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AF-DF and MRC based Hybrid Relay Selection for Cooperative Communication

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Abstract – **Cooperative communications can be extremely proficient in combating fading multipath channels and enhance scope with complexity and cost. Furthermore there is also possibility of improving performance of cooperative communication by optimal relay selection strategies. In basic cooperative communication network there are three type of devices, a source, a destination and a set of relay devices. These relay devices are responsible for forwarding the overheard information from source node to the destination node, thereby providing diversity gain at destination node. But practically not all available relays are efficient. Application of relay selection scheme with cooperative communication techniques not only removes communication overhead from destination node but also will enhance system performance.**

In this regard, this paper is focused towards a hybrid relay selection scheme of cooperative network with cooperative non-regenerative (AF) and regenerative (DF) relying technique. Bit Error Rate (BER) performance is compared using Rayleigh, Rician and Nakagami fading environment.

Keywords – **AF, Cooperative Communication, DF, MIMO.**

I. Introduction

For wireless communication, higher frequency components exhibit bad propagation characteristics while lower frequencies suffer from the problem of low data rates. Due to this reason, the available frequency spectrum which can be used for efficient transmission is limited and hence is a limited resource. For efficient transmission of data there are two main performance measures, Bit Error Probability (BEP) and Spectral efficiency. In communication systems there is a trade-off between these two. Some techniques are spectrally efficient such as SISO system but exhibit higher bit error probabilities. MIMO technique provides better BEPs but are mainly spectrally inefficient. The main objective of researchers is to find a technique which is spectrally efficient and provides considerable BEPs as well.

A relay network is a wide range of network topology frequently utilized as a part of wireless networks, where the source and destination are interconnected using nodes. In its simplest form a cooperative network is composed of a source device, a destination device and a relaying terminal, which supports communication between source and destination. If the direct communication between source destination pair is faulty then the overheard information can be relayed to destination by the relaying node.

In cooperative networks, a user does not only transmit is own information, but also helps other user to transmit their data by relaying their information. The process of relaying overheard information is called as relaying protocol and it can be categorized as:

1. Fixed gain
2. Adaptive

Wireless channel fading and signal interference are two noteworthy causes of wireless performance degradation. Through the use of spatial diversity and multiplexing gain, MIMO systems combined with spatio-temporal signal processing techniques [1], [2] can effectively relieve the harming effects of wireless channel impairments and improve the transmission capacity and the reliability of the links. However, as discussed earlier, because of restricted physical size and cost limitations, multiple antennas on a single node is not always possible to deploy.

Fortunately, cooperative communication [3], [4], [5] has been proposed as a substitute technology, in which spatial diversity can be achieved by coordinating several nodes that are topographically near cooperate and shape virtual antenna networks.

The historical backdrop of cooperative communication has its underlying foundations in the work crafted by Van der Meulen's innovators [6], when he presented the idea of relay channel model. The channel model comprises of the source, the

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destination and the relay, and the principle design is to encourage the data transfer from the source to the destination. Later, Cover and El Gamal [7] studied in depth the relay channel model. They proposed various relaying techniques viz, Decode and Forward (DF) and Compress and Forward (CF). Direct of Point to Point Communication is defined as Communication from a single source to a single destination without the help of any other communicating terminal. It is required that the number of communicating terminals exceeds two for a cooperation to happen. Subsequently, a network with three terminals is a fundamental unit in cooperation. This unit is shaped of the source, the destination and an additional node willing to aid communication. Each wireless user transmits its own information and simultaneously acts as a cooperative agent (relay) for rest of the users in Cooperative Communication.

In a wireless network, we can find a lot of nodes that could be of great help to their neighbours. When the data is transmitted by a node, all neighbouring nodes listen to its transmission.

Cooperative communication expects to process and transmit this information heard, to the respective destination to create a spatial diversity, this in turn increases the system performance.

