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Performance of Multi-Antennas Multi Hopping Relay System

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Abstract

In this paper, multihop cooperative relaying system will be studied. Multi-antennas system will be applied at multi hopping relay nodes to improve Signal to Noise Ratio (SNR) of the transmitted signal at its destination which is not clarified until now. The performance of the system will be compared with using single antenna at relay nodes under different kinds of modulations. Analysis of the system will be made. Fixed power amplify and forward strategy will be used at relay nodes. The multihop system with different number of antennas introduces the benefits of diversity. The performance of multi hop multi-antennas gives improvement in performance approximately 4dB than multi hop single antenna system at symbol error rate (SER) equal to 10^{-2} in two hops using BPSK modulation technique.

Keywords- cooperative relay, multihop, fixed power gain, MRC and multi-antennas.

I .Introduction

Wireless network will be exposed to different channel problems such as fading and path loss. To overcome these problems, relay will be used. Different types of relays will be introduced such as decode-and-forward (DF), amplify-and-forward (AF) or compress-and-forward (CF) **[1]**. Amplify- and-forward relaying technique offers a simpler hardware circuitry for its implementation compared to decode and forward relaying. In this paper, amplify and forward will be used. There are some techniques to improve the performance of the network. One of these techniques is multi hopping **[2], [3]**. The referenced cooperative protocols involve only a single intermediate relay terminal between the source and destination terminals that are considered in **[4]** and these protocols can be easily extended to the case of multiple relaying terminals in parallel or multihop scenarios that cooperate to transmit to the actual destination or next relay. The idea of cooperation is explained in **[5-7].** Other technique to improve the system performance is multi-antennas system that can provide increased in data rates by creating multiple parallel channels and robustness against channel variations by increasing diversity. As far as we know many papers studied the multi-antennas single relay channel **[8], [9]**. But multi-antennas multi hopping at relay are not clarified until now.

In our paper, multi-antennas technique will be applied on multi hop (multi relay) system. This paper presents how infrastructure-based fixed relays with/without multiple antennas can be used for providing diversity gains for a wireless communication and this will be applied on multi hop system. The concept of multihop and multi-antennas diversity will be introduced; where the benefits of spatial diversity are achieved from the concurrent reception of signal that has been transmitted by multiple previous terminals and multiple antennas. The performance of cognitive multihop relay network will be investigated under different number of hops, different number of antennas at relays under different types of modulations. One hop and two hops will be introduced using multi-antennas.
The rest of this paper will be organized as follows: Section II presented multihop system model. In Section III, Simulation results will be made. Finally, conclusions will be made in Section IV.

II. Multihop System Model

In multihop relaying communication, the data transmission technique between source and destination is based on a certain number (k) of intermediate relay nodes transmit/receive antenna using k+1 time slots. The interference between nodes in the system will be neglected. Furthermore, we assume that the source node has complete channel state information (CSI) of all links in the relay network. In practice, the CSI can be using training symbols and feedback to the source node. The relay nodes are assumed to know only the local CSI of their respective links to the source and destination as it is assumed to know its local source to destination and relay to destination channel gains. Relay nodes that used in the system assumed to be fixed power half-duplex relaying. All channels are Rayleigh fading channels with additive white Gaussian noise (AWGN) and Channel coefficient (response) is a zero-mean complex Gaussian random variable (RV). The channels are considered to be slow fading, so that the coefficients are constant over the time duration of one symbol, that is, over one time slot. The channel coefficients and AWGN signals are all mutually independent. Finally, the destination combines the signals from the source and the relay nodes with maximum ratio combine (MRC) to decode source message.

I.I Fixed power amplify and forward relay

There are two AF relaying models fixed power and fixed gain relaying. In fixed power relaying, the relay adjusts its gain as a function of the source-relay (SR) channel gain such that its instantaneous transmit power, when averaged over the noise in the SR channel and the data symbols, is fixed. On the other hand, in fixed gain relaying, the relay gain is fixed. As a result, its instantaneous transmit power depends on the SR channel gain. The fixed gain is set so that the relay meets an average power constraint. While fixed gain relaying is considered easier to implement, fixed power relaying simplifies the design of a power amplifier at the relay **[10].** In multihop system, i^{th} relay will be a source to the $i+1$

relay. When a Relay i transmits its signal, it needs to a constant power Pi **[11], [12].** Let β_i denote the signal amplification factor at Relay i which will be expressed as follows,

$$\beta_i = \sqrt{\frac{p_i}{p_j\left|h_{i,j}\right|^2 + n_{i,j}}} \quad (1)$$

Where $n_{i,j}$ is the additive white Gaussian noise (AWGN) power of the link between transmitting node j and relay node i and p_j, p_i are the power of the transmitting node and relay node, respectively. Thus, a relay inverts the bad effect of its link.

