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PERORMANCE ANALYSIS OF COMPRESS AND FORWARD RELAY USING COOPERATIVE TWO PATH RELAY CHANNELS

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Abstract*— We consider a two-path relay channel (TPRC) with the assistance of two decode-and-forward relays alternatively. Upon successfully decoding a source packet, a relay proceeds to forward the decoded packet to the destination, which brings an interference to the other relay. Owing to this inter relay interference, the decoding result at one relay in the current time slot depends on the decoding result at the other relay in the previous time slot. Exploiting this single-slot memory, the decoding performance of the relays is analyzed using a Markov chain. Furthermore, since the relay transmission is one slot behind the source transmission, the neighbouring source packets received at the destination interfere with one another. Then depending on whether a packet is subject to the residual interference from its previous packet, the decoding performance of the destination can be similarly analyzed using a Markov chain. Thus we can obtain the overall outage probability of TPRC in closed-form expressions. Simulation results are provided to demonstrate the performance of the considered TPRC, where the effects of various parameters are evaluated. By comparisons with existing works, a reasonably good performance is achieved for TPRC with only a single-slot delay.

***Index Terms*— TRPC, Markov chain, relay transmission, source transmission, single slot delay.**

I. INTRODUCTION

In the past decade, cooperative techniques have been studied extensively in order to improve the performance of wireless communications that are vulnerable to the effects of fading as well as interference. By exploiting multiple terminals or antennas that are spatially distributed to collaborate in information delivery, the cooperative relaying is an important technique for enhancing the reliability as well as coverage of wireless communication systems. In the conventional two-hop cooperative relay system where a time-division multiple access (TDMA) half-duplex relay was deployed, two time slots were required to deliver a packet from the source to the destination. To be specific, the source transmitter has to hold its transmission until the previously transmitted packet is relayed, before a new packet can be transmitted. Although a full diversity order can be achieved, the spectrum inefficiency limits the applications of cooperative relaying, e.g., in the scenarios where the data source is a broadcast station that keeps transmitting new packets in each time slot. In order to recover the spectrum efficiency loss due to half duplex relaying, the idea of cooperative two-path relay. In a two-path relay channel (TPRC), two relays alternately help forward the packets originated at the source to the destination. When one relay forwards the previously received packet from the source, the other relay listens to the current packet transmitted from the source. This constitutes a virtual full-duplex relay system that enables the source to transmit a new packet in each time slot. Due to its potential in improving the spectrum efficiency while maintaining some diversity gains, TPRC has attracted recent research interest.

II. OPERATING PRINCIPLE

In this paper we assume perfect synchronization and channel knowledge at all receive stations about receive channels and no channel knowledge about transmit channels. For simplicity each station is equipped with one antenna, hut the scheme can be easily extended to multi-antenna stations by substitution of the scalar by vector and matrix notation. Motivated by the network coding approach we figure out that the relay stations do not have to know and therefore not to be able to decode the information for a successful transmission from the source to the destination. They just have to encode the received signals so that the destination is able to extract the information. In our approach both relay stations amplify the received signals, furthermore the one relay station performs interference cancellation to dispose past symbols and noise. To do this perfectly the interference cancelling station only has to know the amplification factor of the other relay station since of reciprocity of the inter-relay channel. These attractive linear encoding functions result in an equivalent channel model where a space-time delay code is applied.

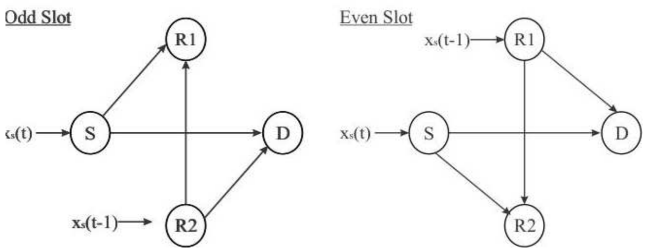


Fig.1.1 A TPRC where two relays R1 &R2 takes turn to compress and forward the packet from S & D

From the above figure, it is observed that the inter-relay channels bring a mutual interaction between the two relays. To be specific, whether the currently transmitted source packet can be successfully decoded by a designated relay depends on whether the previously transmitted source packet was successfully decoded-and-forwarded by the other relay.

