A Comparative Study on Techniques for Coded Receiver in Cooperative Wireless Networks

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Abstract- In a typical digital communication system, several steps are involved in processing of the information both at the transmitting and the receiving ends. This work presents a brief overview of a complete digital communication network system and its sub-units. It mainly focuses on channel coding technique and its importance for reliable communication of data. An extensive survey of literature has presented in this work. Among the communication theory community, this problem is typically referred to as cooperative relaying. Cooperative relaying is studied from two perspectives, depending on how the relays are used: cooperative diversity and cooperative multiplexing. Cooperative diversity improves the reliability of transmission and historically has drawn more attention among the research community. The main motivation for this work is to merge ideas of cooperation and MIMO) with the network architecture of today's wireless system.

Keywords- Soft Demapping, Wireless Networks, Cooperative Networks, Fuzzy Logic, LDPC.

I. INTRODUCTION

Transmitting different samples of the same signal over essentially independent channels is a method by which transmit diversity could be implemented in wireless communications to solve the problems of fading due to multipath propagation [1]. In particular, spatial diversity is generated by transmitting signals from different locations, thus allowing independently faded versions of the signal at the receiver. For some scenarios, in which time or frequency diversity might be difficult to exploit due to delay or bandwidth constraints, multiple transmit or receive antennas at the same terminal are often desirable for providing spatial diversity.

Cooperative Diversity seeks to overcome these limitations by creating a virtual multiple- input multiple-output (MIMO) system where single-antenna terminals, 'e.g.' most handsets and nodes in wireless sensor networks, in a multi-terminal scenario can share their antennas.

Figure 1.1 gives a preliminary explanation of the ideas behind cooperative communication. It shows two mobile users communicating with the same destination. Each mobile has one antenna and cannot individually generate spatial diversity. However, it may be possible for one mobile to receive the others transmitting signal, in which case it can forward some version of "overheard" information of other users along with its own data. Because the transmission paths from two mobiles are statistically independent, this generates spatial diversity.

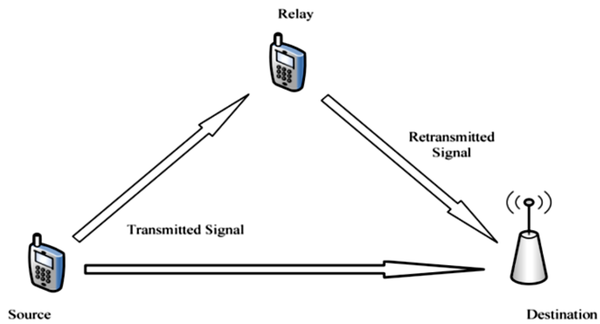

Figure 1.1 Cooperative Communications.

In such a system as the one seen in Figure 1.1, combinations of several relaying protocols and different combining methods are examined to assess their effects on performance. In this work the Amplify and Forward and Decode and Forward transmission protocols when used with several types of combining techniques has been examined. The best combination techniques in each protocol are then studied with different relay positions to investigate their effects on performance.

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 a star network architecture, presented on Figure 1.2 b, 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 user's increases. In other words, as we add more users to the network, the per-user capacity decreases.

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).

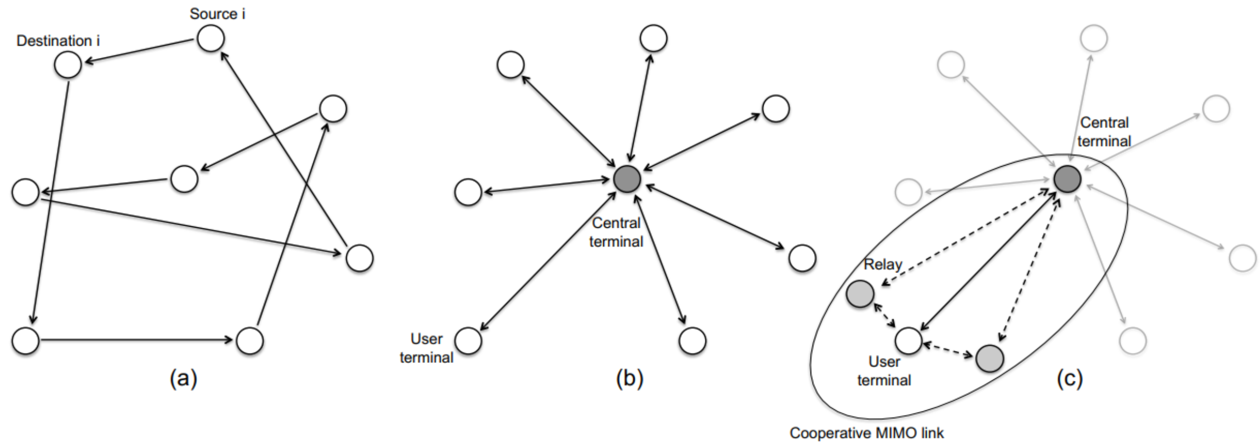

Figure 1.2 Models for (a) ad-hoc network configuration with n source-destination node pairs, (b) star network configuration with one central terminal (shaded) and n user terminals, and (c) cooperative link as a part of star network configuration.

