Joint network/channel decoding algorithm for wireless networks and proof simulation

Youssef Zid, Sonia ZaibiAmmar and RidhaBouallègue

Syscom laboratory, National Engineering School of Tunis, Tunisia

ziidyoussef@yahoo.fr

Abstract

In this journal, we present a joint network/channel decoding (JNCD) algorithm for a wireless network that consists of M users. Previous works studied a small 2-user network. In our work, we consider a network that consists of M mobile station (MS), one relay (R) and one base station (BS). The network/coding process is done on the relay. In order to evaluate the performances ofJNCD,wewill fix another network which does not contain a relay. Then, the adopted reference chain will contain only M senders (MS) and one receiver (BS). The obtained results will be evaluated with a network simulator:Opnet Modeler. Then, we present two grouping algorithm: the first treat the impact of the number of nodes in each group in the network, and the second present the impact of transmission channel characteristics on node grouping.

KEYWORDS

Joint network/channel decoding, network coding, Opnet Modeler.

1. INTRODUCTION

Recent researches focused on network coding [1] because it gains on bandwidth especially [2][3]. Thus, previous work study the case of a small network comprised of 2 MS and one BS. In practice, a network can contain more than two users, this case seems more realistic. In this journal, we will show that JNCD provides a significant improvement compared to conventional transmission system (without JNCD). The major complexity of this approach is the implementation of JNCD algorithm. It is proven in this paper that the application of network coding for wireless networks is gaining interest.

2. NOTATION

Figure 1 depicts the uplink for M mobile station with the help of relay to a base station. The joint network/channel coding is done on the relay. We denote by MS_1, MS2,…,MS_j,…,MS_M , $1 \leq j \leq M$, the set of M transmitters, R the relay, BS the receiver. Each MS_jsend a packet denoted u_j,$1 \leq j \leq M$, of length equal to K bits, to BS. These information are protected against transmission errors with channel encoders which output the code bits x_j, $1 \leq j \leq M$. the length of each code bits is equal to N bits.

Each packetx_j, $1 \leq j \leq M$, is sent to BS through a channel transmission (supposed a Rayleigh channel). The obtained sequence is y_{j4}, $1 \leq j \leq M$. These sequences are interleaved and mixed before being coded by the network coder. Then, we obtain at the network coder output a bit sequence denoted x_4 with length equal to N_r.

3.CHANNEL CODING

The channel coder used in this work is a convolutional code. It was shown in [5], how joint network/channel coding based on low-density parity-check (LDPC) codes can be used for the JNCD. A convolutional code (13,15) with rate equal to 0.5 and constraint length 4 is applied in

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this paper. We assume that the length of each x_j, $1 \le j \le M$, is 1500 information bits. Then, the obtained sequence at the channel coder output has a length equal to 3003 bits. In order to increase the code rate of the system, we proceed to puncturing method. So, we sent only 2000 (instead 3003 bits) from each channel coder. We puncture the parity bits according to the following rule: we transmit every third parity bit. Thus, we transmit only 500 bits from 1500 parity bits. The transmitted bit sequence contains 500 parity bits and 1500 systematic bits. The puncturing process is applied to all M transmitters.

