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A Novel Relay Selection Strategy for Two User Cooperative Relaying Networks

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ABSTRACT: Cooperative diversity is one of the most efficient techniques used to overcome fading in wireless systems which can be accomplished by cooperative communication. Cooperative communications via multiple relay nodes is known to provide the benefits of increase diversity and coverage. We consider Decode and Forward (DF) cooperative diversity system where a source node communicates with a destination node directly and indirectly (through multiple relays). Out of multiple relays need to select a single best relay and then using it alone for cooperative transmission address the need for this strong coordination while still reward the benefits of increased diversity and coverage. We propose three selection methods: Single hop Mini-max, which selects based on maximizing Minimum SNR for single hop, Threshold based Selection combining, which selects relays whose received SNRs are larger than a threshold one among the relays and Threshold based Mini max Relay selection, which selects relays, to maximize the minimal SNR among whose received SNRs are larger than a threshold. Simulations illustrate the performance of the proposed relay selection methods and compared with existing algorithms. Numerical results show that the Threshold based Mini-Max relay selection has better performance than other algorithms. We have shown that the *best-relay selection* not only reduces the amount of obligatory resources, but also maintains a full diversity order ((i.e) capable of being achieved by the normal multiple-relay cooperative diversity system but with large amount of resources).

KEYWORDS: cooperative diversity, relay selection, Rayleigh fading

I. INTRODUCTION

Cooperative communication has recently to become known as a promising technique to combat fading in wireless networks.substantially, cooperative communication takes benefit of the broadcast characteristic of wireless channels. It has been established that cooperation in wireless communications in an significant manner can improve the link quality by exploiting the spatial diversity of multiple terminals [1] –[3]. Cooperative techniques are promising candidates for prominent wireless networks.

Most works so far focus on designing or analyzing relay algorithms that maximize the throughput or minimize the outage probability, given a fixed channel allocation, or minimize the frame error rate of specific cooperative coding schemes [3] –[5]. In these works, either each terminal can act as both source and relay, or/and a pre-determined cooperator is assumed. In a more general scenario, however, the relays may not be pre-determined, but have to be chosen from a set of available terminals. In [6], [7], relay selection algorithms are proposed, which search over a set of *N* candidate relays with optimization criteria as the outage probability or frame error rate.

In [8], the authors proposed a relay selection algorithm that chooses a relay node based on a predetermined threshold that guarantees a satisfying performance. This algorithm compares all the received instantaneous signal to noise ratio (lSNR) at the relay and at the destination which are denoted by $\gamma_{s,r}$ and $\gamma_{r.d}$ With a predetermined threshold γ_t Which is chosen to guarantee a satisfying performance. Then, ISNR of each relay $\gamma_{s,r}$ is compared to γ_t if $\gamma_{s,r}$ is greater than or equal to γ_t then $\gamma_{r.d}$ is compared to γ_t, if γ_{id} is greater than or equal to γ_t then the chosen relay is j. If the ISNR of all the relays fail to pass the threshold, the max, min rule is used to select the relay according to this equation k = arg max (min$\left\{|\gamma_{s,r}|^2 |\gamma_{s,d}|^2\right\}$). In [9], the authors proposed partial relay selection algorithm which does not

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require knowing the whole channel state information. The algorithm is based only on the received SNR from the source to the relay, then the best relay k is chosen according to: k = argmax$\{\gamma_{s,r}\}$. In [10], two relay selection algorithms are proposed one to reduce the number of probed relays and one to achieve the maximum spectral efficiency which is the same as opportunistic relay selection. In [11], three single relay selection schemes are investigated and then several multiple relay selection schemes are proposed. The first relay selection scheme investigated is the Best Relay Selection where the relay with the highest SNR is selected. The second one is Nearest Neighbor Selection where the relay with the strongest channel to the transmitter to the receiver is chosen. The last one is the best worse channel selection in which the relay with the best worse channel is selected. In [12] Threshold based Relay Selection Cooperation (TRSC) protocols are investigated, which generalizes threshold digital relaying to multiple relays. In this protocol only the relays whose received SNRs are larger than a threshold, which we call *reliable relays*, are allowed to retransmit.

In this paper, a Maximum relay selection is proposed; where the Relay is chosen among single path either S-R (or) R-D. In which a link, one which have maximum instantaneous SNR either between the source and the relay or the relay and the destination. The performance of the algorithm is evaluated for decode-and forward protocols. The performance of the algorithm is compared with other existing methods for relay selection.

