SPACE TIME BLOCK CODES IN TWO RELAY NETWORK WITH PHYSICAL LAYER NETWORK CODING

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Abstract Physical Layer Network Coding is a new relaying Technique in which the superposition of Electro Magnetic Waves in air is exploited rather than considering it as nuisance. Our two way relay network model contains two source nodes with two transmitting antennas and one receive antenna. The centre relay node is employed with two receive antennas and one transmitting antenna. Source nodes S1 and S2 transmit information to the relay node R which employs Decode and Forward relaying. The relay node employs network coding on the received signal and retransmits the coded data to the source nodes. We have analyzed the Bit Error Rate performance at the relay node and end-to-end. Since the nodes are employed with two antennas, multiple copies of data is received at relay node which improves the reliability of the system. The system employs well known Alamouti space time block coding which improves the overall error performance.

Index Terms – Relay networks, Physical-layer network coding, Space-time block coding.

Introduction

One of the biggest challenge in wireless communication is how to deal with the interference at the receiver when signals from multiple sources arrive simultaneously. The evolution of wireless communication leads to increase in data rate, reliability and to enhance the signal quality by using different technologies. In order to improve the performance of Bit Error Rate the Physical layer network coding was proposed. In the radio channel of the physical-layer of transmitted through electromagnetic (EM) waves in a broadcast manner. The interference between these EM waves causes the data to be scrambled.

Most communication system designs try to either reduce or avoid interference However instead of treating interference as a nuisance to be avoided, we can actually embrance interference to improve throughput performance. To do multi-hop network we proposed Physical layer network coding (PNC) to create an apparatus similar to that of network coding, but which performs arithmetic at the lower physical layer using the additive property of EM signal reception.

Physical layer network coding

The basic idea of PNC is to exploit the network coding operation that occurs when electromagnetic (EM) waves are superimposed on one another. Network coding (NC) can improve the network performance, facilitate algorithm/protocol design and deal with application specific problems in wireless networks. Recently Inspired by the traditional network layer, physical layer network coding (PNC) has been proposed to further improve the performance achieved by traditional NC schemes. PNC is used for data transmission from source to destination. It can enhance the throughput in two way relay channel.

Most existing studies were based on the assumption that each transmission involves only one transmitter in order to avoid interference. However, physical layer network coding (PNC) has shown that such an assumption can be relaxed to improve throughput performance of a wireless network. In PNC, signals from different senders can be transmitted to the same receiver in the same channel simultaneously. Although PNC scheme does not chance the scaling law, it can improve throughput capacity by a fixed factor. Specifically, for a one-dimensional network, we observe that PNC can eliminate the effect of interference in some scenarios.

The PNC allows nodes 1 and 2 to transmit together and exploits the network coding operation performed by nature in the superimposed EM waves. In first time slot, nodes 1 and 2 transmit information S1 and S2 simultaneously to relay R. Based on the superimposed EM waves that carry S1 and S2 , relay R deduces $S_R = S_1 \oplus S_2$ then in the second time slot, relay R broadcasts to S_R nodes S1 and S2.

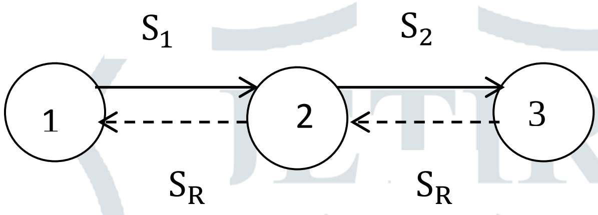

Fig 1: Physical Layer Network Coding

A key issue in PNC is how relay R deduces information from the superimposed EM waves. This process is called as "PNC mapping". More generally, PNC mapping refers to the process of mapping the received superimposed EM waves plus noise to some output packets for forwarding by the relay. PNC mapping could output a packet in a different form

$$S_R = S_1 \oplus S_2$$

All PNC mappings share the key requirements that nodes 1 and 2 must be able to deduce the information from the other node based on the output packet of the relay R and their send information. The main advantage of PNC, however, is the reduced number of time slots needed.

Symbol from node 1: S_1	Symbol from node 2: S_2	Composite symbol Received at relay R $y_{R(I)=} S_1 + S_2$	Mapping to symbol to be transmitted by relay R: a_R
1	1	2	-1
1	-1	0	1
-1	1	0	1
-1	-1	-2	-1

Table 1: PNC Mapping Table

The PNC provide the reduced number of transmission time slots.

