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Adaptive Neuro Fuzzy based Best Relay(s) Selection in Two-Hop Two-Way Relay Channels

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Abstract: In this paper, we suggest an Adaptive Neuro Fuzzy Inference System (ANFIS) based two-way relay channels mechanism for user cooperative networks. The proposed technique is analyzed for multi-user and multi-relay cooperation, over Rayleigh, Nakagami and Rician fading channels. The Hybrid Frequency-Division Multiple Access-Time-Division Multiple Access (Hybrid FDMA-TDMA) is used to access multiple users. The two-hop two-way multiple-user cooperation is achieved by applying Physical Network Coding (PNC) at relay node. Fuzzy Inference System (FIS) produce relay ranking parameter using effective signal-to-noise ratio (SNR) and Cooperation gain as fuzzy parameters as two inputs to the controller at destination. The relay selection is then made by ANFIS using the relay selection parameter. Monte Carlo simulations are performed to obtain the cooperation gain and outage probability of the proposed relay selection scheme.

Keywords: User cooperation, Fuzzy logic, Two-Way Relay channels, Rician Fading, Cooperation gain.

1. INTRODUCTION

The mobile and wireless communication industry aims to provide high speed and reliable communication over harsh wireless channels to attain the increasing data rate demand. It is likely that 4G will appear as an ultra-high speed broadband wireless network Bohlin *et al.,* (2004) in near future. The 4G technology faces several challenges which include reduced power, complexity on terminals and spectral efficiency. Reduced power is the vital factor for 3G system success, despite its increasing data rates. Multiple antenna diversity techniques are commonly used for this purpose but obviously this is not possible for hand-held mobile devices. A need of cooperation among nodes or consumers has motivated new thinking and ideas for the design of communications and networking systems by asking whether cooperation can be used to progress system performance Genc *et al.,* (2008). The authors in (Zinan and Erkip, 2005) have proposed a straightforward algorithm for the relay selection which is based on taking the Signal to Noise Ratio (SNR)'s arithmetic mean on the end node. In Michalopoulos *et al.,* (2006), the authors have proposed the justification to keep a balance between the error performance and total consumed energy. Their relay selection algorithm attains this balancing between the mentioned two parameters. In the study of Okada *et al.,* (2007), the authors have presented a Bit Error Rate (BER) based path selection scheme for cellular networks in a cooperative setup.

In Bletsas *et al.,* (2007 and Madan *et al.,* 2008) multiple opportunistic relaying schemes scenarios have been analyzed by considering high SNR between them as a ranking parameter. In the study of (Adinoyi *et al.,* 2008), the authors have proposed a relay selection algorithm which is based on the comparison of the equivalent SNR value of links spanning 2-hops connecting the source and destination. Gunawardena and Rajathevapresent have presented the simulation and theoretical results for a relay selection scheme based on the source-destination relay's maximum link SNR (Gunawardena and Rajathev, 2008). In the work of (Beres and Adve, 2008), the relay selection can also be performed by the destination based on the highest channel gain between them. In Nam *et al.,* (2008), the set of relays are selected in a way that leads to the minimization of total transmission time expected value. In (Jeong and Lee, 2008), the authors have proposed a relay selection scheme which is adaptive in nature with an added capability of reaching to maximum capacity but have the fairness constraints. In their proposed solution, the relay nomination is the essential task of a relay selection controller, where the decision is made based on the convenience and assurance of the resources in hand and assurance of the Quality of Service (QoS). With imprecise information, fuzzy logic can make quicker intelligent decisions with simple controls. In fuzzy logic, the membership of the elements could be to a certain core. Effective SNR and Delay as fuzzy parameters to produce symbol error rate to observe the performance of their designed system is proposed Shamim *et al.,* (2009). The notion of 'best' relay selection in a multiple relays network solely depends on the paths between the source to relay and from relay to destination node. The authors in Tanoli *et al.,* (2010).

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presented two-way relay channel using Analog Network Coding (ANC) for fixed relay cooperative network.

