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Particle Swarm Optimization Based Power Allocation in Multi-Hop Cooperative AF Relaying Networks

B.Lakshmi Vani[1], Dr.K.Rama Naidu[2]

M.Tech Student, Department of ECE, JNTUA college of Engineering, Anantapuramu, Andhra Pradesh India[1]

Professor, Department of ECE, JNTUA college of Engineering, Anantapuramu, Andhra Pradesh India, India[2]

ABSTRACT: In spectrum sharing cognitive radio systems ,the coverage area of the secondary users can be extended by using cooperative relaying schemes. In this paper, we consider multi-hop AF cooperative relaying to increase the system performance. Power allocation is a major issue in a cooperative wireless system. Particle Swarm Optimization(PSO) power allocation scheme is exploited for communication by considering perfect Channel State Information. By using Extreme Value Theory, the limiting distribution functions of the lower and upper bounds on the end to end signal to noise ratio can be derived. With PSO algorithm, we can minimize the outage probability as a constraint compared to water filling power allocation algorithm. In PSO, the swarm of particles are present, each particle represents a possible solution. By using fitness function, the optimal solution can be obtained. Hence, the system performance can be enhanced by using PSO algorithm for multi-hop cooperative AF relaying.

KEYWORDS: Cooperative communications, AF relaying Scheme, Power Allocation, Extreme value Theory, Particle Swarm Optimization

I.INTRODUCTION

COGNITIVE radio (CR) is a promising wireless technology to resolve the growing scarcity of the indispensable electromagnetic spectrum resources. By use of CR, secondary users (SUs) without explicitly assigned spectrum resources can co-exist with primary users (PUs) licensed with particular spectrum. Major communications regulators like the FCC in US and OFCOM in UK have allowed secondary access for unlicensed devices to the terrestrial TV broadcast bands. Relayed transmission is a promising technique for improving the quality of wireless communications.

Cooperative communication is a new class of diversity; it is used for efficient wireless communication. The basic idea behind the user-cooperation is that of information sharing with multiple nodes in a wireless communication network. The reason beyond is sharing of user cooperation is that desire to share power and data processing with neighbouring nodes for effective case of resources. In cooperation the single antenna users share their antennas. So that it improves communication capacity, speed and performance.

In this work, multi relay cooperative network using AF relaying is considered. AF relaying gives better performance compare to DF when the relay located away from source (when the relay unable to decode the received data perfectly) and has low complexity. PSO based power allocation is applied for multi relay cooperative network and outage performance is compared for both PSO and water filling power allocation ALGORITHMS Cooperative communication provides various advantages over MIMO system. The major concern for the realization of cooperative communication is power allocation (PA). Power allocation is a useful solution to save transmits power and improves the performance of the system. Basically in cooperative communication, the power is allocated to source as well as relay. The problem is how to allocate the power to source node and relay based on link condition and channel state information availability.

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II.RELATED WORK

Related work has been presented in [4], where authors derive expression for symbol error rate when selected relays with high contribution are allowed to participate in communication. An amplify and forward relay network has been studied in [5], where a source communicates with the user having best channel conditions through an intermediate relay that serves to multiple users. Probability density function and cumulative density functions of the received SNR at the best user in Rayleigh fading channels have also been derived.Here, closed form expressions for outage probability, cumulative density function and the probability density function of received SNR have been presented. In [8], authors propose a network coding approach to cooperative diversity featuring the algebraic superposition of channel codes over a finite field. Communication over interference limited wireless networks with the help of network coding has been analysed in [10].

In wireless environment numbers of relays are present, multi-relay cooperative communication efforts the better diversity gain. Whenever cooperation is carried out it is necessary to allocate power to multi-relay system . Luo, Jianghong, et al [20] are illustrate cooperative relaying using DF in a N-node distributed network, the power allocated among the source and relay for minimizing outage probability, however the SER performance also important issue in multi-relay cooperative communication for enhance the system performance and it is need to allocate optimum power allocation for each relay.

III.COOPERATIVE MULTI-HOP SYSTEM MODEL

To extend the coverage area of secondary transmitters and to reduce their interference region and its negative impact on primary users, multi-hop AF RELAYING can be implemented.