That is, with or without the IRI, the decoding result at a relay could be quite different. Similarly, owing to the cooperative relaying transmission that is one-slot behind the source transmission, the signals received from the source and the relay respectively in the same time slot interfere with each other at the destination. Under such a circumstance, whether a source packet can be recovered by the destination depends on whether its one-slot previous packet has been successfully recovered and removed. This single-slot memory coincides with the property of a Markov chain that the next state depends only on the current state and not on the sequence of states that preceded it. We thus propose a Markov framework for analyzing the performance of the cooperative TPRC. The contributions of this paper are summarized as follows.

- Taking into account the effect of IRI, the state transitions between forwarding the source packet upon successful decoding and otherwise staying silent at the two relays alternatively are characterized using a Markov chain. On this basis, the outage probability of the relays is derived in closed-form expressions, which characterizes on average, how frequently the relays are able to provide cooperative relaying transmission to the source.
- With a joint consideration of the two-hop transmissions over two successive time slots, i.e., the decoding result at the relay in the first hop and whether the current packet received at the destination is subject to the residual interference from its one-slot previous packet in the second hop, the overall end-to-end outage probability at the destination is obtained in a closed form based on the proposed Markov framework.
- Extensive simulations are conducted to demonstrate the performance of the considered TPRC, where the effects of different parameters are evaluated. For better illustrations, comparisons with existing work are also provided, which demonstrate a reasonably good performance of TPRC with only a single-slot transmission delay.

A. System Model and Protocol Description

We consider a TPRC as shown in Fig. 1, where $hs;d$, $hs;1$,$hs;2$, $h1;d$, $h2;d$, $h1;2$, and $h2;1$ denote the channel coefficients from S→D, S→R1, S→R2, R1→D, R2→D, R1→R2, and R2→R1, respectively. It is assumed that all users operate in half-duplex mode and the channels are subject to flat Rayleigh fading that keep static within a time slot but change independently from slot to slot. Then we have the corresponding channel coefficient $hu;v \sim CN(0, \delta-1\ u;v)$ where $u \in \{s, 1, 2\}$, $v \in \{d, 1, 2\}$ and $u \neq v$, with the corresponding channel power gain $\gamma u;v = |hu;v|2$ that follows an exponential distribution [24], i.e., $\gamma u;v \sim \exp(\delta u;v)$. We denote $xS(t)$ as the packet originated at S in time slot t, transmitted with target data rate RT. The transmit powers at S, R1, and R2 are denoted as PS and $P1 = P2 = PR$ respectively. For ease of expression, we assume that the additive white Gaussian noise (AWGN) nv at each receiver v is of zero mean and with unit variance. As shown in Fig. 1, a new packet $xS(t)$ is originated from S in each time slot t. In the initial time slot $t = 1$, S transmits a packet $xS(1)$. Without losing generality, we assume that R2 stays silent and R1 attempts to decode this packet.

B. End -To-End Performance Analysis of TPRC

In this section, depending on whether a source packet is successfully decoded-and-relayed to the destination, we analyze the corresponding decoding performance at the destination.

