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Analysis of the Performance of Cognitive Radio Networks Based on Game Theory

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ABSTRACT

Today, cognitive radio is used to increase the efficiency of radio-frequency spectrum. Majority of radio frequency sources from frequency spectrum. In general, there are two telecommunications subsystems in the cognitive radio network. The first subsystem has the permit to use the frequency spectrum and the second subsystem utilizes the frequency of the first subsystem. Having accurate knowledge from the spectrum of the first subsystem (spectroscopy) is very important in the telecommunication models of cognitive radio. In this study, a number of primary users and secondary users are investigated about the telecommunication model in the cognitive radio. The purpose of this study is to improve the effectiveness of spectral algorithm for detection and to evaluate the distribution of spectrum based on game theory. In this algorithm, a coalition game model has been used to evaluate the spectrum to forma coalition to create a stable group of secondary users. The purpose in the coalition game model is to achieve the stable groups of secondary users which find the best coalitions based on the rules of divisions and integration to measure the spectrum. Then the evaluations of spectrum that areresulted by the members of coalition are combined by representatives of coalition groups to decide about the status of the primary system spectrum. Ultimately, the efficiency of the proposed algorithm is evaluated and verified using the computer simulation.

KEYWORDS: *cognitive radio, game theory, distributed algorithm, spectroscopy.*

I. INTRODUCTION

The cognitive radio is a new method to design wireless communication systems which are used to increase the use of radio-frequency spectrum. The most dominant reason to use the knowledge of cognitive radio is the shortage of frequency spectrum. In these days, using the applications that operate wirelessly is increased among the users of mobile phone. Also, many radio-frequency spectrums are available to individuals are dedicated to the present wireless system and only small part of the radio-frequencyspectrum are devoted to licensed wireless applications with dedicated bandwidth(Haykin, 2005). To improve the utilization of the existing spectrum, new spectrum models have been introduced. The ideas in these models are to access to more flexible spectrums and let the secondary users' access to radio spectrums under special conditions (Buddhikot, 2007).

There are three major licensing models: 1- common or shared use 2- exclusive use 3- shared models. In the use of the commonmodel, all users can use the spectrum (Zhao and Sadler, 2007).

The cognitive radio has two important characteristics, which, according to Aklediz's opinion, both havethe capability ofrecognizing and ability to reform.

In fact, the capability of recognizing causes to access to the information of useless spectrum in the radio environment, by which the best parameters are created for the cognitive radio users, so that they can use the spectrum efficiently and without disturbance to primary users (Lee et al., 2009). The ability to rebuild in a radio cognitive is referred to as the ability to program radio dynamics without any modification in hardware components (Yucek and Arslan, 2009). The cognitive radio can be programmed in such a way that it can be used as a transmitter or receiver (Wu and Tsang, 2009).There are manyadvantagesin the technology of cognitive radio that three major radiocognitive is to improve link performance, improve spectral efficiency and reduce potential costs (Visotsky et al., 2005).Of course, the cognitive radio is an emerging technology that has some drawbacks includinghaving the similar radio-software problems and losing control and thesurveillance worries (Saad et al., 2009).

The game theoryexamines the optimization of the send rate in today's telecommunication networks and in frequency-selective interference channels (Ghasemi and Sousa, 2005). The action of these games in the cognitive radio networks to generatemore send rate and to reduce interference and devote the power to users in order to reduce the limitations by checking the conditions for maximum power transmission at each frequency range and obtaining the maximum send rate to another user that they compete with each other (Osborne and Rubinstein, 1994). In this competition, providing the optimal conditions with the changes in the environment and radio channel is effective. The purpose of the present study is to increase the send rate between users and reduce the transmission power and achieve a balance the result in lower data transmission and interference and vulnerability.

II. Methodology

Topology and network dynamics of the secondary users are investigated in this study that using cooperative spectrum causes a reduction in interference between these users and increase the utilization of bandwidth. In this way, the common centralized strategies are introduced and simulated by the game theory. Therefore, the issue was modeled as a non-transferable coalition game, and a distributed algorithm is presented to form a coalition through simple rules of integration and combination.

