Performance Analysis of Non-Binary Joint Network Channel Coding Scheme for Multiple Access Relay Channels

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Abstract—We propose to use Non-Binary Joint Network Channel Coding scheme (NB-JNCC) for multiple access relay channel with relay selection scheme. In Non-Binary Joint Network Channel Coding (NB-JNCC) the effect of fading in wireless channels are successfully battled because of joining both the channel coding and network coding. Here we use low density parity check (LDPC) channel coding and random linear network coding with iterative joint decoding. Such joining of channel coding and network coding can be used to take advantage of both the spatial diversity and redundancy resides in channel codes and network codes. This paper also investigate the relay selection (RS) problem in the system with two source and two relay network, the relays used here is based on Decode-Forward (DF) relay protocol. Our RS scheme is to maximizes the minimum end-to-end receive signal-to-noise (SNR) of all the users involved in the system. Even through a single relay transmits with increased number of cooperating relays the reimbursement of cooperative diversity are increased. In the course of analysis and simulation, here we are going to shown the significant performance improvement in NB-JNCC that is reduced error rate and increased throughput with relay selection than without relay selection.

Index Terms-- Channel coding. Network coding, Multiple access relay channels, Relay selection scheme.

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1 INTRODUCTION

In wireless networks we have high and time varying packet losses due to the effect of fading. One way to provide communication without effect of fading is to introduce channel coding and network coding in the system operation. Channel coding (redundant symbols/ bits at the physical layer) is to add redundant information into inside the packet to recover errors in the original information. Network coding (redundant packets at the network layer) is to add redundant information across multiple packets. The channel coding can be called as *error correction* and the latter network coding can be called as *erasure correction*. Specially, channel coding is a conventional error correction technique it can be used for point-to-point communication over a single channel network. number of redundant bits/symbols.

1* Channel coding being implemented at the physical layer for recovering erroneous bits/symbols during redundant parity check bits/symbols appended to a packet. The error recovery capability based on two constraints it is specific coding strategy and the number of redundant bits/symbols. Conversely, erasure correction is always used as end-to-end communication. It can be operated on the packet level, and can be used at either link layer, network layer, or application layer. The traditional network coding allows the intermediate nodes along multiple interleaved paths to generate redundant network-coded packets without decoding all original packets in a distributed manner [1], [2], while the redundancy on network layer can also be used for error correction.

1.1 Diversity Through Network Coding

Here we are going to discuss how to gain cooperative diversity through network coding in wireless networks in order to combat the effect of channel fading. In [3] it was discussed how to gain cooperative diversity through network coding. In Fig. 1(a) the cooperative diversity concept is used without considering network coding. A simple model in which the cooperative diversity can be gained with network coding is the multiple access relay channel (MARC) in Fig. 1(b). The MARC is the cooperative uplink of two mobile station to the base station.

Fig.1 The uplink from two mobile station to the base station with the help of two relay channel (RC) (a).on the multiple-access relay channel (MARC) (b).

If the uplink for MS 1 and MS 2 is done separately on two relay channels and we want to gain diversity, relay R 1 has to support the uplink of MS 1 by sending one transmission and relay R 2 has to support the uplink of MS2 by sending one transmission. If the uplink for MS 1 and MS 2 is done cooperatively with the help of network coding used in the relay, we use only one transmission of the relay with achieving same diversity gain for both mobile stations.If we fix the allowed number of transmissions from the relay to one, it is possible to gain the full diversity because of the help of network coding. By increasing the number of transmitters we are increase the diversity gain.

1.2 Main contributions and Organization of the Paper

Here we explain how to use joint network channel coding scheme based on LDPC codes for multiple access relay channel. We are selecting the best relay to improve the error performance and good put of a network. Section II. We proposed some preliminaries for our proposed scheme. Section III. We are going to present NBJNCC over multiple access relay channels. Section IV. We present detail about relay selection of this network. We show that NB-JNCC achieves significant performance gains compared to other schemes. Sec. V concludes this paper and discusses future work.

2 NON BINARY JOINT NETWORK CHANNEL CODING

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In this section first we present the channel coding of that corresponding network and to present the network coding of our proposed system.

