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LDPC Code's Decoding Algorithms for Wireless Sensor Network: a Brief Review

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Abstract: As an effective error correction technology, the Low Density Parity Check Code (LDPC) has been researched and applied by many scholars. Meanwhile, LDPC codes have some prominent performances, which involves close to the Shannon limit, achieving a higher bit rate and a fast decoding. However, whether these excellent characteristics are suitable for the resource-constrained Wireless Sensor Network (WSN), it seems to be seldom concerned. In this article, we review the LDPC code's structure brief.ly, and them classify and summarize the LDPC codes' construction and decoding algorithms, finally, analyze the applications of LDPC code for WSN. We believe that our contributions will be able to facilitate the application of LDPC code in WSN.

Keywords: Wireless Sensor Network (WSN), Low Density Parity Check Code (LDPC), anti-interference, soft decision, hard decision.

1 Introduction

The wireless sensor network (WSN) is a distributed network, which is composed of a large number of sensor nodes. These nodes can sense various important information (such as environmental information, area monitoring and target tracing) in the node deployed area, then process and transmit this information to remote users via the wireless network.

The difference between WSN and traditional wired network is the information transmission via the wireless channel. Due to the complex channel, the diverse scenarios as well as mobile/fixed obstacles, the channel state will be influenced. Therefore, the wireless sensor network is susceptible to interference. For the malicious interference in wireless sensor networks, that is also called as interference attack, the more effective anti-interference approach is frequency hopping, however, this approach is almost ineffective for the more intelligent hostile interference, and it cannot resist the environment of noise interference. Besides the above mentioned, the channel coding is taken as a valuable anti-interference technology.

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The channel coding is mainly used to achieve the error correction by adding some error corrected symbols in the transmission information of from the supervision of the. The receiver can use these symbols to check for the errors during the information transmission, and timely correction, and thus reduce the impact of interference. Nowadays, many channel codes are used, such as convolutional code, BCH code, Turbo code and Low Density Parity Check Code code (LDPC). Furthermore, the LDPC code is researched as a hot spot after Turbo code. Because LDPC codes have better error correction performance and flexible coding length, they have been widely used in sensor networks to correct the transmission errors effectively, and improve the network anti-interference capability.

Currently, there are many researches and applications for LDPC codes in broadband wireless communication system, especially, LPDC code with long block lengths is identified as the coding scheme for enhanced Mobile Broadband (eMBB) data channel in the fifth generation (5 G) wireless networks. Although they have perfect performances, it is issue whether they are suitable for wireless sensor networks or not. Hence, we review, classify and analyze LDPC codes for WSN, and wish our contribution will be able to facilitate the application of LDPC code in WSN. The rest of this paper is organized as follows: in section 2 LDPC codes' construction and decoding algorithms are classified. In Section 3. the applications of LDPC code for WSN are analyzed. Finally, some concluding remarks are provided in Section 5.

2 LDPC codes' construction and decoding algorithms

The LDPC code was first proposed by Gallager in his paper [Gallager (1962)], using the maximum likelihood and iterative decoding scheme, but Gallager's research has not been paying much attention because of the limitation of computing power at that time. In 1981, Tanner made a new interpretation of LDPC codes from the point of view of graph theory [Tanner (1981)], but it has not been paying much attention. Until 1993, after the Turbo code was put forward [Berrou and Glavieux (1996)], the LDPC code gradually attracted everybody's attention, and started the vigorous development.

2.1 LDPC codes' construction

Since Gallager does not propose a scheme to construct LDPC codes systematically, many researchers have studied the construction of LDPC codes. LDPC code parity check matrix structure can be divided into two categories, regular code construction and irregular code structure, the classification diagram shown in Fig. 1. The parity check matrix of irregular LDPC codes usually adopts the pseudo-random construction scheme, and the commonly used construction methods are Progressive Edge Growth (PEG) [Hu, Eleftheriou and Arnold (2011)], bit stuffing [Campello, Modha and Rajagopalan (2001)], etc. Regular LDPC code check matrix Pseudo-random construction method is usually used to construct the parity check matrix. However, it is not good for coding. The common pseudo-random construction methods are Mackey construction method [Mackay and Neal (1997)], Ultra-light structure method [Davey and MacKay (1998)], etc. The structured structure because it has good structural characteristics, and thus more convenient hardware implementation. The common structural methods are finite geometrical method [Kou, Lin and Fossorier (2001)], cyclic permutation matrix method [Fossorier (2004)] and combinatorial construction [Ammar, Honary, Kou et al. (2002)], etc., they usually have good cycle and quasi-cyclic characteristics, can be used to achieve a simple feedback shift register coding, which is very suitable for wireless sensor networks such as hardware configuration of the lower network.