System model

Consider a radio cognitive network that includes N transmitter pair of secondary users and only one primary user. Secondary users and primary users can be fixed or animated. Since the focus is on the spectroscopy, we are only interested in a part of the secondary users in the transmitter. The set of all secondary users are shown with $\mathcal{N}=\{1,\ldots,N\}$. In the non-cooperative approach, the secondary users continuously assess the spectrum in order to recognize the present of the primary user. Energy detections are used to recognize the primary user that one of these detections is the main practical detections of sigthenal in the radio cognitive networks. In the setting such networks, Rayleigh fading is considered and the probability of cognition and the probability of false warning to the i[th] secondary user are shown with Pd,i and Pf,i, respectively (Saad et al., 2009).

$$P_{d,i} = e^{-\frac{\lambda}{2}} \sum_{n=0}^{m-2} \frac{1}{n!}\left(\frac{\lambda}{2}\right)^2 + \left(\frac{1+\bar{\gamma}_{i,PU}}{\bar{\gamma}_{i,PU}}\right)^{m-1} \times \left[e^{-\frac{\lambda}{2(1+\bar{\gamma}_{i,PU})}} - e^{-\frac{\lambda}{2}} \sum_{n=0}^{m-2} \frac{1}{n!} + \left(\frac{\lambda \bar{\gamma}_{i,PU}}{2(1+\bar{\gamma}_{i,PU})}\right)^n \right] \quad (1)$$

In this equation, m is the product of the bandwidth time;λ is the threshold value inenergydetection that is considered to be same for all secondary users. (0, 0) is incomplete gamma function and (0) is the gamma function. Furthermore, $\bar{\gamma}_i$ represents the mean SNR of the received signal from the primary user to the secondary user and is equal to $\bar{\gamma}_{i,PU} = \frac{P_{PU} h_{PU,i}}{\sigma^2}$.

P_{PU} is the sending power of preliminaryuser, 2 Gaussian noises variance and $h_{PU,i} = \frac{k}{d^{\mu}_{PU,i}}$ is path loss between prithemary user and sectheondary user. $\kappa$is the path loss and μ is the path loss potential. d_{PU} is the distance between the primary user and the ithsecondary user.

Distributed coalition algorithms

The secondary users for $\mathcal{T}$ =$\mathcal{N}$are divided to the set of $\mathcal{T}$={$T1$,⋯,Tk}.

Phase 1: local measurement

2. Each secondary user performs spectroscopy.

Phase 2: coalition formation

3- Repeat

4- $\mathcal{F}$ = ***Merge*** ($\mathcal{T}$) (the coalition in $\mathcal{T}$ decides to merge).

5- $\mathcal{T}$ = ***Split*** ($\mathcal{F}$) (coalition based on Pareto's order in $\mathcal{F}$decides to split).

6- As long as the merger and division stop.

Phase 3: cooperative standard assessment

7. The secondary user sends the measurement result to the coalition head.

8. The head of each coalition will make a final decision about the initial user presence using the OR rule.

9. The secondary user in the coalition receives the final decision from the head of the team.

The above-mentioned coalition's algorithm begins by giving permission to secondary users to integrate existing coalitions. In this case, the $Ti\in\mathcal{T}$ coalition is searched from the initial section $\mathcal{T}$ and tries to merge with a close coalition. If the merger occurs, the new coalition will be re-searched and attempted to merge. When each coalition Ti performs the marge phase, the resulting unit is equal to $\mathcal{F}$. Then the division is done by all coalitions in section $\mathcal{F}$. After this step, the secondary users measure the standard cooperative spectrum based on the available partition and the output of the coalition is observed.

To provide a duplicate solution for Nash equilibrium in a distributed environment, the layer-to-layer structure is introduced. The first $\boldsymbol{p}*$ Nash equilibrium power allocation is obtained based on the Jacobin repetition assuming the personalization of Lagrange coefficients. Then the Lagrange coefficient zi and μc, m are updated. Algorithm 2 has three main stages. The power of transmission is updated once on a better time scale, for example, every ΔT. Repeat for dual rates are shown by T, while the subiterationis shown for power update by t_T. The relationship between the repetition and its subiteration are shown by$Y = \frac{\Delta T}{\Delta t}$ the Y is a large integer (figure 1) (Wu and Tsang, 2009).

