

Minimum power transmission design for cognitive radio networks in non-stationary environment

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Abstract: In this paper, we develop an approach to allow the cognitive radio to operate in the presence of the licensed user using bio-inspired method called particle swarm optimization. This method is invoked to solve the constrained nonlinear optimization problem for the minimum power transmission and minimum bit error rate in order to reach to maximum capacity. In addition, the received interferences at primary users remain below a specific threshold level as well as the secondary users are guaranteed with their quality of service. We reveal the modulation index in the optimization procedure. A numerical study is performed to show the convergence behavior of the proposed bio-inspired algorithm in a non-stationary environment with a dynamic cost function.

Keywords: cognitive radio, population adaptation, dynamic power control, non-stationary environment.

Classification: Science and engineering for electronics

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1 Introduction

Recently, interest in wireless technology has been increased exponentially. Cognitive radio has emerged as a promising technology for maximizing the utilization of the limited radio bandwidth, while accommodating the increasing amount of services and applications in wireless radio networks. Hence, many studies featuring recent advances in theory, design and analysis of cognitive wireless radio networks have been figured out. The cognitive transmitters should use the environmental information to approach the appropriate parameters, such as modulation type, modulation index, coding format, transmission power level, in order to maximize their data transmission rates under a constrained interference level [1]. One of the main concerns of the networks topology and capacity is the transmission power. Controlling of the transmission power is of vital importance [2]. To avoid the interference to the licensed or primary users, the transmission power of the cognitive wireless radio network should be controlled and limited. In [1, 3, 4], the power control and spectrum sharing limitations have been studied. According to the descriptions in [5], the power control has an effective impact on the probability of bit error rate. Because of dynamic feature of the environment the transmit power control requires a precise study by employing an intelligent algorithm. These researches make it possible for a secondary or cognitive radio network to opportunistically utilize a frequency band initially allocated to a primary network. However, evolutionary power control for cognitive users has not been previously investigated in non-stationary environments considering modulation adaptation and constrained multi-objective problem. But in our work, we considered a non-stationary environment in which the channel and the parameter variations change with their previous values relatively. Although in [6], Zhao et al show one adaptation method and in [7], Islam et al and in [8], Noori et al investigated joint beamforming and power control. In this paper, we proposed an intelligent method to meet the challenges of the cognitive radio network, considering the strict requirement of the protection of licensed users from the interference caused by the unlicensed or secondary users. Due to the variation of radio channel characteristics, as well as the frequency spectrum band availability, cognitive radio networks need to support time varying quality of service requirements. Toward this goal, we formulate an optimization problem, Even though the basic goals of our work are focused on dynamic constrained power allocation, minimizing the interference, mini-

mizing bit- error-rate and maximizing the transmission capacity. To achieve these goals our cognitive radio network employs the swarm intelligence algorithm based on particle swarm optimization algorithm (PSO). A flexible tracking PSO for non-stationary optimal solution is proposed.

2 System model

We consider a system model where the primary network consists of M primary users (PUs) each having a transceiver system. The primary network transmits and communicates with the constant and specific transmission power. In our scenario, the downlink of the primary network is considered. In the secondary network, cognitive radio users are considered to work in the same frequency band as the primary system. The secondary network has also an infrastructure scenario. The transmit powers of cognitive users are limited to a maximum value prescribed by primary users. This network coexists in the same area with secondary users which are cognitive users. The system model of our scenario is illustrated in figure 1. The secondary network has a single base station serving N secondary users so it has an infrastructure scenario.

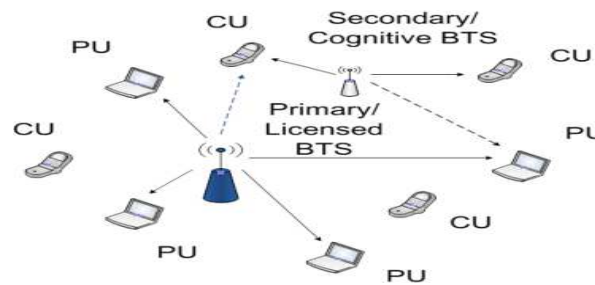


Fig. 1. Conceptual diagram of the system model.

3 Problem formulation and solution

All secondary users are working under control of a cognitive base station, A secondary user or cognitive radio is talking to a receiver using a frequency band licensed to the primary radio, the objective here is considered as to maximize the transmission capacity of the secondary users subject to minimum interference and maximum quality of service of the primary users with minimum transmission power for secondary users. We assume the secondary network is in downlink mode so the kth primary user’s received signal is obtained as follow:

$$y_k^{pu} = x_p \cdot \sqrt{p_p} \cdot g_{pk} + x_c \sqrt{p_c} g_{ck} + n \quad (1)$$

