPCEs is proposed. Simulation results are given in Section 3 and conclusion is given in Section 4.

2. Previous Algorithm and Proposed Algorithm

The behavior of LDPC codes in iterative decoding, especially in high SNR region, has been mainly studied in the context of the combinatorial structures of the codes. They are the stopping set in BEC [11], the trapping set in AWGN channel [12], and the pseudo-codeword [12] which is caused by the property of the locally operated decoder in iterative decoding. The existence of the error floor in the performance curve of LDPC codes are believed to be caused by these combinatorial structures.
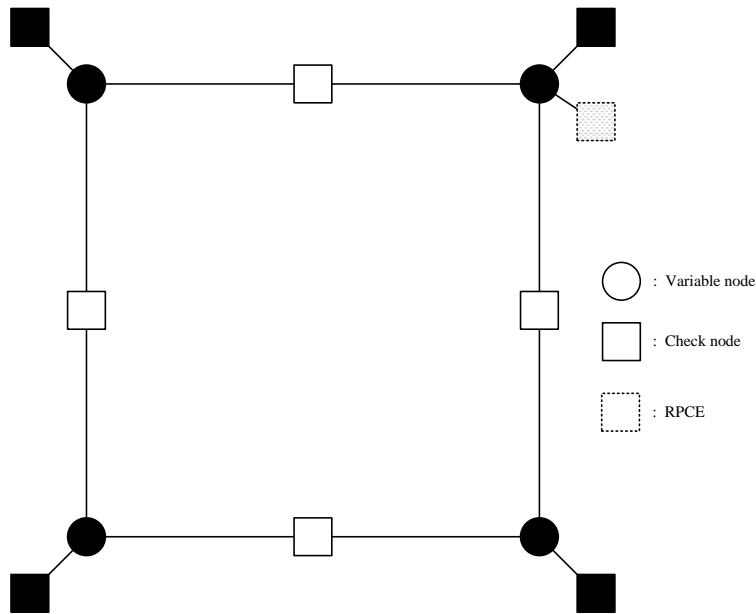

Figure 1. Example of AS with a RPCE

Recently, Laendner [13] showed that these combinatorial properties are affected by the redundant parity-check equations. And Lee [14] showed that a two-stage decoding algorithm using RPCEs had a better performance in (3, 5) Tanner code. Also we proposed the decoding algorithm which can be applied to the general LDPC code using RPCEs [9]. It improves the performance in the error floor by removing the Absorbing set which is the cause of. Figure 1 shows the (4, 4) AS with a RPCE and similar example can show in [15].

It is used only when decoding fails, so the original LDPC code is not changed. Although it is not needed to reconstruct the original code and can be applied to any LDPC code, the decoding complexity is increased. If the iterating number is increased, the performance is improved but complexity is increased. The proposed algorithm is the expanded algorithm based on [9]. Most of the methods are identical. Since previous algorithm was designed for the HDD, it does not show good performance in Soft Decision Decoding (SDD). The reason is that too many candidate variable nodes which can be added RPCEs exist. So, we must decrease the number of candidate variable nodes. In HDD, only one and zero are used in decoding. But in SDD, Log-Likelihood Ratio (LLR) is used. Therefore, if we use absolute

value of LLR, we can decrease the number of candidates. In general, the absolute value of intrinsic LLR corresponding to the received symbol in AS is less than others. Therefore, the following were added to the previous algorithm.

'The Absolute value of intrinsic LLR corresponding to selected variable nodes must less than Mw, where M is the mean of intrinsic LLRs and w is positive value less than one.'

