An Outage Probability in Cooperative MIMO Under Slow Fading Channel

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Abstract

Slow fading channel one of the most important channels which appears widely in cellular mobile system. Although, it has several problems such as bad effects of fading which cause an attenuation to the signal. This paper presents a new scheme in cooperative communication system under slow fading channel to enhance and increase the quality of communication systems performance. This new scheme is called a cooperative multiple input–multiple output Antenna. The main idea of this scheme depends on transmitting multi copy of message via tow paths. Its' performance has compared with MIMO technique in term of outage probability. Thus, the negative effects of fading are mitigated and the outage probability is enhanced. Furthermore, the reliability in communication system under slow fading channel has improved.

Keywords - Slow Fading Channel, Cooperative MIMO, Outage Probability.

1. Introduction

In conventional communication systems, a single antenna at transmitter and receiver is used. It is called Single Input Single Output (SISO). Although this technique has served the humanity for a long time and is still served, it has faced a lot of challenges in a real life. The main challenge is the fading problem which causes an attenuation to the signal. Beside, it has a limited capacity and no diversity. Hence, the reliability is weak. All these problems effect negatively on the outage probability in wireless communication that increase the information signal losses. During the late of 1990s, Dohler and Said have introduced Virtual Antenna Arrays (VAAs) [1]. The new advanced technique is called Cooperative Communication. This technique has the ability to reduce the undesired effects of fading, limited capacity, and reliability. This is based on using each terminal (user) as virtual antenna with each other. In another word, users which have a single antenna, can cooperate with each other at the time of transmitting data. This method enhances communication quality, increases capacity, and reliability and reduces the outage probability [2].

However, due to increasing the users' number and demanding on high data rate services, with huge capacity, and other related problems, new techniques are proposed in wireless communication field. One of this success techniques is called Cooperative Multiple Input-Multiple Output (MIMO) Communication [3,4]. Cooperative MIMO

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scheme uses multiple antennas at both transmitting and receiving terminals. It can effectively mitigate the bad effects of fading in wireless channel and then decreases the outage probability. These antennas are shared by all users. So multiple transmitting and receiving antennas scheme is created here. As a result, the system performance is enhanced [5]. In recent years, Cooperative MIMO Communication has been studied intensively in both industry and academic.

One of the first studies that applied CMIMO in wireless communication system is reported in [6]. In this paper, the capacity and outage probability behavior of the MIMO and cooperative communication systems are analyzed. The analysis is based on the underground tunnel channel model. For MIMO system, this study proves that the MIMO capacity in underground tunnels follows either a log-normal distribution in low SNR regime or a normal distribution in high SNR regime. The optimal MIMO antenna geometry design scheme is proposed. For cooperative communication systems, the outage probability is calculated of such systems in underground tunnels. [6] has proposed an outage-optimal cooperative relay assignment protocol. Its performance significantly outperforms the existing relay assignment protocols in underground tunnel with term of outage probability . The study in [6] can be considered as a special case of CMIMO because it just solves a problems which have a short time and distance.

It is also found that the CMIMO is convenient technology for 4G standards [7]. Cooperative MIMO Communication scheme is only concerned with the base station to mobile station channels, which are fixed to mobile channels [5].

An survey on the cooperative MIMO technique (CMIMO) and its applications in wireless networks field, including wireless sensor networks (WSN), cellular system and mobile ad-hoc is found in [1]. Using the CMIMO technique, network data rate is significantly enhanced, and the consumption of energy is minimized. Representatives CMIMO systems are discussed in term of CMIMO gain. To provide practical CMIMO systems, it is important to model the cooperation overhead and balance the CMIMO gain results [1].

As mentioned previously, slow fading channel is used widely in cellular mobile system. Actually, this channel has the same problems which often appear in other channels in wireless communication. In fact, several studies solved some of these problems, but there is no study yet applies cooperative MIMO technique on slow fading channel to decrease the outage probability.

The purpose of the proposed scheme is to minimize the outage probability and increasing the diversity gain in the communication systems under Alamouti Space Time Block Coding (STBC). This scheme is applied on cellular mobile system. This paper is organized as follow: section 2 is the previous studies in the same field, section 3 is the methodology which is used, section 4 is the results and section 5 is conclusion.

