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Energy Efficient Relay Selection & Optimized Power Allocation Scheme in Cooperative Communication Network

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Abstract – **High data rates, large coverage area and reduce the effect of multipath fading are key points of researcher for wireless communication systems. These facilities are provided by MIMO systems. However, to implement and use multiple antennas are very difficult due to size, power, cost, and weight constraints. So, Virtual MIMO concept was introduced. In cooperative wireless networks, a virtual antenna array is created using several single antenna devices. Hence it is often the case that number of sources and number of relays cooperate to send their data to destination. For the cooperative systems, selection of appropriate relay node is of very important. This research works is focused towards the Fuzzy Logic based relay selection and power allocation (PA) using Gray Wolf Optimizer (GWO) algorithm in cooperative communication system.**

Keywords –**Cooperative Communication, Fuzzy Logic, GWO, MIMO, PA, Relay Selection.**

I. Introduction to Cooperative Communication

Increased demand for wireless communications applications has generated a significant development of wireless networks, in particular several generations of cellular networks in voice and data resources. The radio equipment and wireless services evolve to become more efficient and less costly for its users. Thanks to the work and studies of researchers and experts who understand the environment of the transmission channel and generally multi-user communications. By cons, compared to wired communications, we begin to understand the fundamental performance limits of wireless networks and practical methods to approach. Moreover, given their growing impact in society, the wireless communications remain an important research topic.

The cooperative communication is an interim solution. It proposes to share the antennas of neighbouring nodes to create this diversity. By having a knowledge of the state of the channel, the nodes will lend each other antennas transmitting packets from their neighbours on higher quality channels. This and promising technique can not only circumvent the problems of unstable channels but also increase link capacity. Historically, cooperatives techniques appeared at the physical layer and many proposals have been made in this direction. However, in the upper layers, the inclusion of these cooperatives techniques is still a subject on which many studies must be conducted [1, 2, and 3].

The fundamental standard of cooperative communication is utilizing other communication devices to relay transmission. As appeared in Figure 1, the source node broadcasts information to both the relay node and the destination node. The relay node then advances the transmission to the destination node. The source node views the transfer node as a virtual antenna, empowering MIMO frameworks to be utilized without adding physical antenna.

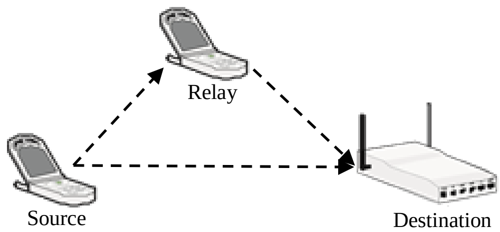

Figure 1: Cooperative Communication

By utilizing the cooperative communication technique, the source node can discover relay nodes which have worthy channels to the destination node, use it to relay the transmission to the destination node, and expanding the dependability of the entire transmission. By selecting relay nodes nearer to it, the source node can likewise spare battery power, since it does not need to transmit at high power and can utilize the relay devices' energy to accomplish the transmission.

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Since the source node in the cooperative communication technique relies on upon the relay nodes to forward the transmission, relay selection for the relay nodes get to be vital with a specific end goal to acquire ideal execution of the cooperative communication framework. By picking the right nodes to relay the transmission, the framework can accomplish higher capacity by utilizing lower assets. In this research work, optimal relay selection and power allocation issue is addressed.

II. System Model

Consider a network arrangement with a transmitter, a receiver and a relaying node each equipped with single antenna. Furthermore it is considered that transmission from source to destination is divided among two phases; the first phase is known as broadcast phase, where source node transmits data to both destination and relaying terminals. And 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.