Agreeable correspondence expects to process and transmit this data heard, to the separate goal to make a spatial assorted variety, which results in the expansion of framework execution.

In cooperative communication, this spatial diversity is called cooperative diversity and is obtained when the destination combines the two received signals. The first signal is transmitted via the direct link by the source and the relay transmits the second signal. (Figure 1).

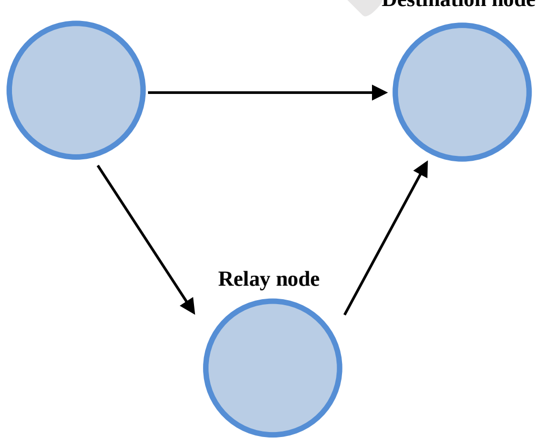

Figure 1: Depiction of cooperative communication system

According to the kind of relaying technique that is used in Cooperation, say Decode and Forward, the data is received from the source, processed and then transmitted to the destination. Here, two signals are combined. These two signals are transmitted through individual paths which is translated into Spatial Diversity with two being the order of diversity.

As a rule, the Cooperative Communication can be isolated into two stages, the information sharing phase and the cooperative transmission phase.

II. Proposed Methodology

Consider a network arrangement with a transmitter, a receiver and two relaying node each equipped with single antenna. Furthermore it is considered that transmission from source to destination is divided in two phases; the first phase is known as broadcast phase, where source node transmits data to both destination and relaying terminals. The second phase is known as relaying phase where relaying node transmits overheard information from source node to the destination node based on the relaying technique employed.

Let h_{sr_i} denote the channel coefficient between source and i^{th} relay, h_{r_iD} represents channel coefficient between i^{th} relay and destination node. η_{s_id}, η_{sr_i} are complex AWGN noise vectors present between source and destination and source to relay nodes respectively. Then the signal propagation in relaying techniques can be given as:

A. Conventional Relay Selection Scheme

The optimal relay selection scheme works on the principle of selecting relay with minimum symbol error rate (SER), while in practice it is hard to analyse. Therefore a sub optimal relay selection scheme which selects relay with minimum SER and which is analysable is required. Max-min relay selection and Harmonic Mean relay selection schemes works on such principle and they are analysable as well [8]. Let h_{si}, h_{id} denotes the instantaneous channel condition between source and i^{th} relay, i^{th} relay and destination. Bletsas et al. [9] proposed two formulas to select any relay among a set of relays: under Policy I, the minimum of the two is selected, while under Policy II, the harmonic mean of the two is used [10]:

- Under Policy I

$$h_i = \min\{|h_{si}|^2 |h_{id}|^2\} \tag{1}$$

- Under Policy II

$$h_i = \frac{2}{\frac{1}{|h_{si}|^2}+\frac{1}{|h_{id}|^2}} = \frac{2|h_{si}|^2|h_{id}|^2}{|h_{si}|^2+|h_{id}|^2} \tag{2}$$

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B. Amplify and Forward (Non-Regenerative Relaying)

In AF scheme, relay node forwards amplified version of received signal to the destination node. Let the source transmitted signal be X_s and the relay transmitted signal is X_{r_i}. In broadcast phase the received signal at the destination and relay will be [11]:

$$y_{sd} = \sqrt{\varepsilon} h_{sd} X_s + \eta_{sd} \quad (3)$$

$$y_{sr_i} = \sqrt{\varepsilon} h_{sr_i} X_s + \eta_{sr_i} \quad (4)$$

In relaying phase, the relay node first amplifies the received signal with a gain factor β and forwards it to the destination. The received signal at destination node in relaying phase will be:

$$y_{r_i d} = \sqrt{\varepsilon} h_{r_i d} \beta y_{sr_i} + \eta_{r_i d} \quad (5)$$

Where $\beta = \sqrt{\frac{1}{|h_{sr_i}|^2 \varepsilon + N_{0,sr_i}}}$ is gain factor between source and relay terminal.