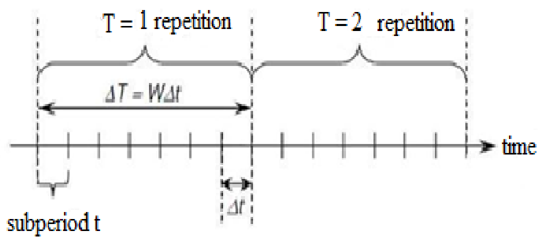

Figure 1Repetition for updating quasi-repetition Lagrange coefficients for updating the power level transmission

III. Discussions And Results

Simulation results

For simulations, the network settings are such that the primary user is located in the center of a square with a 9-km side length. Secondary users are randomly placed in this square and around the primary user. The product of the bandwidth time is set to m = 5. Primary user power equals to P_{PU} = 100mW, secondary user power for reported measured bit equals to Pi = 10mW per i∈$\mathcal{N}$. The noise level is σ^2 = -90dBm. The maximum alert limit is set to α = 0.1 and to waste of road, we have μ =3 and κ =1.

The results from figure 2 and figure 3 represent, respectively, the average of the probability of misdiagnosis and false alarms calculated for different network sizes in the secondary user. These probabilities, on average, on random locations of secondary users are within the limits of the λ-limit detection thresholds, which are within the false alert limit.In figure 2, the proposed algorithm provides a significant improvement in the likelihood of a false diagnosis and reduces this probability to an acceptable level. Of course, there is a gap between the performance of the proposed algorithm and its optimized centralized solution. This distance is due to the fact that the log barrier function used in the distributed algorithm greatly increases the cost when the possibility of a false alert is in the vicinity of α. Figure 3 shows that the mean of false error achieved by the distributed solution is better than the centralizedsolution. Therefore, although the centralized solution has the potential for a false diagnosis, the presented distributed algorithm compensates for the distance through the average false alert. In figure 3, the probability of a false alert based on the average probability of misdiagnosing each secondary user is used. In the drawing and simulation of this case, both the state of existence and the absence of shadow fading are considered.

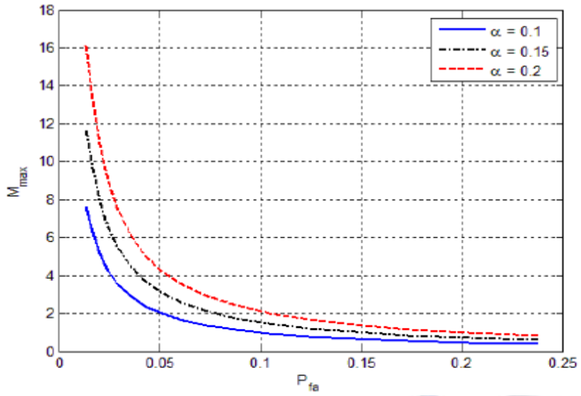

Figure 2 The largest size of the coalition according to the possibility of a false alert

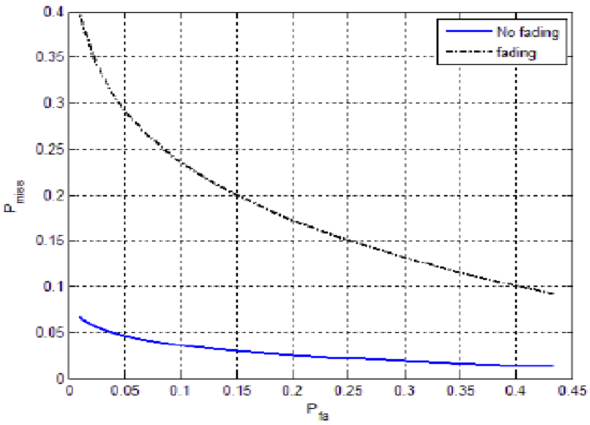

Figure 3 The probability of a false alert according to the average probability of misdiagnosing any secondary user

For the proposed coalition's algorithm, a high bound is considered for the largest coalition that is based on cost modelsand desirability. In figure 4, the average probability of misdiagnosis in the secondary user is shown for different detection thresholds. In this figure, it is seen that the greater the chances of a non-cooperative false alert, the lessthe probability of the non-cooperative false alert, the more advantage the operation of coalition spectroscopy for both concentrated and distributed solutions.