This paper considers user cooperation diversity by taking two users having the capabilities to forward each other's data to the base station. A two-hop two-way multiple-user cooperation model using amplify-and-forward (AF), Estimate-and-forward (EF) and Differential Detect-and-Forward (DetF) schemes are proposed here. The performance analysis has been performed for the fuzzy logic based selection scheme of two-way user cooperation diversity in terms of outage probability and cooperation gain over the orthogonal Rician fading channels. SNR and cooperation gain is taken as the input to the fuzzy controller at the base station while for the combination of two signals, which are received in different time intervals, maximal ratio combining (MRC) is used.

2. MATERIALS AND METHODS

System Model

In multiple-user cooperation diversity several users act as relays for the source terminal are distributed around a destination terminal (base station or Access Point) covering a particular cell area as shown in (**Fig. 1a)**. The communication takes place in both directions simultaneously increasing the throughput. Each relay is composed of one transmit and one receive antenna. The selection of best relays take place at the destination (base station/Access Point) using Fuzzy logic controller. A single relay is used to forward the signal from the user that is out of coverage area. Number of relays is selected for transmission to achieve diversity in addition to the extension in coverage area as shown in (**Fig. 1b)**. (**Fig. 1b)** shows how a source is connected to the base station through a N- hop User cooperation diversity.

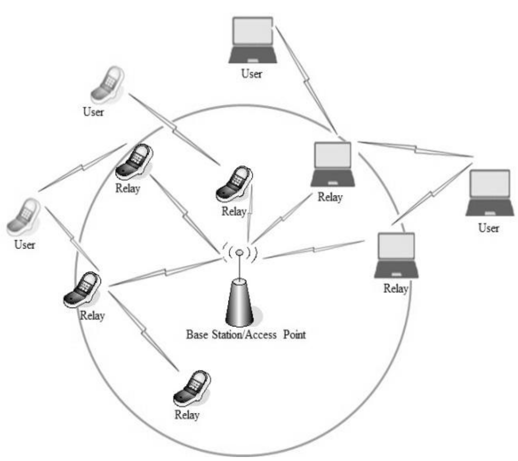


Fig. 1a: Cooperative Network

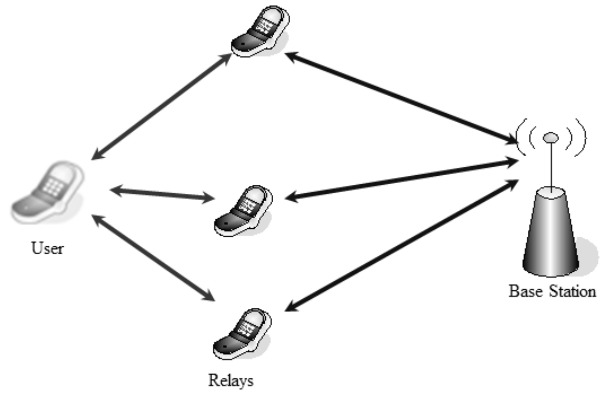
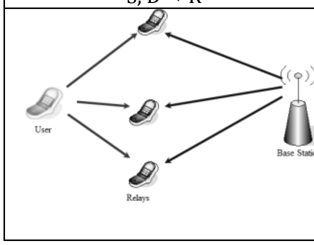
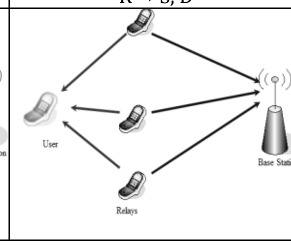


Fig. 1b: Two-Hop Two-Way Multiple-User Cooperation

Table 1: Hybrid FDMA-TDMA based two-way

Phase I	Phase II
S, D → R	R → S, D
	

Hybrid FDMA-TDMA based two-way relay channels

The hybrid FDMA-TDMA based protocol is considered for transmission. Different frequencies are allocated to the users serving as best relays. Diversity is achieved by receiving same signal from other terminal through different relays as given in **(Table 1).**

In two-way relay channels are accomplished by sending the signal from source (user) to destination (base station) and destination to the source through best selected relay(s) (other users) in two phases. In 1st phase, the signals are sent to all best selected relays from source (S) and destination (D), simultaneously. Both the signals received at the relays from 'S' and 'D' are added at the relay. In 2nd phase, the combined signal is broadcasted to both 'S' and 'D'. The signal of other terminal is recovered by subtracting its own transmitted signal from the received signal. User cooperation is achieved when another user is used as a relay in the network.

