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Error Performance Analysis Of Physical Layer Network Coding With Transmit Diversity At Relay

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Abstract---**We analyze the error performance of the physical layer network coding (PNC) protocol with transmit diversity in bidirectional relay networks for binary phase shift keying (BPSK) over Rayleigh fading channels. It is assumed that a bidirectional relay network consists of two sources at transmitter and two sources at receiver and a relay consists of two antennas, where each source node has a single antenna and operates in a half duplex mode, and the PNC over finite GF(2) is employed. In this system, since the signal estimation of the multiple access channel (MAC) at the relay is given by the sum of two exponential functions. Then relay transmit in the form of transmit diversity (alamouti) to the source. Then finally we derive the capacity for system model. Finally we obtain outage probability, outage capacity for the end to end average bit error rate.**
Index Terms**—Bidirectional relay network, end-to-end biterror rate (BER), multiple access channel (MAC), physical-layer network coding (PNC), outage capacity and probability.**

I. INTRODUCTION

BIDIRECTIONAL relay communications have received considerable attention recently due to the high bandwidth efficiency [1]. In bidirectional relay networks, two sources exchange their information with the help of a relay. One of the most well-known protocols in bidirectional relay networks is the physical-layer network coding (PNC). In this protocol, two sources transmit simultaneously their signals to a relay over a multiple access channel (MAC) at the first time slot, and the relay forwards the XORed version of the two received signals to the two sources over a broadcast channel (BC) at the second time slot [2]-[5]. Since the PNC protocol can be easily combined with channel coding schemes and incorporated with network protocols, the performance of the PNC protocol has been widely discussed in the literature. Kim et al. analyzed the achievable rate regions for a half-duplex mode [3].

Normally, in PNC they have been used decode and forward technic in relay but in [6] they have used alamouti code in relay side,therefore Space Time Block Code (STBC) designed for a large number of transmit antennas have to be employed to achieve a high diversity order. However, the STBCs could not achieve a full code rate for more than two transmit antennas with complex constellations. Even for real signal constellations, full rate can be maintained only for particular numbers of transmit antenna [6].Compared with the receive diversity maximal-ratio combining(MRC) scheme of the same diversity order, STBCs incur signal-to-noise ratio (SNR) loss owing to the power spreading across transmit antennas. This SNR loss increases as the number of transmit antennas increases.

In [7], they investigate performance of bidirectional relay systems with multiple antennas at the source nodes that is each source node in equipped with two antennas while there in only one antenna at the relay node and they have been used detect and forward algorithm in relay. From this we get an idea.

In this paper we investigate performance of bidirectional relay systems with multiple antennas at the source nodes and also multiple antenna at the relay. We exploit the transmit diversity, the alamouti code in broadcast phase. We have been used decode and forward (DF) algorithm in relay. By this we can improve the system performance and reduce the system noise.

II. SYSTEM MODEL

Consider, the system model consisting of two sources at transmitter as well as receiver and a relay consists of two antennas. Where source node has single antenna and hence operates at half duplex mode.

We use S_1 ,S_2,S_3 and S_4 are sources in this S_1,S_2 are transmitter source node and S_3,S_4 are receiver nodes and Relay R. Consists of two antennas denoted as $R \in \{r_1, r_2\}$ respectively as Fig 1. Let m_i , denote the binary information of S_i and let X_i=1-2m_i

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denote BPSK modulated symbols of S_i where $m_i \in (0,1)$ and $x_i \in (\pm 1)$ for i=1,2.

We denote complex co-efficient channels between S_i and R by h_i and g_i channels. We also assumed that S_1 and S_3 has Line of sight (LOS) path where S_2 and S_4 also has LOS path