2.1 Channel Coding

In NB-JNCC, we choose non-binary irregular low-density parity-check (LDPC) codes from [6] as the channel coding scheme. The reason for adopting this scheme is three-fold: 1) the LDPC codes can be graphically represented using factor graphs; 2) the adopted codes can approach the Shannon limit of various channels and can be encoded in linear time and in a parallel fashion; and 3) the channel coding/decoding on non-binary Galois field can be seamlessly combined with the network coding/decoding and underlying high order modulation.

Fig .2 Factor graph representation of the integrated code.

An LDPC code [7], [8] is a linear error correcting code specified by a parity-check matrix **H** and a generator matrix **G**, satisfying the relationship **GHT** = **0**. Given **H**, the corresponding generator matrix **G** can be obtained via Gaussian elimination. A source packet u of length *k* is encoded into a coded packet x through x=u**G**, where u and x are row vectors. A key property of LDPC codes is that the parity-check matrix **H** is of low density in terms of the number of non-zero entries. An LDPC code can be represented using a sparse bipartite graph called Tanner graph as shown later in Fig. Decoding of an LDPC code is done in an iterative manner via message passing along edges of its corresponding Tanner graph [9].

At the receiver side, the decoding process stops once the tentative copy satisfies ***HxT*= *0***.The column weight distribution and row weight distribution of the **H** matrix highly affect the code's performance and complexity. Degree-distribution optimized LDPC codes can approach Shannon limit in various channels. In this paper, we use the non binary LDPC codes from [5], [9], whose parity check matrices consist of columns of weight 2 and columns of weight t ($t \geq 3$).

2.2 Network Coding

In NB-JNCC, we choose non-binary random linear network coding as the network coding scheme for the following reasons. 1) Random linear network coding is efficient and sufficient for error recovery. 2) The non-binary operation on a high order Galois field can provide independent network codes with high probability. 3) The randomness of such network coding scheme renders itself applicable to large scale networks as it allows distributed operation on each node without interrupting others. In random linear network coding over a high order Galois field GF(2*q*), the source generates the original packets, groups them into generations and linearly combines packets in a generation using randomly generated coefficients. More specifically, let x1, . . . , xK denote the *K* packets in a generation.

The source linearly combines these *K* packets to compute K'(K'≥ K) outgoing packets, denoted as y1,y2, ……….,yK'. Where yi=Σkj=1 gij xj. The coefficient gij is picked randomly from GF(2*q*). The set of coefficients (gi1, . . . , *gik*) is referred as the *encoding vector* for yi and is carried in packets as overhead. A relay in the forwarding paths stores incoming packets from different routes in a local buffer for a certain period of time, then linearly combines the buffered packets belonging to the same generation. Suppose a relay, *r*, receives *M* incoming packets, x1r, . . . , xMr. Let (fi1, . . . ,fik) denote the encoding vector carried by xir, *i* = 1, . . .,*M*.

Sincetransmitting dependent packets is not useful for decodingat the sink, relay *r* encodes M' new packets, where M, is the rank of the coefficient matrix [fij], *i* = 1, . . .,*M*, *j* = 1, . . .,*K*, and hence M' ≤ min(*M*,*K*). Let y1r , . . . , yrM denote the outgoing packets, yir=**ΣMj=1** , where hijr is randomly selected from GF(2q). Let (gi1r , . . . , *g*ikr) denotethe encoding vector of yir , *i*= 1, . . . , M'. Then gijr=**ΣM j=1** hijr fij. The sink will receive multiple packets in the same generation. These packets are independent with high probability over high order Galois field, thus can be used to recover the original packets.

3 NBJNCC OVER MULTIPLE ACCESS RELAY CHANNELS

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In this section, we present the coding and decoding procedures of NB-JNCC in a simple two-source two-relay topology. This topology allows us to thoroughly explain how NB-JNCC works and obtain analytical results on its performance.