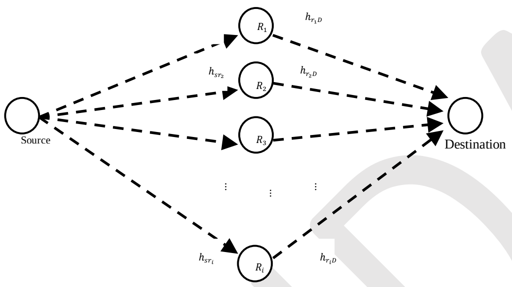

Figure 2: System model for cooperative relaying scheme

Let h_{sr_i} denotes 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 non-regenerative relaying (Amplify and Forward) technique can be given as:

Amplify and Forward 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:

$$y_{sd} = \sqrt{P} h_{sd} X_s + \eta_{sd} \quad (1)$$

$$y_{sr_i} = \sqrt{P} h_{sr_i} X_s + \eta_{sr_i} \quad (2)$$

The distance between a relay node and destination node can be measured by:

$$\mathrm{Dist}_{r_i d} = \sqrt{\left(\mathrm{X}_{sr_i} - \mathrm{X_d}\right)^2 + \left(\mathrm{y}_{\mathrm{sr_i}} - \mathrm{y_d}\right)^2} \quad (3)$$

Using the equation (3), the pathloss for each relay can be calculated as:

$$\text{Path Loss} = 10\alpha \log_{10}\left(\mathrm{Dist}_{r_i d}\right) + \mathrm{C} \quad (4)$$

Where, α is pathloss exponent and C is a constant.

To achieve maximum energy with minimum pathloss, this research work uses fuzzy logic based relay selection algorithm.

Fuzzy Logic based Relay Selection

Fuzzy logic provides a simple way to get the solution to a problem based on inaccurate information, noisy and incomplete.

Instead of using complicated mathematical formulation, fuzzy logic employs a fuzzy set of membership functions and inference rules for the solution that meets the desired objectives. Table 1 shows the fuzzy rules for proposed approach:

Table 1: Fuzzy rules

Rule 1	Path loss is weak and Energy is low	Degree of relevance is very bad
Rule 2	Path loss is weak and Energy is medium	Degree of relevance is bad
Rule 3	Path loss is weak and Energy is full	Degree of relevance is intermediate
Rule 4	Path loss is average and Energy is low	Degree of relevance is bad
Rule 5	Path loss is average and Energy is medium	Degree of relevance is intermediate
Rule 6	Path loss is average and Energy is full	Degree of relevance is good
Rule 7	Path loss is strong and Energy is low	Degree of relevance is bad
Rule 8	Path loss is strong and Energy is medium	Degree of relevance is good
Rule 9	Path loss is strong and Energy is full	Degree of relevance is very good

Degree of relevance selects the appropriate relay to further figure out the channel gain.

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:

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

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

Using the Z-F detection, the estimated signal will be:

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

Here $r_{s,d}$ is estimated signal, ε represents energy of the symbol. $N_{0,sd}$, N_{0,r_id} 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:

$$\bar{\gamma}_{ij} = \frac{E\left[\left|h_{ij}\right|^2\right]P}{N_{0,ij}} \quad (7)$$

Power Allocation using Gray Wolf Optimizer

In this research work, a Gray Wolf Optimizer (GWO) algorithm is used for power allocation in amplify-and-forward cooperative network. First we allocate power to system using equal power, means total power P is taken as 1. The power is allocated to source and relay $P_s = P/2$ and $P_r = P/2$ respectively, after that the system performance is compared with GWO power allocation system performance.

Gray Wolf Optimizer

Gray Wolf (Canis Lupus) is a new population based algorithm which is introduced in 2014 by Mirjalili et al. [4]. GWO algorithm inspired by Gray wolves. The method mimicked the social hierarchy and hunting behaviour of Gray wolves. For simulating the leadership hierarchy in GWO algorithm, four groups are defined: alpha, beta, delta, and omega. Furthermore, the three main steps of hunting, searching for prey, encircling prey, and attacking prey, are simulated.

This algorithm requires a number of parameters to be set, namely: initialize alpha, beta, and delta, number of search agents, maximum number of iterations, number of sites selected for neighbourhood search (out of n visited sites) and the stopping criterion.

