Neuro-Fuzzy based Joint Relay-Selection and Resource-Allocation for Cooperative Networks

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ABSTRACT

This paper focuses on a joint relay-selection and resource-allocation algorithm for an Amplify-and-Forward (AF) cooperative network. In a multiuser scenario, joint relay selection and power allocation is a combinational problem for heterogeneous, i.e., real time (RT) and non-real time (NRT), users. In single relay AF (S-AF) scheme, a source-destination pair selects best relay. Thus only two channels are needed (i.e., one for source-destination direct link and other one for the source-relay-destination indirect link) between a source-destination pair. We propose a Neuro-Fuzzy (NF) based optimal relay selection algorithm for selecting best relay based on link’s signal-to-noise ratio (SNR), link’s delay and degree of mobility between a source-destination pair. The available radio resources are then allocated sub-optimally to the RT and NRT users on priority basis. The priority parameter depends on Quality-of-service (QoS) requirement of the RT and NRT users. We deduce a close form expression of the moment-generating-function (MGF) for independent and non identical Rayleigh fading channels. Performance evaluations reveal that the proposed joint scheme has lower complexity and better outage behavior as compared to the conventional schemes.

Keywords: Relay Selection, Resource Allocation, Outage Probability, OFDMA, Mamdani-Adaptive Neuro-Fuzzy Inference System (M-ANFIS) Architecture

1. INTRODUCTION

Next Generation (xG) wireless system demands higher data transmission rate. This has imposed serious challenges for the wireless system designer. Due to the frequency selective multipath fading, the high rate coverage cannot be achieved by the direct transmission. Multiple-input and multiple-output (MIMO) is a wireless networking technology that exploits the availability of multiple independent radio terminals to improve both the range and capacity of a connection between source and destination. Cooperative relaying techniques have been proposed as an alternative to the MIMO systems because of the technical constraints of MIMO. Relays provide spatial diversity and mitigate slow fading [1]. Recent studies show that the performance of a single relay cooperative network is better than that of multi-relay cooperative network[1, 2].

Orthogonal frequency division multiplexing (OFDM) is another widely accepted technology for next generation (xG) wireless systems. It can mitigate the channel fading and offer high spectral efficiency. The 2-hop transmission with one relay node helps to attain the wider coverage. Thus the performance of a 2-hop system can be improved by OFDM based transmission technique.

Many cooperative relaying schemes have been studied by the researchers. Multi-relay AF (M-AF) is proposed in [2] where M potential relaying nodes, i.e., rᵢ (i = 1, 2, ..., M), relay source information using orthogonal channels. The source, denoted by s, has achieved the diversity order of (M +1). Authors have used the optimal power allocation (OPA) algorithm assuming that the perfect knowledge of all channel gains are known to transmitters and receivers. A selection scheme based on delay at the relay is proposed in [3]. Single relay AF (S-AF) has been discussed in [1, 4]. The performance of the time dependent relay channels has been studied for the fast fading and log-normal fading [5]. The outage probability of an AF relay channel is calculated from the frequency and probability of outages. A simple relay search algorithms has proposed that only utilize the knowledge of average received SNRs at the destination [6]. To the best of our knowledge joint relay selection and resource allocation algorithms for the RT and NRT users based on user priority have not been studied. This paper focuses on an AF based joint relay selection and resource allocation algorithm for cooperative network to study outage performance of RT and NRT users. It is assumed that all the wireless nodes use orthogonal-frequency-division-multiplexing (OFDM) based transmission. We propose a Neuro-Fuzzy (NF) based single relay selection algorithm considering non-identical and independent channel conditions, queuing delay at the relay and energy saving efficiency due to the cooperative diversity. The suboptimal power allocation optimization problem is formed for both RT and NRT users. It maximizes...
the overall data rate of the system subject to the total power, Quality of Service (QoS) requirement and data buffer information. We schedule RT and NRT users based on a priority parameter. This parameter depends on the channel condition, buffer length information and the QoS constraint.