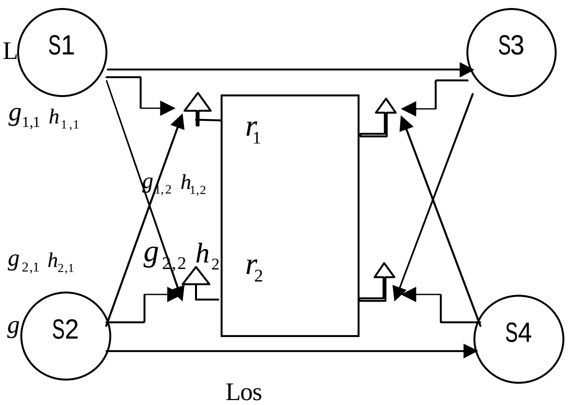

Fig.1. System model

Channels are modulated as follows: $h_i \approx CN(0,\Omega_i)$and $g_i \approx CN(0,\Omega_i)$ for i=1 to n. Where $h \approx CN(m,\Omega)$and $g \approx CN(m,\Omega)$ indicates that h and g are a circularly symmetric complex valued Gaussian random variable with mean m and varience Ω. Finally all the channel coefficients are assumed to be fixed during time slots.

During 1st time slot, the source S_1 and S_2 transmit their BPSK symbols x_1 and x_2 to relay R antennas y_{r1}, y_{r2}. Over the multiple access channel (MAC) with AWGN noise and signal at R is given by,

$$X_{s1} \in \{s_{11}, s_{12}, ...\}$$
$$X_{s2} \in \{s_{21}, s_{22}, ...\}$$

From this we conclude that we get two equation and two unknowns from this we can find value x from;

$$\begin{bmatrix} y_{r1} \\ y_{r2} \end{bmatrix} = \begin{bmatrix} g_{1,1} & g_{1,2} \\ g_{2,1} & g_{2,2} \end{bmatrix} * \begin{bmatrix} x_{1,1} & x_{1,2} \\ x_{2,1} & x_{2,2} \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$x = ((g^H g)^{-1} * g^H) * y_{ri} \qquad (1)$$

Therefore received signal is in the form of R_{yrex}

$$y_{r1} = s_{1,1} * g_{1,1} + s_{2,1} * g_{2,1} + v_1$$
$$y_{r2} = s_{1,2} * g_{1,2} + s_{2,2} * g_{2,2} + v_2 \qquad (2)$$

$$R_{yrex} = y_{r1} + y_{r2} \qquad (3)$$

Where v is the additive white Gaussian noise (AWGN) at R with $v \in CN(0, \sigma_v^2)$. The relay node R assists the bidirectional communication between transmit and receiver using PNC protocol. Where ,the PNC over finite GF(2) is employed. That is relay detects $m = m_1 \oplus m_2$, the Xored version of the two received binary information from the two sources, where $\oplus$ is the bitwise Xor operation.

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During the 2nd time slot Relay R forward the detected symbol $\hat{z}$ to all source nodes S_1, S_2, S_3, S_4 over the broadcast channel by using alamouti scheme. It sends data in the form of $u = \begin{bmatrix} u_1 & -u_2^* \\ u_2 & u_1^* \end{bmatrix}$ that splits the $\hat{z}$ signals into odd and even values then it sends the symbols like alamouti form. That sends first odd values then after send the even one. Then received signals at source S_1 is in the form of

$$\bar{y}_{s1(1)} = [|h_1|^2 + |h_2|^2] y_{r1} + \bar{n}_1 \qquad (4)$$

Then S_1 estimates x_2 by multiplying the detected received symbols y_{rex} with its own symbol x_{s1}; specifically, . Similarly, S_2 estimates x_1 and also same as S_3 and S_4.

$$y_{rex} * x_{s1} = x_2$$

III. ERROR PERFOMANCE ANALYSIS

In this section we obtain average symbol probability (ASP) of the MAC at relay and also obtain (ASP) of the alamouti (BC) at source. We then obtain capacity, probability of outage, outage capacity and ergodic capacity for end to end BER.

A. Approximation of ML Detection for Average Symbol Error Probability of MAC at Relay

In this subsection, we first introduce a very accurate approximation, so-called the max-log approximation, to the ML detection rule of (2) at R. Then we derive average symbol error probabilities of the MAC at R. Since the ML detection metric of (2) is given by the sum of two exponential functions, it is not possible to use the classical minimum Euclidean distance rule, and the error performance analysis becomes extremely difficult. In order to make the analysis tractable, we adopt the max-log approximation:

ln, $(\exp(a_1) + \exp(a_2)) \approx \max[a_1, a_2]$ which is a technique widely used in the literature [8, eq. (14.92)]. Then it is easy to show that the ML detection rule of (2) for z at R can be approximated into

$$\min[M(1,1), M(-1,-1)] \underset{\hat{z}=1}{\overset{\hat{z}=-1}{\succ \atop \prec}} \min[M(1,-1), M(-1,1)] \qquad (5)$$

It will be demonstrated numerically in Section IV that the above approximate ML detection rule gives very accurate results. We define P_{mac} as the instantaneous symbol error probability of the MAC at R.