The main steps of Gray wolf hunting are as follows:

1. Tracking, chasing, and approaching the victim.
2. Pursuing, encircling, and harassing the victim until it stops moving.
3. Attack towards the victim.

For modelling the social hierarchy of wolves until designing GWO, the fittest solution is considered as the alpha (α), accordingly, the second and third best solutions are named beta (β) and delta (δ) respectively. The rest of the candidate solutions are considered to be omega (ω). The x wolves follow these three wolves.

For modelling encircling behaviour, some equations are considered:

$$\vec{D} = \left|\vec{C}.\vec{X}_p(t) - \vec{X}(t)\right| \quad (8)$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A}.\vec{D} \quad (9)$$

Where t is the current iteration, $\vec{A}$ and $\vec{C}$ are coefficient vectors, $\vec{X}_p(t)$ represents the position vector of the victim. The vectors $\vec{A}$ and $\vec{C}$ can be calculated as below:

$$\vec{X} = 2\vec{a}.\vec{r}_2 - \vec{a} \quad (10)$$

$$\vec{C} = 2.\vec{r}_2 \quad (11)$$

Where $\vec{a}$ include are linearly decreased from 2 to 0 over the course of iterations and $\vec{r}_2$ and $\vec{r}_2$ are random vectors in the range [0, 1].

In GWO, the first three best solutions obtained are saved so far and compel the other search agents (including the omegas) to update their positions due to the position of the best search agents. The following formulas are proposed for this regard.

$$\vec{D}_\alpha = \left|\vec{C}_1.\vec{X}_\alpha - \vec{X}\right| \quad (12)$$

$$\vec{D}_\beta = \left|\vec{C}_2.\vec{X}_\beta - \vec{X}\right| \quad (13)$$

$$\vec{D}_\delta = \left|\vec{C}_3.\vec{X}_\delta - \vec{X}\right| \quad (14)$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1.\left(\vec{D}_\alpha\right) \quad (15)$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2.\left(\vec{D}_\beta\right) \quad (16)$$

$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3.\left(\vec{D}_\delta\right) \quad (17)$$

$$\vec{X}(t+1) = \frac{\vec{X}_1(t)+\vec{X}_2(t)+\vec{X}_3(t)}{3} \quad (18)$$

The final position would be in a random position within a circle which is defined by the positions of alpha, beta, and delta in the search space. In other words alpha, beta, and delta estimate the victim position and other wolves update their positions randomly around the victim.

Problem Formulation

At high SNR, assume all channel links are available and the variances are not equal to zero. Here the problem statement is to minimize the error and maximize the SNR ($\bar{\gamma}_{ij}$) (in Equation 7) such that:

$$P_s = k.P \quad (19)$$

$$P_{r_i} = (1-k)P \quad (20)$$

Where, k is power allocation factor with $0 < k < 1$.

$$P_{total} = P_s + \sum_{i=1}^{N} P_{r_i} \quad (21)$$

For single relay:

$$P_{total} = P_s + P_r \quad (22)$$

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In this research work, power allocation factor i.e. k is optimized using GWO.