3.*1 Topology*

The two-source two-relay topology is shown in the Fig. Two sources, S1 and S2 , transmit two independent packets, x1 and x2, to a common sink, *T*. The transmissions of the sources are overheard by the relays (illustrated by the dashed lines). Upon overhearing , x1 and x2, the two relays, R1 and R2, forward redundant packets, y1 and y2 to the sink, respectively.In this way, the sink will see four packets, x1 from source S1, x2 from source S2 , y1 from relay R1, and y2 from relay R2. To focus on the joint decoding procedure at the sink, we assume the channels between the sources and the relays are lossless; our proposed scheme itself does not have such a constraint.

Fig .3. A simple topology with two sources, two relays, and one sink.

3.2 Code Construction

In traditional LDPC coding, the parity-check matrix **H** is designed first to guarantee the sparsity property, and the generator matrix **G** is derived accordingly. **H** should be agreed on by both the transmitter and the receiver or carried by the packet. As aforementioned, many studies [21], [13]–[14] used specific generator matrix at each relay to design joint network channel codes with good equivalent parity-check matrix **H** for good performance and full diversity, where most of them required specific network topology and scheduling. We choose a common pair of **H** and **G** from a well-designed LDPC code [6] for all nodes, while network coding coefficients are generated at each node randomly and carried by the packet. We assume that source *S*1 generates a packet u1 with *k* symbols (each of *q* bits) from Galois field GF(2q), then encodes it into x1 using the common generator matrix **G** of size *k* × *n* as,

$$x1=u1\mathbf{G} \qquad (1)$$

Where x1 and u1 are row vectors of length *n* and *k* respectively. Thus the channel code rate rc = k/n. Similarly, the packet generated at source S2 can be obtained as x2 = u2**G**. Assume packets x1 and x2 are broadcast respectively to the relays and the sink using orthogonal channels (at different time slots or via different frequencies). After receiving packets from the sources (recall that the channels between the sources and the relays are assumed to be lossless in this simple topology), the relays first decode and obtain the original packets, then generate packets using network coding and non-binary LDPC channel coding. The two network codes at relays R1 and R2 are represented as,

$$y1= \alpha 11u1\mathbf{G} + \alpha 12u2\mathbf{G} \qquad (2)$$

$$y2= \alpha 21u1\mathbf{G} + \alpha 22u2\mathbf{G} \qquad (3)$$

Where the network coding coefficients αij (*i, j* = 1, 2) are drawn randomly from GF(2q). Packets y1 and y2 be sent to the sink from R1 and R2 respectively. The sink receives four packets x1, x2, y1 and y2 forms a longer code**.**

[x1x2 y1y2]=[u1u2] [G0α11Gα21G 0Gα12Gα22G]] (4)

Here we assume that the network coding coefficients can be conveyed to the sink without error. The code in (5) can be viewed as an integrated channel code with packets and generator matrix as

(5)

Given the equivalent generator matrix **G′** , one can apply the Gaussian elimination algorithm (over an appropriate Galois field) to obtain the corresponding parity-check matrix **H′**, which satisfies **H′G′T= 0**. One option for decoding is to adopt some version of belief propagation operating on **H′.** Though, it is usually hard and sometimes infeasible to perform this kind of decoding because the integrated belief propagation decoding is too complicated owing to the fact that **H′** is not sparse in general. Thus, we propose a simple iterative joint decoding algorithm.

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3.3 Iterative Joint Decoding

We propose a two-tier iterative joint network -channel decoding scheme, which implements soft decoding and allows information exchange inside and across packets.

3.3.1 Factor-Graph Representation:
Here M represents the coefficients used in the network coding.

We rewrite (5) as

(6)

The proposed joint network-channel decoding relies on iterative message exchanges between two processing components, namely channel decoding and network decoding components. Specifically, as shown in Fig.5.The *extrinsic* information from the network decoding component, Lenc , and the channel information, Lch , are combined to generate the *a priori* information, Lacc, which is fed to the channel decoding; Alternatively the *extrinsic* information from the channel decoding component, Lecc and the channel information, Lch, are combined to generate the *a priori* information, Lanc, which is fed to the network decoding component.