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.

II. LOW-DENSITY PARITY-CHECK CODES

LDPC codes belong to a class of block codes, where the encoding is performed in blocks of data. As their name suggests, its parity-check matrix (H) consists of very small number of non-zero elements. The sparseness of H determines the decoding complexity and the minimum distance of the code. Apart from the requirement that the LDPC matrix be sparse, there is no other difference between the LDPC code and any other block code. In fact, existing block codes can be used with the LDPC decoding algorithms if they can be represented by a sparse parity-check matrix [13]. However, finding a sparse H matrix from existing code is difficult or even impractical in certain cases. Hence, LDPC codes are designed by constructing a sparse H matrix first and then determining the Generator matrix (G) for the code.

For an n-bit code word, the total number of possible combinations of binary vectors is 2n. This n-bit code word consists of k message bits and (n-k) redundant bits. The parity-check matrix H is normally represented in the form shown in Eq. 2.1, where, k×n represents the size of the matrix, having k rows and n columns.

By performing Gauss-Jordan elimination on H, a generator matrix can be obtained in the form shown in Eq. 2.2. Since the row space of G is orthogonal to H, the G and H matrix can be represented by Eq. 2.3.

$$H = [A, I_{n-k}]_{k\times n} \quad \ldots (2.1)$$

$$G = [I_k, A^T]_{k\times n} \quad \ldots (2.2)$$

$$GH^T = 0 \quad \ldots (2.3)$$

where, A is an (n-k)×k binary matrix and I_{n-k} is the identity matrix of order n-k.

The encoding operation in the encoder and the parity-check operation in the decoder are shown in Eq. 2.4 and Eq. 2.5 respectively.

$$C_n = M_k \times G \quad \ldots (2.4)$$

$$C_n^r \times H^T = P_k \quad \ldots (2.5)$$

where, C is the code word, M is the message bits, C^T is the received codeword at the decoder and P is the parity-check bits. P is zero if the parity-check is satisfied.

The LDPC matrix is described by various parameters. The code rate is defined by the ratio of message bits k to code word bits n. The number of non-zero entries in each of the rows and columns of H matrix is collectively known as degree distribution. An H matrix is said to be regular if the degree distribution of rows and columns are uniform, otherwise it is irregular. The H matrix can be represented in graph called Tanner graph. A cycle in the graph is a sequence of connected nodes, which start and end at the same node.

Since LDPC codes are decoded using iterative algorithms, construction of a sparse LDPC matrix is critically important for the overall performance of the decoder. The structure of the LDPC matrix has a direct impact on the BER performance and hardware implementation complexity. Various code construction techniques have been proposed to achieve good error correction performance and low error floor performance1 of the decoder. LDPC matrix construction methods can be either Structured or Unstructured.

III. LITERATURE REVIEW

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	A soft demapping technique using fuzzy logic for LDPC receiver in cooperative wireless networks	S. S. Asari and S. Nandan,	2017	A Soft Information Relaying scheme based on a soft Decode and Forward (SDF) relay protocol is considered
2	Adaptive fuzzy inference system for detection and prevention of cooperative black hole attack in MANETs,	P. S. Hiremath, Anuradha T and P. Pattan,	2016	A novel method that detects and prevents the supportive black hole attack on MANETs is developed. The proposed method is based on adaptive fuzzy inference system
3	Performance analysis and soft demapping for coded MIMO-OFDM systems,	M. Abdullahi and P. Xiao,	2016	Reported a soft output demapper based on MMSE equalizer output to demap the information needed for viterbi decoding
4	A cluster based cooperative technique for Spectrum Sensing using Rely Factor	T. Rasheed, A. Rashdi and A. N. Akhtar,	2015	A Rely Factor (R-F) based scheme is proposed with Cluster based Cooperative Spectrum Sensing (CCSS) to reduce the bandwidth limitations in CRN using energy detection
5	A Fuzzy Multi-Metric QoS-Balancing Gateway Selection Algorithm in a Clustered VANET to LTE Advanced Hybrid Cellular Network	G. e. m. Zhioua, N. Tabbane, H. Labiod and S. Tabbane,	2015	Reported a cooperative traffic transmission algorithm in a joint vehicular ad hoc network-Long Term Evolution Advanced (LTE Advanced)
6	A low complexity soft demapping method for expanded M-QAM constellations	S. Kinjo	2014	Reported a low complexity soft demapping method for expanded M-QAM constellations for the THP systems
7	A Beacon Rate Control Scheme Based on Fuzzy Logic for Vehicular Ad-Hoc Networks,	N. Wang, G. Lei, X. Wang, P. Wang and F. Liu	2014	Reported an efficient beacon rate control scheme based on fuzzy logic in this work

