On the Competitiveness of LDPC Codes in Wireless

Zhang Weijia* and Dushantha Nalin K. Jayakody
School of Computer Science & Robotics, Tomsk Polytechnic University, RUSSIA
COPELABS, Lusófona University, 1749-024 Lisbon, Portugal
*466024965zhang@gmail.com

***Abstract*—As 5G networks begin to be deploy commercially on a large scale, more and more research and industries are beginning to investigate next-generation communication systems. LDPC code is identified as a candidate channel code for 5G due to its design flexibility and high performance in medium and long code blocks. The question of how LDPC codes will perform in the 6G generation and how to maintain their advantages is a question worthy of consideration. In this paper, we briefly discussing the 6G vision and requirements and combining the characteristics of LDPC codes, analyzing how the development potential of LDPC codes in the 6G and maintaining their competitiveness, and providing directional guidance for the subsequent optimization of LDPC codes development.**

***Keywords*—LDPC codes, 6G, requirements, competitiveness**

I. Introduction

Recently, more and more organizations or individuals are involved in Beyond-5G (B5G) or 6G concepts, including academia, industry, government and even the public. Channel code is the foundation of wireless communication, and the next-generation channel code mechanism needs to be researched and broken through first to lay the foundation for future 6G wireless communication systems. In this paper, we will focus on the vision and requirements of 6G and combine the characteristics of LDPC codes, and try to outline the application and optimization scheme of LDPC codes in 6G generation, and provide directional guidance for the subsequent development of LDPC codes optimization. The following sections of this paper are organized as follows: Section 2, which discusses main possible future scenarios of 6G; Section 3, which discusses main directions of future LDPC codes development; Section 4, which makes a competitiveness analysis of LDPC codes; Section 5, which provides a summary of the whole paper.

II. 6G VISION

There is no doubt that compared to 5G, 6G will have wider coverage, higher data transmission rate, higher reliability, lower latency.

Each communication technology update, communication content will be more and more towards the real. Extended reality (XR) services (encompassing augmented, mixed, and virtual reality (AR/MR/VR)) can greatly improve people's sensory experience, which are the most promising evolutionary direction for future mobile communication, entertainment, and office equipment. In recent years, XR devices and XR technology have been fully developed, and there are more and more application scenarios. There is no doubt that many companies have taken XR devices as the future research direction [1] [2]. With the arrival of 6G, which will provide peak rates of Tb/s and lower latency, this will greatly improve the network environment for XR devices, and with the continued maturation of XR technology and the enrichment of XR content. With the arrival of 6G, XR devices will be at the breaking point.

In the future, when IoT devices are more and more functional, complex and targeted, the IoT clusters will be formed as show in Fig 1, while IoT central devices for different scenarios will be determined. The center of the IoT clusters will gradually turn from people to devices. IoT devices will also be combined with cloud computing, distributed, and blockchain technologies to achieve decentralization in order to build device-centric IoT clusters. The ideal system will be one that is completely free of human intervention [3].

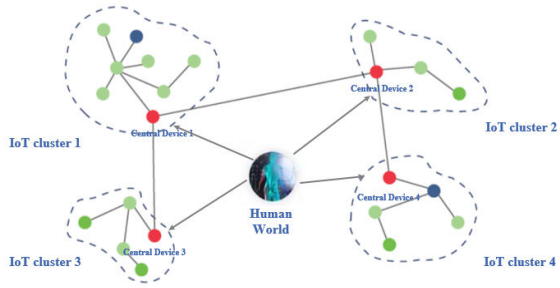

Fig. 1: IoTs clusters communication model.

III. FUTURE DIRECTIONS OF LDPC CODES IN 6G

From the 6G vision analysis, it is clear that the peak rate of 6G in 2030 will reach Tb/s and should also have extremely low latency and can support the simultaneous linking of large-scale IoT devices. Therefore, the optimization direction of LDPC codes should be relevant to the needs of the 6G vision. In general, LDPC codes optimization direction can be divided into two categories, one is the new combination with 6G popular technologies, such as Thz, optical communication, etc, and the other is the optimization of LDPC codes system itself, such as in structure, encoder, and decoder algorithm.