A. *Multi-hop Cooperative Relaying System Model:*

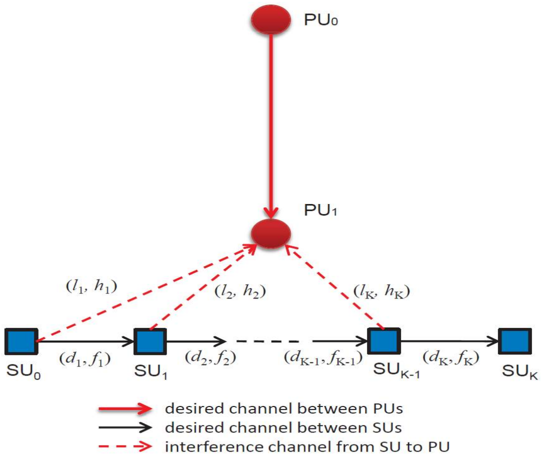

Fig 1.Spectrum Sharing Based secondary multi-hop Relaying network

In the secondary multi-hop AF relaying link, all SUs work in a time-division multiple access (TDMA) fashion and equal time slots of a transmission frame are allocated to each SU along the multi-hop path. Also, only one SU transmits to its next node along the multi-hop relaying path during each time slot. With these assumptions in mind, based on [10], [13], the end-to-end (e2e) received SNR at the final destination SU_K, can be expressed as

$$\gamma_{e2e} = \left(\sum_{k=1}^{K}\frac{1}{\gamma_k}\right)^{-1} \quad (1)$$

where γ_k denotes the received SNR at the *k*th secondary node (k = 1, · · · ,K), defined as

$$\gamma_k \triangleq \frac{P_{k-1}}{\sigma_k^2} d_k^{-\epsilon} |f_k|^2 \tag{2}$$

where d_k and f_k denote the distance and the channel fast-fading coefficient between consecutive secondary nodes SU_{K-1} and SU_K , $\in$ refers to the path-loss exponent (generally, $\in \geq 2$ in free space and $\in = 4$ in most practical scenarios), P_{k-1} indicates the transmit power at SU_{K-1}, and σ_k^2stands for the additive white Gaussian noise (AWGN) variance at SU_K. For notational convenience, the secondary source node in Fig. 1 is denoted by SU_O .The actual power values will greatly affect the end-to-end SNR at the destination node. To overcome this we establish optimal power allocation at the source and destination nodes.

B. *Optimal Power Allocation:*

The Optimal Power Allocation at the secondary nodes along the multi-hop link can be established and then based on that the value of optimal transmit power during each transmission slot at each secondary node can be determined.Assume that the average tolerable interference power at the primary receiver is *W* dB with respect to the noise power. Also, the distances corresponding to the desired link and the interference link at each hop are assumed to remain fixed during a communication between the secondary source and its destination Thus, to maximize the achievable data rate at the *k*th hop, we need to optimize the transmit power at SU_{K-1} with respect to *W* and the instantaneous fast-fading fluctuations of the corresponding desired channel and interference channel. By Applying the well-known Lagrangian multiplier method, we optimize the power by using power allocation parameter λ_{k-1} by setting average interference power constraint.

With the help of water-filling power allocation algorithm, the power allocation can be determined by so-called water level. If the gain of the desired channel is smaller than the lower bound, then transmit power is zero, otherwise no data will be transmitted.

C. *Statistics of the end-to-end SNR:*

To find the statistics of end-to-end SNR at the secondary destination, first we need to derive the exact distribution functions and MGF of the end-to-end SNR. For further processing while gaining insight into system performance, a pair of lower and upper bounds on the SNR are proposed and their limiting distribution functions as the number of hops $K \to \infty$ are developed, by using extreme value theory. The exact distribution functions and MGF of the end-to-end SNR can be derived with the help of higher level statistics such as Tricomi confluent hyper geometric and Gaussian hyper geometric functions[14].

Although the exact CDF and MGF of the end-to-end SNR were developed as above, they are a bit on the complex side for further processing. In order to proceed and in particular to gain illuminating insights into system performance, in the next subsection we propose a pair of lower and upper bounds on the end-to-end SNR and study its limiting distribution functions, by using the extreme value theory. The limiting distribution functions of the lower and upper bounds on the end-to-end SNR can be derived to reduce the complexity of higher hops.