Where x_p and x_c are the transmitted signals of the primary and secondary base stations, respectively. g_{pk} and g_{ck} are the fading path gains from primary and secondary base stations to the kth primary users as we consider the non-stationary environment based on channel parameters variation and n denotes zero mean additive with Gaussian noise with variance n^2 . Define p_p and p_c as

the transmitted power of primary and secondary base stations, respectively. Also power p_c is constrained by a maximum transmit power limit p_{\max} .

$$p_c \leq p_{\max} \quad (2)$$

Assuming that the secondary users signal are uncorrelated with zero mean, in downlink mode, we can express the i th secondary user received signal as:

$$y_i^{cu} = x_c \cdot \sqrt{p_c} \cdot g_{ci} + x_p \cdot \sqrt{p_p} \cdot g_{pi} + n \quad (3)$$

Where g_{pi} and g_{ci} denote the fading path gains from primary and secondary base stations to the i th secondary users. The total amount of received interference I_{Pu} at the k th primary user is given by:

$$I_{Pu} = (p_c) \cdot (g_{ck})^2 \quad (4)$$

Here, we should define the maximum tolerable interference of k th primary user and the maximum transmission power constraint of the secondary users as follows: for downlink mode

$$(p_c) \cdot (g_{ck})^2 \leq Q_{\text{int}} \quad (5)$$

Where Q_{int} is the maximum tolerable received power at the primary receiver. Making this assumption the capacity of primary users are guaranteed and relatively we define interference constraint. We calculate signal to interference plus noise ratio of secondary users for downlink mode as:

$$SINR_{cu} = \frac{(p_c) \cdot (g_{ci})^2}{(p_p) \cdot (g_{pi})^2 + n^2} \quad (6)$$

Therefore, with the mentioned objective, a power control strategy based on dynamic programming is developed subject to the mentioned secondary and primary networks constraints in the dynamic environment condition. Here we assume the channel capacity of primary users are guaranteed and secondary users are try to have no harmful effect on them. The channel capacity of secondary users C_{cu} is calculated as follow:

$$C_{cu} = \lceil \log_2(1 + SINR_{cu}) \rceil \quad (7)$$

The purpose of this letter is to determine optimal transmit power for all possible fading channel status in a non-stationary conditions so as to maximize the channel capacity under both maximum transmit power and peak interference temperature constraints, however adapting the modulation index M for M -ary PSK modulation and reducing the probability of bit error rate in regard of the reference bit error rate 10^{-5} have been considered. In our algorithm the modulation index M will be adjusted by PSO. With considering a penalty function, we can convert the constrained optimization process into an unconstrained one to meet problem constraints simultaneously. The cost

function's behavior is dynamic due to non-stationary environment specifications as:

$$\text{Max } C_{cu} = \left[\log_2 \left(1 + \frac{(p_c) \cdot (g_{ci})^2}{(p_p) \cdot (g_{pi})^2 + n^2} \right) \right] \quad (8)$$

Subject to : Min p_c

$$(p_c) \cdot (g_{ck})^2 < Q_{\text{int}}$$

Based on Eq. (8) the problem can be transformed to

$$\text{Min } L = -C_{cu} + \lambda_0((p_c) - p_{\text{max}}) + \lambda_1((p_c) \cdot (g_{ck})^2 - Q_{\text{int}}) + \lambda_2(p_c) \quad (9)$$

Where $\lambda_i = \{\lambda_0, \lambda_1, \lambda_2\}$ is the Lagrangian multiplier. We assumed the modulation to be M-ary PSK. In this case from communication theory the probability of bit error rate (BER) is defined as:

$$P_{be} = \frac{2}{\log_2 M} Q \left[\sqrt{2 \log_2 M \frac{P_c}{n^2} \cdot \sin \left(\frac{\pi}{M} \right)} \right] \quad (10)$$

Where Q is the Marcum function. As we know the channel capacity and probability of bit error rate are loosely linked together but in our simulation because of adapting modulation index and non-stationary fading channel gains conditions the additional constraint to reach the lowest BER is considered. Hence, a new dynamic cost function with new Lagrangian multipliers that should be minimized is defined as:

$$\text{Min } L = -C_{cu} + \lambda_0((p_c) \cdot (g_{ck})^2 - Q_{\text{int}}) + \lambda_1(p_{be}) \quad (11)$$

To achieve the optimal performance, Lagrangian multiplier λ_i is adjusted to let the transmit power p_c satisfy all constraints. Here Lagrangian multipliers, transmit power p_c , modulation index M are adjusted by PSO to optimize the problem under all constraints in a fading non-stationary environment.