3.3.2 Network Decoding Component

The right part of Fig.5.illustrates the network decoding for the *k*-th symbol, x1,k in packet x1 where for ease of exposition, xnc1,x represents x1,k in the network decoding component. We propose a *selection* updating rule for network decoding is described below. For the particular matrix **M** , suppose that any two rows of **M** are linearly independent (this assumption holds for NB-JNCC with high probability over a high order Galois field), then any row can be represented as a linear combination of any two other rows.

Fig.4.Message exchange illustration for the *k*-th symbol x1,k of packet x1 between channel decoding and network decoding in the proposed iterative joint decoding of NB-JNCC. Circles represent symbol nodes, dark filled rectangles represent parity check constraints of channel coding, blank rectangles represent constraints of network coding, and a rectangle node with an equal sign inside means that the connected two symbol nodes are equal.

Thus, we can generate the *extrinsic* information for each packet using *a priori* information from two other packets. The *a priori* information from x2 and y1 is used to generate the extrinsic information of x1 using the parity-check node updating rule in standard sum-product based LDPC decoding [9].

4 RELAY SELECTION WITH JOINT NETWORK CHANNEL CODING FOR MULTIPLE ACCESS RELAY CHANNEL

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In this section we are going to propose the relay selection scheme. We consider a DAF relaying protocol, where the relays decode the received signals before forwarding them to the destination. Similar to [15]–[16], we focus on the scenario where the link from the source to the relay is much more reliable than the link from the relay to the destination.

4.1 Relay Selection Algorithm

Now consider the relay selection algorithm where only a single relay, which optimizes the system performance, is selected. For different selection criteria, the selection decision procedures are different. Realizing that the average sum BER of two users is dominated by the worse user, here, we consider a simplified selection criterion for which the instantaneous BER of the worse user is minimized. We refer to such a selection criterion as the ***Min–Max selection criterion***.

For two source, two relay network an RS scheme is developed, in which a "linear marking" mechanism is used to maximize the minimal SNR among all users. First an initial feasible relay node assignment is randomly chosen, by which each user–destination pair communicates with the help of a relay node. The relay assignment algorithm is then adjusted in a number of iterations. During each iteration, the user that has the minimal SNR denoted min searches a better relay such that its SNR can be increased. If the better relay has been assigned to another user (say User *a*), User *a* tries to change to another relay (say Relay *b*) under the condition that the resulted SNR is higher than min.

If Relay *b* has been assigned to another user, further adjustment to that user's relay assignment is needed. So the relay adjustment of the user with the minimal SNR may have a chain effect on the relay assignment of multiple users. If there exists such an adjustment, the minimal SNR of all the users is increased, and the scheme moves to the next iteration; otherwise, the scheme terminates, which means that the minimal SNR of all the users is maximized. The worst-case complexity (measured by the number of comparison operations) of the RS scheme is O(N Nr2). Note that the RS scheme optimizes only the worst user's performance. In this min-max relay selection the minimal SNR among the users is maximized. This equivalently means that the minimum achievable data rate of all users is maximized and the maximum outage or error rate of all users is minimized.

4.2 Performance Evaluation

Now, let us calculate the BER expression of this network using the *Min–Max* selection criterion. If we let be the BER in the link from relay *i* to user *j*, then the average BER of two users in this link, which is denoted by , is equal to As previously discussed, it can also be approximated by using the BER of the worse user as follows:

(7)

Let represent the instantaneous BER in the link from relay *i* to user *j*. Let the pdf of *z* is given by,

Let,

Pri,max(γrd|ℎri,min(k)) = max{Pri,u1 (γrd|ℎri,u1 (k)), Pri,u2(γrd|ℎri,u2 (k))}

(9)

denote the error probability of the worse user for the signals transmitted from relay *j*. Then, based on the *Min–Max* selection criterion, among all relays, a single relay, which is denoted by *S*, is selected such that the instantaneous BER of the worse user is minimal, i.e.,

S=argmin(Pri,maxγrdhri,mink}

i=1,....,N (10)

The other unselected relays will stay in the idle states. Since Q(x) is a monotonic decreasing function of x, the min-max criterion in ( ) Can be written as,

S=argmax γimin k

=argmax{minhr1,u1k2, hr1,u2k|2 (11)

Where is the minimum of the two instantaneous SNRs of the links from relay i to the two users, i.e.,

(12)

Where . Based on (11) and (12), the pdf of zmin is given by [18],

fzminz=2γrd-1exp-2rd-1 z (13)

Then the exact asymptotic BER rate of the min-max scheme is given in the below theorem.