2. Related Work

Study in [8] present that decode and forward (DF) better than compress and forward (CF) and even approaches the lower outage bound when the relay is close to the transmitter. Whereas the relay is close to the receiver, CF performs better than DF. CF approaches the lower outage bound when the relay approaches the receiver.

Proposed work in [9] evaluates the performance of V-BLAST with several detectors in slow fading channels. The results of this scheme is compared in the proposed work. [9] proved that the MIMO is an important key technology for the Fourth generation wireless networks.

[10] studied the secrecy outage of a two-user slow fading broadcast channel. This work finds that the region can be effectively expanded with high available power, good average channel qualities or loose secrecy outage probability constraints.

Two strategies are proposed in study [11] to dynamically select one out of a pool of M slow fading channels, modeled as autoregressive processes of order 1. Study also suggest to adopt a randomized strategy when one channel shows higher autocorrelation. Study finally propose two ways to approximate a best response selection strategy for the transmitters.

The proposed hybrid BS-TDMA/SDMA in [12] provides a significant throughput gain over the conventional hybrid BS-TDMA/SDMA when the inter-cell interference level is high and each BS supports the small number of user stations. The hybrid BS-TDMA/SDMA in slow fading channel can be considered as a potential candidate for the practical multi-cell downlink MIMO systems using BS cooperation.

3. Methodology

3.1 Transmission and Receiving Mechanism

In communication real life, a lot of channels are used for transmitting and receiving data, e.g AWGN, Fast Fading Channel and Slow fading Channel. Actually, the type of channel used depends on some parameters such as communication environment, position of the users and base station. In this work, the research methodology and results are built on the basis of slow fading channel type. Slow fading is a result of buildings shadowing, mountains, hills and other objects. This thesis focus on 2x4 Cooperative MIMO scheme as shown in Figure (1). The same scenario is occurred in a different antenna numbers of cooperative MIMO scheme.

Let us assume that the tow users in cellular mobile network communicate system with a base station. Each user has two antennas for transmitting and receiving, while the base station has four antennas. This system type is called a 2x4 cooperative MIMO antenna depends on numbers of antennas at transmitting and receiving terminals and numbers of antennas at base station. In cooperative MIMO communication, each user behaves as a source and also acts as a relay. The base station supervises all the communications activities. From the point of view of user 1, the cooperation between tow users is achieved when the user 1 transmits 4 copies of its information message through two paths. The first two copies travel via direct path between the user 1 and base station. The remaining of tow copies travel to the base station via user 2 as cooperating partner. The same scenario is occurred with user 2 . The mechanism of transmission is reciprocal process. In the first time slot, when user 1 transmits to the base station, the cooperating partner is in hibernate case (stop transmission). In the second time slot the reverse operation is occurred, where the cooperating partner transmits, while user 1 is in hibernate case, as shown in the table1.1. The same scenario is occurred to others type of cooperative MIMO depends on the number of antennas at both transmitter and receiver terminals.

Table (1): transmitting cases of user and partner

Terminal	Time Slot 1	Time Slot 2
User 1	Send	Hibernate
Cooperating partner	Receive	Send
Base station	Receive	Receive

Actually, the result of transmitting multi copies via different paths appears as an increasing in capacity and diversity gain, hence more reliability has been ensured. If one path is weak, then a copy of the data received on another path maybe just fine. In fact, transmitting multi copies of information message via different paths is the main difference between MIMO technique and cooperative MIMO scheme. where one path only is used for transmitting data on MIMO technique. Figure (1) shows the model of 2x4 cooperative MIMO communication between two cellular users and base station [5].

