INTERNATIONAL JOURNAL OF INNOVATIVE TRENDS IN ENGINEERING (IJITE) ISSN: 2395-2946
ISSUE: 60, VOLUME 39, NUMBER 02, MARCH 2018

An Extensive Literature Review on Spatially-Coupled LDPC Coding in Cooperative Wireless Networks

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Abstract - wireless communication is now a key element of our everyday life. From radio, television to mobile phone, wireless communication has revolutionized our society. One challenge in designing wireless communication systems is to deal efficiently with the varying nature of the channel due to signal fading, which may cause poor performance because of a resulting loss of signal power without reducing the power of the noise. One of the most important contributions to the evolution of wireless networks in recent years has been the advent of MIMO technologies, which create the transmission diversity by using multiple, receive and transmit antennas. For timely control actions, the controller needs reliable system state information in real time. In other words, both transmission reliability and delay are important in control applications. Classical codes, including block and convolutional codes, are inappropriate for such applications because block codes attain reliability only at infinite delays; while convolutional codes with finite memory-length result in non-zero error probability. Thus, classical codes are not suitable for control applications. This investigation provides a brief background about channel models, LDPC codes, decoding algorithms, and density evolution analysis.

***Keywords- Cooperative Wireless Networks, MIMO, convolutional codes, Spatially-Coupled LDPC Coding*.**

I. INTRODUCTION

In the last two decades wireless communications have evolved from the classic broadcast applications (radio and TV) to the mobile telephony and widespread use of the wireless internet. This evolution has had a profound impact on human lives - it made communication personal. For example, instead of calling a landline number that was tied to a physical location, one is today calling a cellular number that is tied to a specific person. Development of wireless communication systems made us connected virtually everywhere. Instead of accessing the internet from a location with the wired internet connection, each person has access to internet at the touch of their finger no matter where they are.

One approach to increase the spectral efficiency that has recently drawn a lot of attention among the communication community is to use cooperation among wireless terminals. The modern wireless networks, however, are not ad-hoc in nature. For example, the cellular (GSM, CDMA, LTE, LTE-Advanced) and WLAN (802.11b,g,n,ac) standards adopted.

Star network architecture, presented on Figure 1.1b, with one central terminal (base station in cellular and access point in WLAN) and multiple user terminals (mobile stations). According to the star network architecture, transmissions only happen between the central terminal and the user terminals and the spectral efficiency of the network remains constant as the number of users increases. In other words, as more users are added to the network, the per-user capacity decreases.

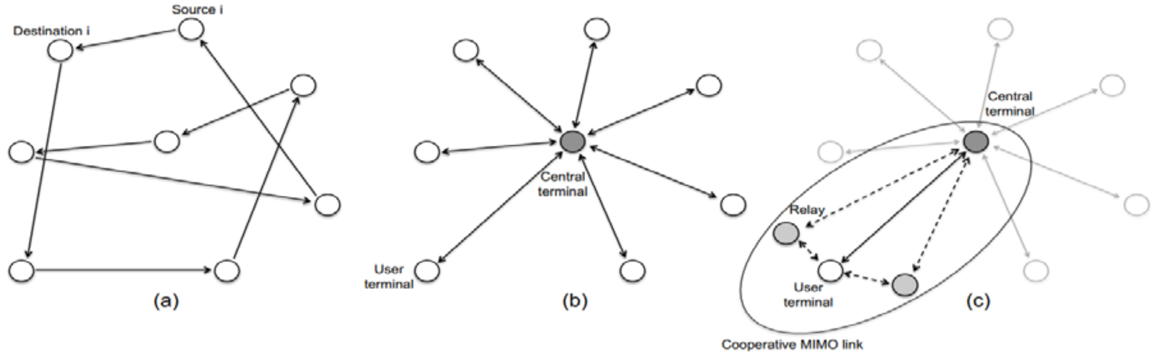

Figure 1.1 Models for (a) ad-hoc network configuration with n source-destination node pairs,(b) star network configuration with one central terminal (shaded) and n user terminals, and (c) cooperative link as a part of star network configuration.

Recognizing the benefits of cooperation, standards committees have started including different forms of cooperation in LTE and WLAN standards. For example, the latest release of LTE standard includes support for cooperation between base stations called Cooperative Multi Point (CoMP). There is a lot of research effort in showing that the CoMP can be efficiently implemented in the future versions of the LTE system. Another example is the introduction of relays in LTE standard to improve the coverage in existing LTE cells. While these steps point to the right direction, the benefits in terms of capacity scaling are far from promised by cooperation schemes from.