B. Performance analysis of Transmit diversity at relay

Diversity is a technique of transmitting multiple copies of the same signal. This technique requires a number of signal transmission paths known as diversity branches and each branch carries the same information with approximately uncorrelated or dissimilar multipath fading characteristics. The diversity technique also requires combining circuit so as to combine signals from each diversity branch or select only best signal out of different received signals [1].

In wireless mobile communications, diversity techniques are widely used to reduce the effects of multipath fading and improve the reliability of transmission without increasing the transmitted power or sacrificing the bandwidth. The diversity technique requires multiple replicas of the transmitted signals at the receiver, all carrying the same information but with small correlation in fading statistics. The basic idea of diversity is that, if two or more independent samples of a signal are taken, these samples will fade in an uncorrelated manner, e.g., some samples are severely faded while others are less attenuated. This means that the probability of all the samples being simultaneously below a given level is much lower than the probability of any individual sample being below that level. Thus, a proper combination of the various samples results in greatly reduced severity of fading, and correspondingly, improved reliability of transmission.

C.Alamouti's scheme

The Alamouti's scheme is historically the first space-time block code to provide full transmit diversity for systems with two transmit antennas [1]. It is worthwhile to mention that delay diversity schemes can also achieve a full diversity, but they

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introduce interference between symbols and complex detectors are required at the receiver. In this section, Alamouti's transmit diversity technique; including encoding and decoding algorithms have being represented.

Alamouti space time encoding: In Fig. 2 has shown the block diagram of the Alamouti's space-time encoder. Let us assume that an *M*-ary modulation scheme is used. In the Alamouti's space-time encoder [5], each group of *m* information bits is first modulated, where $m = \log_2 M$. Then, the encoder takes a block of two modulated symbols x_1 and x_2 in each encoding operation and maps them to the transmit antennas according to a code matrix given by

$$X = \begin{bmatrix} x_1 & -x_2^* \\ x_2 & x_1^* \end{bmatrix}$$

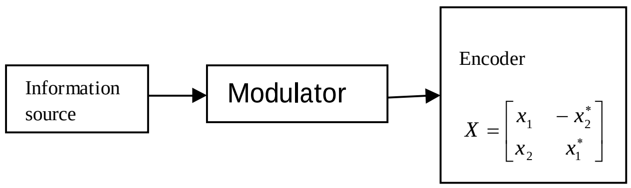

Fig. 2 Block diagram, for alamouti space time encoder.

The encoder outputs are transmitted in two consecutive transmission periods from two transmit antennas. During the first transmission period, two signals x_1 and x_2 are transmitted simultaneously from antenna one and antenna two, respectively. In the second transmission period, signal $-x_2^*$ is transmitted from transmit antenna one and signal x_1^* from transmit antenna two, where x_1^* is the complex conjugate of x_1 . It is clear that the encoding is done in both the space and time domains. Let us denote the transmit sequence from antennas one and two by x^1 and x^2 , respectively.

$$x^1 = \begin{bmatrix} x_1 & -x_2^* \end{bmatrix}$$

$$x^2 = \begin{bmatrix} x_2 & x_1^* \end{bmatrix}$$

The key feature of the Alamouti's scheme is that the transmit sequences from the two transmit antennas are orthogonal, since the inner product of the sequences x^1 and x^2 is zero, i.e.

$$x^1.x^2 = x_1 x_2^* - x_2^* x_1 \quad (6)$$

The code matrix has the following property

$$X.X^H = \begin{bmatrix} |x_1|^2 + |x_2|^2 & 0 \\ 0 & |x_1|^2 + |x_2|^2 \end{bmatrix}$$

$$= \left(|x_1|^2 + |x_2|^2\right) I_2 \quad (7)$$

where I_2 is the 2×2 matrix.