Best Relay(s) selection technique

The base station selects the relays for transmission based on some threshold SNR values and cooperation gain (G_{ci}). If SNR (>γth) then this relay is selected. The base station broadcasts a reference packet for route establishment in the proactive phase to the selected relays. If a relay receives a packet twice, the duplicate packet is discarded. Source selection of the relays is based on the reactive procedure where the RREQ (relay request) packets are flooded in the channel. The relays having SNR ($> \gamma$ th) between S→ R and R→D links and Cooperation Gain ($G_{ci} > 1$), forward these packets to base station by the routes established in the proactive stage. The BS after normalizing the SNR and G_{ci} value using ANFIS, then finds the best relay ranking parameter (BRSP), m_i by the relation:

$$m_i = nor(\gamma_i) + nor(G_{ci}) \quad (1)$$

The base station organizes the relays in descending order based on the SER (symbol error rate) values and then picks the required number of relays. The route reply (RREP) packet is returned by the wireless port to the originator (source) after the relays have been selected for it. The SNR (γ) of X → Y link can be written as:

$$\gamma xy = \frac{|h_{xy}|^2 E_{xy}}{N_0} \quad (2)$$

Where, E_{xy} in the Equation (2) shows the transmitted symbol energy at terminal x, $|h_{xy}|^2$represents the channel gain through the X → Y link and N_o is the noise variance. The cooperation gain of *i*-th relay is given as:

$$G_{ci} = \frac{SER(NC)}{SER(C)} \quad (3)$$

Where NC is no cooperation and C shows the cooperation in the Equation (3).

In a cooperative network, all the relays are not selected for a transmission but only those with amplitude of fading gains of some threshold value (Jeong and Lee, 2008). **(Fig. 2)** shows how the Cooperation gain and SNR of the relays in the network are used in the system implementation.

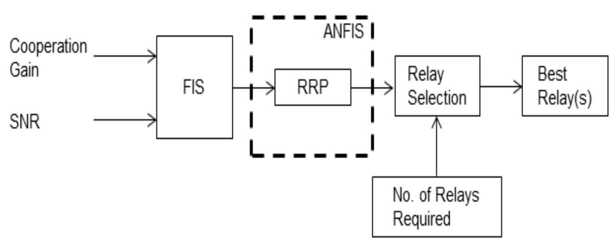


Fig. 2: ANFIS based relay selection

Channel Model

Assuming Rician Fading channel α_{sd}, α_{id} and α_{si} are gamma distributed random variables given by:

$$f(a_{xy}) = \frac{1+K_{xy}}{\Omega xy}\left[\begin{matrix}\exp\left(-\frac{1+K_{xy}}{\Omega_{xy}}\alpha_{xy} - K_{xy}\right) \\ \times \quad I_\circ\left(2\sqrt{\frac{K_{xy}(1+K_{xy})}{\Omega_{xy}}}\alpha_{xy}\right)\end{matrix}\right] \quad (4)$$

where K_{xy} is defined as the rice factor of the X-Y fading channel.

ANFIS Controller

A. Fuzzification

Effective SNR and cooperation gain are selected as input parameters and their crisp values are assigned degree of membership from 0 to 1. The degree of membership shown in the **(Fig. 3)** and **(Fig. 4)** are the degree of memberships for SNR and cooperative gain, respectively, which are used as relay selection parameters at the destination. Their combined effect is shown in the **(Fig. 5)**, which gives us the relay ranking parameter at the ANFIS controller. The degree of membership is chosen to fuzzy linguistic terms. In the fuzzy set A, the membership of the elements x belonging to the base set X is described by the membership function, μA(x). For the fuzzy input/output parameters, the bell shape Gaussian membership function has been considered in this work. The bell function is a three parameters a, b, and c dependant and is given by:

$$f(x; a, b, c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad (7)$$

Where the variables a, b and c in the Equation (7) are the shape parameters. The linguistic values used to represent previous circumstances and the future consequences are represented as:

$$F(\gamma) = F(G_{ci}) = \{L; M; H\} \quad (8)$$

$$F(RRP) = \{NS, C, S\} \quad (9)$$

Where F shows the function of linguistic variable. L, M and H shows the Low, Medium and High priorities respectively. Similarly, NS, C and S show the Not Selected, Considered and Selected options for the linguistic function F over the linguistic variable, respectively.