In addition to the cooperation between wireless terminals, another key idea that enables linear increase in spectral efficiency with the number of nodes in is using Multiple-Input Multiple-Output (MIMO) transmissions between the clusters of cooperating nodes. MIMO is a widely recognized technique to improve spectral efficiency of point-to-point communication links, by sending independent data streams across transmit antennas. Point-to-point MIMO has been an integral part of many modern wireless standards, including LTE, LTE-Advanced, HSPA+, 802.11n and WiMAX.

While using point-to-point MIMO enables drastic spectral efficiency increase, it has limitations that have quickly been reached in most of the standards that use this technique. To achieve desired spectral efficiency scaling, the channels between transmit and receive antennas need to be statistically independent. This requirement is satisfied by having enough separation between antennas at each of the terminals. For example, for 2.4 GHz ISM band the minimum distance between antennas is at least 6 cm and increases for lower carrier frequencies used in cellular. Keeping in mind the size of today’s cellular and WiFi devices, it means that most of them can have 1, 4 antennas, which has already been implemented in modern devices. This means that using point-to-point MIMO has already reached its limits.

II. CHANNEL CODING

LDPC codes a start with an overview of the communication model formalized by Shannon and his famous channel capacity formula. Following that, representation methods of LDPC codes are presented alongside two classifications. Then summarize the design approaches to LDPC codes among which some well known construction algorithms are detailed. Effective tools used for asymptotic analysis are also included. Different versions of the BP algorithm are described for decoding LDPC codes with variable complexity and performance.

Shannon’s classical problem: how efficiently to transmit a message across a noisy channel such that the receiver can determine the message with high accuracy in spite of an imperfect channel. Aim to devise reliable channel coding schemes that offer capacity-approaching performance while introducing low delay or latency at the same time.

Shannon formalized a basic point-to-point communication model along with separate source coding and channel coding theorems, as shown in Fig. 2.1. The information source is generally regarded as a stream of bits, and the sink represents any user of the information. The function of the pair source encoder/decoder refers to removing redundancy from the source and recovering the original information at the sink, i.e. a process called data compression and restoration.

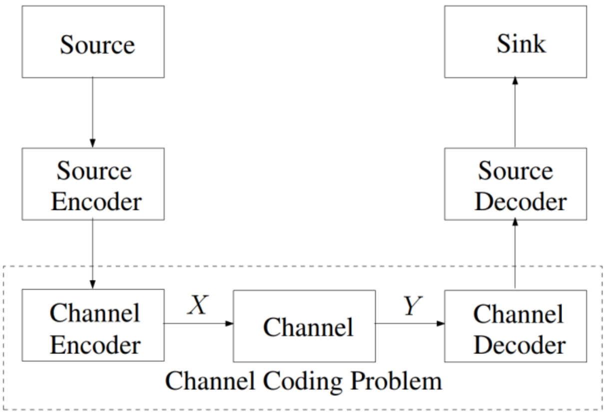

Figure 2.1: Shannon’s point-to-point communication model with source-channel separation.

Correspondingly, as a physical medium of transmission, the channel is modelled as a probabilistic mapping “function”. Throughout the work only consider the channel coding problem where the channel encoder is employed to protect the information bits from an impairing channel by adding redundant sequences, and the decoder has the task of recovering the original bits, given the received data, despite the existence of noise, different types of signal distortion and interference.

The ratio of the number of information bits K to the total number of transmitted bits N is defined as the code rate.

$$R = \frac{K}{N}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

where $0 < R < 1$. Even though one can resort to a physical solution, e.g., using higher power signals, to improve communication reliability, it is more desirable to implement reliable transmission by a system solution, i.e., channel coding. Channel coding theory is concerned with strategies to create practical encoding and decoding systems.

Low-density parity-check codes were invented by Gallager However, due to the computational effort in implementation, the codes had been neglected until they were recovered by Mackay and Neal LDPC codes are block codes with parity-check matrices which contain only a small proportion of non-zero entries.