Assuming that the received SNRs at *K* consecutive hops are i.i.d, the limiting CDF and PDF of the upper bound are given by

$$\lim_{K\to\infty} F_{\gamma_{e2e}^{\text{upper}}}\left(\frac{\lambda\eta}{(K-1)\sigma^2}\gamma\right) = 1 - \exp(-\gamma) \tag{3}$$

$$\lim_{K\to\infty} \frac{\lambda\eta}{(K-1)\sigma^2} f_{\gamma_{e2e}^{\text{upper}}}\left(\frac{\lambda\eta}{(K-1)\sigma^2}\gamma\right) = \exp(-\gamma) \tag{4}$$

The limiting distribution functions CDF and PDF of the lower bound are given by

$$\lim_{K\to\infty} F_{\gamma_{e2e}^{\text{lower}}}\left(\frac{\lambda\eta}{K(K-1)\sigma^2}\gamma\right) = 1-\exp(-\gamma) \tag{5}$$

$$\lim_{K\to\infty} \frac{\lambda\eta}{K(K-1)\sigma^2} f_{\gamma_{e2e}^{\text{lower}}}\left(\frac{\lambda\eta}{K(K-1)\sigma^2}\gamma\right) = \exp(-\gamma) \tag{6}$$

By using the limiting CDF and PDF of the lower and upper bounds, we can evaluate the system performance by calculating outage probability and achievable data rate. By increasing the number of hops, we can estimate the performance exploiting extreme value theory for mathematical tractability.

IV.PROPOSED POWER ALLOCATION SCHEME

A. *Particle Swarm Optimization:*

Particle Swarm Optimization is optimizing technique; it gives the best optimum value for a given problem by using objective function. PSO contains a swarm of particles, each particles in this swarm gives a possible solution. This optimizing technique is working based on the population search, and gives a best solution by iteration method [11]. In PSO algorithm, all particles are move towards its optimum value. For each iteration all the particles in this swarm are updated by its position and velocity for optimization ability. In PSO each particle maintains its position evaluated fitness and velocity. Let $\mathbf{p}_m(t)$ denote the position of particle m in the n_x -dimensional search space at time t . The position of the particle is changed by adding velocity $\mathbf{v}_m(t+1)$ to the current position as

$$\mathbf{p}_m(t+1) = \mathbf{p}_m(t) + \mathbf{v}_m(t+1) \tag{7}$$

For the global best PSO (called "*Gbest* PSO" hereafter), the neighbourhood for each particle is the entire swarm. The social component of the particle velocity update reflects information obtained from all the particles in the swarm. In this case, the social information is the best position found by the swarm, referred to as $\mathbf{y}\hat{}$. The velocity of particle m is updated as

$$\mathbf{v}_m(t+1) = \mathbf{v}_m(t) + c_1\mathbf{r}_1(t)[\mathbf{y}_m(t) - \mathbf{p}_m(t)] + c_2\mathbf{r}_2(t)[\hat{\mathbf{y}}(t) - \mathbf{p}_m(t)] \tag{8}$$

where $\mathbf{v}_m(t)$ is the velocity of particle m at time step t ,c_1 and c_2 are positive acceleration constants used to scale the contribution of the cognitive and social components, respectively, and $\mathbf{r}_1(t)$ and $\mathbf{r}_2(t)$ are n_x -dimensional vectors whose elements are uniformly distributed in the range [0,1]. The personal best position $\mathbf{y}_m(t)$ associated with particle m at time step t is the best position that the particle has visited since the first step. Then the fitness function measures how close the corresponding solution is to the optimum.

B. *Description of the Proposed Algorithm:*

Aim of the proposed algorithm is to.optimize the power allocation along the secondary multi-hop AF cooperative relaying. The proposed algorithm is consists of four main steps.

(i)Obtaining Partial CSI:

During the CSI collection slot, the system collects the CSI at those symbol times in the slot. Based on this partial CSI, the system calculates the power allocation using the proposed scheme. Then, during the data transmission slots, actual data are transmitted with the power allocated in the CSI collection slot. Hence, the proposed scheme significantly reduces overhead required for the CSI collection and calculation

(ii) Deriving Instantaneous optimum Value:

We considered 20 particles and 5 iterations to obtain the optimal point. The optimum point axes are (0,0). The particles were randomly distributed in the grid. In each iteration, the particles have inferred each other about their position and velocity. Thus, they have flown around the grid, making a swarm. If the iteration is finished, the PSO algorithm finds the optimum point that is closest.