Using the Z-F and MMSE detection the estimated signal will be:

$$r_{s,d} = \frac{h_{sd}^* \sqrt{\varepsilon}}{N_{0sd}} y_{sd} + \frac{h_{r_i d}^* \ \beta \ h_{sr_i}^* \sqrt{\varepsilon}}{|h_{r_i d}|^2 \beta^2 N_{0,sr_i} + N_{0,r_i d}} \quad (6)$$

Here $r_{s,d}$ is estimated signal, ε represents energy of the symbol. $N_{0,sd}, N_{0,r_i d}$ represent noise power spectral density between source-destination and relay-destination pair respectively. The received SNR between a pair of nodes i, j will be:

$$\overline{\gamma_{ij}} = \frac{E\left[|h_{ij}|^2\right]\varepsilon}{N_{0,ij}} \quad (7)$$

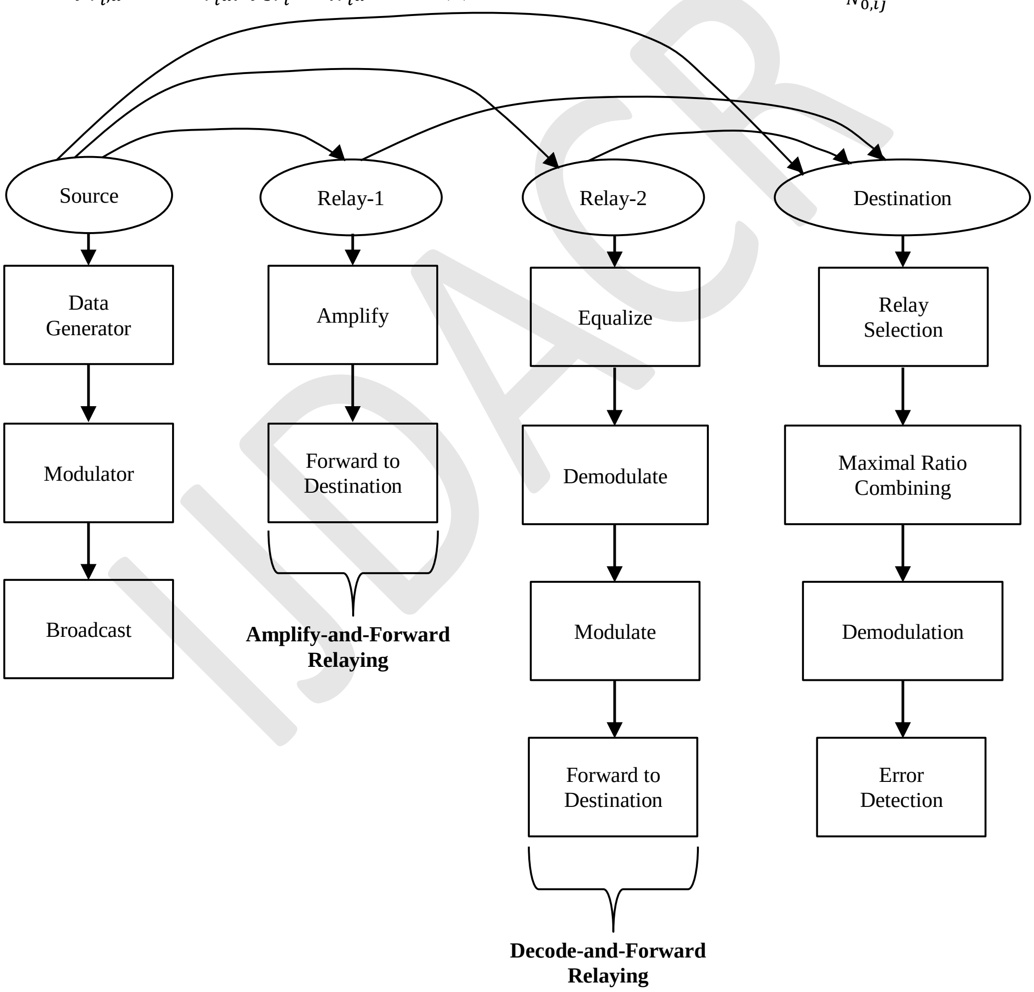

Figure 2: System model for hybrid cooperative relaying scheme

C. Decode and Forward (Regenerative Relaying)

Decode and forward relaying scheme is regenerative since relay node first decodes the information received from source node, before forwarding it to destination. For a signal S, the transmission is carried out in two phases. In first phase, source broadcasts $\sqrt{\epsilon} S$ to available relays and destination nodes. Where ϵ represents transmission power. The

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received signal at destination and i^{th} relay will be same as given in equations (3) and (4). The instantaneous SNRs of channel between source to destination and channel between source to i^{th} relay are given by $\gamma_{sd} = \epsilon|h_{sd}|^2$ and $\gamma_{sr_i} = \epsilon|h_{sr_i}|^2$ respectively. In second phase, the relay first estimates the received signal to obtain the estimated signal$\hat{s}$ then amplifies $\hat{s}_i$ with amplification factor β and transmits $x_i = \sqrt{\epsilon.B}.\hat{s}_i$ to the destination node. The received signal at destination will be:

$$y_{r_i,d} = \sqrt{\epsilon.B}.\hat{s}_i.h_{r_id} + \eta_{r_id} \quad (8)$$

Destination node combines signal received in two phases i.e. y_{sd} and $y_{r_i,d}$. The combined signal will be:

$$y_D = g_1 * y_{sd} + g_2 * y_{r_i,d} \quad (9)$$

Where g_1 and g_2 are weight coefficients. Then the final estimate $\hat{s}$ is given by:

$$\hat{s} = arg \min_{S\in\{-1,1\}} \left|y_D - \sqrt{\epsilon}\left(g_1 h_{sd} + g_2\sqrt{\beta} h_{r_id} S\right)\right|^2 \quad (10)$$

Let S being BPSK modulated then the conditional bit error rate probability is given as:

$$P_{error} = \left(1 - Q(\gamma_{sr_i})\right) Q\left(\frac{\sqrt{2\epsilon}\,(g_1 h_{sd} + g_1\sqrt{\beta} h_{r_id})}{\sqrt{|g_1|^2 + |g_2|^2}}\right) + Q\left(\sqrt{2\gamma_{sr_i}}\right) Q\left(\frac{\sqrt{2\epsilon}\,(g_1 h_{sd} - g_1\sqrt{\beta} h_{r_id})}{\sqrt{|g_1|^2 + |g_2|^2}}\right) \quad (11)$$

D. Maximal Ratio Combining (MRC)

Assume a system with N_d diversity branches, the instantaneous output SNR is given by [12]:

$$\mathrm{SNR} = \left(\frac{E_b}{N_0}\right) \frac{\left|\sum_{i=1}^{N_d} \mu_i \beta_i e^{j\theta_i}\right|^2}{\left|\sum_{i=1}^{N_d} \mu_i\right|^2} \quad (12)$$

Where E_b is bit energy; N_0 is noise spectral density, μ_i is the combining weight and β_i and θ_i are the magnitude and phase of the received signal respectively.