III. LITERATURE REVIEW

SR. NO.	TITLE	AUTHORS	YEAR	APPROACH
1	Spatially-coupled LDPC coding in cooperative wireless networks,	D. N. K. Jayakody, V. Skachek and B. Chen,	2016	A new technique of spatially-coupled low-density parity-check (SC-LDPC) code-based soft information relaying scheme
2	LDPC Coded Angular Modulation Scheme for Cooperative Wireless Networks,	D. N. K. Jayakody,	2016	A new methodology for soft information forwarding (SIF) based on a novel technique known as soft angular modulation (SAM).
3	Relay Selection Based on Bayesian Decision Theory in Cooperative Wireless Networks	L. Ferdouse and A. Anpalagan,	2015	Addresses the selection problem of the relay node and proposes posterior probability-based relay node selection methods
4	Effects of imperfect channel estimation in three-node cooperative wireless network,	J. M. Choi and J. S. Seo,	2015	Analyze the effect of the imperfect channel estimation on the equalization performance in three-node cooperative wireless network
5	Deployment strategy analysis for underwater cooperative wireless sensor networks	Z. Iqbal and H. N. Lee,	2015	Proposed scheme is cooperative spatial-domain coding combined with the LDPC-coded OFDM system
6	An LDPC Coded Adaptive Decode-and-Forward Scheme Based on the EESM Mode	X. Chen and M. X. Xie	2014	Introduces the adaptive DF scheme based on the minus exponential effective-SNR mapping (EESM) model
7	A Multi-base Station Cooperative Algorithm for LDPC-OFDM System in the HF Channel	X. B. Li, S. Zhang, F. H. Zhao and H. W. Zhang,	2014	A multi-base station cooperative algorithm is designed for high frequency (HF) channel, and a LDPC cooperative decoding algorithm is proposed,
8	LDPC coding with soft information relaying in cooperative wireless networks,	D. N. K. Jayakody and M. F. Flanagan,	2013	Investigates soft information relaying (SIR) for low-density parity-check (LDPC) coded transmission in wireless networks.

D. N. K. Jayakody, V. Skachek and B. Chen, [1] This research exploration proposes a new technique of spatially-coupled low-density parity-check (SC-LDPC) code-based soft information relaying scheme for a two-way relay system. Introduce optimized SC-LDPC codes in relay channels. A more precise model is proposed to characterize the soft noise on the soft symbols, using a pre-calculated look-up table at the destination. This requires less signalling overhead compared to existing soft noise modelling techniques. Also introduce a variance correction factor to provide a rectification to the equivalent total noise variance at the destination. Finally, modify the LLR former at the destination which is tailored to the proposed soft information relaying technique. Simulation results demonstrate that the proposed relay protocol yields an improved BER performance compared to competitive schemes proposed in the literature.

D. N. K. Jayakody, [2] This work investigates a new methodology for soft information forwarding (SIF) based on a novel technique known as soft angular modulation (SAM). In this new relay scheme, the soft symbols are embedded into phases at the relay. This is more advantageous as refrain to forward real values (under bandwidth constraints) via wireless channels. This makes the proposed scheme practically feasible. The proposed system provides a means of using distributed low-density parity- check (LDPC) coding in conjunction with a new soft encoding scheme (puncturing), which is useful even under indigent source-relay link conditions. This also precludes the amplitudes of generated symbols descent to zero, as happens with most of the existing soft forwarding methods. Ordinarily, such schemes suffer from error propagation to the destination when the signal-to-noise ratio (SNR) of the source-relay link is low; however, our system avoids this problem by regenerating soft versions of the source symbols at the relay. Furthermore, also propose a computationally efficient formula for log-likelihood ratio (LLR) at the destination. Simulation results demonstrate that the proposed scheme can maintain very good performance under poor source relay SNR conditions.

L. Ferdouse and A. Anpalagan [3] Wireless networks use relay nodes as cooperative nodes to gain maximum diversity. Relay selection is one of the key challenging problems in multiuser wireless cooperative networks. This exploration addresses the selection problem of the relay node and proposes posterior probability-based relay node selection methods. In these methods, all calculations are derived by either source or destination, consider both amplify-forward and decode-forward methods, and apply Bayesian decision theory to select the relay node. In the source-based method, each source node considers all the relay nodes' channel information to estimate posterior probability using Bayes theorem, whereas in the destination-based method, the destination node considers all source node channel information to calculate posterior probability. Numerical results show that our proposed relay assignment methods maximize the overall data rate of the networks and work well independently of the number of relay nodes or source-destination pairs in the network.