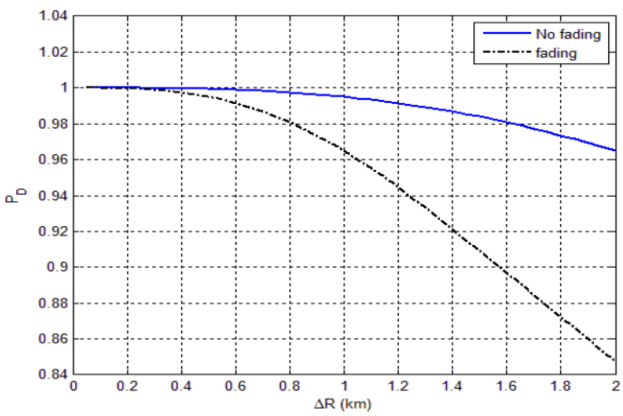

Figure 4 The probability of correct diagnosis based on the average distance between the secondary user and the primary user

After the structure of the network is formed, it is let the first secondary user move in direction of horizontal axis (x-axis) while other secondary users remains motionless. Due to these displacements, the users' desirability are changed that the mean of these changes in desirability is shown in figure 5. The more distance the secondary user and the primary user have, the less desirability there is.The figure 5 shows that how does the formation of the comparative coalition through the merging and dividing act in the moving radio cognitive network.This figure shows the amount of desirability of the system according to SNR for λ =26.The results show that the efficiency of the networkis increased with the increase in the SNR level of the secondary user. In the figure 6, λ =26 has been considered that this figure shows that the more the secondary users are, the better efficiency it could be achieved. It is necessary to say that the more the secondary users are, the more complex the system is and as a result, the power consume increases that is not desirable.

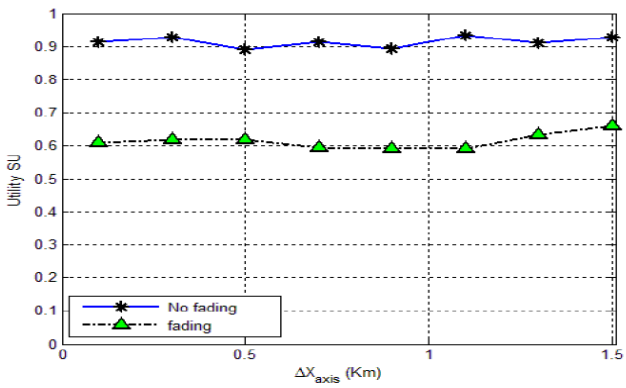

Figure 5 the mean of the desirability of the secondary user according to the displacement and movement in the network in the direction of x-axis

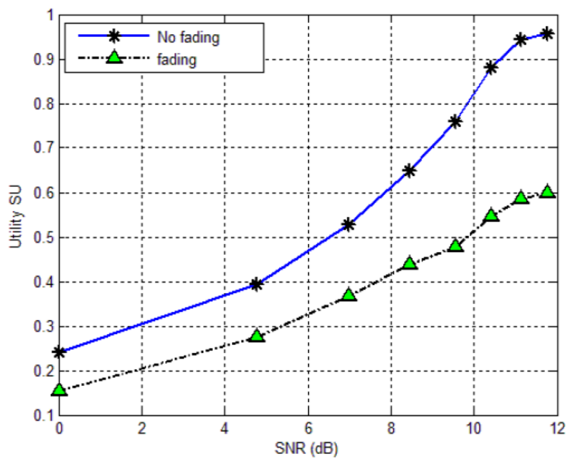

Figure 6 the mean of desirability of the secondary used according to the amount of SNR

In the figure 7, the coalition resulted from distributed algorithm for 20 secondary used in one network is evaluated and compared to high bond

M_{max} that is computed in the previous part.First, because the probability of non-cooperative false alert increases, the maximum amount and mean value of coalition reduces. These results show that in general, the network topology is combination ofa large number of small coalitions and to a few of large coalitions even in the situation that the probability of false alert is low and the probability of cooperation is high. The figure 8 shows the product of bandwidth time. This figure 8 shows that the product of bandwidth has no effect on the desirability, but the increase in the bandwidth can has a negative effect on the probability of false diagnose of the secondary users. Figure 9 is draw based on the different abilities of primary user. This figure shows that it is not necessary thatthe high power of the primary user causes the better desirability, because the increase in the power of primary user cause the interference in the coalition that it is a factor to reduce the desirability.

