협력 통신 기법을 이용한 시공간 다이버시티 중계 전략

Space-Time Diversity Relaying Strategy using Cooperative Communication Technique

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요약

본 논문에서는 협력 통신 기법을 이용한 새로운 시공간 다이버시티 중계 시스템을 제안한다. 하나의 협동 그룹에 1개 이상의 중계 단말을 추가하여 프레임 에러 여부 및 채널 상태 정보 등의 상태정보를 서로 공유한다. 채널 상태 정보가 좋은 단말만을 선택하여 다중안테나를 이용한 시공간 다이버시티 중계전송을 시작한다. 또한 제안하는 중계전송을 위해 협동그룹 내의 새로운 중계단말 간의 교신 프로토콜을 제안한다. 이 방식에 대해 수신신호 대 송신신호 비(Er/Es)를 측정하여 성능이 개선됨을 증명하였으며, 플랫 페이딩(flat-fading) 채널에서의 시뮬레이션을 통해 기존의 협동다이버시티에 비해 혁신적으로 성능이 향상됨을 보인다.

■ 중심어 : | 협력 다이버시티 | 협력 통신 | 시공간 부호화 | 시공간 중계 |

Abstract

In this paper a new space-time diversity relaying strategy using cooperative communication technique is proposed. More than one relaying terminals are included in one cooperative group to share their state information, such as frame error rate and channel state information. The best terminals are selected to send bit information using space-time diversity relay system. An implementation for the proposed scheme is also presented using the TDMA cooperative protocol. The resulting receive signal to transmit signal ratio and computer simulation demonstrate that the proposed strategy outperforms the conventional cooperative system.

■ keyword : | Cooperative Diversity | Cooperative Communication | Space-Time Coding | Space-Time Relaying |

I. 서론

In the cooperative communication, one or more terminals intermediate between transmitter and receiver in cases where the direct communication is not reliable. Benefits of this include overcoming dead-spots, reduction of transmit power, and capacity increase [1-4]. The mobile radio channel may suffer

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from effects of fading. Several diversity techniques have been developed in order to mitigate the fading effects by using copies of the signal which pass through uncorrelated fading channels. Space-Time Coding (STC) has been proposed as a transmit diversity technique exploiting multiple transmit antennas, which provides diversity gain by introducing temporal and spatial correlation or the signals transmitted from different antennas [5-8]. The combination of the above two methods exploiting spatial diversity using a collection of distributed antennas has also been proposed [9][10]. Especially in [10], Miyano proposed a method about STC-cooperative diversity relaying scheme.

Because the number of relaying terminals in a cooperative group is equal to the number of transmit antennas of the employed STC, the performance of relaying transmission may be deteriorated when some relay's received signal-to noise ratio (SNR) is worse than the average SNR or its bit error rate is higher than the average. To handle these problems, this paper proposes a new strategy where more than one (N) terminals are included to the required number (M) of terminals in a cooperative group. Among $M+N$ relaying terminals, only those having superior received SNR are selected and space-time block encoded.

This paper evaluates end-to-end bit error rate (BER) performance of both non-regenerative and regenerative scheme by computer simulations. The communication protocol between relaying terminals is also to be proposed here. The performance improvement is demonstrated in terms of the receive to transmit signal ratio of relay terminals as well as end-to-end BER.

II. System Model

In the previous STC cooperation schemes, the number of relaying terminals (M) depends on the employed space-time coding. But in the proposed scheme, which is shown is [Fig. 1], one cooperation group contains $M+N$ relaying terminals. Each relaying terminal shares its status information such as the channel information and frame error information. Bared on the shared status information, the terminals with good status are selected by partnering procedure. In [Fig. 1], five relaying terminals ($M=4$, $N=1$) consist of one cooperative group. The selected relaying terminals through the

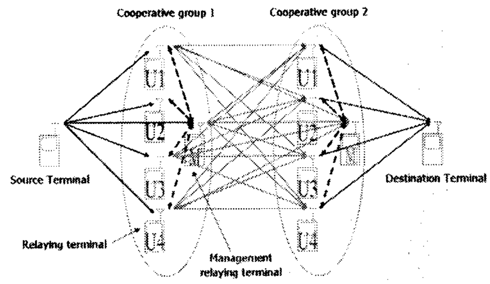

Fig 1. The proposed cooperation system model

partnering process in the first cooperative group are U1, U3, U4, and M1. On the other hand, in the second cooperative transmitted through space-time coding. Each relay terminal retransmits the received signal in non-regenerative manner or in regenerative manner. In non-regenerative manner, each relay terminal of a cooperative group encodes the received signal with different code each others without any kind of decoding, and then transmit the encoded version to the next hop simultaneously. In regenerative manner, each relay terminal of a cooperative group fully decodes the received signal, and then encodes and transmits the decoded signal as in non-regenerative case. We are attempting to achieve spatial diversity through the use of cooperative relaying with space-time code, taking into account that relay channels are noisy.