S. S. Asari and S. Nandan,[1] Relays in wireless networks are used to achieve cooperative diversity. Various relaying schemes such as Amplify and Forward (AF), Decode and Forward (DF), etc. exists. But in this exploration, a Soft Information Relaying scheme based on a soft Decode and Forward (SDF) relay protocol is considered. In order to be efficient under poor source relay link conditions, low density parity check (LDPC) coding scheme and higher order modulation scheme called Quadrature Amplitude Modulation (QAM) are used. In the existing method, log likelihood ratio (LLR) values (soft values) are computed at the destination for LDPC decoding. Since it is a complex and probabilistic based approach, the chances of occurring errors will be more. Because of this reason, a soft computing method called fuzzy logic system is proposed. The Fuzzy logic provides more information about the transmitted data, so that perfect data can be decoded and reconstructed at the destination without error. So that the proposed system provides better performance in terms of low bit error rate (BER).

P. S. Hiremath, Anuradha T and P. Pattan,[2] A MANET (mobile adhoc network) is a group of computing nodes or cell or other devices used for communication which are capable of communication among each other with no support of an infrastructure that is fixed. MANET in fact is self sufficient group of cellular consumers which talk to each other with the help of cellular nodes, described by certain wireless links. In these applications, in order to offer quality services for MANETs, many routing protocols have been designed. In this exploration work, a novel method that detects and prevents the supportive black hole attack on MANETs is developed. The proposed method is based on adaptive fuzzy inference system for MANET in order to detect and prevent the cooperative black hole attack. The popular protocol utilized in MANET is on-demand distance vector (AODV) protocol, and is simulated using NS2. The simulated results of the proposed method are compared with that of an adaptive method [17], wherein source node checks all nodes activity by using DAT table that maintains from-node-to-next-node's information and declares black hole node by channel overhearing method. It is observed that the proposed method based on adaptive fuzzy logic system shows better performance as compared to adaptive method in terms of throughput, end-to-end delay and packet delivery ratio.

M. Abdullahi and P. Xiao,[3] Multiple input multiple output-Orthogonal frequency division multiplexing (MIMO-OFDM) is a viable solution for providing high data rate services in harsh channel environments. The optimum receivers for them are those based on the maximum likelihood criterion. However, they have a prohibitive complexity especially when channel dimensions are high and coding is employed. Zero Forcing (ZF) and Linear Minimum Mean Square Error (MMSE) receivers on the other hand provide practicable and low complexity solutions for detection, but require soft demappers to deduce the soft bits information contained in each of the received symbols. In this work, we present the ZF and MMSE receiver analysis of a bit interleaved and coded MIMO-OFDM system and propose a soft output demapper based on MMSE equalizer output to demap the information needed for viterbi decoding. A comparison of the proposed soft demapper with conventional soft demappers in literature show a significant performance improvement. We also noticed that it is more advantageous to apply the proposed demapper on a MIMO-OFDM system employing higher modulation schemes.

T. Rasheed, A. Rashdi and A. N. Akhtar,[4] Recently, a low cost and reliable remote sensing infrastructure has emerged as one of the fundamental requirements for communication in sensor nodes of Cognitive Radio (CR) applications. To achieve this, an Energy Efficient Wireless Sensor Network (EEWSN) has significant importance for monitoring the entire CR Network (CRN). The foremost important aspect in CRN is the spectrum sensing for which different techniques have been proposed. In this investigation, a Rely Factor (R-F) based scheme is proposed with Cluster based Cooperative Spectrum Sensing (CCSS) to reduce the bandwidth limitations in CRN using energy detection, which is the least complex spectrum sensing technique. The R-F based scheme is worked out on Signal to Noise Ratio (SNR), local sensing difference and threshold of energy detector of each sensor node. All these factors are combined using Fuzzy Logic to enhance the detection performance of sensor nodes. The results are shown in the form of Receiver Operating Curves (ROC) by simulations.