(iii) Evaluating a fitness Function of the PSO:

The fitness function of the PSO algorithm is the outage probability function. Outage probability is defined as the probability that the instantaneous end-to-end SNR falls below a prescribed threshold value γ_{th}.

$$F_{\gamma_{e2e}^{\text{upper}}}(\gamma_{\text{th}}) \le \mathrm{P}_{\text{outage}}(\gamma_{\text{th}}) \le F_{\gamma_{e2e}^{\text{lower}}}(\gamma_{\text{th}}) \tag{9}$$

(iv) Allocating Power using the gbest of the PSO:

After finding the optimal solution among all the possible solution by calculating fitness function followed by iterations. In this way the power allocation can be optimized along multi-hop cooperative relaying along secondary transmission.

C. Pseudo code for PSO Algorithm:

```
Step 1: Generate initial random particles
Step 2:  Calculate the velocity of each particle by using eq. (8).
Step 3:  Obtaining the Personal best position by calculating the fitness function.
            if ($Pbest_{current}$ <  $Pbest_{prev}$)
                  set the personal best position.
           else
                update the personal best position
           end
Step 4:  Obtaining the Global best position by calculating the fitness function.
            if ($Gbest_{current}$ <  $Gbest_{prev}$)
                  set the Global best position.
           else
                update the Global best position
           end
Step 5: Allocating power using the Gbest of the PSO
Step 6: Optimization of the power between the source and destination can be done
Step 7: go to step 3.
Step 8: End.
```

V.SIMULATION RESULTS AND DISCUSSIONS

To evaluate the performance of the proposed PSO algorithm, the simulation is implemented with MATLAB. For ease of mathematical tractability of the above theorems, it is assumed that the variances of AWGNs at all nodes are identical. In general, however, AWGNs at different nodes may have different variances and different channels may have different average power gain values. Actually, for ease of theoretical analysis, the variance of AWGN and the average value of channel power gain can be absorbed without loss of generality into a single parameter, namely, average SNR. In the simulation experiments, the number of hops is set to an even integer (k=2,4,8)and all secondary nodes are deployed sequentially along a straight line. In the ensuing Monte-Carlo simulations, the gain of channel fast-fading is subject to Rayleigh distribution with unit mean, and the variance of AWGNs at all nodes is set to unity. Furthermore, the energy of each transmitted symbol is set to unity but is scaled before transmission by a constant corresponding to the average SNR. The power allocation can be done by using PSO algorithm.

The performance metric outage probability is defined as the probability that the instantaneous end-to-end SNR falls below a prescribed threshold value γ_{th}. Furthermore, since outage probability is a monotonically decreasing function of the end-to-end SNR eq(9). In order to confirm the effectiveness of the preceding analysis, extensive simulation experiments are performed to compare the simulation results of outage probability with the numerical results of the above lower and upper bounds.

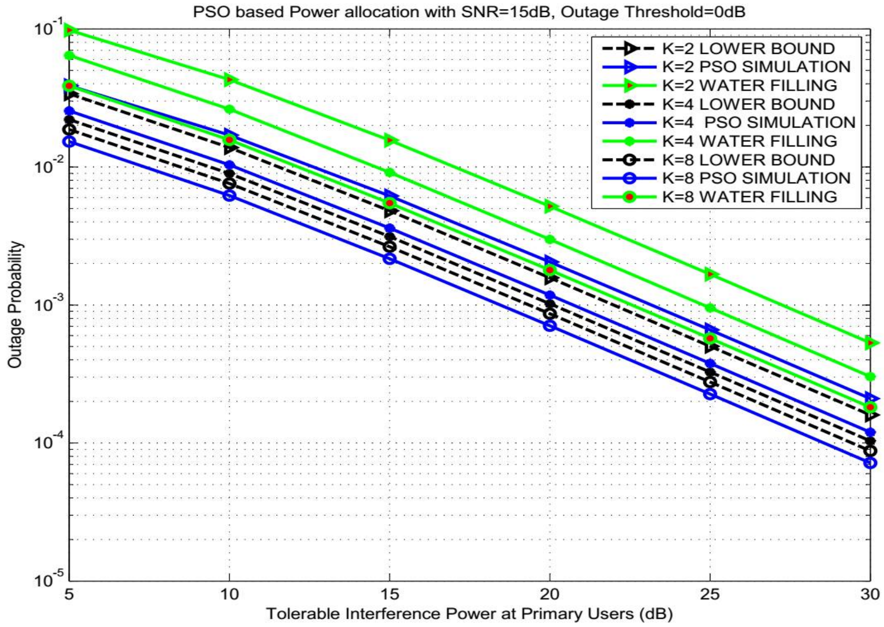

Fig. 2.Outage Probability versus tolerable interference power for different number of relaying hops