III. Cooperative Space-Time Code over Flat Fading Channel

This chapter describes the proposed cooperative diversity relaying method taking the example of two hop non-regenerative method. The flat fading environment is assumed which has the same channel coefficient while one code-block is being transmitted.

[Fig. 2] shows the conceptual diagram of the proposed system. Transmitting and relaying signals experience the fading and the thermal noise (AWGN). The

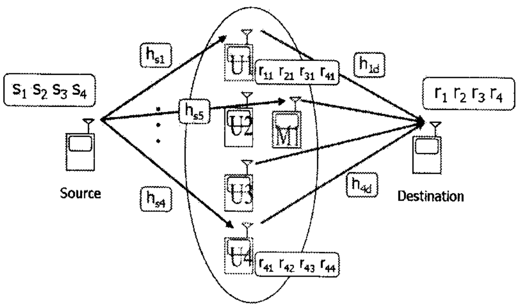

Fig 2. Proposed ST cooperation system when one more terminal is added

space-time code adopted in this paper is quasi space-time block code (Quasi-STBC) proposed by Jafarkani [7], which is presented as in Eq. (1). The coefficients in each column represent the signals sent by each relaying terminal, while those in each row are transmitted simultaneously.

$$C=\begin{pmatrix} c_1 & c_2 & c_3 & c_4 \\ c_2^* & -c_1^* & c_4^* & -c_3^* \\ c_3^* & c_4^* & -c_1^* & -c_2^* \\ c_4 & -c_3 & -c_2 & c_1 \end{pmatrix} \quad (1)$$

We model the received symbols at the relay terminals, when the source is transmitting complex symbol $s_i(i=1,2,3,4)$ to the j th relay terminal through the channel having complex fading coefficient $h_{sj}(j=1,2,3,4)$, as

$$r_{ij}=h_{sj}s_i+n_{ij} \quad (2)$$

where r_{ij} and n_{ij} are the received symbol and AWGN at the j th relay terminal, respectively. The j th relay terminal encodes a block of four received symbols with the code associated with the j th row of the symbol block C and transmits the encoded version. The received symbols r_i at the destination are described as

$$r_1= \ r_{11}h_{1d}+r_{22}h_{2d}+r_{33}h_{3d}+r_{44}h_{4d}+n_1 \quad (3)$$

$$r_2=-r_{21}^*h_{1d}+r_{12}^*h_{2d}-r_{43}^*h_{3d}+r_{34}^*h_{4d}+n_2 \quad (4)$$

$$r_3=-r_{31}^*h_{1d}-r_{42}^*h_{2d}+r_{13}^*h_{3d}+r_{24}^*h_{4d}+n_3 \quad (5)$$

$$r_4= \ r_{41}h_{1d}-r_{32}h_{2d}-r_{23}h_{3d}+r_{14}h_{4d}+n_4 \quad (6)$$

where n_i is AWGN at the destination and h_{jd} includes the effects of channel between the j th relay terminal and the destination and amplify operation at the j th relay terminal. To simplify the equations, we use the following notations,

$$H_j=\begin{cases} h_{sj}h_{jd} & (i=1,4) \\ h_{sj}^*h_{jd} & (i=2,3) \end{cases} \quad (7)$$

$$N_1= \ n_{11}h_{1d}+n_{22}h_{2d}+n_{33}h_{3d}+n_{44}h_{4d}+n_1 \quad (8)$$

$$N_2=-n_{21}^*h_{1d}+n_{12}^*h_{2d}-n_{43}^*h_{3d}+n_{34}^*h_{4d}+n_2 \quad (9)$$

$$N_3=-n_{31}^*h_{1d}-n_{42}^*h_{2d}+n_{13}^*h_{3d}+n_{24}^*h_{4d}+n_3 \quad (10)$$

$$N_4 = \; n_{41}h_{1d} - n_{32}h_{2d} - n_{23}h_{3d} + n_{14}h_{4d} + n_4 \quad (11)$$