J. M. Choi and J. S. Seo,[4] In this work, analyze the effect of the imperfect channel estimation on the equalization performance in three-node cooperative wireless networks. Specifically, consider a distributed time-reversal space-time block coded single-carrier (D-TR-STBC-SC) system over frequency-selective fading channels with amplify-and-forward (AF) half-duplex relaying. Through the comprehensive analysis of mean-square-error (MSE), it is shown that, unlike the point-to-point communications, the imperfection of the channel knowledge leads to the unstable performance of channel equalization under the condition of high quality reception from relay-to-destination link. The analytical results show the main reason for such phenomenon. The validity of the theoretical analysis is demonstrated through the computer simulations.

Z. Iqbal and H. N. Lee, [5] Wireless sensor networks (WSNs) are widely used for underwater environment monitoring. Because of the harsh underwater environment, WSNs face the challenges of erroneous communication, lower lifetime, less robustness, and cost constraints. In this work, propose a cooperative WSN which uses a cooperative coded OFDM (COFDM) system and network coding to deal with the shadowing phenomenon present in the underwater communication channel. The proposed scheme is cooperative spatial-domain coding combined with the LDPC-coded OFDM system. The designed system is analyzed using random and grid deployment strategies for the required number of sensors, bit-error rate (BER), and cost of the network.

X. Chen and M. X. Xie, [6] User Cooperation is a promising technology to obtain diversity gain at terminals. According to the traditional decode-and-forward scheme, relay node help to transmit source node's information with fixed number of modulation symbols all the time. It is not optimal in view of spectral efficiency, especially when the channel state is good. This investigation introduces the adaptive DF scheme based on the minus exponential effective-SNR mapping (EESM) model. The optimal number to relay is predicted accurately. Furthermore, adaptive modulation is supported. The reliability requirement is satisfied, and the radio resource is saved for transmitting new information. Theoretical analysis and simulation results indicate that the adaptive DF scheme improves the spectral efficiency significantly.

X. B. Li, S. Zhang, F. H. Zhao and H. W. Zhang, [7] Based on LDPC-OFDM system, a multi-base station cooperative algorithm is designed for high frequency (HF) channel, and a LDPC cooperative decoding algorithm is proposed, which adopts information combining strategy based on the probability measure. The center station in the system model uses the multiple signals received from the relay stations to update its received initialization information. This strategy can combine the cooperative communication strategy with LDPC iterative decoding effectively in order to achieve both diversity gain and encoding gain. Simulation results show that the cooperative strategy with the multi-relay stations has better performance in the bit error rate than direct transmission strategy. The decoding performance of DF strategy with a relay station with respect to that of AF strategy has a gain of about 0.7dB at BER = 10^{-3}.

D. N. K. Jayakody and M. F. Flanagan,[8] This research investigates soft information relaying (SIR) for low-density parity-check (LDPC) coded transmission in wireless networks. Introduce a new scheme for soft parity symbol generation at the relay, which features two key strategies: a two-step soft parity generation process, and a prescaling technique. The two-step soft parity generation procedure is designed to allow efficient relay processing, while yielding an overall (i.e., destination) parity-check matrix structure with desirable properties. The pre-scaling method prevents the amplitudes of generated soft symbols successively converging to zero, as happens with some existing soft forwarding methods. Finally, propose an appropriate LLR former at the destination which is tailored to the proposed soft parity generation technique. Simulation results demonstrate that the proposed relay protocol yields an improved BER performance compared to competitive schemes proposed in the literature.

IV. PROBLEM STATEMENT

The effects of fading can be combated by using diversity in time, frequency or space, by transmitting the signal over multiple channels that experience independent fading. Utilizing spatial diversity by employing multiple-antenna systems is a well-known technique. However, for practical reasons, multiple antennas are not always applicable for a variety of mobile devices. An alternative concept is given by cooperative communication where several nodes in a wireless network can achieve spatial diversity by relaying messages from each other.

Cooperative transmission is considered to be a useful technique for increasing the diversity, the robustness, and the efficiency of the communication system. The improved robustness due to the additional diversity can be alternatively traded off in order to increase the data rate, save transmission power, or extend the coverage range of the network. For the bilayer lengthened LDPC convolutional codes, the rate-compatible LDPC convolutional codes and the generalized multi-edge-type LDPC convolutional codes, when analyzing the performance of these codes, there is a hidden assumption in the proofs that the variable nodes of different type have the same received distribution.