The remaining section is organized as follows: section II introduces the system model. Section III and IV discuss a NF based S-AF relaying and suboptimal power allocation algorithms respectively. Section V presents the simulation results. Finally, we conclude our work in section VI.

2. SYSTEM MODEL

As shown in Fig. 1, a base station (BS) communicates with $k_u$ number of RT and $k_b$ number of NRT users through Relays $r_i$ and $\psi = k_u + k_b$. $N_u$ and $N_b$ are the number of subcarriers of RT and NRT users respectively and $N = N_u + N_b$. The NF based relay selection algorithm selects the best relay that allows the destination ($d$) to receive two copies of source ($s$) information in two time slots. In the first time slot, $s$ transmits information to $r_i$ and $d$. In the second time slot, $r_i$ forwards $s$ transmission. It is assumed that fading channels between the $s - r_i$ and $s - d$ are Rician and the fading channel between $r_i - d$ follows Nakagami-m distribution. It is also assumed that all channel gains are perfectly known to the transmitters and receivers and the source uses OFDMA based downlink transmission. The instantaneous signal-to-noise (SNR) of the $k$-th user using $n$-th subcarrier is $\gamma_{kn}^{xy} = P_{kn} r_{kn}^{xy} / \sigma^2$, where $(x, y) \in \{(s, r_i), (s, d), (r_i, d)\}$. Let $h_{kn}$ denotes the channel coefficient between $x$ and $y$. $P_{kn}$ denotes the transmit powers of $x$ node and $\sigma^2$ is variance of the additive white Gaussian noise (AWGN). Thus the average SNR is written as $\bar{\gamma}_{kn}^{xy} = E(\gamma_{kn}^{xy})$. The data rate of the $k$-th user through $r_i$ using $n$-th subcarrier, denoted by $R_{kn}^{r_i}$, is given as [7, 8]

$$R_{kn}^{r_i} = \frac{1}{2} \log_2 \left( 1 + \frac{\gamma_{kn}^{xy}}{\gamma_{kn}^{sr_i} + \gamma_{kn}^{sdi}} \right)$$

(1)

$$\approx \frac{1}{2} \log_2 \left[ 1 + \frac{1}{\sigma^2} \left( 1 + \Gamma_k P_{kn} r_{kn}^{xy} / \sigma^2 \right) \right]$$

(2)

$$= \frac{1}{2} \log_2 \left[ 1 + \frac{1}{\sigma^2} \left( 1 + \frac{1}{\gamma_{kn}^{sr_i} + \gamma_{kn}^{sdi}} \right) \right]$$

(3)

where, $\Gamma_k$ is the SNR gap which can be expressed as $\Gamma_k = 1.5 \left[ - \ln 5 (BER) \right]$. $P_{kn}$ and $P_{kn}^{r_i}$ are the source and $i$-th relay transmit powers. Thus, the total power is $P_{kn} = P_{kn}^{r_i} + P_{kn}^{sr_i}$. Let $P_{kn}^{sr_i} = \varepsilon P_{kn}$ then $P_{kn}^{r_i} = (1 - \varepsilon) P_{kn}$. The equivalent channel response of the $k$-th user using $n$-th subcarrier

$$h_{kn}^2 = \varepsilon |h_{kn}^{sr_i}|^2 + (1 - \varepsilon) |h_{kn}^{sdi}|^2$$

(4)

where $\varepsilon$ is the OPA factor defined in [2]. Equiv. (3) can be written as

$$b_{kn}^{r_i} = \frac{1}{2} \log_2 \left( 1 + \frac{\Gamma_k P_{kn} h_{kn}^2 r_{kn}^{xy}}{\sigma^2} \right)$$

(5)

The achievable data rate of the $k$-th user, i.e., $b_k$, can be expressed as

$$b_k = \sum_{n=0}^{N_b} \rho_{k,n} b_{kn}^{r_i}$$

(6)

where $\rho_{k,n}$ is the subcarrier allocation indicator. $\rho_{k,n} = 1$, if $n$-th subcarrier is allocated to $k$-th user; else $\rho_{k,n} = 0$. The data rate of each RT/NRT user is limited by its buffer occupancy, that is, $b_k \leq \mathcal{B}_{\min}(L_k, L_r)$, where $L_k$ and $L_r$ are the buffer length of the $k$-th user and $i$-th relay respectively. $\mathcal{B}_{\min}()$ is a function of buffer length.

