# IMPLEMENTATION OF JOINT NETWORK CHANNEL DECODING ALGORITHM FOR MULTIPLE ACCESS RELAY CHANNEL BASED ON CONVOLUTIONAL CODES

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***ABSTRACT***

*In this paper, we consider a Joint Network Channel Decoding (JNCD) algorithm applied to a wireless network consisting to M users. For this purpose M sources desire to send information to one receiver by the help of an intermediate node which is the relay. The Physical Layer Network Coding (PLNC) allows the relay to decode the combined information being sent from different transmitters. Then, it forwards additional information to the destination node which receives also signals from source nodes. An iterative JNCD algorithm is developed at the receiver to estimate the information being sent from each transmitter. Simulation results show that the Bit Error Rate (BER) can be decreased by using this concept comparing to the reference one which doesn't consider the network coding.*

***KEYWORDS***

*Joint network/channel decoding, network coding, wireless network.*

## 1. INTRODUCTION

In the last years, researchers focused on cooperative communications [6][7] via relay. Then, by using this concept, the spatial diversity gain can be achieved. The principle task of the relay is firstly to combine information from different transmitters by using network coding [1]. Then, this mechanism, i.e. network coding, performs the gains on bandwidth especially [2][3]. In the next stage, the relay forwards the resulting signal to the destination node. In order to improve the throughput of wireless networks, the destination node receives the signals from different source nodes in the direct links, and eventually the one from the relay. In literature, This scheme is called Multiple Access Relay Channel [8] (MARC). The relay model in such scheme has been widely exploited. So, it was shown in [9][10] that several relaying architectures may be used like Amplify And Forward (AAF), Decode And Forward (DAF) and Compress And Forward (CAF). Indeed, authors proposed in [8] a joint network channel coding based on turbo codes for the MARC scheme with two transmitters.

David C. Wyld et al. (Eds) : NETCOM, NCS, WiMoNe, CSEIT, SPM - 2015
pp. 01–08, 2015. © CS & IT-CSCP 2015 DOI : 10.5121/csit.2015.51601

In a real case, the mentioned scheme cannot always be applied even it gives an improvement in throughput of wireless networks. So, practically ,a real network can contain more than two senders. Several algorithms are used at the relay to improve the performance of such scheme. In this case, the classical network coding at the relay, which consist to the XOR operation of signals from source nodes, cannot be applied. Authors presented in [11] a joint network channel coding for the MARC scheme with two senders based on distributed turbo code for the relay channel. They compared the proposed system to the one using separate network channel coding and proved that the use of joint network channel coding is necessary to exploit in a good way the redundant signal provided by the relay. Then, if the network and channel coding are treated separately, some performance loss is expected since the network decoder can't use the soft information computed by the channel decoder. Similarly, the channel code cannot exploit the redundant information of the network code. This concept is supported in [12][13][4] where authors proved that capacity can be achieved by conceiving channel and network coding as a single non-separated data processing stage. In addition, there are several joint channel network coding scheme like time division decode and forward MARC model presented in [5] in which authors proposed distributed regular LDPC codes as the joint network channel code at the relay. The same concept is proposed in [11] by using turbo-code-based joint channel network coding scheme.

In this paper, we propose a JNCD algorithm applied to the MARC scheme with large source nodes. The proposed scheme contains also one relay and one destination. We refer to [11] and we modify the joint network channel coding used at the relay. The redundant information provided at the relay is transmitted to the destination which receives eventually information from source nodes. An iterative decoding algorithm is presented at the destination to estimate the information being sent from each source.

This paper is organized as follows: the next section presents the considered MARC system model. In section III, a joint network channel coding algorithm is presented, then, a detailed description of the channel coding and network coding process is done. In section IV, an iterative joint network channel decoding algorithm is presented to estimate the source information's being sent from the transmitters. The section V presents the reference scheme. In section VI, the performance of the proposed decoding algorithm are evaluated and compared to the classic scheme which doesn't consider network coding.

## 2. SYSTEM MODEL

Fig. 1 depicts the system model of the proposed MARC scheme. It consists to wireless network that contains $M$ Mobile Stations (MS), one Base Station (BS) and one Relay (R). We denote by $MS_1, MS_2, \ldots, MS_j, \ldots, MS_M$, $1 \le j \le M$, the set of $M$ transmitters. Each $MS_j$ generates a source information vector denoted $u_j, 1 \le j \le M$, of length equal to K bits. The source information's are firstly encoded with a channel coder in order to protect them from error transmission. Thus, the obtained sequence at the output of the $j^{th}$ channel encoder is BPSK modulated to obtain $x_j$ with length equal to N. In PLNC, there are two stages to recover the information being sent from each source at the destination. In the first one, the sources $MS_j$, $1 \le j \le M$, send their information simultaneously to the destination node and the relay over a Rayleigh channel. Then, the received message at BS, respectively R, is expressed as follows:

$$y_{D,j} = h_{D,j} x_j + n_{D,j} \quad (1)$$

respectively

$$y_{R,j} = h_{R,j} x_j + n_{R,j} \quad (2)$$

Where $h_{D,j}$ and $h_{R,j}$ are complex channel fading coefficient. $n_{D,j}$ and $n_{R,j}$ are zero mean and Gaussian noise with variance $\sigma_D^2$ and $\sigma_R^2$ .