It is a very simple idea, but it can effectively decrease the number of candidates. Until now, the value of w was an arbitrary value. In AWGN channel, intrinsic LLR is $2r/\sigma^2$ where r is received value and σ is standard deviation of noise.
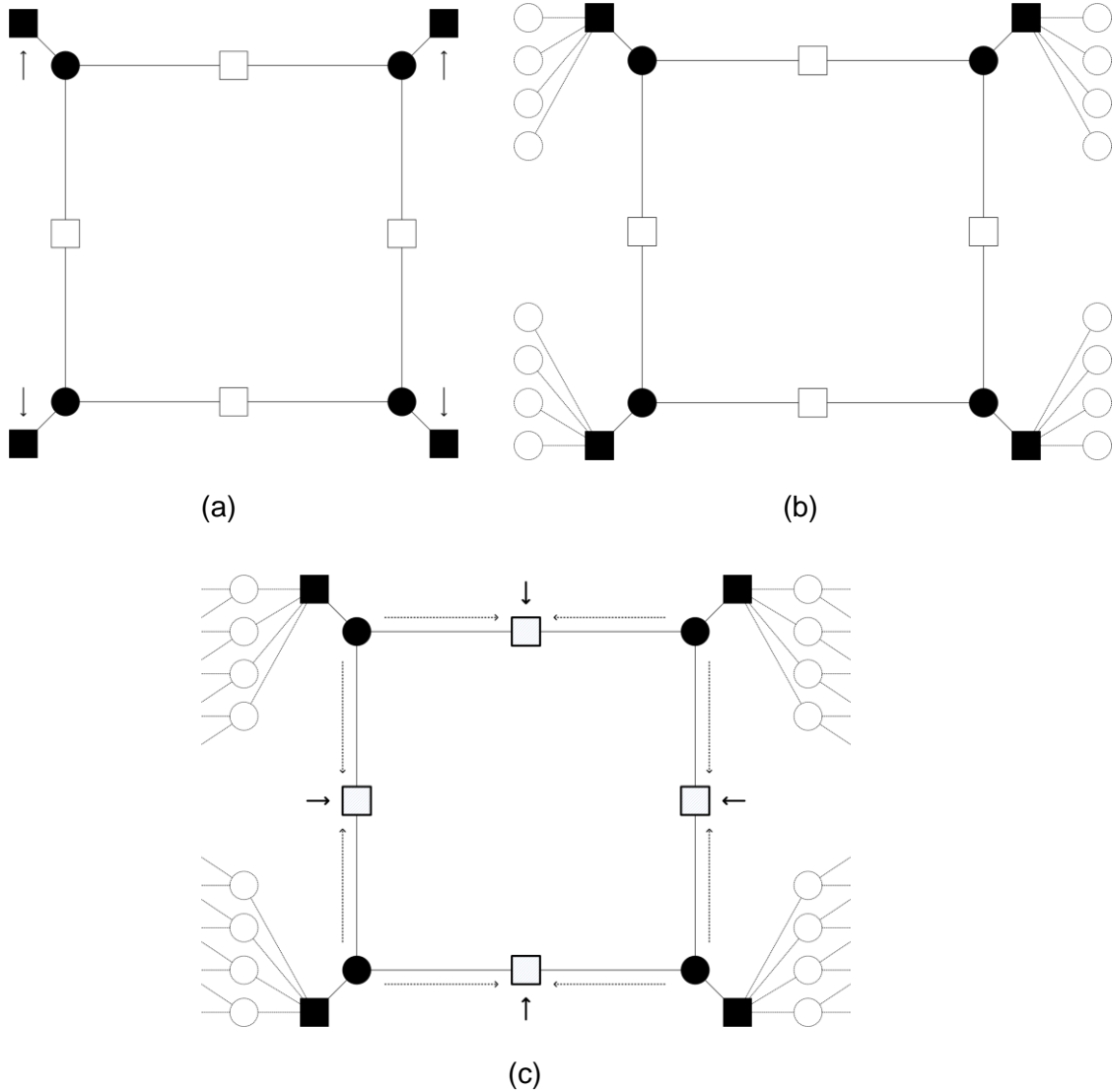

(a)

(b)

(c)

Figure 2. The Basic Process of Previous Algorithm

Figure 2 shows the basic process of previous algorithm. It shows the method which can find the check node in the (4, 4) AS using the unsatisfied check node (check sum is one) and suppose (3, 5) Tanner LDPC code. The key idea is that the check node in AS is connected to the multiple variable nodes in AS. We can easily find variable node in AS using similar method because the variable node in AS is also connected to the multiple check nodes. Lastly, we add RPCEs to selected variable node.