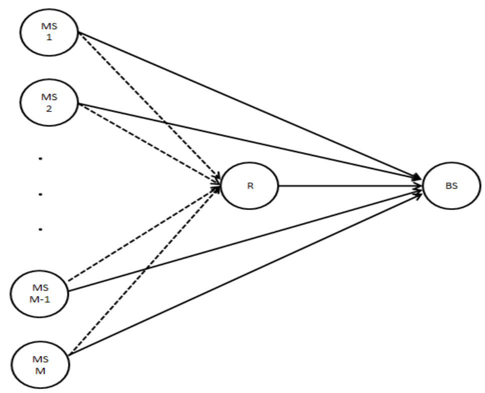

Figure 1.Uplink of M mobile station with the help of relay to a base station

4. NETWORK CODING

The network coding principle is the data combination at the input of network coding block. This process is done at the relay. This block contains M+1 sub-blocks: M channel decoders and one network coder. Then, at the network coder input, we found the noisy version of all x_j, $1 \le j \le M$. Each packetis decoded by a convolutional decoder. Then, we obtain at the j^{th} decoder output the packet $\hat{u}_{j4}$, $1 \le j \le M$. all these packet will be the input of the network coder after being interleaved. The interleaving processes is described as below: $\hat{u}_{14},\ldots,\hat{u}_{j4},\ldots,\hat{u}_{M4}, 1 \le j \le M$, are coded alternately by a convolutional coder. It hassimilar properties to the coder used for the M transmitters.This process is depicted in Figure 2.

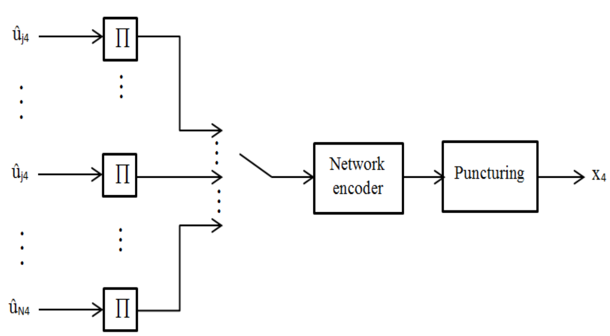

Figure 2.Network encoder at the relay

Then, we obtain at the network coder input a bit packet with length M*1500. After network coding process, the obtained packet has a length equal to M*1500*2+3 bits (whose M*1500+3 parity bits).

Then, we will puncture the obtained packet.In this section, we adopt the same puncturing system being used in section IV. Then, if we denote by R_r the code rate and by N_r the number of transmitted parity bit, the code rate of the system can be written as follows:
$R_r = M*K/N_r = 2*M*1500/M*2000 = 3000/2000 = 1.5$

5. JOINT NETWORK/CHANNEL DECODING

The JNCD is illustrated when we use two or more decoders at the receiver. It involves the combination of data provided by each decoder in order to ameliorate the system performances. In the case of 2-user network, we used only three decoders in JNCD block. In this work, the network contains M transmitters and one relay, so, we use at the receiver M+1 decoders which are SISO (Soft Input Soft Output). Figure 3 depicts this block for 4-user network.

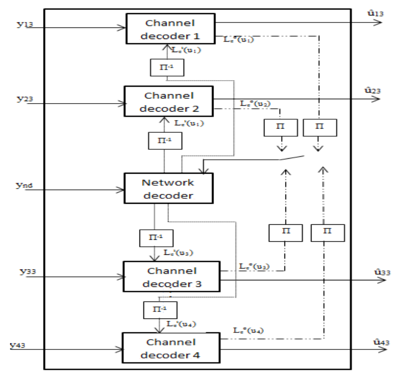

Figure 3.Joint network/channel decoding block

The JNCD block has as input the transmitted packet from each mobile station and the combined packet transmitted from the relay. It contains always M+1 SISO decoder: M channel decoder and one network decoder. Since all decoder are SISO, each one must provide additional information. We denote by $L_e^o(u_j)$, $1 \leq j \leq M$, the extrinsic information provided by the j^{th} channel decoder. Thisinformationis interleaved and mixed. The network decoder needsthese quantities, i.einformation being interleaved and mixed, to decode y_{nd}. Using these two quantities as it input (y_{nd} and $L_e^o(u_j)$, $1 \leq j \leq M$), the network decoder provide an additional information denoted $L_e^o(u_1, \ldots, u_M)$ which contains a part related to each u_j. The goal is to extract the corresponding part to each channel decoder. We denote by $L_e^i(u_j)$, $1 \leq j \leq M$, the additional information corresponding to the j^{th} channel decoder. All thesepackets must be disinterleaved before being used by channel decoders.

6. SIMULATION RESULTS

In order to evaluate the performances of JNCD forM-user network, it is usually to fix a reference chain. In our case, this chain contains M mobile station and one base station.There is no relay. The channel coder and the puncturing system used for the reference chain are the same beingused for the chain operating with JNCD.