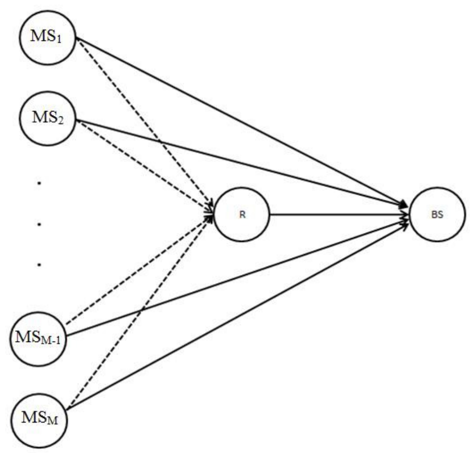


Fig. 1. System model for a network comprised of M users

In the next stage, a joint channel network coding is performed at the relay. It consists to the combination of signals being sent from the sources node $MS_j, 1 \le j \le M$. A detailed description of this process is done in the next section. The relay R provides itself redundant information which is sent to the destination node.

The main goal is to decode information being sent from the mobile stations at the destination node by using an iterative JNCD algorithm. It consists to $M$ channel decoder and one network decoder. The last one provides information to each channel decoder in order to improve the decoding processes of the corresponding signal.

## 3. Joint Channel Network Coding For M-User Network

### 3.1 Channel coding

As mentioned previously, each transmitter $MS_j$ encode its source information in order to protect it from transmission error. The channel encoder used in this work is a convolutional code (37,21) with rate equal to 0.5 and constraint length 4. We assume that the length of each source information vector $u_j$, $1 \le j \le M$, is 1500 information bits. After channel encoding process, the j$^{th}$ encoder provides bit sequences of length equal to 3003 bits.

In order to increase the system rate, a puncturing method is used. So, the number of transmitted bits in each sequence is reduced. Then, we send only 2000 bits instead of 3003 from each channel coder. The choice of the transmitted bits must respect the following rule: we transmit only the third parity bit. Thus, we transmit only 500 from 1500 parity bits. As a result, the transmitted bit sequence from $MS_j$ contains 500 parity bit and 1500 systematic bit. The proposed puncturing process is applied for all transmitters.

## 3.2 Network Coding

The network coding process consists to mixing information from different users. In the MARC scheme with two sources, it is done in a general way by computing the XOR of the corresponding sequences. The resulting sequence is used at the destination as additional information which improves the decoding process. This concept cannot be applied to network with large number of transmitters. We present in this section the network coding principle at the relay for the proposed M-users network.

Since the considered scheme has *M* transmitters, the network coding block contains *M*+1 sub-block: *M* channel decoders and one network encoder. The j^th channel decoder has as input the sequence $y_{R,j}$ corresponding to the j^th source node. The classic decoding process is performed for all channel decoders in order to get an estimation of the source information being sent from mobile stations. Then, we obtain at the output of the j^th channel decoder a bit sequence denoted $\hat{u}_{j,4}$, $1 \le j \le M$. They are firstly interleaved and encoded by a convolutional encoder with the same characteristics as those used for mobile stations. This process is depicted in figure 2.

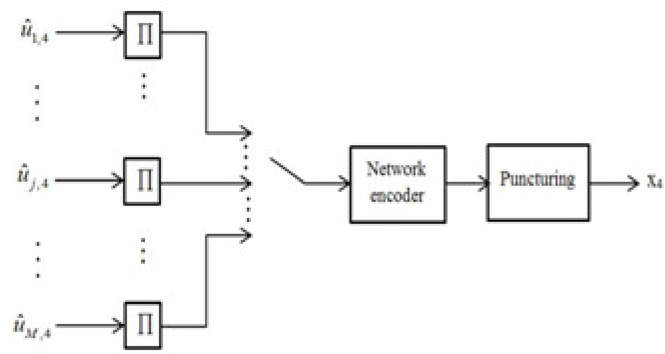


Fig. 2. Channel coding process in network codingblock

The network coding block contains *M* channel decoders, so, the network encoder has as input a bit sequence with length equal to $M \times 1500$.

At this stage, the network coding is performed by using a convolutional code (37,21) with rate equal to 0.5 and constraint length 4. Then, we obtain at the output of network coding block a bit sequence with length *L* equal to

$L = M \times 1500 \times 2 + 3$ bits, whose $M \times 1500 + 3$ parity bits.