From (5) and (6), we list the received signal $yd(t)$ at D in different time slots in Table I, which consists of the current packet $xS(t)$ that is transmitted by the source directly, as well as the one-slot previous packet $xS(t-1)$ that is forwarded by Rj , upon successful decoding. In existing works on TPRC, it is a common assumption that the channel is subject to slow fading that remains static during a block that consists of multiple time slots. A receiving window is then considered during which *all* source packets go through the same channel realization. This brings a correlation between the output signals at the destination, where either a relay copy is received for each and every source packet, or no relay copy is received [8].Then with a joint decoding of all received signals within the receiving window, the average capacity per time slot can be characterized. In contrast, a relatively fast fading TPRC is considered in our article where the channels keep changing independently from slot to slot, then whether a source packet can be decoded and forwarded to the destination in each time slot is not only determined by the channel realization in that time slot, but also affected by the IRI. In other words, a neat form of the channel matrix that spans over the receiving window cannot be guaranteed. Thus it is intractable to characterize the capacity of the considered TPRC by setting a long receiving window together with a joint decoding of all received signals within this window.

C. Cooperative Diversity

Cooperative diversity is a cooperative multiple antenna technique for improving or maximizing total network channel capacities for any given set of bandwidths which exploits user diversity by decoding the combined signal of the relayed signal and the direct signal in wireless multi hop networks. A conventional single hop system uses direct transmission where a receiver decodes the information only based on the direct signal while regarding the relayed signal as interference, whereas the cooperative diversity considers the other signal as contribution. That is, cooperative diversity decodes the information from the combination of two signals. Hence, it can be seen that cooperative diversity is an antenna diversity that uses distributed antennas belonging to each node in a wireless network. Note that user cooperation is another definition of cooperative diversity. User cooperation considers an additional fact that each user relays the other user's signal while cooperative diversity can be also achieved by multi-hop relay networking systems.

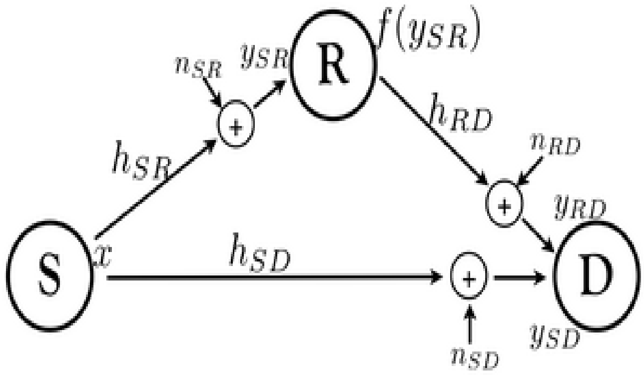
D. Relaying Strategy

The simplest cooperative relaying network consists of three nodes, namely source, destination, and a third node supporting the direct communication between source and destination denoted as relay. If the direct transmission of a message from source to destination is not (fully) successful, the overheard information from the source is forwarded by the relay to reach the destination via a different path. Since the two communications took a different path and take place one after another, this example implements the concept of **space diversity** and **time diversity**. The relaying strategies can be further distinguished by the amplify-and-forward, decode-and-forward, and compress-and-forward strategies:

- The **amplify-and-forward** strategy allows the relay station to amplify the received signal from the source node and to forward it to the destination station.
- Relays following the **decode-and-forward** strategy overhear transmissions from the source, decode them and in case of correct decoding, forward them to the destination. Whenever unrecoverable errors reside in the overheard transmission, the relay can not contribute to the cooperative transmission.
- The **compress-and-forward** strategy allows the relay station to compress the received signal from the source node and forward it to the destination without decoding the signal where Wyner-Ziv coding can be used for optimal compression.

E. Amplify and Forward

The amplify-and-forward relay protocol is a protocol defined for wireless cooperative communications. An example of a wireless communication network in which cooperation improves the performance of the system is the relay network.



In this case, the relay just amplifies its received signal, maintaining a fixed average transmit power.

A) Decode And Forward

The decode-and-forward relay protocol is a protocol defined for wireless cooperative communications. An example of a wireless communication network in which cooperation improves the performance of the system is the relay network. The relay decodes and re-encodes the received signal, then it forwards it to the destination. This processing of the signal at the relay is also know as making a hard decision, as the information sent by the relay does not include any additional information about the reliability of the source-relay link. When encoded modulation is used this protocol is also known as **Detect-and-Forward** as the processing of the relay is detection of the signal.