THz as a new frequency band between microwave and light wave has not been fully developed. THz band, spectrum resources are very rich, with high transmission rate and easy to achieve the integration of communication detection, etc, focusing on meeting the needs of the Tb/s level of high-capacity, ultra-high transmission rate systems, so THz communication is an advantageous broadband wireless access technology in future mobile communication [4]. LDPC codes can reduce the signal fading of Thz, improve Thz communication distance and data bit rate [5], and the combination of LDPC codes and

Thz can now reach 352Gb/s data throughput [6], which is a significant progress towards Tb/s level data throughput.

VLC has been proposed as an emerging solution for the next generation wireless network [7]. Compared with radio communication, VLC has many attractive advantages [8]. Firstly, VLC technology can provide a large amount of potentially available spectrum (THz-level bandwidth), and the use of spectrum is not limited and does not require the authorization of spectrum regulators. Secondly, VLC does not generate electromagnetic radiation, and is not easily affected by external electromagnetic interference, widely used in the electromagnetic interference sensitive, and even must eliminate electromagnetic interference of special occasions. Thirdly, the network built by VLC technology can effectively avoid the transmission of information by external malicious interception, to ensure the security of information. Finally, VLC technology supports the rapid establishment of wireless networks, which can easily and flexibly set up temporary networks and communication links, reducing Low network usage and maintenance costs. LDPC codes can reduce the BER and energy consumption of VLC, and improve the communication distance of VLC [9].

The research of AI technology in wireless communication also gives a new optimization tool for channel code research. The optimization of AI technology for LDPC codes mainly focuses on the optimization of LDPC codes decoding algorithms. Among many machine learning methods, neural networks and deep learning are the most commonly used means for channel decoding algorithm optimization. The min-sum decoding algorithm of LDPC codes is well suited to be unfolded with deep learning, which can optimize the excessive parameters of the min-sum algorithm and reduce the computational complexity, and the min-sum algorithm optimized by deep learning has better BER performance [10]. The correct and efficient usage of AI techniques to optimize LDPC codes can exploit the value of LDPC codes even more.

IV. Competitiveness of LDPC Codes in 6G

TABLE I: Comparison of LDPC,Polar,Turbo.

Channel code	**LDPC**	**Polar**	**Turbo**
Advantages	Suitable for parallel decoding	Theoretical performance is optimal	Good anti-fading and anti-interference ability
Disadvantages	Short code performance is inferior to Polar	Not enough industrial support	Large decoding delay

From Tab 1, we can see that Turbo codes do not meet the requirement of low latency of 6G vision, the existing channel code only LDPC, Polar can achieve the 6G corresponding performance requirements, so the biggest competitor of LDPC codes is Polar codes, which is the only code scheme that can be mathematically and rigorously proven to reach the Shannon limit [11].

In terms of throughput and latency performances, LDPC codes have a natural advantage because LDPC codes use the sparsity of the checksum matrix, which makes the decoding complexity linear with the code length, so that decoding can still be performed efficiently w ith l ong c ode l engths and LDPC can use an efficient p arallel d ecoding a rchitecture to ensure decoding accuracy and low latency at high throughput rates. The mainstream decoding algorithm of Polar codes is considered as successive cancellation list (SCL) decoding [11], and the mechanism of SCL is bit-by-bit decoding, which is not easy to implement with high parallelism, resulting in relatively large latency.

In terms of BER performance, the channel polarization characteristic of Polar codes and SCL decoding algorithm ensure that Polar codes are theoretically the best among all channel codes. In practice, the short code BER performance of Polar code is better than LDPC code, and the long code BER performance is comparable to LDPC code, but LDPC code BER performce is better under high SNR [12] [13].