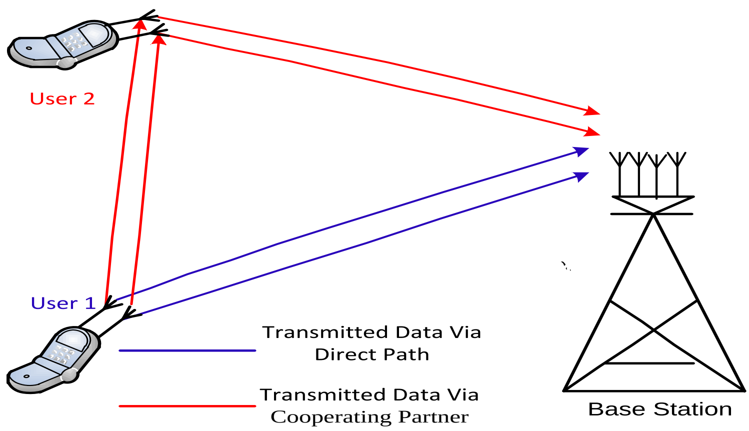

Figure (1): The model of 2x4 cooperative MIMO communication between two cellular users and base station.

3.2 Outage Probability Analysis

The outage probability P_{out}, is one of the typical performance criteria of diversity systems operating over slow fading channels [13]. In a non-cooperative technique, the outage probability in slow fading channel is usually high [5]. Hence to overcome this problem, a proposed cooperative MIMO scheme is applied to decrease the outage probability under three mechanism of data transmission, Alamouti, O-STBC and QO-STBC. Typically, the user 1 transmits multiple copies of information message via tow paths. First path is considered a non-cooperative, where user 1 transmits direct to the base station. During this transmission, the channel is slow fading with instantaneous SNR, and instantaneous capacity of MIMO [5,13]. The capacity of MIMO is given by Equation (1)

$$C = \log_2 \det\left(I_{N_R} + \frac{SNR}{N_T} HH^H\right) \text{ [14]} \quad (1)$$

Where I_{NR} is the unit matrix, N_T is the number of transmitter antennas, H is the channel information or channel matrix, and H^H is the transpose of H matrix.

If a data rate R code is used, then the channel will be in an outage case, whenever C < R, as the Equation (2) implies, when $C_{(MIMO)} < R$, the outage case is called the outage probability [5]. The outage probability of slow fading MIMO channels with CSIT distribution for a transmission rate R is defined as [15]:

$$P_{Out(MIMO)} = Pr\left\{\log_2 \det\left(I_{N_R} + \frac{SNR}{N_T} HH^H\right) < R \right\} \text{ [15]} \quad (2)$$

Equation (3.3) indicates that the outage probability occurs when the data rate (R) is more than the capacity.

The outage probability is found by summation the probabilities density function (PDF) of SNR over the outage event. The second path which is used to transmitting is via cooperating partner. It is considered as a Cooperative MIMO channel. In this case ,computation of the outage probability is complicated [13] because there are many SNRS, SNR1, SNR2, SNR3,.. SNRn [10]. Actually, the capacity of cooperative SISO antenna can be given by Equation (3)

$$C_{CSISO}(SNR_{1,BS}, SNR_{2,BS}) = (0.5)\log_2(1 + SNR_{1,BS,}) + 0.5\log_2(1 + SNR_{2,BS}) \text{ [5]} \quad (3)$$

Whereas the Capacity of Cooperative MIMO antenna is given by Equation (4)

$$C_{CMIMO}(SNR_{1,BS}, SNR_{2,BS}) = (0.5)\log_2\left(I_{N_R} + \frac{SNR}{N_T} HH^H{}_{1,BS,}\right) + 0.5\log_2\left(I_{N_R} + \frac{SNR}{N_T} HH^H{}_{2,BS}\right) \quad (4)$$

Where I_{NR} is the unit matrix, N_T is the number of transmitter antennas, H is the channel information or channel matrix, and H^H is the transpose of H matrix.

4. Results Analysis

This section shows and discusses a variety results of the proposed scheme for a cooperative communication system under slow fading channel that uses Alamouti STBC method. The effect of proposed scheme on outage probability is tested by the comparison the obtained results with results of previous studies has not used the cooperative communication technique (MIMO technique).

4.1 Outage probability of Alamouti STBC 2x2 CMIMO scheme

Figure (2) shows the outage probability of the Alamouti STBC for a 4X2 MIMO technique, and 2x2 proposed cooperative MIMO scheme, with a transmission rate equals to 5 bits per transmission for both techniques.