III. Simulation and Results

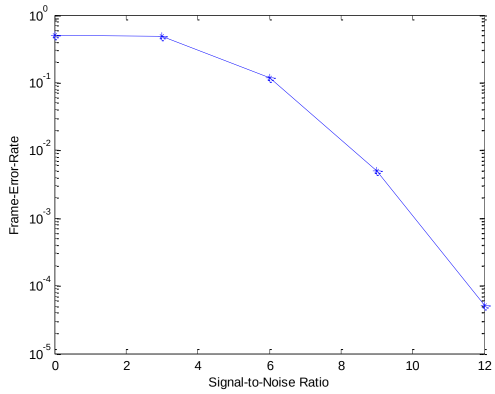

Figure 3: Frame error rate graph of proposed Fuzzy based relay selection

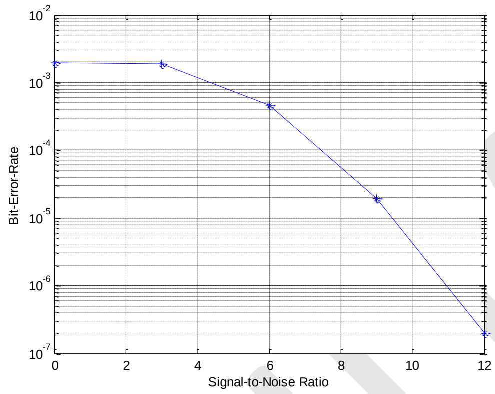

Figure 4: BER vs. SNR graph of proposed Fuzzy based relay selection

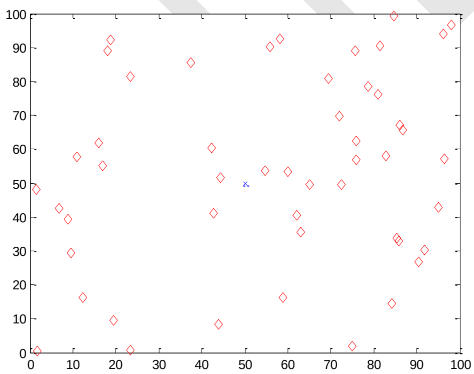

Figure 5: Deployment of random nodes

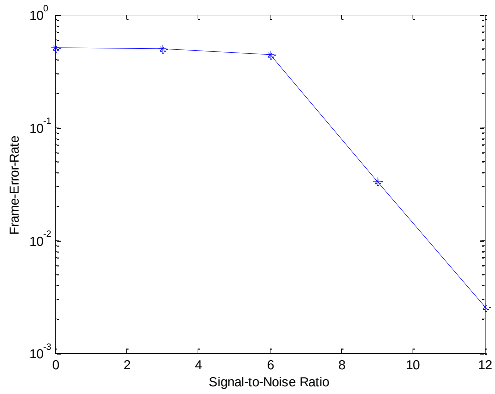

Figure 6: Frame error rate graph of proposed GWO based power allocation

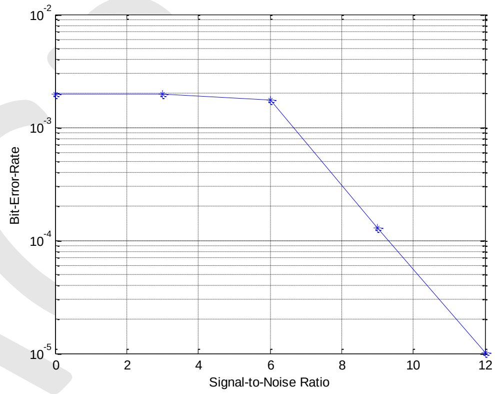

Figure 7: BER vs. SNR graph of proposed GWO based power allocation

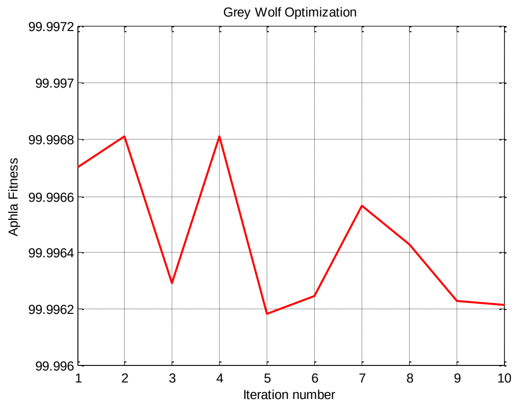

Figure 8: Fitness function graph

IV. Conclusion

This research works is focused towards the Fuzzy Logic based relay selection and power allocation (PA) using Gray Wolf Optimizer (GWO) scheme for cooperative communication system. Non-regenerative relaying technique established on Fuzzy Logic based relay selection has been developed along with GWO optimized power allocation technique. Frame Error Rate and Bit Error

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Rate are chosen as performance evaluation criteria and simulation results for SNR vs. BER has been presented.

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