3. Simulation Results in LDPCA Code

General LDPCA code's original rate is 1/2. Systematic code is not changed the code performance, so most of the systems use the systematic code. If the code is systematic, in LDPCA code, variable nodes can be divided into nodes corresponding to message and corresponding to parity. If we can change the number of variable nodes only corresponding to parity, then we can easily change the code rate. The LDPCA code is a LDPC code that can effectively change the number of variable nodes corresponding to parity using Accumulate syndrome [6]. When we use the LDPCA code, generally suppose that the LDPCA code's parity bits (or Accumulate syndrome) are always correct. Note that, the LDPCA code can also use BP algorithms in decoding.

To apply the proposed algorithm, the value of w must pre-appointed. In fact the value of w must be chosen differently depending on the channel or decoding result. In this paper, however, its value was fixed. ($w = 0.5$) Under an existing AWGN channel it is impossible to simulate because the LDPCA code's parity bits are always correct. So the message symbol adds to the noise which is made by Signal to Noise Ratio (SNR) in AWGN channel, but the parity symbol does not add to the noise. Its SNR is not considered the noise corresponding to parity symbol. Figure 3~6 show the performance using the proposed algorithm in LDPCA code. In Figure 3, 4, LDPCA code's DVC rate (parity length/message length) is 0.5. In Figure 5, 6, LDPCA code's DVC rate is 0.75. Once decoding failure has occurred, add a new RPCE and remove a previous RPCE. The maximum iteration number of adding RPCE is ten. In general, the iteration number must be changed depending on the channel. The LDPCA code with RPCE shows better performance than original LDPCA code.

In Figure 3, the maximum gain is 0.5dB. In Figure 5, the maximum gain is 0.7dB. The better performance shows in the error floor because the number of candidates is reduced. The reason that it does not show better gain is that the check node degree is very large. Accumulate syndrome means the check node which is made by adding multiple check nodes. So, if the DVC rate is low, the code performance is decreased. In general, as the check node degree is increased, the number of candidates is also increased. In that case, the number of the low cycle AS is increased and it has a bad effect.

Table 1 shows the average DVC rate about 50 frames in 7 different channels using LDPCA code with message length = 1584. Each rate is minimum rate when decoding reconstructs the original frame. If the original DVC rate is increased, the gain is relatively increased. We can confirm that the channel 1's gain is 0.08 and it is larger than the channel 4's gain. And the number of RPCEs also influences the performance. In Table 1, the performance with two RPCEs is better than with one. In Figure 3~6, only one RPCE is added. If more RPCEs are added, additional gain can be expected. But it is very important that confirm the number of RPCEs. Because the RPCE may improve the performance, but unfortunately, the RPCEs do

not always give good effects. If too many RPCEs are added, it can degrade the code performance. Also if the check node degree is higher, it can generate the error spreading.
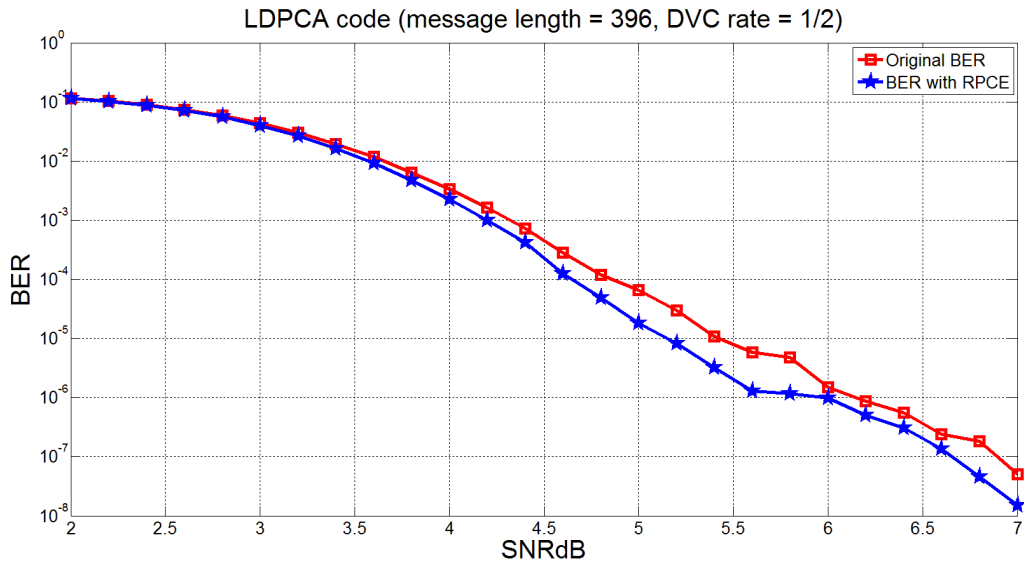