3. NF BASED S-AF SCHEME

Optimal relay selection is a complex evaluation process. It depends on the attributes of all the relays and the utilities of an individual relay are weighted subjectively. The fuzzy logic and approximate reasoning can simplified this complex decision making process. Artificial Neural Network is a parallel distributed information processing technique that can learn the behavior of system [9]. A rule-based fuzzy system is developed which represents a preliminary model. It is then trained by Gradient Descent learning algorithm. After the training procedure, the modified membership functions of the proposed system are retrieved.

3.1 Relay Selection Parameters

3.1.1 SNR

The link SNR, denoted by $\gamma_{kn}^{r_i}$, can be written as

$$\gamma_{kn}^{r_i} = \gamma_{kn}^{sr_i} + \min \left( \gamma_{kn}^{sr_i}, \gamma_{kn}^{sdi} \right)$$

(7)
3.1 Mean Delay Estimation

A practical communication system has limited data buffer length. The packet arrival (λ) and service processes (μ) follow the Poisson distribution. The queue size is fixed and can hold only V packets. When, μ > λ, ⇒ D_q = 0 where, D_q is the mean queuing delay. When μ < λ, the probability to have v packets in the queue (v ≤ V), denoted by p(v), is written as [10]

\[ p(v) = \left\{ \begin{array}{ll}
\frac{\lambda^v}{v!} e^{-\lambda} & \text{if } \mu \neq \lambda \\
1 & \text{if } \mu = \lambda.
\end{array} \right. \]

(8)

The mean number of packets in the queue is \( Q = \sum_{v=0}^{V} v \times p(v) \). Since the queue length of \( r_i \) is fixed, the queuing delay at \( r_i \), i.e., \( D_{r_i} \), is bounded by some maximum value \( D_{r_i}^{max} \). It can be calculated as [11]

\[ D_{r_i}^{max} = V \times r_i / \mu r_i. \]

(9)

3.1.3 Energy Saving

Cooperative diversity reduces node energy consumption. In case of non-cooperative communication (NC), the total energy consumption per information bit, i.e., \( E_{kn}^{NC} \), can be expressed in [4] as

\[ E_{kn}^{NC} = a^{sd} + (P_{cck_{rx}} + P_{cck_{rx}}) / b_k, \]

(10)

where \( a^{sd} \) is the required energy/bit at the receiver for target BER (BER_T), \( b_k \) is the bit rate, \( c^{rv} \) is the peak-to-average power ratio and \( \eta^{rv} \) is the drain efficiency. In case cooperative communication, the total energy consumption per information bit at the \( l \)-th link, i.e., \( E_{kn}^{IC} \), can be written as

\[ E_{kn}^{IC} = a^{rd} + \eta^{rd} + (2P_{cck_{rx}} + 3P_{cck_{rx}}) / b_k. \]

(11)

The energy efficiency of cooperation is defined as the percentage of energy saving, i.e., \( E_{kn}^{sav} \), achieved by cooperation at the \( l \)-th link. Mathematically,

\[ E_{kn}^{sav} = \left( E_{kn}^{NC} - E_{kn}^{IC} \right) / E_{kn}^{NC}. \]

(12)