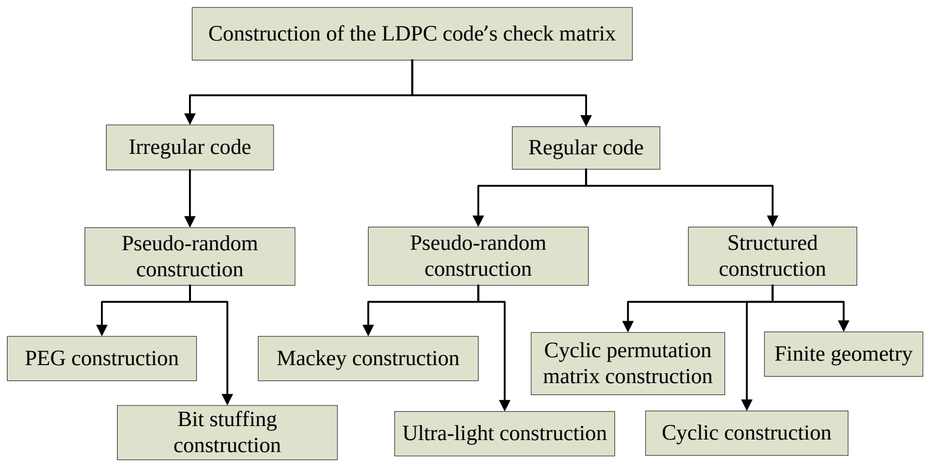

Figure 1: Construction of LDPC code check matrix

2.2 LDPC codes' decoding algorithm

LDPC code decoding algorithms are divided into hard decision decoding and soft decision decoding two categories, the common soft decision decoding algorithm has confidence propagation decoding algorithm (Belief Propagation, BP) [Kschischang, Frey and Loeliger (2001)], and product decoding, improved BP decoding algorithm [Wei and Akansu (2001)] and so on. These soft decision algorithms usually have very good decoding performance, especially some irregular LDPC codes, which can get very low bit error rate when the SNR is low. However, these algorithms also have high decoding complexity. Although the simplified APP [Massey (1963)] and APP-Based decoding algorithms have lower decoding complexity, the decoding complexity is still higher than that of the hard decision algorithm, while the hard decision algorithm. But it has much lower decoding complexity than the soft decision method, which is incomparable by the soft decision method.

The hard decision algorithm of LDPC code is mainly Bit Flipping Algorithms (BF) algorithm, Weighted Flipping Algorithms (WBF) algorithm, improved WBF algorithm and multi-bit flipping algorithm etc. The first hard decision decoding algorithm is BF algorithm proposed by Gallager. The algorithm only relies on the check information to calculate the decision condition. It can flip several bits in one iteration, and the computation is very low, but the performance is also poor. Then, Y.Kou improved the BF algorithm and proposed the WBF algorithm. The WBF algorithm introduced the amplitude information of the bits in the decision condition calculation, which made the bit flip more reliable.

The modified WBF algorithm [Zhang and Fossorier (2004)] and the improved MWBF algorithm [Jiang, Zhao, Shi et al. (2005)] etc have been further improved based on the WBF algorithm.The performance of the hard decision decoding algorithm is further improved, but the computation complexity of the algorithm is inevitably enhanced because the computation of the decision condition introduces a new calculation amount and its single iteration is only one bit to be flipped .In order to reduce the computational complexity, a variety of multi-bit inversion algorithms are proposed, such as Gradient Descent Bit Flipping Algorithms (GDBF) [Wadayama, Nakamura, Yagita et al. (2010)], Adaption Weight Multi-bit Flipping Algorithms, AWMBF) [Chen (2013)]. These algorithms reduce the computational complexity by inverting multiple bits in a single iteration, but the decoding performance is unavoidably affected by more complex decision conditions, so as to achieve better decoding performance. The Multi-Threshold Bit-Flipping Algorithm (MTBF) proposed in Liu et al. [Liu, Niu and Zhang (2015)] can flip multiple bits in a single iteration by setting multiple thresholds, which is similar to the decoding complexity of the standard BF algorithm, but there are still a few gaps in the decoding performance compared to the AWMBF algorithm and some hybrid algorithms [Torshizi, Sharifi and Seyrafi (2013); Torshizi, Sharifi, Daneshgar et al. (2014)].

3 Applied analysis of Ldpc code for WSN

LDPC code has good anti-interference and anti-noise ability in wireless communication, and has lower decoding complexity than Turbo code, more suitable for hardware implementation, and flexible coding, error platform is low, can meet different application requirements, so in the field of wireless sensor networks has also been a lot of research and application.

When applying LDPC codes to wireless sensor networks, in addition to improving the anti-jamming performance of the network, but also to other advantages of the network can be summarized as follows:

3.1 Enhance energy efficiency

Although the application of LDPC codes will introduce more computational complexity and increase the energy consumption of nodes from the point of energy consumption of coding and decoding, however, the good anti-interference ability of LDPC codes allows the sensor nodes to use lower transmission energy consumption, reduce the packet loss rate of the network and reduce the number of retransmissions, but the energy efficiency of the network can be improved. According to the study in Goel et al. [Goel and Shanbhag (1999); Wang, Ju, Gao et al. (2018); Wang, Shen, Li et al. (2018); Liu and Liu (2018)], compared with the un-encoded system, the transmit power of wireless sensor network can be reduced by 55% to 75%, and the energy efficiency of the network can be increased by 30% to 50%.

3.2 Increasing transmission distance

Since LDPC codes can improve the energy efficiency of sensor networks, the network with LDPC codes can have longer transmission distance at the same power consumption, which can reduce the number of nodes deployed in the network and reduce the network

Protocol complexity, and further reduce the deployment cost of the network.

4 Conclusions

For WSN, as the transmission channel is open, and the deployed scenarios are diversity, the information transmission has to face many noise or malicious interference. Since 1962, the Low Density Parity Check Code (LDPC) had been proved to have better error correcting capability, especially, it was identified as the coding scheme for 5 G eMBB data channel in 2016. However, the long block lengths and the higher computational complexity in LDPC are whether suitable for esource-constrained WSN or not. It is an issue to influence LDPC's application for WSN directly. In this paper, we review the LDPC code's structure brief.ly, and them classify and summary the LDPC codes' construction and decoding algorithms in detail. Significantly, from Code length, storage and decoding complexity, we analyze and present some viewpoints that the trade-off between decoding complexity, storage and energy efficiency is key to LPDC application in WSN.

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