The remainder of the paper is organized as follows. In Section II, we present the cooperative system model studied. The proposed relay selection strategy is described in Section III. In Section IV, we present simulation results of our proposed strategy in comparison with other existing strategies. This is followed by the conclusions in Section V

II. SYSTEM MODEL

We first consider a simple two-source, multiple access-relay topologies as shown in Fig.1.It shows our system model, which consists of two users, *N* RSs and a Detination.All nodes are assumed to be equipped with single antennas and operated in half-duplex mode. Two transmission stages are adopted [13]. In the first stage a source broadcasts its information to RSs and the Destination. Afterwards, a feedback from the Destination exploited to indicate failed or successful direct transmission between the user and the destination. Once a failed transmission occurs, one of the potential RSs who have correctly decoded the data from the user is selected to retransmit the user's information to the destination. This incremental relaying scheme can be viewed as an extension of hybrid ARQ in the relay context, where the relay retransmits to exploit spatial diversity. Solid lines in the figure represent the first-stage transmissions and dash lines represent the possible second-stage transmissions. For illustration, the *N*-th relay is not able to correctly decode the data from all sources, so that it does no chance to retransmit in the second stage.

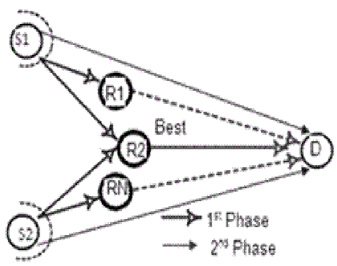

Fig 1: System Model

All Links experience independent Rayleigh fading. We assume a general modulation scheme for which the bit error probability can be expressed as $P_b(\gamma) = b\, erfc\sqrt{a\gamma}$. Where a, b > 0. Note that typically b depends on the minimum distance in the constellation and a depends on the number of neighbors with minimum distance; the bit error probability of most practical modulation schemes can be approximated by selecting (b, a). The SNRs of the S − D, S − Ri and Ri − D links are denoted by $\gamma_{sid}, \gamma_{sri}\ and \gamma_{rdi}$ respectively. To simplify the analysis, we assume that all the relays have the same average SNRs to the source and to the destination, i.e., $\gamma_{sri} = \gamma_{sr}$ and $\gamma_{rdi} = \gamma_{rd}$ for i = 1, 2, . . . ,N. Hence, the link SNRs are characterized by $\gamma_{sd}, \gamma_{sr} and \gamma_{rd}$.

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A. CHANNEL MODEL

We assume that all lossy channels suffer from slow fading: fading keeps constant across one packet and vary from packet to packet independently. We model the channel as Rayleigh fading with additive white Gaussian noise:

$$y = hx + w; \quad (1)$$

Where $y \in$ C, $x \in$ C and $w \in$ C denote the received signal, the transmitted signal and the additive noise respectively, and $h \in$ C denotes the fading coefficient. Since $|h|$ follows the Rayleigh distribution, $|h^2|$ follows an exponential distribution with mean $1\frac{1}{\lambda}$,. Thus the probability density function (pdf) of $|h^2|$ can be written as:

$$p(z) = \lambda e^{-\lambda Z} \quad (z = |h^2|) \quad (2)$$

Moreover, w is modeled as a zero-mean complex Gaussian random variable with two-dimensional variance $N0$. Then the transmit signal to noise ratio (SNR) can be defined as

$\gamma = \frac{E_s}{N0}$ where $Es = E(|x^2|)g$. Thus the instantaneous receive signal to noise ratio is

$$\gamma|h^2| = \frac{E_s|h^2|}{N0} \quad (3)$$

and the average receive signal to noise ratio is $\gamma E|h^2| = \frac{E_s}{\lambda N0}$. Here $E(.)$ denotes the expectation operation.

III. PROPOSED RELAY SELECTION STRATEGY

In the second-mode of transmission, just single relay has been selected out of N-relays to forward the received signals. This is depending on the SNR of the channel link between the sources and relay node, R_j^{best} may be a more suitable relay will prefer to complete the transmission.

The following notations are used: $\gamma_{s,r}$ denotes ISNR between the sources and relay r and $\gamma_{r,d}$ denotes ISNR between relay r and the destination.

A. SINGLE HOP MINI-MAX RELAY SELECTION

The *Single hop Mini-Max* relay selection algorithm is described as follows:

$\gamma_{sr} = Min\{\gamma_{sri}\}$
$\gamma_{rd} = Min\{\gamma_{rid}\}$
Decision is made based on $Max\{\gamma_{s1d}, \gamma_{s2d}, \gamma_{srid}\}$
Where $\gamma_{srid} = Max\{\gamma_{sri}, \gamma_{rid}\}$, $i = 1,2, \ldots N$

The drawback of the algorithm is that it consumes the powers of the relay nodes, since all the relays must be determined the maximum ISNR on both sides of the relays.

