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Performance evaluation of multicast relay network using LDPC and convolutional channel codes along-with XOR network coding

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Abstract

In this paper, we have compared the performance of joint network channel coding (JNCC) for multicast relay network using low density parity check (LDPC) codes and Convolutional codes as channel codes while exclusive or (XOR) network coding used at the intermediate relay nodes. Multicast relay transmission is a type of transmission scheme in which two fixed relay nodes contribute in the second hop of end-to-end transmission between base transceiver station (BTS) and a pair of mobile stations. We have considered one way and two way multicast scenarios to evaluate the bit error rate (BER) and throughput performance. It has been shown that when using XOR network coding at the intermediate relay nodes, the same transmission becomes possible in less time slots hence throughput performance can be improved. Moreover we have also discussed two possible scenarios in the proposed system model, in which both diversity and multiplexing gain has been considered. It is worth notifying that BER and throughput achieved for LDPC codes is better than Convolutional codes for all the schemes discussed.

Keywords cooperative relaying, network coding, multicast relay networks, LDPC codes, convolutional codes

1 Introduction

Modern wireless networks are being designed for cooperation rather than mere co-existence. The basic purpose of this cooperation is to increase the link quality, reliability and the data rate of the system. Diversity techniques are considered as an effective way to combat fading. The main idea of diversity is to provide the receiver with multiple versions of the transmitted signal to maximize the probability that at least one version of the transmitted signal is not degraded severely by the wireless fading channel. Conventionally, diversity could be deployed in three different approaches: time, frequency, and space [1–2]. The signals received from different paths linking the transmitter and receiver are combined according to different criteria [3]. However, besides these conventional diversity schemes a new concept of cooperative diversity [4–5] has emerged recently as a solution to get realization of (virtual) multiple antenna systems. The ultimate goal of a cooperative relay network is to process the multiple received signals in such a way to obtain a better quality with high probability of successful reception (reduced BER). The relay channel can be thought of as an auxiliary channel to the direct channel between the source and destination. The end-to-end transmission can be classified in two stages in time domain: broadcasting phase and relaying phase [6]. The relays can be used in three different relaying protocols: amplify-and-forward (AF), compress and forward (CF) and decode and forward (DF) [7–8]. In our work we have considered DF relays.

The new concept of network coding (NC) has been evolved as an interesting extension of the more traditional routing paradigm. Actually NC was originally proposed in Ref. [9] in order to improve the throughput in wired networks by performing some processing on received packets at the intermediate nodes. The performance of JNCC for multiple-access relay channel (MARC) is discussed in detailed in Refs. [10–11]. Similar analysis

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with destination-relay feedback is made in Refs. [12–15]. The principle of JNCC is to use the redundancy in the network code to support the channel code for better error protection. A recent work in Ref. [16] shows the impact of JNCC for DF based relay networks. In Ref. [17] outage analysis of JNCC and its dependence on interleaving pattern is studied. In Ref. [18], a JNCC based on LDPC is proposed by constructing joint network-channel parity check matrix. A JNCC scheme to improve the bandwidth efficiency of relay based network is proposed in Ref. [19] and an iterative joint physical layer network coding is introduced in Ref. [20].

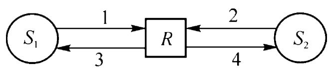
In this paper we have evaluated the performance of JNCC for 2-hop multicast relay network using LDPC and Convolutional codes. We have also considered one-way and two-way multicast schemes in two different scenarios. First, in which the entire data from source is transmitted to both the relays in order to achieve the diversity gain and secondly the data is transmitted in two chunks one to each of the two relays to get the multiplexing gain. The BER and throughput performance of both one-way multicast schemes has been investigated for LDPC and Convolutional channel codes with and without implementation of XOR based network coding.

The rest of the paper is organized as follows. Sect. 2 explains network coding concept followed by some description of JNCC. In Sect. 3, we explain our system model for 2-hop multicast relay based network. Sect. 4 discusses one-way and two-way multicast scenarios followed by simulation results, while final conclusion is presented in Sect. 5.

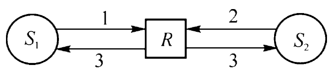
2 Description of XOR network coding

Generally speaking, the network coding protocols can be classified in two categories: digital network coding and the analog network coding. If the network coding is applied at the relay at the signal level, it is known as analog network coding or physical-layer network coding. However, digital network coding is generally applied at the relay at the packet level. The packets received from the cooperating users are first decoded and then combined using bitwise XOR operation or some other combining method. The main benefit of this technique is the orthogonal use of access methods, which helps minimizing interference between the different users. It also provides the possibility of interaction between the channel coding scheme used by the different users cooperating each other and the network coding used. Due to this interaction it becomes opportunistic to use more efficient network coding schemes and efficient decoding algorithms at the BTS. Generally, network coding needs to be employed at the intermediate nodes (relay in our case) in order to achieve bandwidth optimality and maximize the information flow. This new area is now widely being investigated as a means to facilitate multicast transmission, i.e., transmitting common information from a sender to multiple receivers. Although complex network coding schemes also exist, however in our work we have used simple form of network coding which involves XOR operation.

Consider a simple network shown in Fig. 1(a) which comprises of two source nodes S_1, S_2 and an intermediate relay node R. The source S_1 has a data A which it wants to send to source S_2, and similarly source S_2 has data B which it wants to send to source S_1. In order to accomplish the required task, four time slots are required as if there is only cooperation involved but without network coding. That is, during the first time slot T_1, the source S_1 sends data A to the relay. And during the second time slot T_2, the source S_2 sends data B to the relay. The relay after receiving A, B sends A to S_2 in the 3rd time slot and sends B to the source S_1 in the 4th time slot as shown below.



(a) 4-time slots scheme



(b) 3-time slots scheme

Fig. 1 Time slot schemes for multiple Access relay channel

However if the network coding is applied at the relay, the same task can be accomplished in three time slots as shown in Fig. 1(b). In this case, the relay after receiving A and B from S_1 and S_2 respectively in first two time slots, perform XOR operation between A and B and forwards the $A \oplus B$ to both S_1 and S_2. Both the resources extract their required data by again performing XOR operation.

$$A \oplus (A \oplus B) = B \tag{1}$$

$$B \oplus (A \oplus B) = A \tag{2}$$

So, by using simple XOR network coding at the relay and also performing XOR operation at the sources, significant throughput improvement can be achieved. Fig. 2 depicts the situation.