Now, wewill present the performances of joint network/channel decoding algorithm for 4-user network.Thus, in order to evaluate the performances of the chain presented in Figure 1, we must make comparison between the conventional chain and the other operating with JNCD.

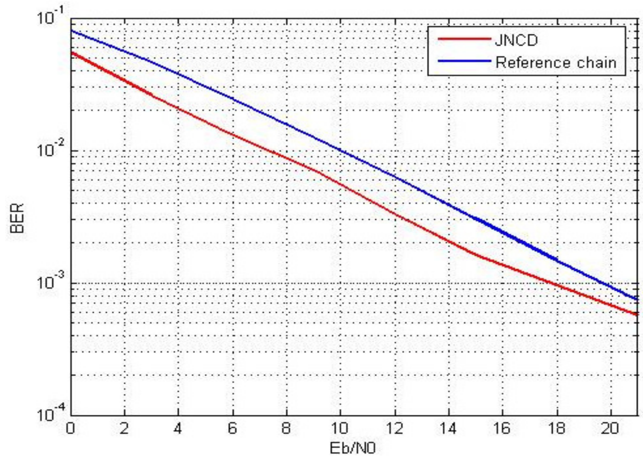

Figure 4. Bit Error Rate of system applying joint network/channel decoding and reference chain

Figure4 depicts the bit error rate (BER) for these two chains depending on the value of the ratio of Energy per Bit to the spectral noise density (Eb/N0). This curve shows that by using joint network/channel decoding algorithm in aM-user network, we can improve the performances of classic chain. The gain can achieve approximately 2 dB.

7. PROOF SIMULATION

In order to prove the previous results, we use a network simulator to make an optimal grouping algorithm of nodes in the network. Previous works **[7][8]** illustrates that grouping by pair of users is optimal. There are a few simulators that can present the network performances, we choose Opnet Modeler. It accelerates the R&D process for analyzing and designing communication networks, devices, protocols, and applications. Users can analyze simulated networks to compare the impact of different technology designs on end-to-end behavior. Modeler incorporates a broad suite of protocols and technologies, and includes a development environment to enable modeling of all network types and technologies including : VoIP, TCP, OSPFv3, MPLS, IPv6 …**[6]**

We demonstrate firstly that the grouping by pair of users is optimal, so, we present the bit error rate (BER) for two differentscenarios: the first treats the case of 2-user grouping, and the second treats the case of 5-users grouping. Figure 5 represents BER in these two cases depending on Eb/N0.

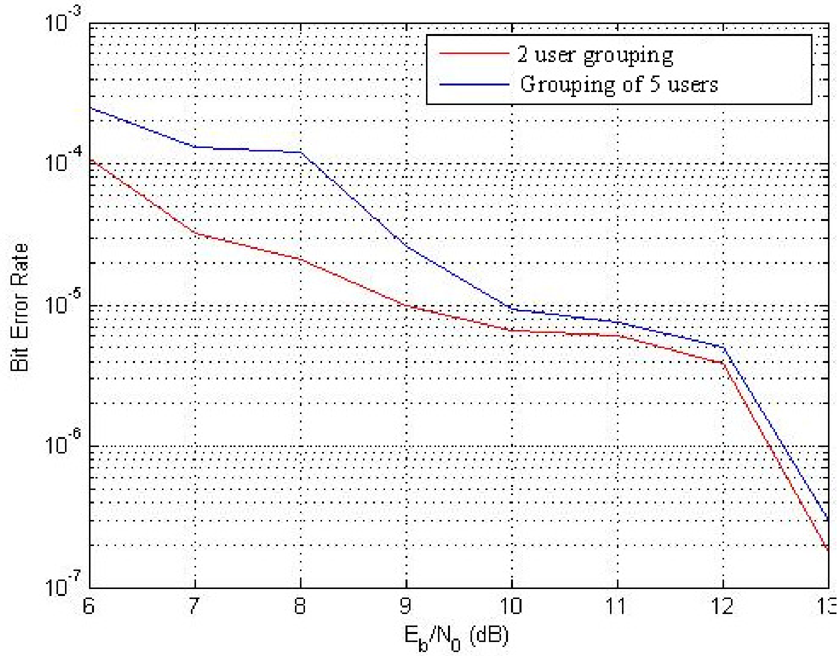

Figure 5.Bit Error Rate for 2 user and 5 users grouping in a system applying network coding