I.II Multi-antennas multi hop system model

1. One hop multi-antennas system model

Wireless cooperative relay system using multi-antennas at the relay will provide multiple copies of the same information signal which are transmitted over multi path than using only one antenna. As illustrated in Figure 1 using two antennas in one hop (one relay) system and one antenna at source mean that the signal transmitted from the source will be broadcast over two channels and then the received signals at the relay at the first time slot are expressed by

$$y_{s,i_n} = \sqrt{P_s}\, h_{s,i_n}\, x + n_{s,i_n} \quad \textbf{(2)}$$

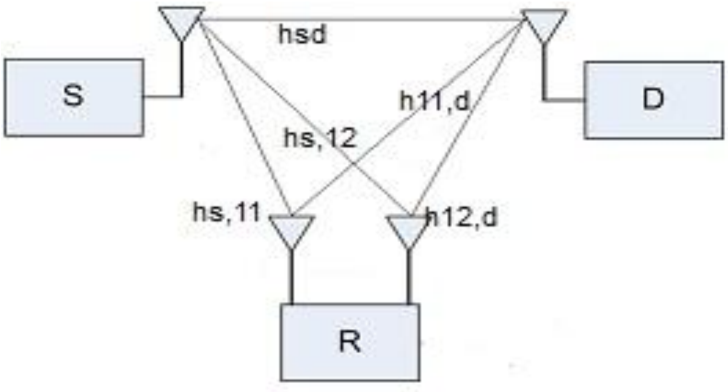

Fig. 1: One hop with two antennas system model.

Where x is the zero-mean and unit-energy transmitted symbol, P_s is the source power, $h_{s,in}$ is the channel response between source and relay number i with antenna number n and $n_{s,i_n} \sim CN\,(0,\ \sigma^2_{s,i_n})$ is the complex Gaussian noise samples between source and relay. The received signals at the destination at the same time slot is,

$$y_{sd} = \sqrt{P_s}\, h_{sd}\, x + n_{sd} \quad \textbf{(3)}$$

At the second time slot, relay will combine the two signals using MRC and amplify it with fixed power gain (β_i) and then broadcast to destination using its two antennas as each antenna will broadcast combined amplified signal to destination in different channels. In MRC suitable weight (w) to each receiving signal will be selected depending on the value of the SNR of the receiving signal at the receiving node.

Then the maximal ratio combined signal at relay is introduced by,

$$X_i = \sum_{n=1}^{m} w_{s,i_n}\, y_{s,in} \qquad for \begin{cases} n = 1,2 \ldots m \\ i = 1,2, \ldots, k \end{cases} \quad (4)$$

As m is the number of antennas at the relay. Then X_{in} will be sent to the destination and the received signal at destination will be donated by,

$$y_{i_n,d} = \beta_i\, h_{i_n,d}\, X_{in} + n_{i_n,d} \quad \textbf{(5)}$$

Finally, all the received signals at destination through all time slots will be maximal ratio combined and will be defined as,

$$Y1_{(MRC)} = y_{sd}\, w_{sd} + \sum_{n=}^{m} w_{i_n,d}\, y_{i_n,d} \quad (6)$$

2. Two Hop Multi-Antennas System Model

In this section, by increasing number of relays with two antennas at each relay, it gives the signal the chance to go through more paths than one hop with two antennas and two hops with one antenna. At the first time slot, source broadcast its signal and then destination will receive it and also the two relays with two antennas will receive it through four different paths. The received signal at each relay at each antenna will be given by Equation **(2).** Then at the second time slot each relay the received signals will also be combined with MRC using a suitable weight. The combined signal at each relay can be expressed using Equation **(4)** and then the combined signal will be amplified using β_i that can expressed using Equation **(1)** and forward to the destination and to the second relay. The received signals from each relay at the destination can be determined by Equation **(5)**.