In terms of industry support level, LDPC codes have been developed for nearly 60 years and has been widely used in WIFI, WIMAX and DVB-S2, etc [14]. LDPC codes have a strong industrial base, and the practical application is extremely competitiveness. Polar codes development years are too short, many things need to be implemented from theory to hardware design, system design, so the potential of Polar codes has not been fully exploited.

V. Conclusion

LDPC codes are not the best channel codes in any aspect of performance, but on the whole, they are the most competitiveness codes. LDPC codes' long code position is almost unshakable at present, and with the increase of 6G data throughput, the advantages of LDPC codes will be further strengthened, and LDPC codes will also play an important role in 6G communication system.

References

[1] Hamish Hector, "Google glass 2: everything we know and want to see," techradar, 2022, https://www.techradar.com/features/google-glass-2-everything-we-know-and-want-to-see/, Accessed on 22 July 2022.

[2] VIVE Team, "Htc vive announces new products and content at ces 2022," VIVE Team, 2022, https://blog.vive.com/us/htc-vive-announces-new-products-and-content-jan-2022/, Accessed on 05 Jan 2022.

[3] F. Hussain, S. A. Hassan, R. Hussain, and E. Hossain, "Machine learning for resource management in cellular and iot networks: Potentials, current solutions, and open challenges," *IEEE communications surveys & tutorials*, vol. 22, no. 2, pp. 1251–1275, 2020.

[4] J. Wells, "Faster than fiber: The future of multi-g/s wireless," *IEEE microwave magazine*, vol. 10, no. 3, pp. 104–112, 2009.

[5] C. Liu, C. Wang, and J.-C. Cao, "Performance analysis of ldpc codes on ook terahertz wireless channels," *Chinese Physics B*, vol. 25, no. 2, p. 028702, 2016.

[6] J. Ding, Y. Tan, Y. Wang, J. Zhang, M. He, F. Zhao, L. Zhao, W. Zhou, Y. Shi, M. Zhu *et al.*, "352-gbit/s single line rate thz wired transmission based on ps-4096qam employing hollow-core fiber," *Digital Communications and Networks*, 2022.

[7] M. A. Arfaoui, M. D. Soltani, I. Tavakkolnia, A. Ghrayeb, M. Safari, C. M. Assi, and H. Haas, "Physical layer security for visible light communication systems: A survey," *IEEE Communications Surveys & Tutorials*, vol. 22, no. 3, pp. 1887–1908, 2020.

[8] Y. Zhao, G. Yu, and H. Xu, "6g mobile communication network: vision, challenges and key technologies," *arXiv preprint arXiv:1905.04983*, 2019.

[9] B. Pamukti, F. Arifin, and N. M. Adriansyah, "Low density parity check code (ldpc) for enhancement of visible light communication (vlc) performance," in *2020 International Seminar on Application for Technology of Information and Communication (iSemantic)*, 2020, pp. 262–266.

[10] Q. Wang, S. Wang, H. Fang, L. Chen, L. Chen, and Y. Guo, "A model-driven deep learning method for normalized min-sum ldpc decoding," in *2020 IEEE International Conference on Communications Workshops (ICC Workshops)*, 2020, pp. 1–6.

[11] E. Arikan, "Channel polarization: A method for constructing capacity-achieving codes for symmetric binary-input memoryless channels," *IEEE Transactions on information Theory*, vol. 55, no. 7, pp. 3051–3073, 2009.

[12] D. N. K. Jayakody, "Ldpc coded angular modulation scheme for cooperative wireless networks," in *2016 IEEE 84th Vehicular Technology Conference (VTC-Fall)*. IEEE, 2016, pp. 1–5.

[13] K. Zhu and Z. Wu, "Comprehensive study on cc-ldpc, bc-ldpc and polar code," in *2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*, 2020, pp. 1–6.

[14] M. Sarvaghad-Moghaddam, W. Ullah, D. N. K. Jayakody, and S. Affes, "A new construction of high performance ldpc matrices for mobile networks," *Sensors*, vol. 20, no. 8, p. 2300, 2020.