3.2 M-ANFIS

Fig. 2 shows a Mamdani-Adaptive Neuro-Fuzzy Inference System (M-ANFIS) architecture. It consists of five layers. The nodes in the Layer 1 (L1) generates the membership grades using Fuzzification process. The nodes in the Layer 2 (L2) produces the firing strengths or the rule weight coefficient. Layer 3 (L3) calculates the qualified consequent membership functions (MFs) based on the firing strengths. The qualified consequent MFs are aggregated to generate overall output MF in the layer 4 (L4). Finally the output MFs are converted into crisp output value in the layer 5 (L5). This process is called Defuzzification. In this paper, all the membership functions(MFs) are bell-shaped functions. Fig. 3 shows MFs of inputs and output after training. The layer relations of M-ANFIS model are depicted as below:

\[ L1 : O^1_l = \mu_{Apq}(x_p) = \frac{1}{1 + (x_p - c_{pq}/a_{pq})^{2^{pq}}}, \]

(13)

\[ L2 : O^2_l = \omega_l = \frac{4}{\sum_{p=1}^{\omega_l} \mu_{Apq}(x_p)}, \]

(14)

\[ L3 : O^3_l = \omega_l \circ B_l, \]

(15)

\[ L4 : O^4_l = \sum \omega_l \circ B_l, \]

(16)

\[ L5 : \Theta_l = f_l(O^4_l). \]

(17)

where, \( A_{pq} \) is the linguistic value of the input parameters \( x_p, l = 1, 2, ..., p \times q \) and \{\( a_{pq}, b_{pq}, c_{pq} \}\} is the parameters set. Let, \( I_p \) is the input to node, \( p = 1, 2, 3 \). \( I_1 : \gamma_{tot}, I_2 : D \) and \( I_3 : E_{sav} \). \( A_{pq} \) is the
linguistic label, \( q \in \{1, 2, 3\} \equiv (\text{Low}, \text{Medium}, \text{High}) \) of the node functions. \( O_{k,l} \) is the membership function of \( \Phi_{pq} \). The firing strength of the rules are \( w_{pq}^r \), \( B_{pq} \) is the linguistic value of the relay selection factor, \( l = 1, 2, ..., q^l \). The COA (center of area) defuzzification method is considered. The MFs of input and output of the NF controller after training are shown in Fig. 3.

### 3.3 Weight Updating

The aim of the weight update is to adjust the shaping parameters of the membership function and thereby minimizing the overall error, defined by \( \epsilon_l \). Mathematically,

\[
\epsilon_l = \sum_k (d_k - o_k)^2, \tag{18}
\]

where, \( d_k \) and \( o_k \) are the \( k \)-th component of the \( l \)-th desired and the predicted output vectors respectively. The weight updating formula in M-ANFIS can be derived as

\[
\Delta w_l = -\eta \frac{\delta \epsilon_l}{\delta w_l} = -\eta \frac{\delta \epsilon_l}{\delta B_{pq} \delta w_l}, \tag{19}
\]

\[
w_l^{\text{new}} = w_l^{\text{old}} - \eta \frac{\delta \epsilon_l}{\delta B_{pq}}, \tag{20}
\]

where \( \Theta_l = f_l(\sum \omega_l \circ B_{pq} + \phi) \) \( f_l \) and \( \Theta_l \) are the activation function and output of q-l link. \( \eta \) is the learning rate, \( \phi \) is the bias and \( \Delta w_l \) is the difference between the \( l \)-th new and old weight. The error signal \( \frac{\delta \epsilon_l}{\delta w_l} \) starts from the output layer and goes backward until the input layer is attained. The error signal of the present node can be derived by error signals in previous layer nodes. The shape parameters are tuned as follows

\[
X_i(t + 1) = X_i(t) - \eta \frac{\partial \epsilon_l}{\partial B_{pq}}, \tag{21}
\]

where \( X_i \rightarrow a_{pq}, b_{pq}, \) and \( c_{pq} \) are shaping parameters.