Two way relay network:

A typical two-way relay network (TWRC), is the three node two way relay channel shown in Fig.1.N1(Node 1) and N3(Node3) are nodes that exchange information , but they are out of each other's transmission range, N2(Node 2) is the relay node between them. This system has found applications in many scenarios. In satellite communication, the satellite serves as a relay to facilitate information exchange between two mobile stations on the earth.

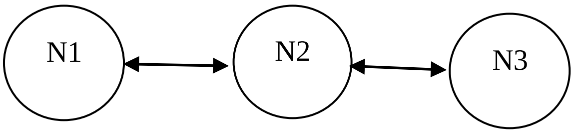

Figure 2: A 3 node linear network

Each node is equipped with an omni-directional antenna, and the channel is half duple so that transmission and reception at a particular node must occur in different time slots.

System model

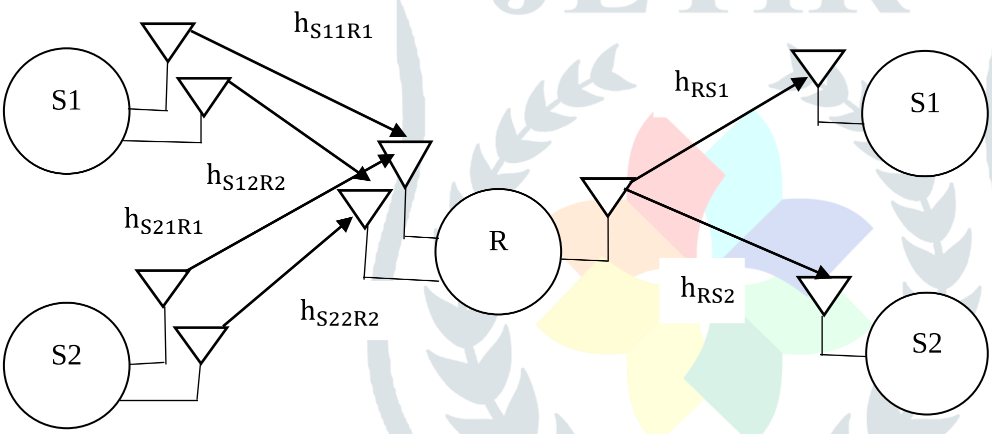

Figure 3: Two way relay network model

A two-user network model contains two source nodes and one relay nodes. Source nodes S1 and S2 transmit information to the relay node R. Node R can be decided through some relay selection algorithms. Node R works in Decode-and-Forward (DF) relaying mode. All the nodes are equipped with number of antennas.

The transmission is divided into two phases: broadcasting and relaying. During the broadcasting phase source nodes broadcast information to relay node; whereas during the relaying phase, the relay node forwards the received information to the destination node (source nodes) after necessary processing. Here the BPSK modulation is adopted, the transmit power of each node is equal, the channel is Rayleigh flat fading.

In transmission, the source nodes first implement BPSK modulation to get the symbols, and the symbols will be processed with the Alamouti STBC.

Space Time Block Coding:

Space time block coding is a technique used in wireless communication to transmit multiple copies of data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data transfer.

Alamouti STBC

A complex orthogonal space-time block code for two transmit antennas was developed by Alamouti. The Alamouti scheme exploits the spatial and time diversity to improve the quality of the received signal with a less complex processing at the transmitter and linear decoding at the receiver.

In our system model, during the broadcasting phase, the information transmitted by two source users is,

$$X_1 = \begin{bmatrix} x_{11} & -x_{12}^* \\ x_{12} & x_{11}^* \end{bmatrix}$$

$$X_2 = \begin{bmatrix} x_{21} & -x_{22}^* \\ x_{22} & x_{21}^* \end{bmatrix}$$

Here we use 4x2 Alamouti scheme , transmits four symbols using four transmit antennas in two transmission periods. The received signals at relay node R from source S1 in two consecutive time slots in the broadcasting phase are,

$$\begin{matrix} y_{S1R1}^1 \\ y_{S1R2}^1 \end{matrix} = \begin{bmatrix} h_{S1R11} & h_{S1R12} \\ h_{S1R21} & h_{S1R22} \end{bmatrix} \begin{matrix} X_{11} \\ X_{12} \end{matrix} + \begin{matrix} n_{S1R1}^1 \\ n_{S1R2}^1 \end{matrix}$$

$$\begin{matrix} y_{S1R1}^2 \\ y_{S1R2}^2 \end{matrix} = \begin{bmatrix} h_{S1R11} & h_{S1R12} \\ h_{S1R21} & h_{S1R22} \end{bmatrix} \begin{matrix} -X_{11}^* \\ X_{12}^{\ *} \end{matrix} + \begin{matrix} n_{S1R1}^2 \\ n_{S1R2}^2 \end{matrix}$$