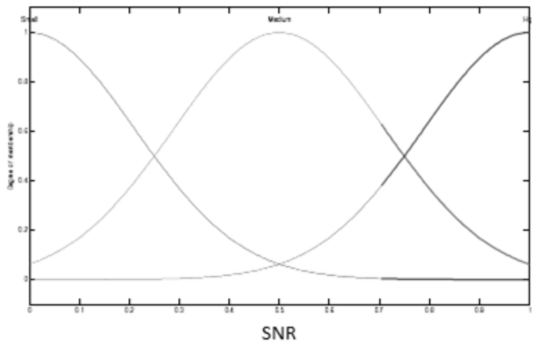


Fig. 3: Membership function for SNR.

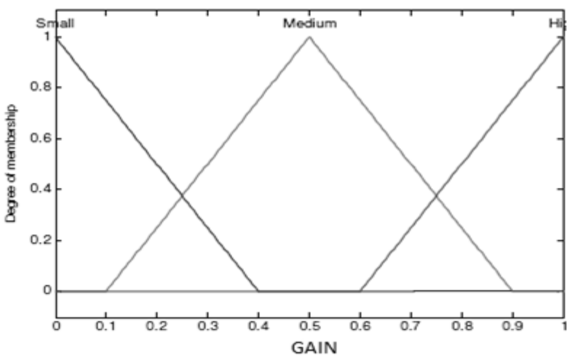


Fig. 4: Membership Function for Cooperative Gain.

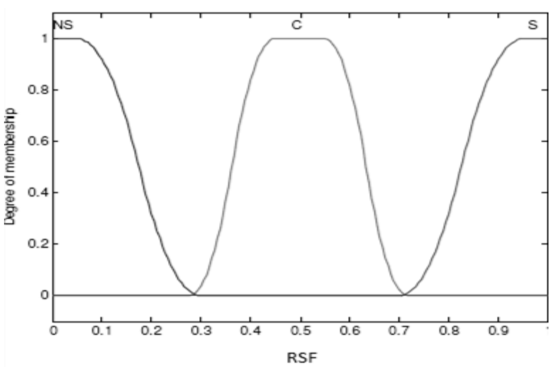


Fig. 5: Membership function for Relay ranking parameter.

B. *Adapting System*

The rules for computing the relay ranking parameter were introduced to the Mumdani inference system. A total of 9 rules were considered from the rule base called functional fuzzy system.

The strength of each rule must be considered for the decision f an appropriate output membership function. The results obtained from this procedure are provided to intelligent adaptive neuro fuzzy system. ANFIS uses the real time channel state data to adjust curves produced by fuzzy inference system. It generates its own rule base learning from the provided data. The resulting selection factor follows a normalized pattern, relays with better selection factor are given more preference and those with relatively lower selection factor are further reduced in ranking.

C. *Defuzzification*

For the defuzzification process, the input is a fuzzy set leading to a single number output. The range of output values dictates the aggregate of a fuzzy set hinting at the defuzzifcation for the reason to determine one single output from the given set. The centroid calculation defuzzication method has been used in our work, which returns under the curve center area.

Assuming that mi be the value of RSP and µout(mi) be the membership grade, then the Center-Of-Area (COA) defuzzification formula provides crisps value m as follows: (Beres and Adve, 2008)

$$m^* = \frac{\sum_{i=1}^{N} m_i \mu_{out}(m_i)}{\sum_{i=1}^{N} \mu_{out}(m_i)} \quad (10)$$

3. RESULTS AND DISCUSSION

The performance of the proposed scheme for user cooperation diversity is analysed in terms of outage probability and cooperation gain over Rician fading channels. 106 bits are generated for Monte Carlo simulation.**(Fig. 6)** depicts the result for the cooperation gain against different *m* values over Nakagami-m fading channels, for different SNR values considering BPSK modulation scheme. Since, an increase in the cooperation gain can be seen with an increase in SNR, therefore, it can be concluded that the availability of good channel results in better cooperation. By increasing m value significant results are obtained for higher SNR values.