G. e. m. Zhioua, N. Tabbane, H. Labiod and S. Tabbane,[5] Intelligent transportation systems are currently attracting the attention of the research community and the automotive industry, which both aim to provide not only more safety in the transportation systems but other high-quality services and applications for their customers as well. In this exploration propose a cooperative traffic transmission algorithm in a joint vehicular ad hoc network-Long Term Evolution Advanced (LTE Advanced) hybrid network architecture that elects a gateway to connect the source vehicle to the LTE Advanced infrastructure under the scope of vehicle-to-infrastructure (V2I) communications. The originality of the proposed fuzzy quality-of-service (QoS)-balancing gateway selection (FQGwS) algorithm is the consideration of QoS traffic class constraints for electing the gateway. Our algorithm is a multicriteria and QoS-based scheme optimized by performing the fuzzy logic to make the decision on the appropriate gateway. Criteria are related to the received signal strength (RSS) and load of the cluster head (CH) and gateway candidates (GwCs), as well as the vehicle-to-vehicle link connectivity duration (LCD). Simulation results demonstrate that our algorithm gets better results than the deterministic scheme for gateway selection. Moreover, results show the efficiency of the FQGwS algorithm as it adapts its gateway selection decision to the cluster density and the relative velocity of the source node.

S. Kinjo, [6] Wireless communication systems based on the Tomlinson-Harashima precoding (THP) suffer from modulo operation error in noisy environments. The error leads to a fatal performance degradation when soft-input forward error correction is used because the conventional soft demapper provides erroneous log-likelihood ratio (LLR). In this investigation reported a low complexity soft demapping method for expanded M-QAM constellations for the THP systems. We apply the conventional fast demapping procedure to the expanded M-QAM constellations, and show that the computational complexity of the developed demapper is successfully reduced. Computer simulations are given to show the effectiveness of the proposed demapper.

N. Wang, G. Lei, X. Wang, P. Wang and F. Liu, [7] According to IEEE 802.11p protocol, vehicles should periodically broadcast and exchange beacon messages to ensure the cooperative awareness of each other. However, high beacon generation rate may consume a large amount of channel bandwidth and thus lead to severe deterioration of network performance. To solve this problem, we propose an efficient beacon rate control scheme based on fuzzy logic in this exploration. Fuzzy logic is proved to be available to handle with imprecise and uncertain information in control problems. Our scheme uses channel busy ratio (CBR), local density and mobility factor as fuzzy factors to obtain the fuzzy result in order to control the beacon rate of vehicles. The scheme is evaluated in our simulation platform, comprised of VISSIM traffic simulator for realistic traffic simulation and NS-3 network simulator for inter-vehicle communications. Simulation results clearly demonstrate the performance of our proposed scheme.

IV. PROBLEM FORMULATION

The aim of the digital communication system is to transmit the message efficiently over the communication channel by incorporating various data compression (e.g. DCT, JPEG, MPEG)[3], encoding and modulation techniques, in order to reproduce the message in the receiver with least errors. The information input which is generally in the analogue form is digitized into a binary sequence which is also known as an information sequence. The source encoder is responsible for compressing the information sequence to represent it with less redundancy. The compressed data is passed to the channel encoder. The channel encoder introduces some redundancy in the binary information sequence that can be used by the channel decoder at the receiver to overcome the effects of noise and interference encountered by the signal while in transit through the communication channel. The communication channel is the physical medium used to transmit signal from the transmitter to the receiver. A range of noise and interference can affect the information signal during transmission depending on the kind of channel medium,e.g. thermal noise, atmospheric noise, man-made noise and the medium could be air, wire or optical cable. The reconstructed information message at the receiver is probably an approximation of the original message because of channel decoding errors and distortion introduced by the source encoder and decoder.

V. CONCLUSION

This work presents an extensive survey of literature on a soft demapping technique using fuzzy logic for LDPC receiver in cooperative wireless. This work addresses various issues and challenges associated with designing hardware efficient high performance LDPC decoders. Some of the innovative techniques for reducing the complexity of decoding algorithms and methodology for constructing a flexible LDPC matrix for partially-parallel decoders are presented. A wireless network system can traditionally be viewed as a set of nodes trying to communicate with each other. However, from another point of view, because of the broadcast nature of wireless channels, one may think of those nodes as a set of antennas distributed in the wireless system. Transmission between these antennas suffers from much degradation which inspires considerable research on how to effectively combat these negative effects that impair signal transmission. The BER estimator should be immune to the transmitter/receiver scheme, channel condition, interference model and other information about the entire communication system, although these elements impacts the system performance and the reliability of the BER estimate.

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