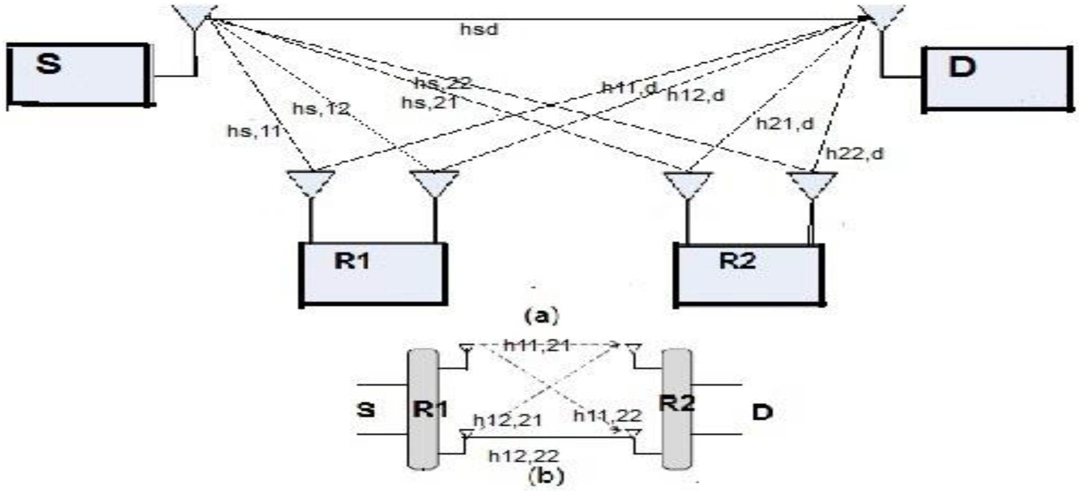

Fig. 2: Two hops with two antennas system model

As illustrated in Figure 2 in the same second slot the first relay send its combined and amplified signal to the second relay through four paths so the received signals at the second relay can be expressed by,

$$y_{i_n,(i+1)_n} = \beta_i X_i h_{i_n,(i+1)_n} + n_{i_n,(i+1)_n} \quad \textbf{(7)}$$

At the third time slot, the four signals will be combined with MRC using a suitable weight

The maximal ratio combined signal at the second relay is given by,

$$X_{i+1} = \sum_{n=1}^{m^2} w_{i_n,(i+1)_n} \, y_{i_n,(i+1)_n} \quad (8)$$

Then X_{i+1} will be amplified using β_{i+1} and then transmitted to the destination. The received signal at destination can be expressed as,

$$y_{(i+1)_n,d} = \beta_{i+1} X_{i+1} h_{(i+1)_n,d} + n_{(i+1)_n,d} \quad (9)$$

Finally at the destination , all the received signal through the three time slots will be maximal ratio combined and then the final combined signal equation is donated by,

$$Y_{2(MRC)} = y_{sd} \, w_{sd} + \sum_{n=1}^{m} w_{i_n,d} \, y_{i_n,d} + \sum_{n=1}^{m} w_{(i+1)_n,d} \, y_{(i+1)_n,d} \quad (10)$$

III. Simulation Results

In this part, an approximate symbol-error-rate (SER) will be presented versus signal to noise ratio for multi-hop system with K relays with different number of antennas at the relay and for several modulation schemes. Modulation schemes that studied are Binary Phase Shift keying (BPSK), Quadrature Phase Shift keying (QPSK) and 8-Phase Shift Keying (8PSK). The total frame duration is equal to 200 ms. the number of packet is equal to 5000.all the result that will be taken after all signals from all the chanells are combined using MRC. It can be shown from Figure 3 and Figure 4 that BPSK is the modulation scheme that gives good performance in multihop system. In Figure 3 using two antennas at the relay in one hop system model improve the system performance than using one antenna at the relay in also one hop system model. For example at BPSK at SER equal to 10^{-2} the SNR in two antennas differs from one antenna in one hop system approximately by 3 dB. In Figure 4 at BPSK in two hops system using two antennas at relays improves the performance when SER equal to 10^{-2} by approximately 4 dB than using only one antenna. These results prove that by increasing number of hops and number of antennas the performance of the system will be improved.