4 Numerical results

In simulation model, we consider some simulation results to investigate performance of the proposed scenario the primary and secondary users are randomly distributed over the considered area. A secondary network coexists and/or shares the radio spectrum with a primary network to which the spectrum is licensed, in an infrastructure scenario. The channels between the transmitters and receivers are assumed to be Rayleigh faded and the channel parameters change during transmission such a non-stationary environment, so our tracking algorithm should follow its best performance. The channel gains are independent across sub channels. Empirically, our results suggest that the velocity limit can be set to $V_m=0.09$ and the acceleration coefficients can be set to $C_1=2$ and $C_2=2$. In addition in our optimization algorithm, the two Lagrange multipliers have been set as the particles. Hence, in our PSO algorithm the two Lagrange multipliers will be set during each iteration to their best values. Path noises are independent zero-mean complex

Gaussian random variable with variance 1. The maximum transmit power for secondary users are assumed to be 8×10^{-4} for a 10^5 Hz bandwidth. Interference from primary users to base station is ignored. Interference constraint of all primary users is 10^{-4} and we consider phase shift keying (PSK) modulation type and assume different possible modulation indices to find the best index during iterations and minimum probability of bit error rate for a given modulation scheme and a given channel type. Our results show that, the maximum transmission power constraint with maximum transmission capacity, considering related modulation index in possible minimum BER are satisfied by the secondary network in a non stationary condition. By making average global information of the best particles, the accuracy of the best particles has been raised and all the changes of the search space have been detected by algorithm. We can realize the behavior of the cost function and its convergence attributes of PSO by novel tracking of our algorithm and better performance of it by increasing number of particles. It is clear that the all constraints are fulfilled. Figure 2 shows the difference between the probability of bit error rate of simulation is less than the target probability of bit error rate of 10^{-3} .

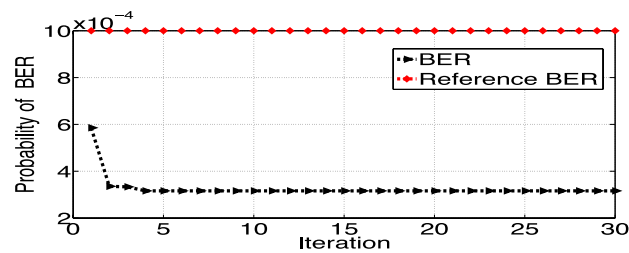


Fig. 2. Probability of bit error rate of the secondary users.

In figure 3.a, the average transmission power of secondary users for a non-stationary environment with Rayleigh fading channel is shown and it is clearly reached to optimal value by six iterations as it arises. Also, in figure 3.b, it can be seen that the transmission capacity arises with increasing the amount of transmission power; however the power will be limited by our simulations constraints and primary user interference. We can clearly see the difference between the maximum capacity of secondary users using maximum transmission power and optimal transmission power.

As we see from our results our algorithm convergence reaches during six iterations and in order to be sure about it the maximum iteration defined. Furthermore, the fitness functions steer the evolution of the PSO in the correct direction to optimize the given multi-objective functions for the secondary users with the defined constraints in a non stationary environment.

5 Conclusion

We have proposed a PSO assisted minimum transmission power design in cognitive or secondary radio network in a non stationary environment. The

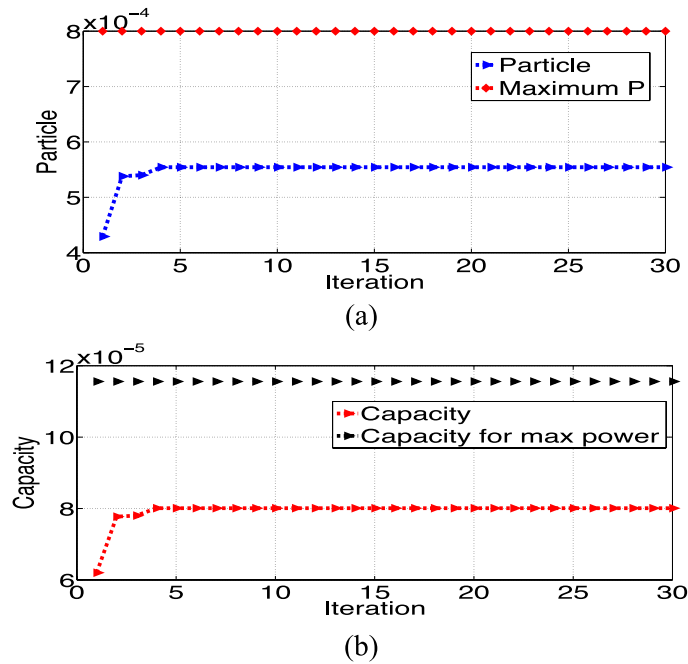


Fig. 3. (a) Convergence of transmission power with PSO solution and (b) Transmission capacity of the secondary users.

scenario is formulated in the downlink mode of the secondary user network to maximize the transmission capacity of secondary users. However, the minimum transmission power of each cognitive or secondary user is considered. We have developed transmission power control approach which PSO adjust the parameters, while maintaining a quality of service for the primary user. The proposed PSO aided algorithm provides improved performance by using appropriate modulation index while imposing a reduced bit error rate of secondary user. Proposed scheme shows the performance of a heuristic improvement in cognitive radio performance in a dynamic environment.

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