IV. NUMERICAL RESULTS

In this section, we will provide detailed simulation results to compare the performance of the network coding protocol with two scheme, the direct transmission and the alamouti scheme .As per our discussion, by using alamouti scheme in relay performance of the signal to noise ratio is better than performance of the MAC at source to relay.

A. *Performance analysis of signal to noise ratio at relay and source*

We use MAC layer for source to relay transmission. In this MAC layer we have established Maximal Ratio Combining .Therefore for SNR=10dB the BER is at 10^{-1}. Since we have established the alamouti scheme (Transmit Diversity) at relay. Relay combine data in the form of decode and forward technique it transmits in the form of alamouti scheme. Therefore, for

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SNR=10dB the BER is 10^{-3} this is shown in fig 3.By this comparison alamouti scheme is better than the normal network coding

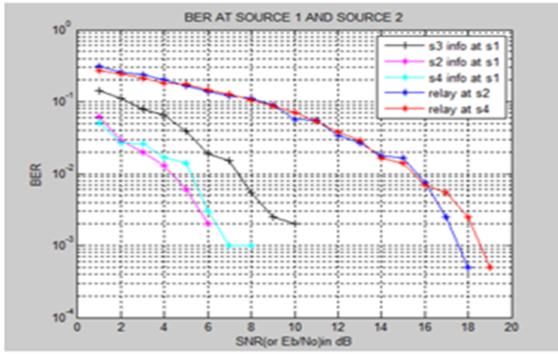

Fig. 3. End to end average BER for both mac phase and alamouti scheme.

B. *Outage Capacity and outage probability*

Consider the source are separated at distance of $d = 1$ m and the relay are situated at the centre of two sources, $d_{in} = d_2$ m for $n \in [1,2,\ldots,N]$. Here we had find both outage capacity and the outage probability .

Therefore, the SNR values increased the outage probability has been drecreased and outage capacity has been increased . Normally we have SNR=10dB then the outage probability is 0.4.From this, if SNR increased the probability has been reduced and SNR=10dB then the outage capacity is 0.94.From this, if SNR increased the capacity has been increased it is shown in fig.4 & fig.5.

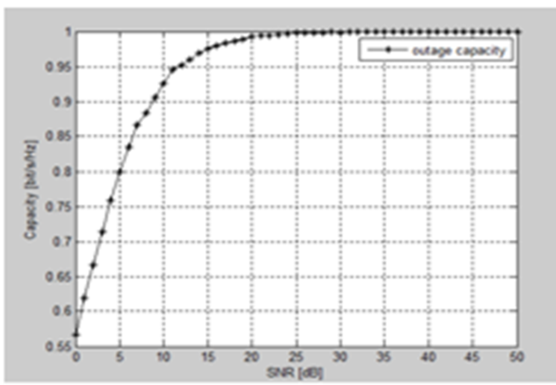

Fig. 4.outage capacity for average end to end system probability

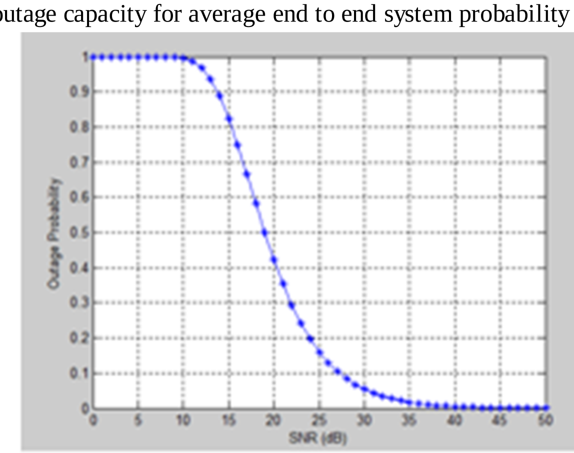

Fig.5. outage probability for average end to end system model

V. CONCLUSION

In bidirectional relay networks , previously they have presented system model with multiple antennas at the source nodes (i.e.) each source node in equipped with two antennas while there in only one antenna at the relay node and they have been used detect and forward algorithm in relay. Further, We exploited the transmit diversity, the alamouti code in broadcast phase and used decode and forward (DF) algorithm in relay node for the proposed system model. By using transmit diversity, We have improved the system performance and also reduction in system noise The outage capacity and outage probability have been evaluated for the proposed system model. As SNR increases the outage probability and outage capacity have been decreased. The confirming simulation results Fig.3 show that the proposed protocol can achieve better system performance and also Fig.4 and Fig.5 shows that as SNR increases the outage probability and outage capacity gets decreased.