B. THRESHOLD BASED SELECTION COMBINING (T-SC)

The proposed scheme is based on the ratio of the SNR of each link to the SNR of the best link at the same instant of time .

(i.e) $\frac{\gamma_i}{\gamma_{max}}$, $i = 1,2, \ldots N$

Where γ_{max} = max $\{\gamma_1, \gamma_2, \ldots \gamma_N\}$ is the maximum SNR received at each time instant, and γi is the SNR in the ith branch, $i = 1, 2 \ldots$, N.

The combining rule is then stated as follows: if $\frac{\gamma_i}{\gamma_{max}}$ is larger than or equal to a specified threshold T (where $0 \leq T \leq 1$), the link is combined, otherwise, it is discarded. Equivalently, one could compare each γ_i, to γ_{th}, where $\gamma_{th} = T.\gamma_{max}$

The T-SC scheme thus combines only the significant link at any time, discarding the weak ones whose energy are below the threshold value. Processing resources, notably power, are therefore not dissipated in combining very weak link that have no appreciable contribution to the total combined SNR—extending battery life for mobile units.

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Significant links for different mobile situations can be selected by proper choice of *T* suitable for the fading environment and the mobile scenario concerned. The scheme compares the strength of each link to a predefined threshold, and combines only those links that pass the threshold test. Threshold based Selection combining relay selection algorithm is described as follows;

$\gamma_{s1d} > \gamma_T$ =Select s_1d Link

$\gamma_{s2d} > \gamma_T$ =Select s_2d Link

The decision is made based on $Max\{\gamma_{s1d},\gamma_{s2d},\gamma_{srid}\}$

C.THRESHOLD BASED MINI-MAX RELAY SELECTION

In this min-max relay selection the mechanism is used to maximize the minimal SNR among all users.. This equivalently means that the minimum achievable data rate of all users is maximized and the maximum outage or error rate of all users is minimized. It is described as follows

For this system model a T-Mini-max relay selection scheme is developed, , which optimizes the system performance, is selected. For different selection criteria, the selection decision procedures are different.

(i.e) $\gamma_{s1d} > \gamma_T$ =Select s_{1d} Link

$\gamma_{s2d} > \gamma_T$ =Select s_{2d} Link

$\gamma_{srd} > \gamma_T$= Select s_{rid} Link

Decision is made based on $Max\{\gamma_{s1d},\gamma_{s2d},\gamma_{srid}\}$

IV. SIMULATION AND RESULTS

In this section, numerical results are represented to evaluate the performance of Single hop Mini-max relay selection algorithm. The simulation parameters are as follows. The number of bits is N=10,000 the type of modulation is binary phase shift key (BPSK), the number of relays is three and the number of pilot bits used for channel estimation is 10 bits.

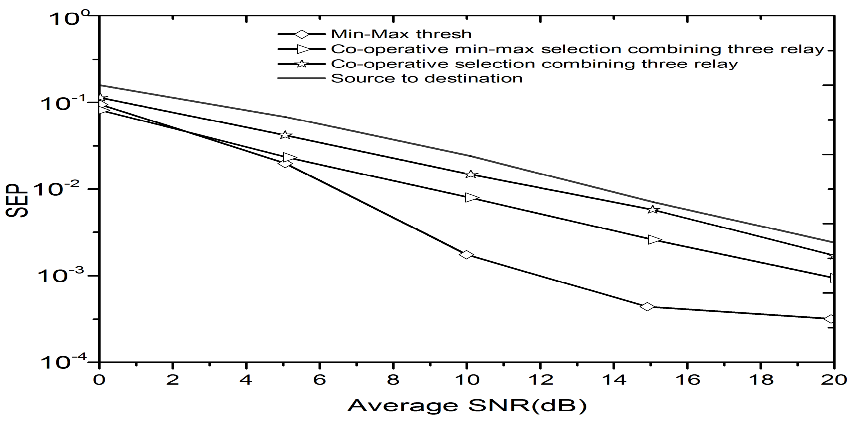

Fig. 2: Performance comparison of various types of relay selection algorithms

The BER of the network using this relay selection algorithm for Single hop Mini-max relay selection algorithm is shown in Fig. 2. The results show that BER is decreased for the proposed scheme compared to the selection combining. In 10^{-3} 0.2 dB is reduced for the proposed scheme.