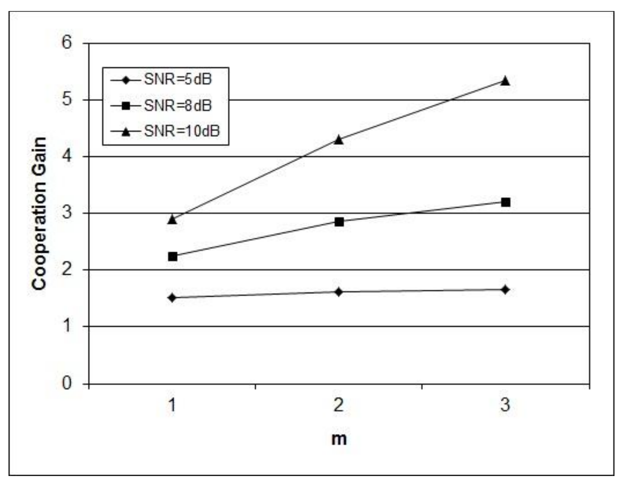


Fig. 6: Cooperation gain versus *m*-factor over Nakagami-m fading channels for different *SNR* values.

The system was simulated in different scenarios to check the effect of SNR on the BER by considering different modulation schemes. As can be seen in the **(Fig. 7),** overall, the BER decreases as the SNR value increases. However, high trend of BER has been noted for Binary BPSK EF and Differential DetF-RS as compared to the Differential AF-RS scheme. The main reason is that the noise along with the original signal amplifies at the relay in AF-RS scheme.

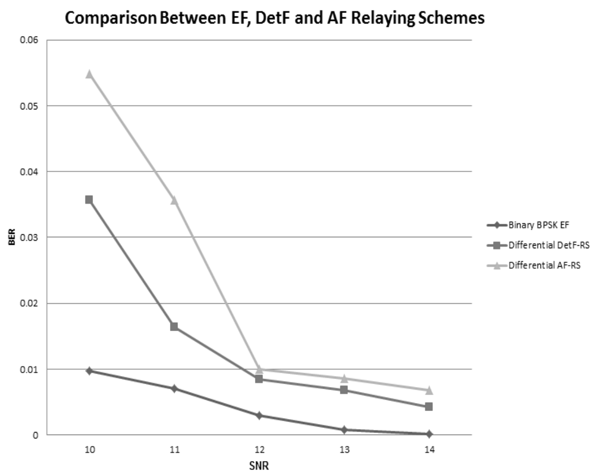


Fig. 7: BER for multi-hop estimate and forward relaying scheme.

(Fig. 8) shows outage probability vs SNR (dB) comparison between different K values and number of best relays selected. As can be seen in the figure, the outage probability increases with a decrease in the SNR value, overall Comparatively, the signals received through the relays are combined using MRC improves the performance by increasing the diversity.

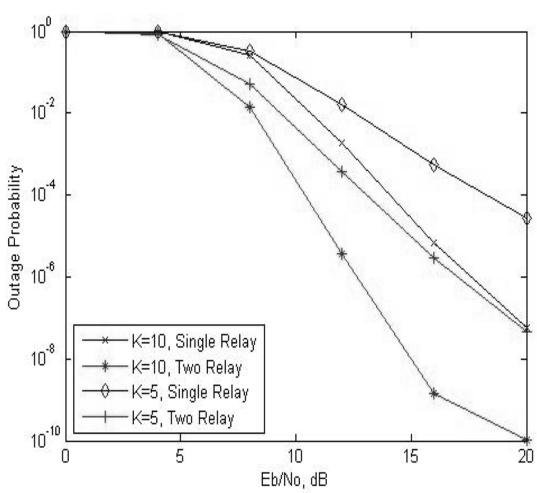


Fig. 8: Outage Probability comparison between different *K* values and number of relays.

4. CONCLUSION

In this paper, we proposed adaptive neuro fuzzy logic technique for selecting best relay(s) by considering SNR and cooperation Gain as selection parameters in two-way relay channels using physical network coding. We then take into account the outage probability of the system over Rayleigh, Nakagami, Rician fading channels and prove improvement through results in the performance of the system by the selection of relays through fuzzy logic controller. As most of the research works assume perfectly secure channels. By considering the security and integrity of the data and relays, in future we will implement the system on higher layers.

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