Theorem

The average sum BER of the min-max selection criterion is given by,

(14)

It can be further approximated at high SNR as,

PRS γrd≈ 2N-2ΓN+12π γrd-N+O(γrd-N) (15)

Let us discuss the selection decision procedure for S-RS-NC. Similar to [19], to perform selection at the relay nodes, each relay needs to listen to the request-to-send (RTS) and the clear-to-send (CTS) packets from two source nodes, respectively. Based on that condition, each relay node estimates its channel power gains from two source nodes. Then, a back off timer is set to be inversely proportional to the relaying channel quality .The best relay with the largest γimin (k) and the smallest back-off timer can occupy the channel first. Thus, S-RS-NC based on the *Min–Max* criterion can be implemented in a decentralized way.

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5 SIMULATION RESULTS

We consider simulation results for the two cases that is NBJNCC with relay selection and without relay selection. Let us first consider case 1 where the network performance only consider the joint network channel coding procedure for two source and two relay network. Fig.(5)depicts the Generation error rate (GER) and Fig.(6) depicts the Bit error rate (BER) and Fig(7) shows the good put over the signal to noise ratio (SNR) Eb/N0 in dB with 2 cases. From the slope of the error rates curves we can recognize the diversity which is provided by the use of the relay selection and the use of joint network channel coding. This system achieves the full diversity gain. However, as the redundancy which is contained in the transmission of the relay cannot be efficiently exploited by NBJNCC. As the redundancy which is contained in the transmission of the relay is received with a higher SNR, it is more important to exploit it efficiently.

The number of successfully decoded generations at the sink over the total number of generations is generation error rate. Fig (5) shows the plot of SNR with GER. Here we observe that NB-JNCC with min- max leads to much faster decrease in GER than NB-JNCC. Such as at GER of 10-1, the performance gain of NB-JNCC is about 17 db while the performance gain of NB-JNCC with min-max is about 28 db. We achieve the improved performance in proposed system.

Fig (6) shows the plot of SNR VS BER. The BER is the packets are successfully decoded and we get number of bits has been changed. At 45 db the NB-JNCC achieves the 10-1 BER. While using min-max the performance gain about 0 BER at 45 db. In fig (7) we shown the good put performance with SNR. The good put is the number of packets in successfully decoded generations at the sink per second. In this way, we ignore the packets in partially recovered generations. NB-JNCC with min-max achieves as much higher good put than the other two schemes because more generations can be recovered. NB-JNCC with min-max achieves higher good put than the without min-max because more generations are recovered.

Fig.5. Generation error rate (GER) of system applying non-binary joint network-channel coding (NBJNCC) with and without min-max relay selection.

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Fig.6. Bit error rate (BER) of system applying non-binary joint network-channel coding (NBJNCC) with and without min-max relay selection.

Fig.7. Good put of system applying non-binary joint network-channel coding (NBJNCC) with and without min-max relay selection.

5 CONCLUSION

We proposed to use non-binary joint network-channel coding (NBJNCC) based on LDPC code for the multiple-access relay channel (MARC). Such a system could be used for the cooperative uplink for two mobile stations to a base station with the help of a relay. NBJNCC for the MARC generalizes distributed channel codes for the relay channel. We showed with simulation results that NBJNCC for the MARC increases cooperative diversity compared to distributed channel codes for the relay channel.

Although the diversity gain can be also achieved with this network, NBJNCC allows to more efficiently exploit the redundancy which is contained in the transmission of the relay. Simulation results confirmed that the Bit error rate of NBJNCC with relay selection outperform the one of without relay selection by up to 0 BER at the rate of 45 dB. By analyzing the performance of the network it can be sure that the performance of the network is improved by increasing the number of relays and selecting the best relay for second phase transmission. By using various relay selection scheme we achieve the reduced error rate and increased throughput of the network.

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