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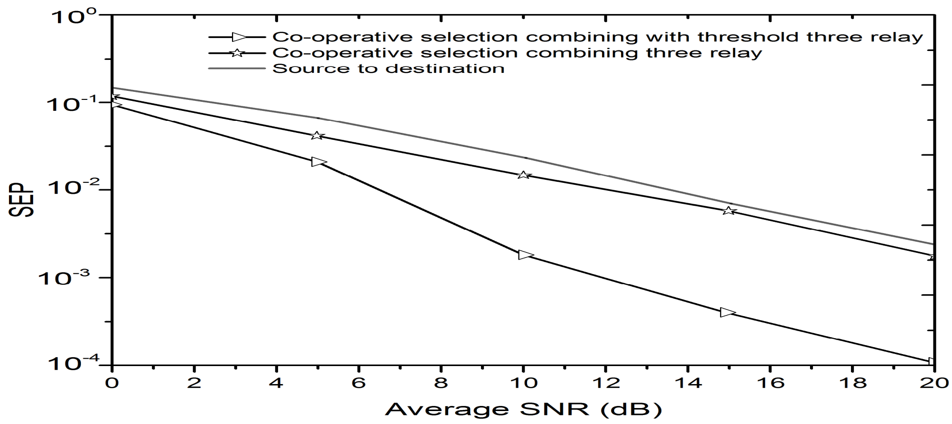

Fig.3 Performance comparison of various types of relay selection algorithms

Fig 3 shows the BER performance for the existing relay selection schemes with a proposed scheme (Threshold based selection combining).The result shows that better performance than the existing one. At 10^{-3} 5dB is reduced than the existing method. Simultaneously BER is also decreased.

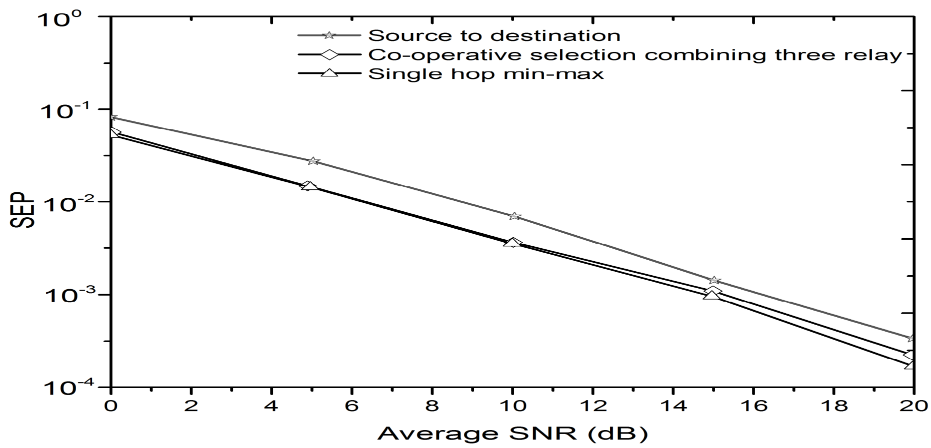

Fig.4 Performance comparison of various types of relay selection algorithms

In Fig 4, Threshold based relay selection scheme was proposed. The result shows that at 10^{-3} there is a better performance (i.e) 8 dB is reduced compared to the Mini-max relay selection scheme. By comparison with these three proposed algorithm Threshold based Mini-max relay selection achieves better performance than other two proposed schemes.

IV. CONCLUSIONS

We have analyzed the performance of the *best*-relay selection scheme for cooperative diversity networks in order to minimize the BER, operating over independent Rayleigh fading channels. In this paper, we have proposed three relay selection algorithm (i.e.) Single hop Mini-max, Threshold based Selection combining and Threshold based Mini max Relay selection. The result shows that, the first method (i.e.) Single hop Mini-max relay selection scheme

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shows good performance than selection combining scheme. In the second method, Threshold based Selection combining shows better performance than selection combining. But by comparing these two proposed relay selection schemes ,Threshold based Selection combining achieves better result than single hop mini-max method. In the third scheme, Threshold based Mini-max method achieves better performance than Threshold based Selection combining. From this I conclude that among the proposed relay selection scheme Threshold based Mini-max achieves better performance. We further provide closed-form, analytical approximations of these algorithms' performance, which help simplify the process of finding the optimal number of cooperating relays, and yet to show a Simulation results for close match between these approximations and the numerical values.

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