F. Compress and Forward (Cf):

Compress-and forward (CF) for relay networks is capacity achieving, it is only trivially so, i.e., it falls back to hashing without quantization. A potentially better strategy is to decode as much as possible and to compress the residual information, i.e., a combination of decode-and-forward (DF) and CF. Indeed such a strategy was shown to be optimal by Kang and Ulukus for a certain class of diamond relay networks consisting of a source, a noisy relay, a noiseless relay, and a destination.

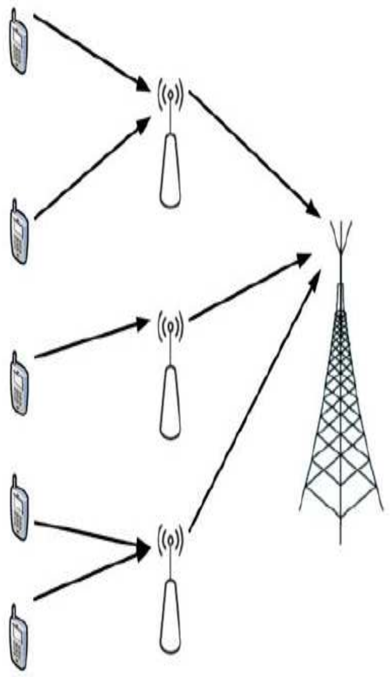
III. PARAMETRIC ANALYSIS

A. Relay Transmission

Relay in wireless networks provides another way to improve performance and potentially save energy. By deploying relay nodes, more connections between the source node and the destination node are built and data from the source node can be delivered through multiple wireless links. Due to independence among different fading channels/links, diversity gain can be obtained and SE can be consequently improved. Therefore, the time to transmit a fixed amount of data reduces and so does the consumed energy. If advanced resource allocation schemes are applied, energy can be further saved. In a typical relay system, a transmission period consists of two phases: broadcasting and multiple access. During the broadcasting phase, the source node sends data to the air, which may be received by the relay nodes or both the relay and the destination nodes. During the multi-access phase, the relay nodes or both the source and relay nodes transmit data to the destination nodes. Note that the nodes to transmit and to receive in these two phases depend on the specific protocols. The transmission schemes at the relay nodes can be *amplify-and-forward* (AF) or *detect-and-forward* (DF) transmission methods. As shown in two kinds of relay systems are considered in the literature, pure relay systems and cooperative relay systems. For the pure relay systems, the role of the relay nodes is only to help the source node to transmit data while in the cooperative relay systems, all the nodes act as information sources as well as relays.

B. Pure Relay Systems

For pure relay systems, a critical problem is how to use the relay nodes efficiently, including how many relay nodes are needed for data delivery and how the relay nodes are configured. The EE-SE trade off of pure relay systems in AWGN relay channels has been investigated, where the optimal power allocation among relay nodes is proposed to maximize EE. It has been shown that the performance (either consumed energy or data rate) depends on the transmission strategy of each node, the locations of the relay nodes, and the data rate used by each node. Two sub-optimal communication schemes, common rate and common power schemes, are proposed to capture the inherent constraints of networks, bandwidth and energy. Demonstrates the impact of the hop number, node locations, and data rate on EE. Although power allocation and the number and locations of nodes affect the EE significantly, such joint design is very complex and may not be suitable for some practical scenarios. Some simple and effective relay transmission strategies have been proposed. In order to simplify the relay network, only two hop communications are set up between the source and the destination nodes.