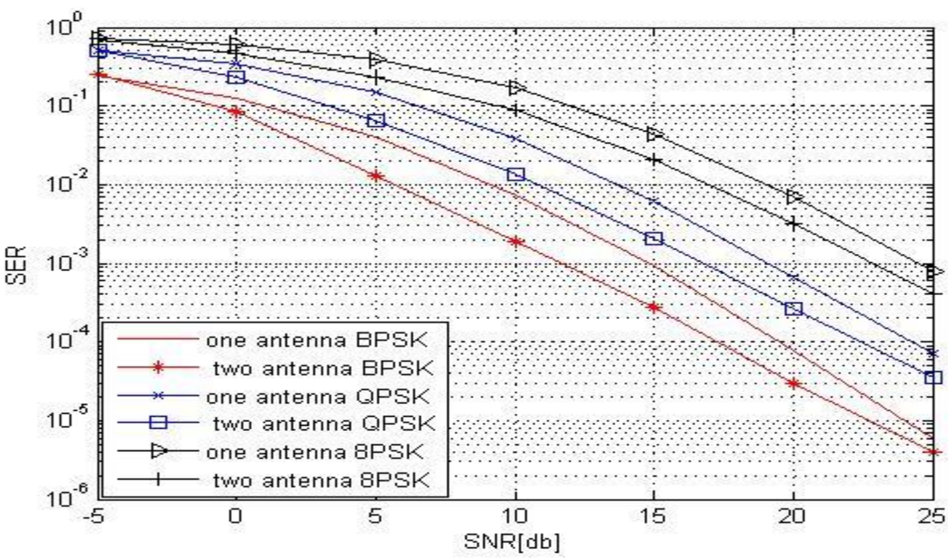

Fig. 3: SER performances for different modulation scheme in one hop one and two antennas.

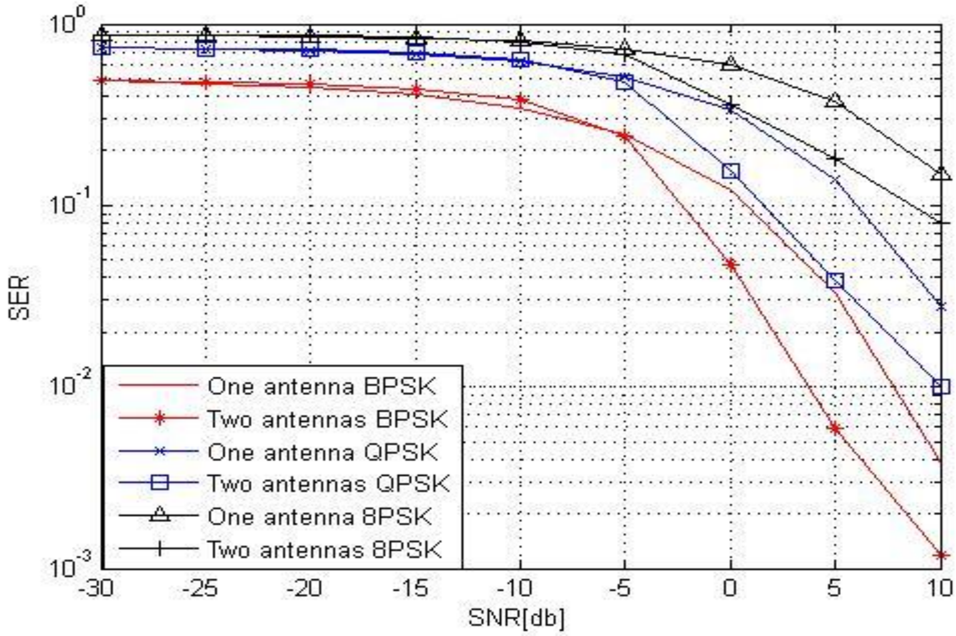

Fig. 4: SER performance for different modulation scheme in two hops one and two antennas.

IV. Conclusions

Multi-antennas multi hops wireless communication systems with K fixed power amplify and forward cooperative relays were introduced at various modulation schemes. It can be obvious that using multihop multi-antennas system improves the performance of the system approximately by 4dB than single antenna multihop system but if this number of hops increases over specified number, the interference will increase. To avoid this interference, the system will be more complex.

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