According to Figure 5, we note that grouping users by pair is better than grouping by 5 users.
There is another approach to group users in a network: it is to group users passing through complementary transmission channel. So, there are two possible scenarios: in the first, we state one channel transmission associated to one mobile station as bad, and we simulate the other. In our case, we state the SNR for the first mobile station to 1 dB. In the second scenario, we state one channel transmission associated to one mobile station as good, and we simulate the other.
We obtain the next table:

Table 1.BER of MS2 when MS1 cross a bad or a good channel transmission

SNR of BS2	BER of MS2 when (SNR(MS1) = 14 dB)	BER of MS2 when (SNR(MS1) = 1 dB)
1	0.00032	0.0019
2	0.00025	0.0011
3	0.00022	0.00097
4	0.000057	0.00075
5	0.000049	0.00067
6	0.000041	0.00059
7	0.000038	0.00058
8	0.000035	0.00047
9	0.000033	0.00045
10	0.000032	0.00044
11	0.000026	0.00042
12	0.000023	0.00035
13	0.000018	0.00033
14	0.0000027	0.00032

Figure 6 depicts the impact of user grouping on the BER of a system applying network coding.

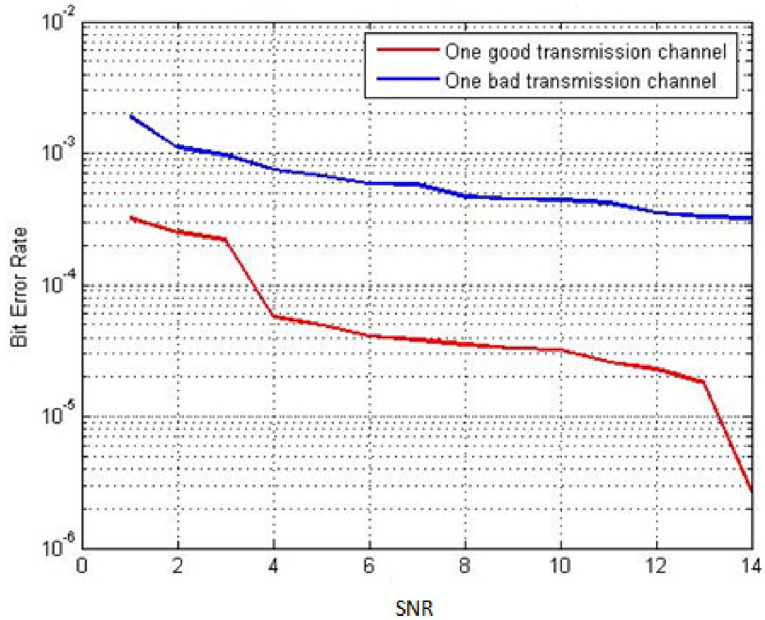

Figure 6.Bit Error Rate of one mobile station when the other cross a good or a bad transmission channel

According to Figure 6, we note that grouping by pair of users whose one cross a good transmission channel is better than any other grouping algorithm. In others words, giving a network, we try to group users by pairs respecting the fact that one of them cross a good transmission channel.

CONCLUSION AND PROSPECTS

In this journal, we presented a joint network/channel decoding algorithm for a wireless network that contains M users, one relay and one receiver. The implementation of this algorithm remains complex since the decoder must contain M+1 decoders (always SISO) and it has to take into account the information exchange between all these decoders. Simulation results show that these proceeds can give an improvement in terms of gain mainly. In the first part of this work, we supposed that all senders cross the same channel transmission. This hypothesis is not always true. So, we used Opnet Modeler in order to found an optimal grouping algorithm. Then, it was proven that grouping by pairs of users respecting the fact that one of them cross a good transmission channel is the better case.

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