The received signal at the relay node R from source S2 in two consecutive time slots in broadcasting phase are,

$$\begin{matrix} y_{S2R1}^1 \\ y_{S2R2}^1 \end{matrix} = \begin{bmatrix} h_{S2R11} & h_{S2R12} \\ h_{S2R21} & h_{S2R22} \end{bmatrix} \begin{matrix} X_{21} \\ X_{22} \end{matrix} + \begin{matrix} n_{S2R1}^1 \\ n_{S2R2}^1 \end{matrix}$$

$$\begin{matrix} y_{S2R1}^2 \\ y_{S2R2}^2 \end{matrix} = \begin{bmatrix} h_{S2R11} & h_{S2R12} \\ h_{S2R21} & h_{S2R22} \end{bmatrix} \begin{matrix} -X_{21}^* \\ X_{22}^{\ *} \end{matrix} + \begin{matrix} n_{S2R1}^2 \\ n_{S2R2}^2 \end{matrix}$$

The received signals are combined and proposed with the PNC. During the relaying phase , the relay node R transmit received signal to the destination nodes(source nodes).The received signal at the two source nodes are,

$$r_k = r_{ij} * \ h_i + n_i$$

Where r_k is the received signal at the k^{th} source node, h_i is the channel used to transmit the received signal and n_i is the noise.

Simulation results:

In this section, the simulation results shows the performance of the system model on Bit Error Rate(BER) is reduced. The Gaussian distributed source samples are generated by the two usersand PNC encoded at the relay. The source nodes are assumed to use BPSK modulation, Each node makes Alamouti STBC processing before transmission and they are with equal transmit power. We plotted the BER performance curve against various SNR. Figure 4.1 depicts the simulated and theoretical BER curve.

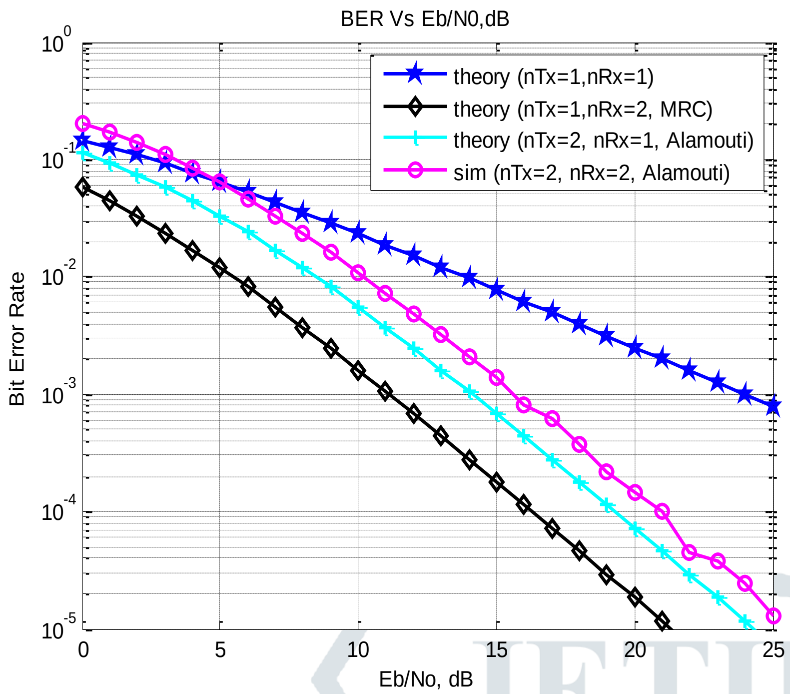

Figure 4: SNR Vs BER plots for broadcasting phase.

In this simulation, the performance of BER is compared with theoretical value for 1Tx and 1Rx antenna, 1Tx and 2Rx antenna employing MRC and 2Tx and 1Rx antenna of Alamouti coding.

The two sources are equipped with two transmit antennas. We can see that BER performance of system is improved when the number of antennas is increased. We can see that the performance with 1Tx and 1Rx antenna is poorer compared with multiple antennas at nodes. The simulated BER with 2Tx and 2Rx antennas at 25 dB is 10^{-5}. For increasing values of SNR, the bit error rate is found to be decreasing. The theoretical value approximately matches with the practical BER value.