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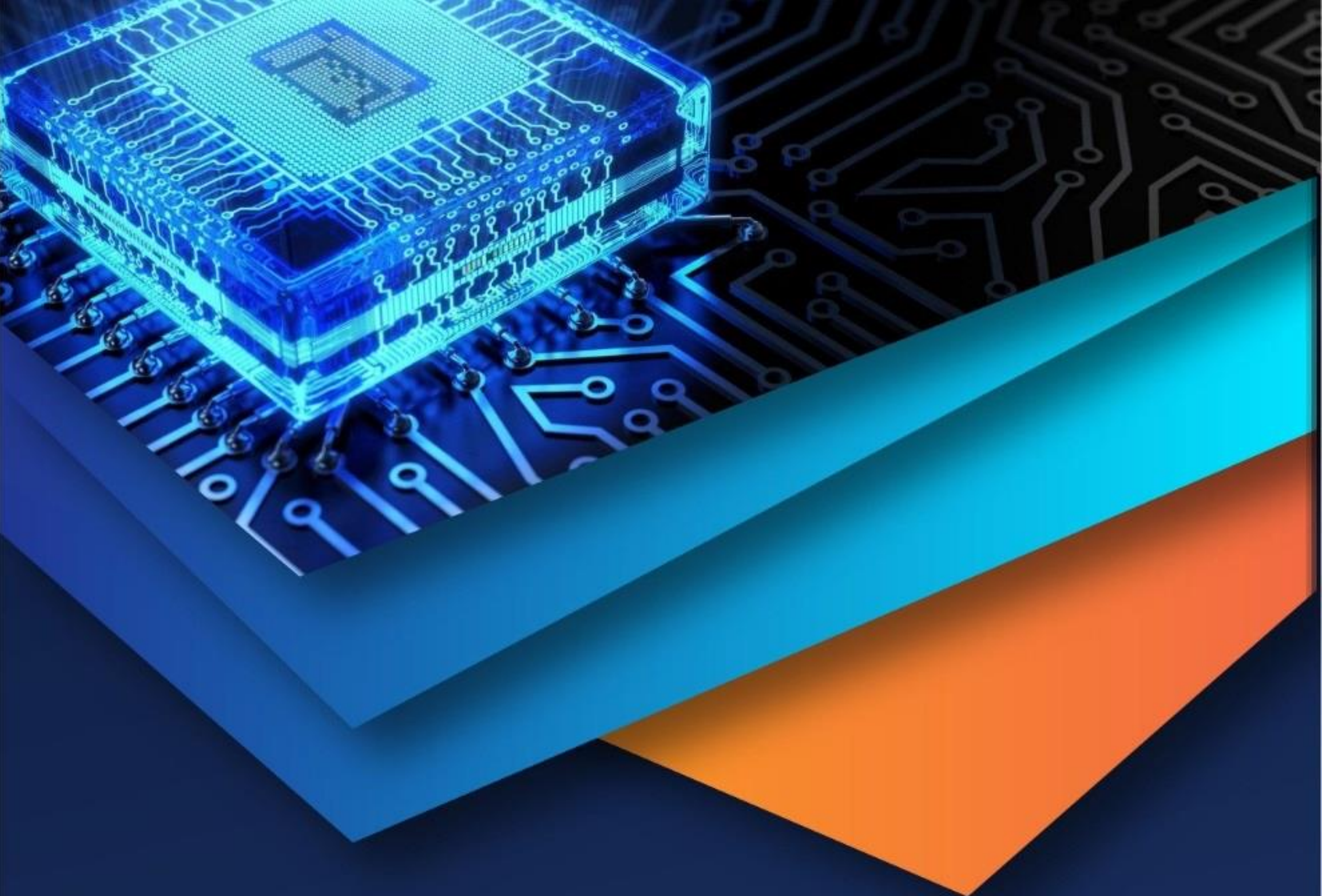

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