The received symbols of the destination can be summarized as follows,

$$\begin{pmatrix} r_1 \\ r_2^* \\ r_3^* \\ r_4 \end{pmatrix} = H \begin{pmatrix} s_1 \\ s_2^* \\ s_3^* \\ s_4 \end{pmatrix} + \begin{pmatrix} N_1 \\ N_5^* \\ N_3^* \\ N_4 \end{pmatrix} \quad (12)$$

where

$$H = \begin{bmatrix} H_1 & H_2 & H_3 & H_4 \\ -H_2^* & H_1^* & -H_4^* & H_3^* \\ -H_3^* & -H_4^* & H_1^* & H_2^* \\ H_4 & -H_3^* & -H_2 & H_1 \end{bmatrix} \quad (13)$$

The signals at the relay terminals, which pass through uncorrelated channels, may have different signal-to-noise ratio (SNR) each other. For proper combining of these signals at the destination terminal. This paper proposes grouping the terminals having good SNR's. To do this, the relay terminals should share the channel information and the suitable terminals should be selected. The communication protocol for that is also to be proposed and described in the following chapter.

IV. Communication Protocol between Relaying Terminals

In a one cooperative group, there are management relay and/or assistant relay according to their operational strategies. Management relay manages the channel state information of other terminals. As a result, the management relay itself knows all the channel information of the terminals, which can be called managing mode as in [Fig. 3](a). The role of the assistant relay is the same as of the other terminals. All the terminals in a cooperative group share the channel state information, which is called shared mode as in [Fig. 3](b). Hybrid mode is the form of mixing both modes above which is shown in [Fig. 3](c). [Fig. 3] also shows the partnering procedure. [Fig. 4] shows the TDMA frame protocol for the above modes. In [Fig. 4](d) there are two managing relay with $M = 4$, $N = 2$, which shows that are the number of managing relay increases, the partnering procedure can be done more quickly.

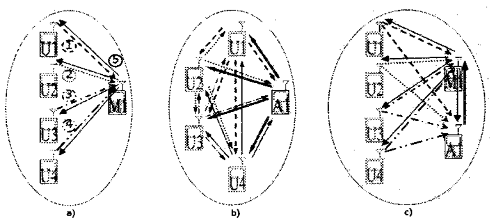

Fig 3. Partnering procedure a) one management terminal is added b) one assistant is added c) one management terminal and one assistant terminal are added

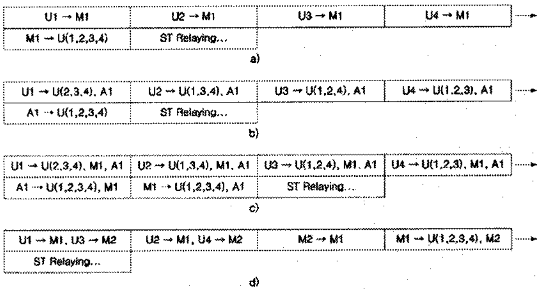

Fig 4. Partnering procedure in TDMA slot

V. Simulation

We investigate the diversity gain and the BER of the proposed scheme and the *Er/Es* of the relay terminals. It is assumed that fading is independent for each transmit and receive antenna pair and all receivers have the same noise characteristics. Furthermore, the channel is assumed to be static during the transmission of one frame which consists of 108 symbols and to be perfectly estimated in the receiver. Quasi-space time block code is assumed to be ideally assigned for each relay terminal selected among the cooperative group. In computer simulations, non-regenerative and regenerative relaying schemes are considered. In the non-regenerative type, each relaying terminal measures the signal-to-noise ratio (SNR), shares this information with other relaying terminals, and then selects the terminals with high SNR. The selected terminals retransmitting signals after normalizing the power of the received signal from Eq. (14). In the regenerative type, the selected terminals demodulate the received signals, decide the symbols, and then retransmit the space-time encode signals.