To obtain the maximum instantaneous output SNR, Cauchy-Schwarz inequality is applied, giving the maximum value as [13]:

$$\mathrm{SNR} \le \left(\frac{E_b}{N_0}\right) \frac{\left|\sum_{i=1}^{N_d} \mu_i\right|^2 \left|\sum_{i=1}^{N_d} \beta_i e^{j\theta_i}\right|^2}{\left|\sum_{i=1}^{N_d} \mu_i\right|^2} = \left(\frac{E_b}{N_0}\right) \sum_{i=1}^{N_d} \beta^2{}_i = \sum_{i=1}^{N_d} \mathrm{SNR}_i \quad (13)$$

The only condition to reach this maximum value is to set:

$$\mu_i = c\beta_i e^{-j\theta_i} \text{ for } i = 1,2, \dots .N_d \quad (14)$$

Where c is some arbitrary complex constant. Therefore in MRC, the magnitude of the combining weight is proportional to the magnitude of the received signal, and the phase of the combining weight is the negative value of the phase of the received signal.

The maximum SNR in equation (13) also suggests that MRC can create an output in the form of SNR equivalent to the total of the individual SNRs in every assorted diversity branch. It takes after that MRC can suggest the benefit of delivering an adequate outcome; SNR nevertheless when none of the SNR in particular branches is satisfactory.

III. SIMULATION AND RESULTS

The performance of proposed algorithms has been studied by means of MATLAB simulation.

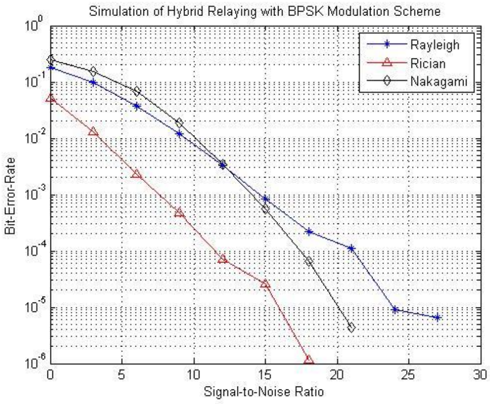

Figure 3: BER performance comparison for Hybrid Relaying for different fading channel in BPSK

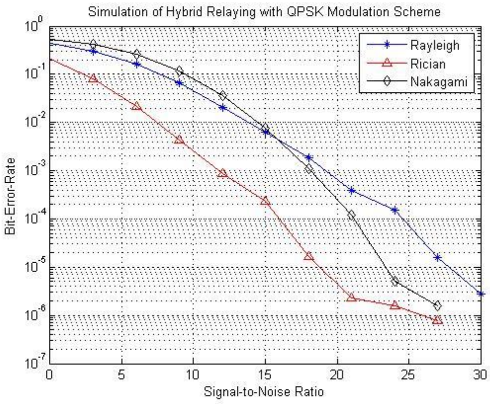

Figure 4: BER performance comparison for Hybrid Relaying for different fading channel in QPSK

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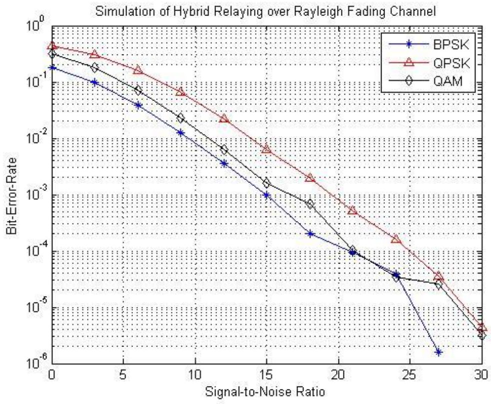

Figure 5: BER performance comparison for Hybrid Relaying for various modulation schemes

IV. Conclusion

In this paper, hybrid relay selection architecture is developed for regenerative (decode and forward) and non-regenerative (amplify and forward scheme). This system architecture utilizes the benefits of cooperative communication to enhance system performance. Hybrid relay selection scheme is applied to the adopted system architecture. To evaluate system performance Rayleigh fading scenario has been considered. Furthermore, the receiver is assumed to be equipped with linear and non-linear equalizers.