The obtained bit sequence is punctured by using the same method being described in section 3.1 to obtain the signal $x_4$ So, we transmit only the parity bit at the third place. Consequently, in order to transmit $M \times 3003$ bits, only $M \times 2000$ bits ($M \times 1500$ systematic bits and $M \times 500$ parity bits) are transmitted to the destination node. Then, if we denote by $R_R$ the system rate at the relay, and by $N_R$ the number of transmitted parity bit, the network code rate can be written as follows:

$$R_R = MK / N_R = 2 \times M \times 1500 / M \times 2000 = 3000 / 2000 = 1.5 \qquad (3)$$

The sequence $x_4$ is BPSK modulated and transmitted over a Rayleigh channel to the destination node. We denote the received message by $y_{D,R}$.

## 4. JOINT NETWORK/CHANNEL DECODING

The notion of JNCD is illustrated when the system contains two or more decoders. It involves the combination of data provided by each decoder in order to ameliorate the system performances. For the MARC scheme with two transmitters, the JNCD block must contain three decoders: two channel decoders and one network decoder.

The proposed scheme in this paper contains *M* mobile stations, so, there are *M* channel decoders and one network decoder in the JNCD block. All these decoders are Soft Input Soft Output (SISO). Figure 3 presents the JNCD block for 4-users network.

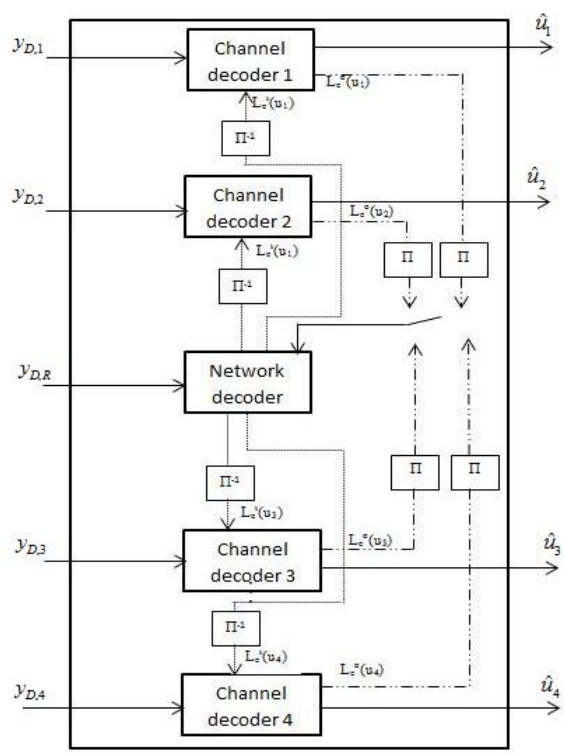


Fig. 3. joint network/channel decoding block for 4-users network

The JNCD block has as input the transmitted sequence from each mobile station and the combined sequence provided by the relay. Since all decoders are SISO, each channel decoder provides additional information called extrinsic information which is denoted by $L_e^o(u_j)$, $1 \le j \le M$. These quantities are firstly interleaved and mixed. Then, the resulting sequences will be the inputs to network decoder. It uses the quantities as additional information to decode the message $y_{D,R}$ transmitted from the relay. The network decoder provide itself en extrinsic information denoted $L_e^o(u_1,\ldots,u_M)$. this quantity contains a part related to the transmitted signal from $MS_j$.

The main goal is to extract the part corresponding to each channel decoder in the JNCD block. We denote by $L_e^j(u_j)$, $1 \le j \le M$, the desinterleaved information corresponding to the j$^{th}$ channel decoder. As a result, each channel decoder takes as input the signal $y_{D,j}$ and the quantity $L_e^j(u_j)$ provided by the network decoder. The decoding process is performed for each channel decoder, and a posteriori information is given from each one which will be the input for the network decoder.

This process is repeated until the total number of iterations is reached. An estimation of the transmitted information from the mobile stations is given.

## 5. REFERENCE CHAIN

In order to evaluate the performances of the JNCD algorithm, it is usually to fix a reference chain to which we compare the performances of the proposed scheme. Then, in the classic way, the network coding is not performed, so, the source information's are sent from mobile stations to the destination in a direct link without any additional information. Figure 4 depicts this reference chain. It contain *M* senders and one receiver, there is no relay.