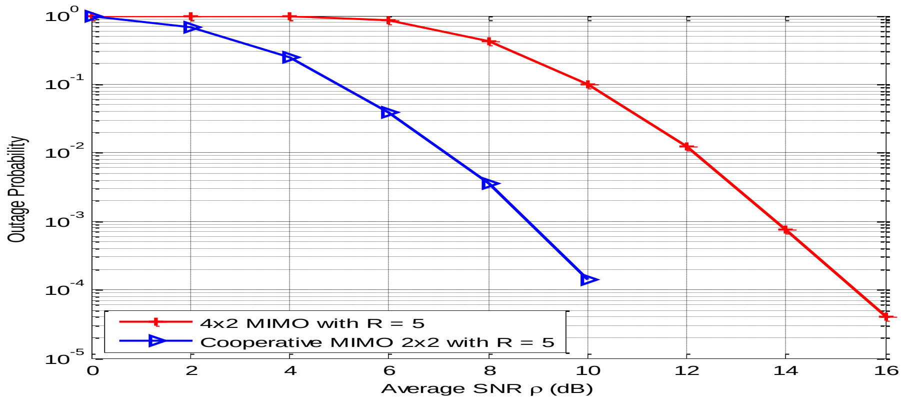

Figure (2): Outage probability of the Alamouti STBC 4×2 MIMO and 2x2 proposed cooperative MIMO scheme

At high SNR, the curves significantly show that the diversity gain of the Alamouti STBC for a 2×2 proposed cooperative MIMO scheme equals to 5dB at the same transmission rate for the both techniques. The figure also illustrates that the outage probability of Alamouti STBC for a 4×2 MIMO technique is equal to 10^{-1} at SNR = 10 dB, while the outage probability of the Alamouti STBC for a 2×2 proposed cooperative MIMO scheme is equal to 10^{-4} at the same SNR. It is clearly noted that the outage probability of the proposed scheme is lower than the outage probability of MIMO technique although the number of transmitter antennas in the proposed scheme is less than the number of transmitter antennas in MIMO technique. Actually, the reason behind the enhancement of outage probability is because of the benefits of diversity in a cooperative communication technique.

4.2 Outage probability of Alamouti STBC 4x4 CMIMO scheme

Figure (3) exhibits the outage probability of the Alamouti STBC for a 7X7 MIMO technique, and 4x4 proposed cooperative MIMO scheme, with a transmission rate equals to 10 bits per transmission for both techniques.

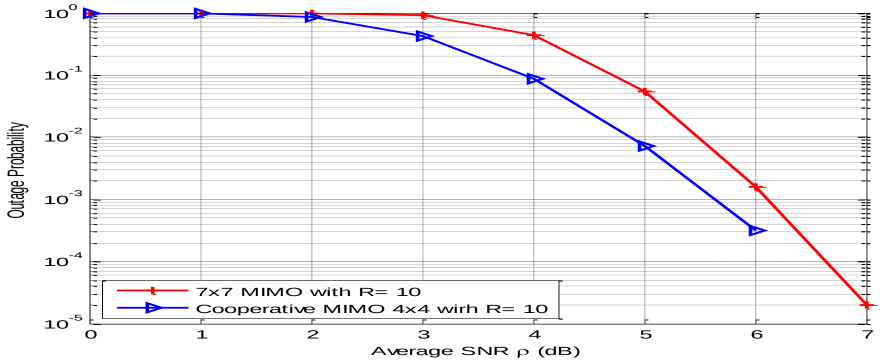

Figure (3): Outage probability of the Alamouti STBC 7×7 MIMO and 4x4 proposed Cooperative MIMO scheme

As can be seen from the simulation result at high SNR, the proposed cooperative MIMO scheme has a diversity gain equal to 0.5 dB compared with a diversity gain of other technique. From point view of outage probability, it is observed that the outage probability of Alamouti STBC for a 7×7 MIMO technique equals to $10^{-2.9}$ at SNR = 6 dB, while the outage probability of the Alamouti STBC for a 4×4 proposed cooperative MIMO scheme equals to $10^{-3.8}$ at the same SNR. Hence, the outage probability of the proposed scheme is lower than the outage probability of MIMO technique, although the number of antennas in MIMO technique are increased by three antennas compared with the proposed cooperative MIMO antennas. Thus, the performance of the proposed scheme is considered better, thanks to higher diversity.