### 3.4 Selection Criterion

We have constructed a mapping model between the relay selection parameters and relay selection factor, denoted by \( \Theta_{r_i} \), using M-ANFIS. The NF based algorithm selects \( r_i \) for user \( k \) using \( v \)-th subcarrier that has the maximum value of \( \Theta_{r_i} \). Mathematically,

\[
\Theta_{r_i} = \arg \max_{r_i} \Psi(\rho_{k,n}, D_q^{r_i}, P_{\text{data}}^{r_i}). \tag{22}
\]

### 4. POWER ALLOCATION

We consider the problem of resource allocation in order to guarantee the QoS of both the RT and NRT services. The throughput of the RT service users are constant, this is due to the minimum data rate requirements of the RT users, i.e., \( b_k = R_{k,\text{min}} \); for all \( k \), where, \( R_{k,\text{min}} \) is the minimum data rate requirement of the \( k \)-th user. The overall system throughput, denoted by \( T \), will increase if the throughput of the RT service users increases. The resource allocation problem of the system can be formed as

\[
\arg \max_{(p_{k,n}, P_{k,n})} [T] = \arg \max_{(p_{k,n}, P_{k,n})} \left( \sum_{k=0}^{k_a} b_k + \sum_{k=0}^{k_b} b_k \right), \tag{23}
\]

This is a non-linear optimization problem. It is difficult to solve directly and the complexity of this problem is very high. Thus the optimization problem in Eqn. (23) can be transformed into two suboptimal problems as

**Problem I: RT users**

\[
\text{minimize} \sum_{k=0}^{k_a} \sum_{n=0}^{N_n} P_{k,n} \quad \text{subject to} \quad b_k = R_{k,\text{min}}, \quad P_{k,n} > 0; b_k \leq \Im \left( \min [L_k, L_r] \right). \tag{24}
\]

**Problem II NRT users**

\[
\text{maximize} \sum_{k=0}^{k_b} b_k \quad \text{subject to} \quad P_a + P_b = P \quad P_{k,n} > 0; b_k \leq \Im \left( \min [L_k, L_r] \right), \tag{25}
\]

where \( P_a = \sum_{k=0}^{k_a} P_k = \sum_{k=0}^{k_a} \sum_{n=0}^{N_n} P_{k,n} \) and \( P_b = \sum_{k=0}^{k_b} P_k = \sum_{k=0}^{k_b} \sum_{n=0}^{N_n} P_{k,n} \). \( P_k \) is the power of the \( k \)-th user, and \( P \) is the total power.

We allocate less number of subcarriers with high SNR to the user at cell edge to achieve the minimum data rate. Because the user at the cell edge suffers high path loss. In order to ensure the minimum QoS to all RT and NRT service users at the cell edge, a scheduling parameter must be set. The QoS requirements of the different users are different. The priority parameter, i.e., \( W_k(q) \), is given as \( \left[ R_{k,\text{min}} \times \frac{R_k(q)}{R_k(q - 1)} \right]^{-\alpha} \times h_{k,n}^\alpha \). \( \tag{26} \)

where \( R_{k,\text{min}} \) is the minimum rate constraint of \( k \)-th user, \( R_k(q - 1) \) is the average rate at the end of \( (q - 1) \)-th frame of \( k \)-th user, and \( R_k(q) \) is the number of bits which should be sent out at the \( q \)-th frame to satisfy the users demand, \( L_k(q) \) and \( L_r(q) \) are the data buffer length of the \( k \)-th user and \( r \)-th relay at the \( q \)-th frame respectively, and \( \alpha \) is the priority selection factor, \( \alpha = 0 \) if \( b_k < R_{k,\text{min}} \) else \( \alpha = 1 \). We follow the bit allocation algorithm in \( \text{[7]} \). Subcarriers are first allocated to the RT users to achieve the minimum data rate requirement then the remaining
subcarriers are allocated to NRT user to maximize the overall throughput.