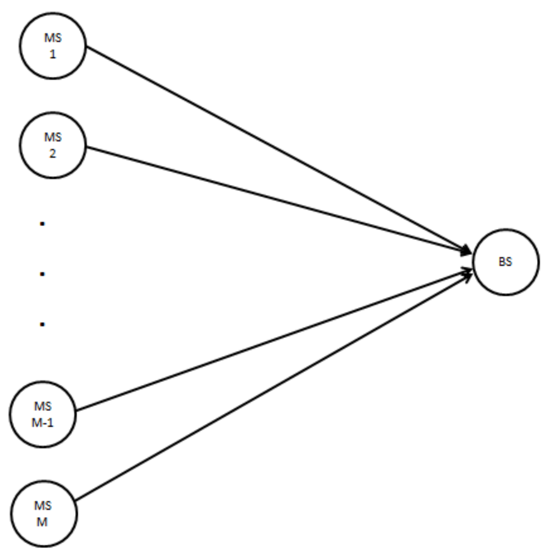


Fig. 4. Reference chain

The reference chain contains *M* transmitters and one receiver. Then, these mobile stations encoded its packets by using a channel decoder with the same characteristics as those using in the MARC scheme. The resulting quantities are sent in a direct link to the receiver over a Rayleigh channel. In addition, in order to get a meaningful comparison between the two chains, the same puncturing system used in the MARC scheme is adopted, so, from each transmitter, 2000 bits (1500 systematic bits and 500 parity bits) are sent instead of 3003. At the receiver, all punctured bits are replaced by 0.

## 6. SIMULATION RESULTS

In this section, we present the performances of joint network/channel decoding algorithm for the proposed MARC scheme which consists to *M* users. The number of mobile stations is set to 4. The characteristics of the convolutional code used in this work are presented in section II. In addition, we present the performances of the proposed scheme for the convolutional encoder (7,5). Then, we study the impact of the channel encoder on the performances of the JNCD algorithm. Thus, in order to evaluate the performances of the JNCD algorithm, we must make comparison between the conventional chain and MARC scheme.

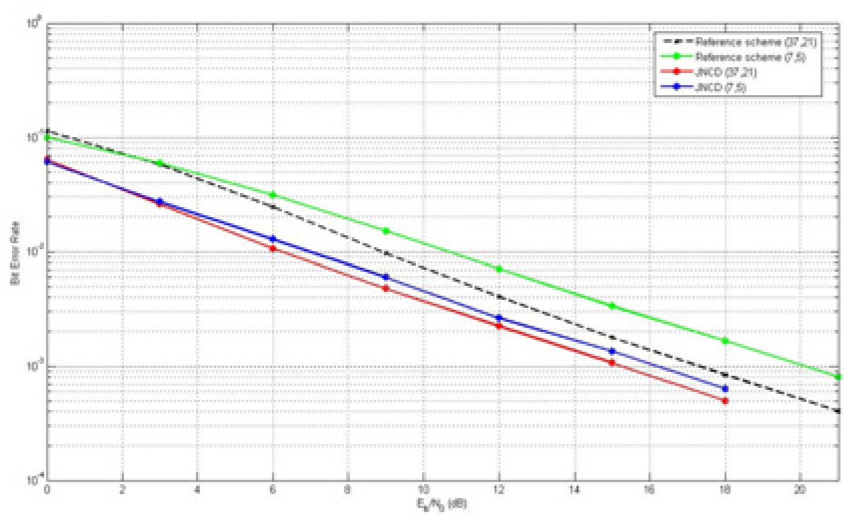


Fig. 5. Bit Error Rate of System applying joint network/channel decoding and reference chain

Figure 5. depicts the bit error rate (BER) for the two chains depending on the value of the ratio of Energy per Bit to the spectral noise density (Eb/N0) when using the two convolutional codes (37,21) and (7,5).. According to this figure, we can see that the BER decrease significantly comparing to the standard scheme in the two cases. Then, if the code (37,21) is used, the gain can achieve approximately 2.5 dB, and it achieves 3 dB for the code (7,5).

On the other hand, we can see that by using the JNCD decoding algorithm, we can achieve approximately the same performances for the two convolutional encoders. So, this algorithm corrects the errors in a good way unlike the standard scheme for which there is a difference of 2 dB between the standard scheme using the code (37,21) and the one using (7,5).

## 7. CONCLUSION

In this paper, we presented the joint network/channel decoding principle for MARC scheme that consists to *M* users, one relay and one receiver. A convolutional encoder is used as a channel code at the mobile stations. In order to increase the system rate, a puncturing method was presented. Indeed, a new design of the network decoding at the relay was presented. Finally, an iterative joint network channel decoding algorithm was developed to estimate the source information being sent from each mobile station. The implementation of this algorithm remains complex since the decoder contains *M*+1 decoders (always SISO). It has to take into account the information exchange between the channel decoders and the network decoder. Simulation results are presented for the two codes (37,21) and (7,5). It is shown that the JNCD algorithm give an improvement of gain mainly. So, a gain of approximately 2.5 dB is always achieved. In addition, simulation results shows that the JNCD algorithm can correct errors in good way even there is a significant difference in terms of gain between standard schemes when using two different convolutional codes.

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