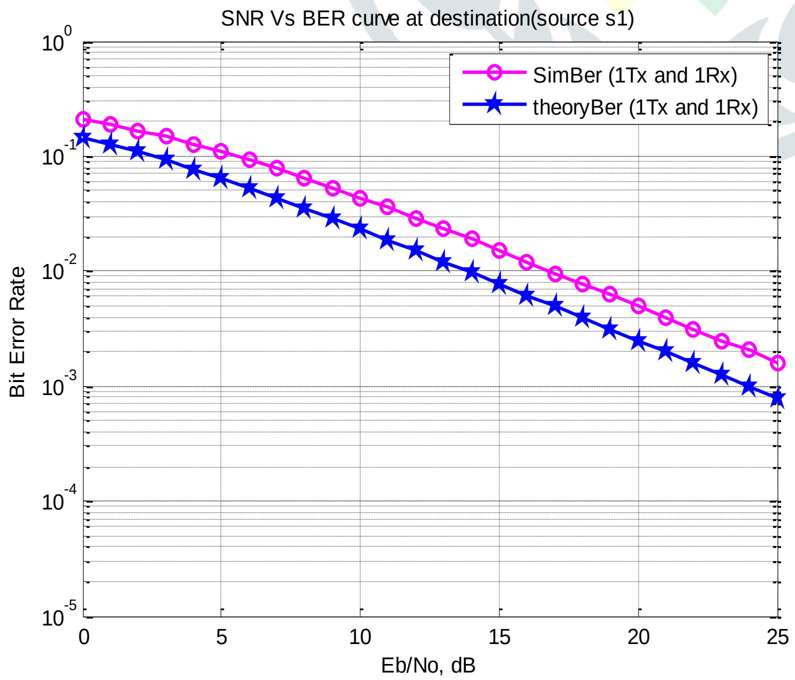

Figure 5: SNR Vs BER curve for relaying phase – relay node to source S1 node

The above figure shows that BER curve at the relaying phase – relay node to source S1 node. Here the relay node and source nodes have only one transmitting antenna and one receiving antenna respectively. The simulated BER has achieved at nearly 10^{-3} at 25dB SNR value.

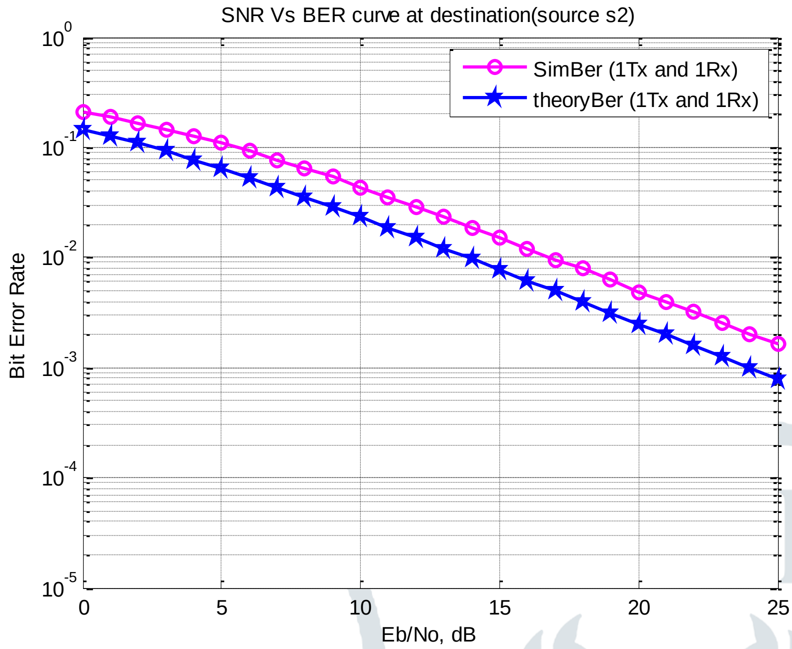

Figure 6: SNR Vs BER curve for relaying phase – relay node to source S2 node

The above figure shows that BER curve at the relaying phase – relay node to source S2 node. Here the relay node and source node have one transmitting antenna and one receiving antenna respectively. The simulated BER has nearly 10^{-3} at 25dB SNR value. The thoeretical BER approximately matches with the simulated BER.

Conclusions:

In this paper, PNC based two way relay transmission jointly with STBC in wireless networks is proposed. The simulation shows the scheme provides better BER performance at the relay node as well as destination node. The PNC provide the reduced number of transmission time slots. When the nodes are equipped with two antennas, it gives the better BER performance compared to the node equipped with one antenna.

The system model of our project has two way relay network. In future works, we have to find the throughput of our system model and we can design the cooperative communication network which will give better BER and throughput performance.

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