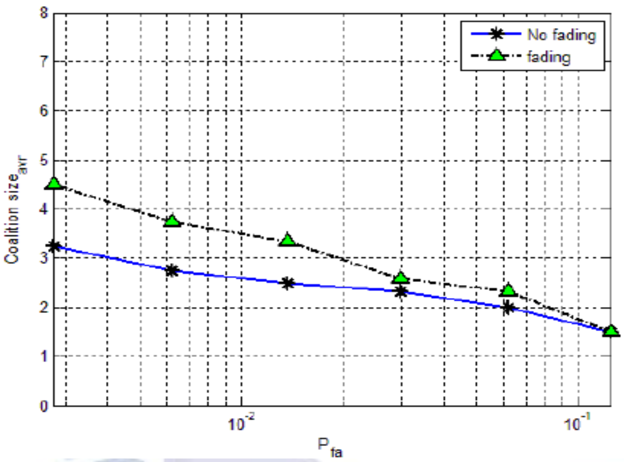

Figure 7 The size of coalitions compared to the probability of false alarms

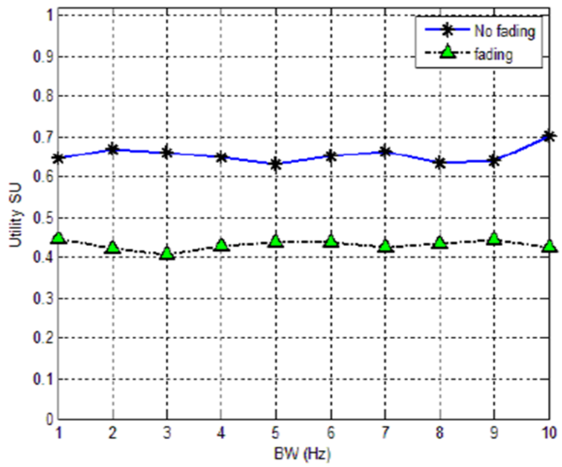

Figure 8the desirability mean of secondary useraccording with width of different bands

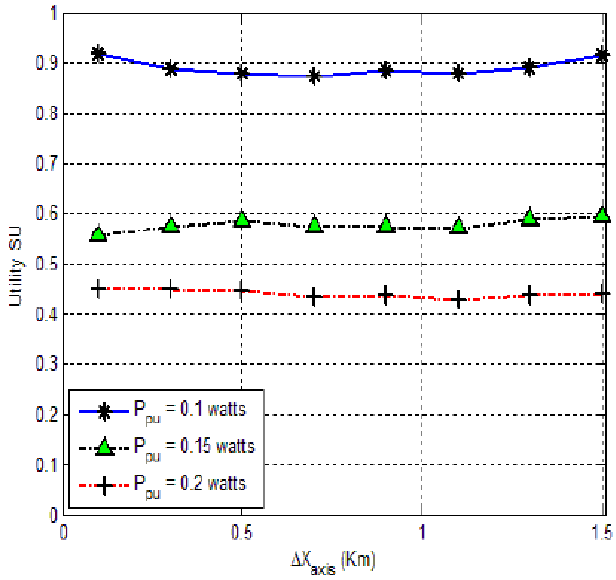

Figure 9 the desirability mean of the secondary user according to different probabilities of primary user's true diagnosis and movement in the direction of horizontal axis

IV. Conclusion

In this study, a distributed algorithm is presented to evaluate cooperative spectrum in the radio cognitive networks. The issue of cooperative evaluation is modeled in the form of a coalition game withnon-transferable desirability in the radio cognitive network and a distributed algorithm is extracted to form coalition.The structure of the proposed algorithm network is evaluated. The results show that:

1. Using the above algorithm, the most numbers of secondary users could be present in the coalition.
2. Theproposeddistributed algorithm reduced the average probability of misdiagnosis in the secondary usersin compared to non-cooperative network.
3. The secondary users can adapt to the structure of network independently through the proposed algorithm.
4. The proposed algorithm increases the average desirabilityof using spectrum for users.

The increase of the power of primary user reinforces the interference between secondary users and reduces the desirability of the channel. Also, the increase in the number of the secondary users increases the desirability of the system, but it should be considered that the mean of the presence of the secondary users in a specific network should not beincreasing and infinite. It means that althoughthe increase in the number of secondary users causes the increase in the desirability of radio cognitive, it increases the interferences in the specific area of a network after a period of time that is not desirable. The signal to noise ratio depends on the average distance between the primary users and secondary users and the dividingof the coalitions based on the game theory, when SNR is high and the distances are low, will reduce the growth ofdesirability.

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