V. CONCLUSION

In this work a survey of literature on cooperative communication and LDPC coding has been proposed. One of the most important contributions to the evolution of wireless networks in recent years has been the advent of MIMO technologies, which create the transmission diversity by using multiple, receive and transmit antennas. While solving the capacity problem for general relay networks and finding advanced and implementable schemes that can reach the maximum theoretical capacity of relay networks is complicated and may require a long-term research, researchers are also focusing on how to optimize the performance of current cooperative communication schemes under the constraints of available resources such as transmission power, bandwidth, data rate, etc. Wireless relaying is identified as a promising technique to offer spatial diversity and to extend the coverage of wireless networks. In a wireless relay network, the relay acts as the 'intermediary' for data exchange among different users. LDPC convolutional codes, also known as spatially coupled LDPC codes, have attracted considerable attention in the last decade due to their promising performance in channel coding.

REFERENCES

[1] D. N. K. Jayakody, V. Skachek and B. Chen, "Spatially-coupled LDPC coding in cooperative wireless networks," 2016 IEEE Wireless Communications and Networking Conference, Doha, 2016,

[2] D. N. K. Jayakody, "LDPC Coded Angular Modulation Scheme for Cooperative Wireless Networks," 2016 IEEE 84th Vehicular Technology Conference (VTC-Fall), Montreal, QC, 2016, pp. 1-5.

[3] L. Ferdouse and A. Anpalagan, "Relay Selection Based on Bayesian Decision Theory in Cooperative Wireless Networks," in Canadian Journal of Electrical and Computer Engineering, vol. 38, no. 2, pp. 116-124, Spring 2015.

[4] J. M. Choi and J. S. Seo, "Effects of imperfect channel estimation in three-node cooperative wireless network," 2015 IEEE 26th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), Hong Kong, 2015, pp. 228-233.

[5] Z. Iqbal and H. N. Lee, "Deployment strategy analysis for underwater cooperative wireless sensor networks," 2015 International Conference on Information and Communication Technology Convergence (ICTC), Jeju, 2015, pp. 699-703.

[6] X. Chen and M. X. Xie, "An LDPC Coded Adaptive Decode-and-Forward Scheme Based on the EESM Model," 2014 International Conference on Wireless Communication and Sensor Network, Wuhan, 2014, pp. 148-152.

[7] X. B. Li, S. Zhang, F. H. Zhao and H. W. Zhang, "A Multi-base Station Cooperative Algorithm for LDPC-OFDM System in the HF Channel," 2014 International Conference on Wireless Communication and Sensor Network, Wuhan, 2014, pp. 21-27.

[8] D. N. K. Jayakody and M. F. Flanagan, "LDPC coding with soft information relaying in cooperative wireless networks," 2013 IEEE Wireless Communications and Networking Conference (WCNC), Shanghai, 2013, pp. 4317-4322.

[9] J. Laneman, D. Tse, G. Wornell, "Cooperative diversity in wireless networks: efficient protocols and outage behavior," IEEE Trans. Inf. Theory, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

[10] G. Kramer, M. Gastpar, and P. Gupta, "Cooperative strategies and capacity theorems for relay networks," IEEE Trans. Inf. Theory, vol. 51, pp. 3037–3063, Sept. 2005.

[11] J. Laneman, D. Tse, G. Wornell, "Cooperative diversity in wireless networks: efficient protocols and outage behavior," IEEE Trans. Inf. Theory, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

[12] G. Kramer, M. Gastpar, and P. Gupta, "Cooperative strategies and capacity theorems for relay networks," IEEE Trans. Inf. Theory, vol. 51, pp. 3037–3063, Sept. 2005.

[13] Z. Si, R. Thobaben, and M. Skoglund, "Bilayer LDPC convolutional codes for half-duplex relay channels," in Proc. IEEE Int. Symp. Inf. Theory, Aug. 2011, pp. 1464–1468.

[14] J. L. Fan, "Array codes as low-density parity-check codes," in Proc. 2nd Int. Symp. Turbo Codes, Brest, France, Sep. 2000, pp. 543–546.