Using the Lagrange multiplier and Karush-Kuhn-Tucker conditions [7], we get the solutions of the above optimization problems. By taking the derivatives of $L$ and after some algebraic manipulation, we can get the following solution for RT users

$$
P_{k,n} = \sigma_k^2 \left( \frac{m_k}{\sum_{n=1}^{m_k} |h_{k,n}|^2} \right)^{1/2}. \tag{27}$$

where, $m_k$ is the number of predetermined best subcarrier set [7] allocated to the $k$-th user to achieve $b_k = R_{k_{\text{min}}}$ The supported rate of the $k$-th RT user can be written as

$$
b_k = \sum_{n=0}^{m_k} \rho_{k,n} \cdot \frac{1}{2} \log_2 \left( \frac{2^{2R_{k_{\text{min}}}} |h_{k,n}|^2} {\prod_{n=1}^{m_k} |h_{k,n}|^2} \right)^{1/2}. \tag{28}$$

Similarly, We can write the solution of the Problem II:NRT users as

$$
P_{k,n} = \frac{1}{n_k} \left( P_k + \sum_{n=0}^{n_k} \sigma_n^2 \frac{1}{|h_{k,n}|^2} \right)^{1/2} \tag{29}$$

The supported rate of the $k$-th NRT user can be written as

$$
b_k = \sum_{n=0}^{n_k} \frac{1}{\rho_{k,n}} \cdot \frac{1}{2} \log_2 \left[ \frac{1}{n_k} \left( P_k + \sum_{n=0}^{n_k} \sigma_n^2 \frac{1}{|h_{k,n}|^2} \right) \right] \tag{30}$$

where $\gamma_{\text{th}} = 2^{2R_{k_{\text{min}}}-1}$, and the transmitted data rate is $R_{k_{\text{min}}}$.

The joint probability density function (PDF) of two independent non identical Rician and Nankagami-$m$ fading channels can be calculated by using [17]. After few steps, it can be written as

$$f_{\gamma_{k,n}}(\gamma) = \frac{1 + K}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \exp \left( -K - \frac{(1 + K)\gamma_{k,n} - m\gamma_{k,n}}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right) \times \sum_{x=0}^{m} \left( \frac{m + x + 1}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right)^{x} \times \left( \frac{K (1 + K)}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right) \times K_{m-y} (2\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}) \tag{32}$$

where $K_q(\cdot)$ is the $q$-th order modified Bessel function of the second kind, which is defined by [17, eq.(8.432)]. $\gamma_{u,v} = P_u \sigma_u^2 / N_0$ is the average SNR between the $u-v$ link with variance $\sigma^2_{u,v}$. Substituting $K = 0$ and $m = 1$ in Equ. (32), we have

$$f_{\gamma_{k,n}}(\gamma) = \frac{2\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} {\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \exp \left( -\left( \frac{1}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right) \gamma \right) \times \sum_{x=0}^{m} \left( \frac{m + x + 1}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right)^{x} \times K_{1} (2\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}) \tag{33}$$

This is the joint PDF of independent and non identical Rayleigh fading channels. Equ. (33) is same that of [18]. The moment-generating-function (MGF) is given by the expression

$$\mathcal{M}_{\gamma}(s) = e^{s \gamma_{u,v}} \cdot \mathcal{M}_{\gamma_{u,v}}(s) \tag{34}$$

Now the close-form MGF can be obtained by using the joint PDF given in 33. After some mathematical manipulation and using [17, eq.(6.621.3)], the MGF of $\gamma_{u,v}$ can be expressed as

$$\mathcal{M}_{\gamma_{k,n}}(s) = \frac{1 + K}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \exp (-K) \times \sum_{y=0}^{m} \left( \frac{m + x + 1}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right)^{x} \times K_{m-y} (2\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}) \tag{35}$$

where $\alpha = \left( \frac{1 + K}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}} \right), \beta = 2 + \frac{m(1 + K)}{\gamma_{k,n}^{2\gamma_{k,n}} - 2^{2b}}, \nu = x + 2m - y + 1, \psi = m - y + \frac{1}{2}, \varpi = x + m + \frac{1}{2}$.
\( \beta_1(\cdot, \cdot, \cdot) \) is the gauss hypergeometric function which is defined in \([17, \text{eq.}(9.100)]\). Now the MGF of \( \gamma_{a,b} \) can be shown as

\[
\mathcal{M}_{\gamma_{sd}}(s) = \left( 1 - \frac{s \gamma_{sd}}{m} \right)^{-m}.
\]