Bit error rate is considered as a performance evaluation parameter and Zero (0) BER is taken as reference level. Simulation results on the basis of Bit-Error-Rate vs. Signal-to-noise Ratio has been presented. It was found that the proposed hybrid relay selection in cooperative system improves system performance since it is utilizing two relays. In previous research work [14], they utilized single relay scheme which offered lower BER performance as compared to proposed hybrid relay selection scheme.

Reference

[1] Su, Weifeng, Zoltan Safar, and KJ Ray Liu. "Space-time signal design for time-correlated Rayleigh fading channels." In *Communications, 2003. ICC'03. IEEE International Conference on*, vol. 5, pp. 3175-3179. IEEE, 2003.

[2] Valenti, Matthew C., and Neiyer Correal. "Exploiting macrodiversity in dense multihop networks and relay channels." In *WCNC*, pp. 1877-1882. 2003.

[3] Sendonaris, Andrew, Elza Erkip, and Behnaam Aazhang. "User cooperation diversity. Part I. System description." *IEEE Transactions on communications* 51, no. 11 (2003): 1927-1938.

[4] Xie, Liang-Liang, and Panganamala R. Kumar. "A network information theory for wireless communication: Scaling laws and optimal operation." *IEEE Transactions on Information Theory* 50, no. 5 (2004): 748-767.

[5] Van Der Meulen, Edward C. "Three-terminal communication channels." *Advances in applied Probability* 3, no. 1 (1971): 120-154.

[6] Laneman, J. Nicholas, and Gregory W. Wornell. "Energy-efficient antenna sharing and relaying for wireless networks." In *Wireless Communications and Networking Conference, 2000. WCNC. 2000 IEEE*, vol. 1, pp. 7-12. IEEE, 2000.

[7] Cover, Thomas, and A. EL Gamal. "Capacity theorems for the relay channel." *IEEE Transactions on information theory* 25, no. 5 (1979): 572-584.

[8] Zhi-Yong Liu, Weihai, "Single and Multiple Relay Selection for Cooperative Communication under Frequency Selective Channels", IEEE Region 10 Conference, TENCON, pp. 1-4, October 2013.

[9] A. Bletsas, A. Lippman, and D. P. Reed, "A simple distributed method for relay selection in cooperative diversity wireless networks based on reciprocity and channel measurements," *in Proc. 61st IEEE Semiannu. Vech. Technol. Conf, vol. 3, Stockholm, Sweden, pp. 1484–1488*, May 30–Jun, 1 2005.

[10] Varshney, Neeraj, Amalladinne Krishna, and Aditya K. Jagannatham. "Selective DF protocol for MIMO STBC Based Single/Multiple Relay Cooperative Communication: End-to-End Performance and Optimal Power Allocation", *IEEE Transactions on Communications, Vol. 63, Issue 7, pp. 2458 – 2474,* May 2015.

[11] Zou, Yulong, Xianbin Wang, and Weiming Shen. "Optimal relay selection for physical-layer security in cooperative wireless networks." *IEEE Journal on Selected Areas in Communications* 31, no. 10 (2013): 2099-2111.

[12] Dietze, Kai, Carl B. Dietrich, and Warren L. Stutzman. "Analysis of a two-branch maximal ratio and selection diversity system with unequal SNRs and correlated inputs for a Rayleigh fading channel." *IEEE Transactions on wireless communications* 1, no. 2 (2002): 274-281.

[13] Horn, Roger A., and Roy Mathias. "Cauchy-Schwarz inequalities associated with positive semi definite matrices." *Linear Algebra Appl* 142, no. 1 (1990): 63-82.

[14] Khair, Ummul. "Performance of hybrid relay selection in cooperative communications system." In *Information Technology, Information Systems and Electrical Engineering (ICITISEE), 2017 2nd International conferences on*, pp. 402-405. IEEE, 2017.