$$\hat{s}_j = r_j / |h_j| \tag{14}$$

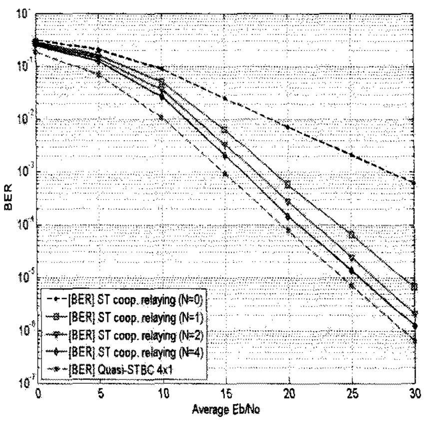

Fig 5. Performance of two-hop ST non-regenerative cooperation system

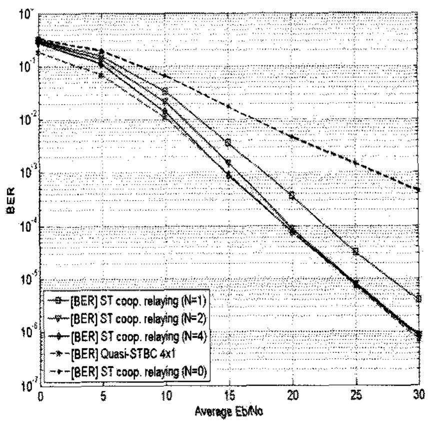

Fig 6. Performance of two-hop ST regenerative cooperation system

The space-time code used in the relaying transmission is the quasi space-time block code and QPSK modulation method is used. [Fig. 5] and [Fig. 6] are the BER curve for the non-regenerative and regenerative type for two hops. Compared with the conventional scheme with $N=0$, incase of $N=1$, the performances are improved by up to 9.2 dB and 9.0 dB when the BER is 10^{-3}, which are shown in [Fig. 5] and [Fig. 6]. As N increases, the performance gain becomes smaller which is shown in the performance curves of [Fig. 5] and [Fig. 6]. On the other hand, it is

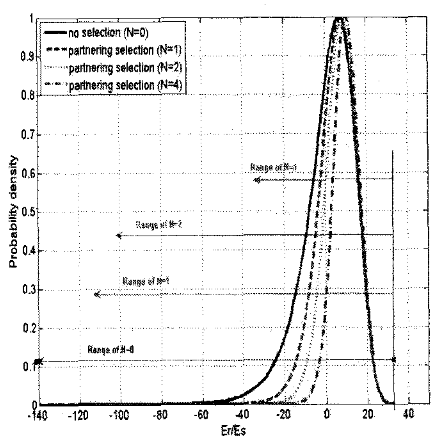

Fig 7. The histogram of *Er*/*Es* of relayer on 1st cooperative group when *Er*/*Es* = 20 dB

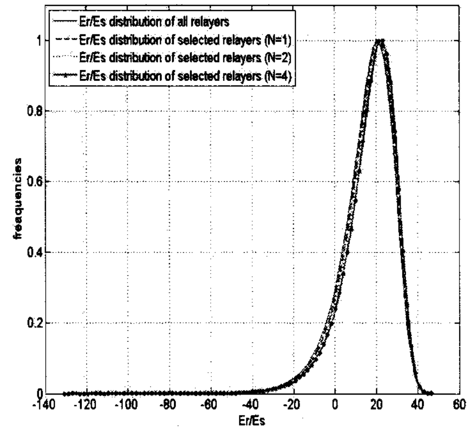

Fig 8. The histogram of *Er/Es* of relayer on 2nd cooperative group when *Er/Es* = 20 dB

meaningful to investigate the distribution of *Er/Es* incooperative relay group, which explains why the performance improvement occurs in terms of *Er/Es*. [Fig. 7] shows the histogram of the Er/Es of the selected relay terminals in the first cooperative group when *N* is 0, 1, 2, and 4. As *N* increases, the portion of the worse *Er/Es* decreases. [Fig. 8] is the histogram measured for the second cooperative group. Performance gain is almost obtained in the first cooperative group.

VI. 결론

This paper focused the multi-hop cooperative relaying system of terminals with one antenna. To mitigate the wireless fading environment, this paper proposed *M+N* cooperative group, even though *M* is sufficient for space-time encoding. The *M* relaying terminals should be selected by partnering among *M+N* after the receive-signal-to-transmit-signal ratio (*Er/Es*) being measured. The partnering protocols and procedures are also proposed. In the computer simulations, the BER performance was shown for the non-regenerative and regenerative relaying types for 2-hop, and proves that the method proposed in this paper has superior performance compared with the conventional cooperative relaying system.

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