The performance of the system can be evaluating by calculating outage probability versus tolerable interference power at primary users.Fig.2 shows the effect of number of hops on the outage probability, by increasing the number of hops i.e, the value of K increases from 2 to 8,outage probability becomes more and more tight with the lower bound especially in the medium to high tolerable-inference-power regions. These observations demonstrate the effectiveness of the previous limiting performance analysis even when the number of relaying hops is small. The outage probability is minimised by using PSO algorithm which outperforms the water-filling algorithm. By this, we can enhance the system performance effectively.

Fig.3. below shows the outage probability versus tolerable interference power at PUs (dB) graph in which the lower bound is tighter with the simulation results than the upper bound. This is because when the received SNRs at consecutive hops are i.i.d., the end-to-end SNR approaches its upper bound. In other words, the outage probability of multi-hop AF relaying under spectrum-sharing constraint is dominated by the tolerable interference power at the primary receiver and it is highly predictable by the lower bound. The PSO simulation is more approximate to the lower bound when compared to Water-filling simulation. By this, we can infer that PSO power allocation scheme outperforms the water-filling algorithm.

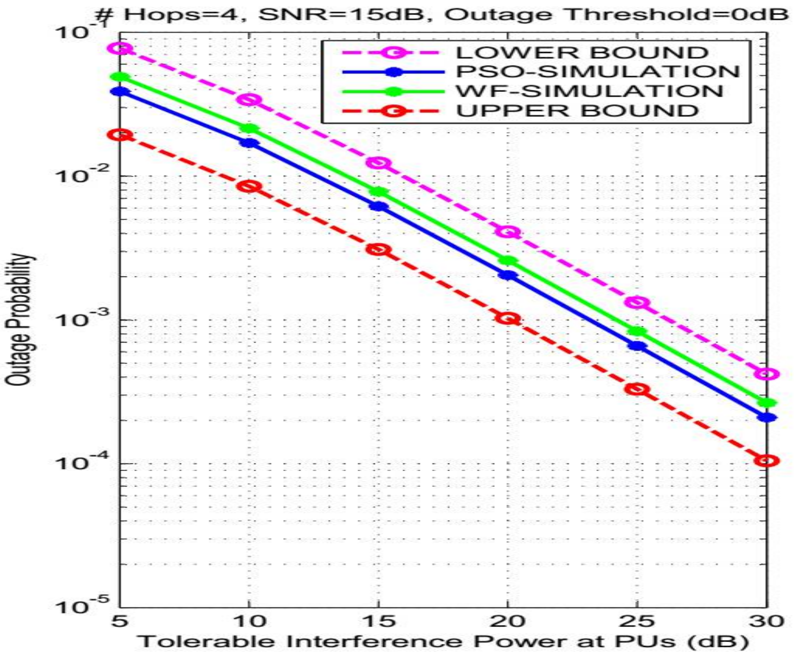

Fig. 3.Outage Probability of multi-hop Spectrum Sharing with lower and upper bounds

VI. CONCLUSION AND FUTURE SCOPE

The performance AF protocol has been analysed for multi-hop relaying in Rayleigh fading channel. From the simulation results, it is observed that he system performance is improves, whenever the number of relays increases. By this way the problems of wireless communication system like fading, shadowing and path-loss are reduced by using relay as a third station. Minimizing Outage Probability is defines as optimization problem with source and relay power as constraints. The simulation results showed that the proposed PSO algorithm performs better compared to existing water-filling algorithm. By this, the coverage area of secondary users can be extended.

The work can be extended for relay selection and diversity combining techniques in adaptive modulation environment By selecting the relay, we can allocate power to the required relay in which multiple relays are present from source to destination.

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