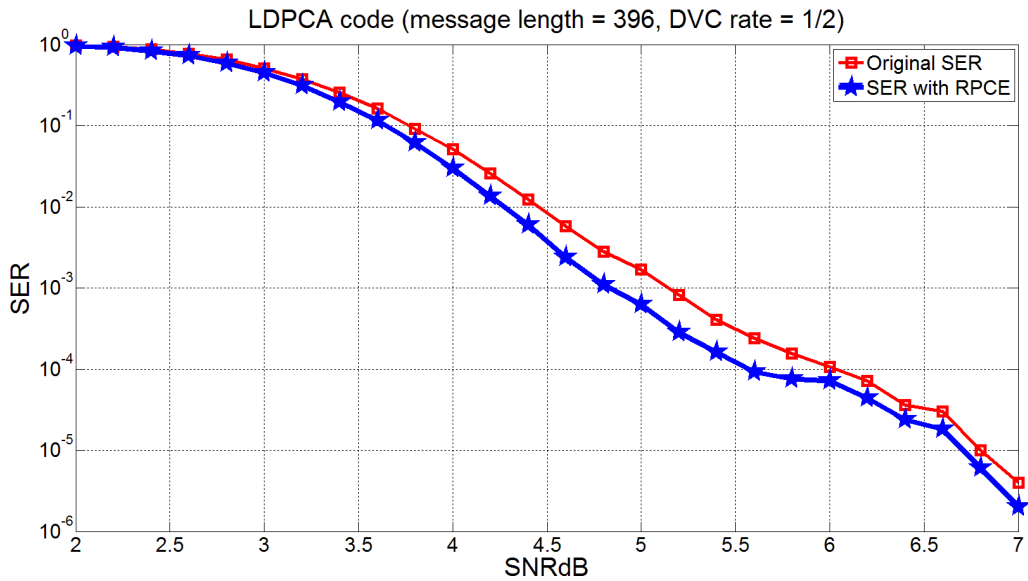**Figure 3. BER of LDPCA code (m = 396, DVC rate = 1/2)**

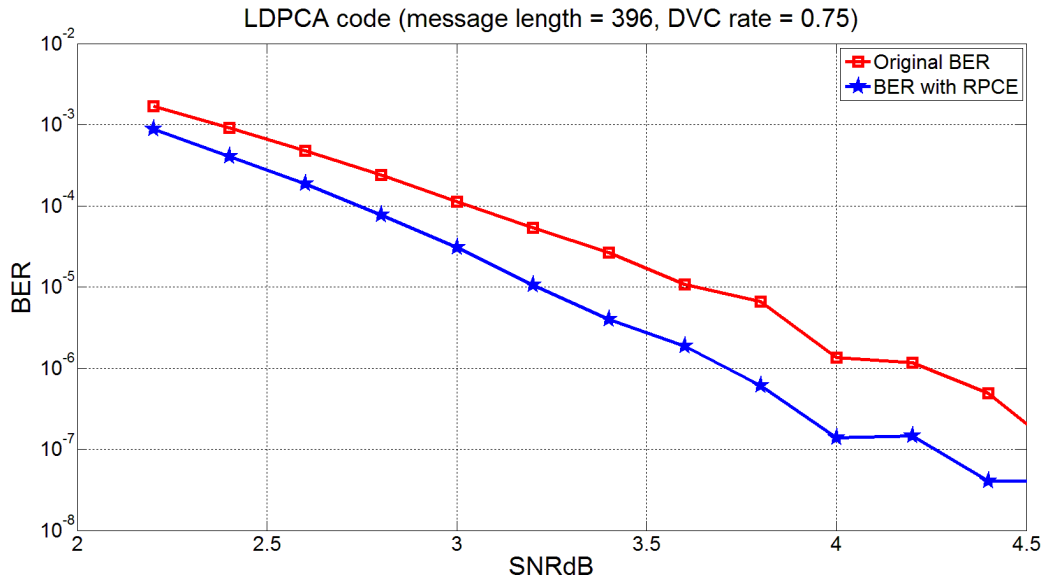**Figure 4. SER of LDPCA code (m = 396, DVC rate = 1/2)**