Under the assumption of non identical fading channels, a close form expression of the moment generating function of \( \gamma_{ri} \), can be obtained by multiplying the MGF of the \( \gamma_{sd} \) and \( \gamma_{sr,di} \), i.e

\[
\mathcal{M}_{\gamma_{ri}}^{\gamma_{ri}}(s) = \mathcal{M}_{\gamma_{sd}}(s) \mathcal{M}_{\gamma_{sr,di}}(s).
\]

The close form expression of \( \mathcal{M}_{\gamma_{ri}}^{\gamma_{ri}}(s) \) can be used to calculate the outage probability as \([19]\)

\[
P_{\text{out}} = L^{-1} \left( \frac{\mathcal{M}_{\gamma_{ri}}^{\gamma_{ri}}(s)}{s} \right) \bigg|_{\gamma_{th}}
\]

where \( L^{-1} \) is the inverse Laplace transform. Using MGF-based approach, the end-to-end outage probability can be calculated by using any numerical techniques \([12]-[20]\).

6. SIMULATION RESULTS

We consider a single cell cellular system. The cell-radius of the cell is 1000 m. A BS is placed at the center of the cell whereas the fixed infrastructure relays are placed 500 m away from BS. The total number of subcarriers is 64 and path loss exponent is 3.5. We generate \( N_a=3 \) and \( N_b=5 \) randomly in the cell. The total transmit power of each link is 30 dBm. Depending on the value of \( \epsilon \), the source and relay powers are distributed. Each subcarrier experiences a Rice-Nakagami-m fading with rms delay spread of 300 ns \([11, 21]\). We assume the path loss model of IEEE 802.11 with relay \([11]\) and define the average SNR as \( 1/\sigma^2 \). We allocate 20 and 10 subcarriers in the Fixed A and Fixed B schemes respectively.

The outage probability of the best selected relay (for \( \gamma_{sd} = \gamma_{sr} = \gamma_{ri} \)) is shown in Fig. 4. Solid curve shows the analytical result. The dash-symbol curve gives the outage performance of NF based selected relay. A close match is observed between the two curves.

Fig. 5 shows the throughput analysis of NRT users. Our algorithm maintains almost the same data rate as the algorithm in \([8]\). However, it outperforms the fixed allocation. The slight difference in performance is due to allocation of best carriers to the worst users in our case while algorithm in \([8]\) allocates best carriers to the best users. It is also observed from Fig. 5 that dynamic resource allocation is better than the fixed allocation. For low value of SNR, the throughput of the Fixed A performs better than Fixed B. However, Fixed B performs better than Fixed A for high SNR values. It is due to the allocation of more subcarriers in low SNR region and allocation of more power in high SNR region.

Fig. 6 presents the outage probability analysis of the RT users. We compare our proposed algorithm with adaptive resource allocation proposed in \([8]\) and fixed allocation schemes. The proposed algorithm outperforms in algorithm \([8]\) and fixed allocations. It is observed that the outage probability is reduced if more subcarriers are allocated to the users.

The computational complexity of the joint optimal relay selection-OPA is \( O([N^R + N^K]) \) whereas the complexity of proposed joint NF based optimal relay selection-suboptimal power allocation algorithm is \( O([NKl]) \) in worst case, where \( l \) is the length(Fuzzyattributes).

7. CONCLUSION

We proposed an intelligent relay selection and suboptimal power allocation algorithms for an OFDMA based cooperative communication network. The relay selection and power allocation have been done based on a priority parameter. Simulation results reveal that the outage probability of NF based relaying in non-identical and independent Rice-Nakagami-m fading channels is almost the same as that of analytical result. The data transmission rate of NRT users is
lower than the algorithm proposed in [8]. The outage performance of RT users is better than the algorithm in [8]. The complexity of the joint relay selection and power allocation algorithm is lower than that of the Zhang algorithm and optimal algorithm. We will extend our work considering the partial CSI instead of full CSI and SVD-BP (singular value decomposition-back propagation) to reduce the number of rules in rule based system.

References


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