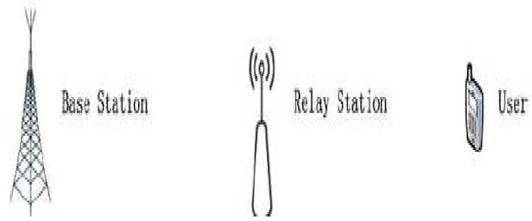


Fig.3.1 Basic Diagram of Pure Relay System

The research results have shown that relay systems can improve EE significantly. However, several important issues are still open. Relay Transmission Considering the Overhead: Additional time and power may be used for resource allocation during the relay transmission . How to minimize the total energy consumption taking the additional overhead into account is not known clearly. Energy-Efficient Bi-Directional Relay Systems: Bi-directional relaying is a booming technique and provides more opportunity to save energy.

IV. SIMULATION RESULTS

This paper proposes a novel non rigid inter-subject multichannel image registration method which combines information from different modalities/channels to produce a unified joint registration. Multichannel images are created using co-registered multimodality images of the same subject to utilize information across modalities comprehensively. Contrary to the existing methods which combine the information at the image/intensity level, the proposed method uses feature-level information fusion method to spatio-adaptively combine the complementary information from different modalities that characterize different tissue types, through Gabor wavelets transformation and Independent Component Analysis (ICA), to produce a robust inter-subject registration.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN

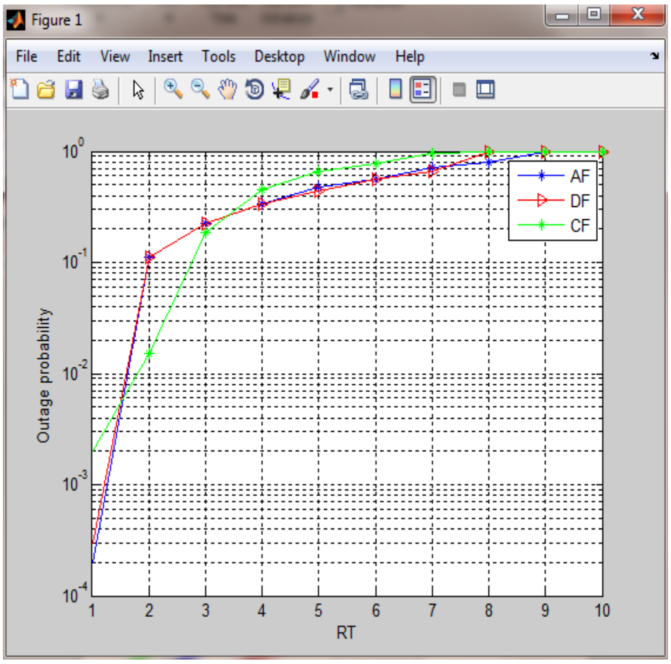


Fig.4.1 Outage Probability Vs RT:

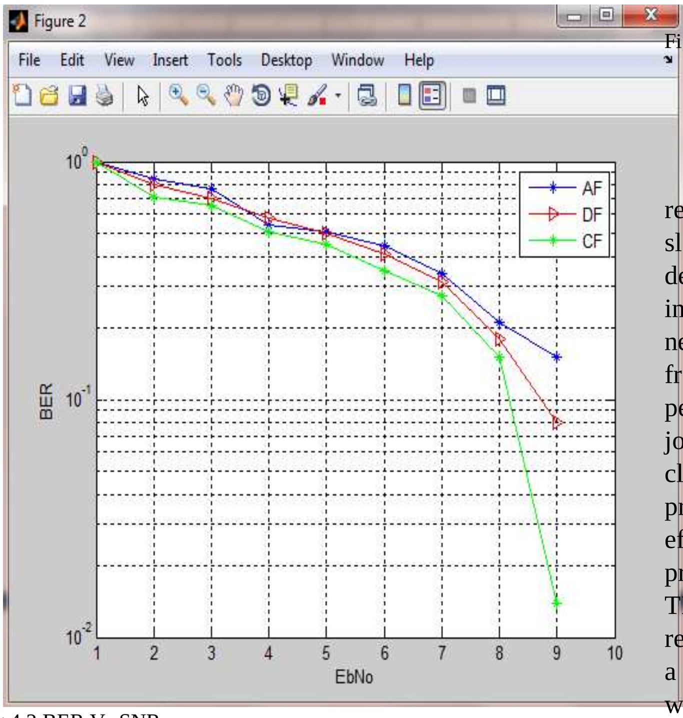


Fig.4.2 BER Vs SNR:

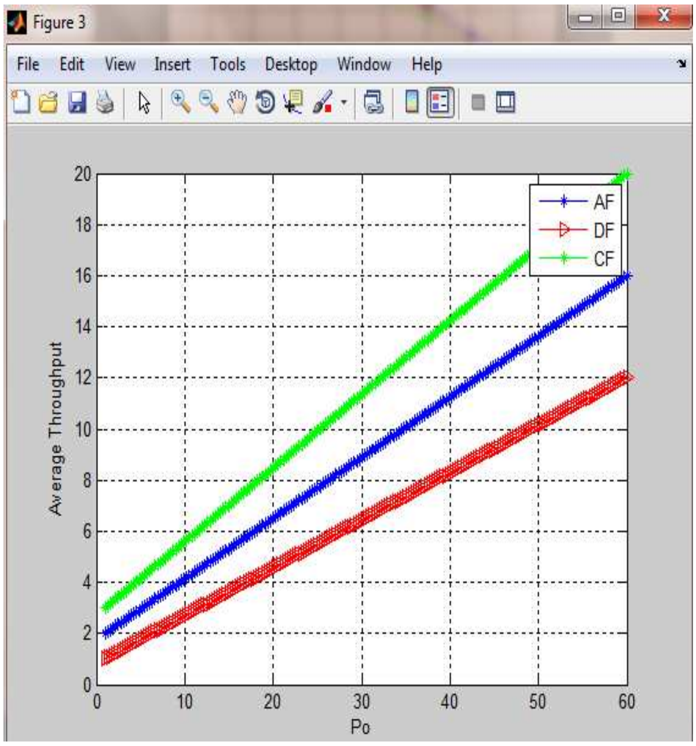


Fig.4.3Average Throughput Vs Total Power:

V. CONCLUSION & FUTURE WORK

A cooperative TPRC with two DF relays is considered on relatively fast fading channels that stay static within a time slot but change independently from slot to slot. In view of the dependence between the two relays that is brought by the inter-relay channels as well as the dependence between the neighbouring packets received at the destination, a Markov framework is established to analyze the decoding performances of the relays as well as the destination. With a joint consideration of all possibilities over the two hops, closed-form expressions are derived for the end-to-end outage probability and average throughput of TPRC. To evaluate the effects of different parameters, simulation results are provided to demonstrate the performance of the considered TPRC. By comparisons with existing relay networks, a reasonably good performance is achieved for TPRC with only a single-slot transmission delay. A possible extension of our work is to develop a Markov framework for a general multi-path relay system with opportunistic relaying, in which the dependence between the relays can be similarly analyzed. By allowing the source to transmit simultaneously with the opportunistic relaying in each time slot, this multi-path relay channel is expected to achieve a higher spectrum efficiency compared to the conventional opportunistic relaying networks in which two time slots are required to deliver a source packet before a new packet can be transmitted, while maintaining a higher diversity order compared to the cooperative TPRC in which only two relays are deployed.

We can use other relay types instead of decode and forward relay. The Gaussian relay channel when the relay and destination have correlated noises. This noise model introduces a new wrinkle in the analysis of decode-and-forward relaying, which removes the correlation information. We derive specific relationships between the channel gains and correlation coefficients for which decode-and-forward and compress-and-forward are capacities achieving, thereby increasing the class of relay channels for which capacity is known. We also show the relative performance of these two strategies against each other and against the max-flow min-cut upper bound for a range of channel conditions and noise correlations.

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