4.3 An effect of increasing transmission rate on the outage probability and diversity gain.

In the previous results, a variety of results of outage probabilities of Alamouti STBC cooperative MIMO scheme are shown. they show that the proposed scheme has lower outage probability and better performance compared with MIMO technique without cooperation. All the previous outage probabilities results have been taken at one transmission rate value for both techniques. Hence it is desired to evaluate the effect of increasing the transmission rate on the outage probability curves and diversity gain. Figure (4) shows the results of outage probability for each techniques at several transmission values, (R=5, R=10 and R=20).

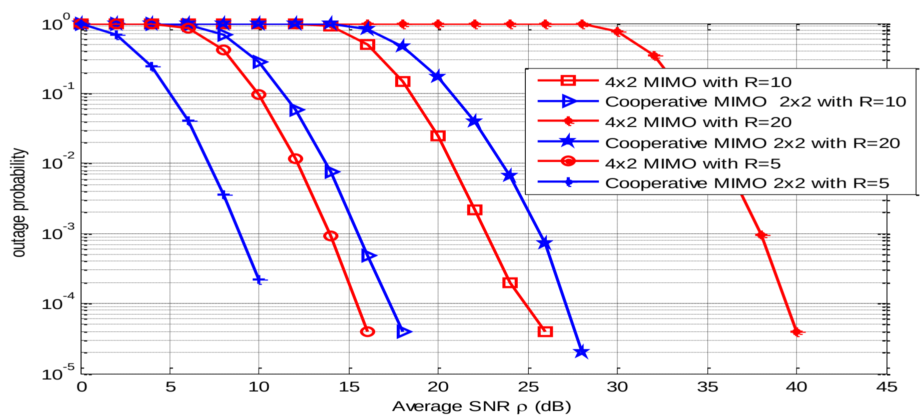

Figure (4): An effect of increasing transmission rate on the slopes of outage probability curves and diversity gain.

Firstly, when the transmission rate is a constant and equals to 5 (R = 5) bits per transmission for proposed cooperative MIMO and MIMO technique, it is observed that the outage probability of proposed scheme (2x2 cooperative MIMO) is lower than the outage probability of 4x2 MIMO with a difference in diversity gain equals to 5 dB. Secondly, if the transmission rate is increased to 10 (R = 10) bits per transmission for both techniques. It is observed too that the outage probability of Alamouti STBC cooperative 2x2 MIMO (proposed scheme) is lower than the outage probability of 4x2

MIMO with a difference in diversity gain equals to 8 dB. Finally at increasing the transmission rate to 20 (R = 20) bits per transmission, as shown in the slopes of curves , the outage probability of proposed scheme is better in performance than 4x2 MIMO without cooperation, with a difference in diversity gain is equal to 13 dB. By comparison the diversity gain results for each case, it is clearly observed that the performance of proposed scheme enhances with increasing transmission rate (high data rate transmission). All the previously results and discussion of Figure (4) can be summarized as the table (1) below shows.

Table (1): An effect of increasing transmission rate on the slopes of outage probability curves and diversity gain.

Transmission Rate bit/s/Hz	SNR	Outage Probability Of 4x2 MIMO	Outage Probability Of 2x2 Cooperative MIMO	Diversity Gain
5	10 dB	10^{-1}	$10^{-3.9}$	5 dB
10	17 db	$10^{-0.9}$	$10^{-4.8}$	8 dB
20	27 db	1	$10^{-4.9}$	13 dB

5. Conclusions

In this study, a new scheme for MIMO cooperative communication system under slow fading channel is presented. The proposed scheme has compared with MIMO technique and evaluated in terms of outage probability. It helps to enhance the cooperation scheme performance. MATLAB Simulation and numerical outage probability results demonstrate that the proposed cooperative MIMO scheme provides significantly less outage probability and better diversity gains over MIMO techniques without cooperation.

6. References

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