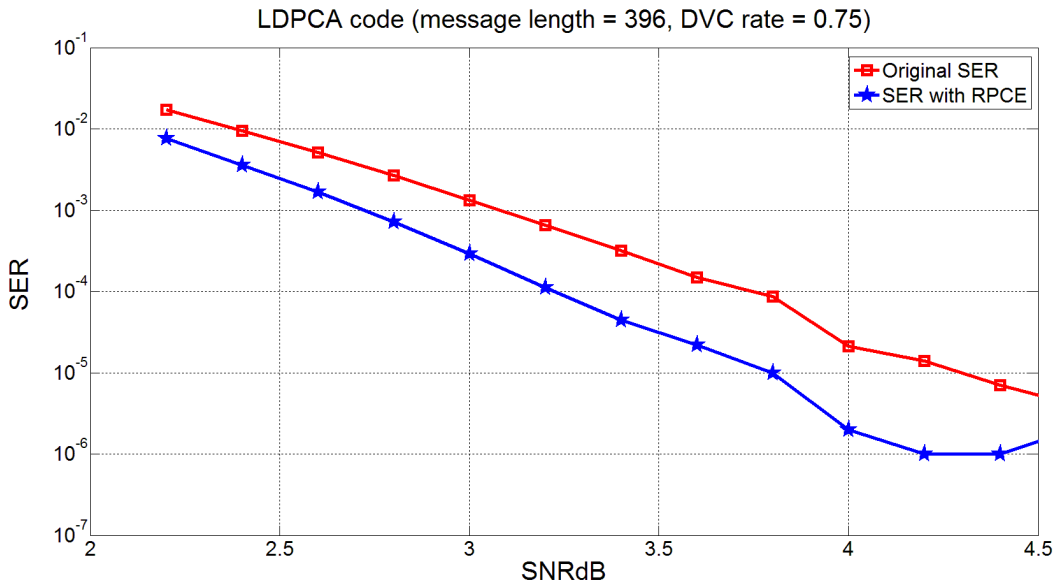**Figure 5. BER of LDPCA code (*m* = 396, DVC rate = 0.75)**

Figure 6. SER of LDPCA code (*m* = 396, DVC rate = 0.75)

Table 1. Simulation Results in DVC Channel

Channel Number	1	2	3	4	5	6	7	Mean
Original LDPCA	0.424	0.336	0.191	0.136	0.257	0.241	0.165	0.250
With one RPCE	0.416	0.329	0.186	0.133	0.252	0.233	0.157	0.244
With two RPCEs	0.414	0.327	0.184	0.132	0.252	0.232	0.156	0.241

4. Conclusion

In this paper, we have proposed the algorithm for the LDPCA code which is used in DVC. When the algorithm is applied, the experiment shows some performance improvement. The proposed algorithm has a huge advantage of being applied to both LDPC and LDPCA. Although there is a disadvantage of increasing complexity, the problem is less important because the increase of the decoder complexity on DVC is acceptable. If additional complexity is allowed, we will be able to create more improvements on performance by increasing the number of attempts. The proposed algorithm is affected by rate, iteration number and the number of RPCEs. These parameters are very important to improve the code performance. With reference to its contents, devising a more refined algorithm remains as a future research topic.

Acknowledgements

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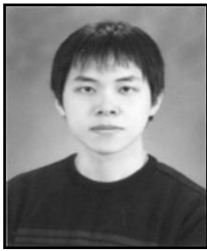
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