Self-organizing Algorithm for Fairness in Joint Admission and Power Control for Cognitive Radio Cellular Network

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Abstract

The ever-increasing growth in wireless applications and services indicates the importance of effective use of the limited radio spectrum. Cognitive Radio enables unauthorized secondary users opportunistic access to channels not used by primary users if interference with primary users (PUs) does not exceed pre-defined limits. System modules may be removed according to different Quality of Service (QoS) and SINR required for the base station (BS). This paper is proposing a joint admission and power control scheme (JAPC) as a self-organizing algorithm (SOA) to solve the problem of the fairness related to secondary users (SUs) in cognitive cell. Results show that the proposed scheme obtains more fairness and bitrate compared to previous work.

Keywords

Power control • Cognitive radio (CR) • Fairness • Admission control • Quality of service (QoS) • Self-organizing algorithm (SOA) • Joint admission and power control scheme (JAPC)

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1 Introduction

In cellular communications, licensed wireless primary users (PUs) cannot assign to all frequency channels anytime and anywhere, this because it may leads to create many holes in the spectrum. Cognitive radio (CR) technology enables improved spectrum use efficiency. In cellular CR networks, unlicensed secondary users (SUs) can transmit using free spectrum, and ensures not interrupts to the PUs operations (Shaat 2012). The secondary users (SUs) can be work with the base station (BS) by ensuring that, there are no interferences with the primary users (PUs) above pre-defined threshold (Saeed et al. 2010). In cognitive radio networks (CRN), different SUs define the type of Quality of Service (QoS) and may vary depending on the type of unit. However, these networks may facing interference limitations on the PUs and SUs QoS requirements. Therefore, solutions must be found to provide an effective energy intake and control scheme (Saeed et al. 2006).

Traditional algorithms cannot be applied directly because they treat all users with the same criterion. Therefore, these algorithms are not able to solve CR networks issues if the users have different criterions. Accordingly, the use of CR approach in cellular networks is a practical challenge. The challenge is that it requires accurate and rapid sensing of the spectrum (Xiang 2011). CR concept enables secondary users to access the primary users channels with simultaneous transmission when the core network sufficiently protected. Generally, simultaneous transmission control with defining the Pus, SUs powers and selecting desirable SUs for the network is one of the most important challenges (Al-Hmoudi et al. 2011; Baykas 2012). The complexity lies in the mechanism of finding the best channel assignment for the units. Therefore, one of the most important requirements that the possible solutions to these problems must meet is to maintain the overall system productivity and reduce energy consumption.

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In CR networks, different SUs need QoS at different levels and therefore make different payments based on the level of QoS provided (Dimitrakopoulos 2011; Suliman et al. 2015). The problems of joint admission and power control in the cognitive cell on the part of the network operator are the increase in revenue from SUs that are subject to interference constraints on the QoS requirements for both PUs and SUs (Naghian and Baghaie 2002). In addition, there different schemes that proposed to solve the previous problem. One of these solutions is Joint Admission and Power Control scheme (JAPC) (Nahla et al. 2021; Xin and Wang 2008). The shared ability and acceptance control of Joint Admission and Power Control scheme is inviting approach, which helps to realize the concept of coexistence between both PUs and SUs. It also allows both of them to work on the same spectrum without harmful interference. (Saeed et al. 2009b; Saeed and Mokhtar 2012).

This paper presents a new contribution that differs markedly from previous studies. In this paper, we formulate the problem of the fairness to SUs. Secondly, we propose a self-organizing algorithm (SOA) scheme with dynamic system of power control to solve the formulated fairness problem. The results of using SOA were expected to enables much fairness than other schemes.

2 Literature Review

In the past, few studies have been done regarding co-acceptance allocation problems related to control and power in CRN. Researchers in Zhang et al. (2007), investigate on the power allocation control problem in cellular CRN. Authors explained how to ensure QoS for Pus and SUs, which can be translated into degree and signal-to-interference ratio as well as noise (SINR). The authors also pointed that the density and mobility of secondary users influences the possibility of their support due to the limitations mentioned. In addition, they review the possibilities to increase the total revenue of cellular cognitive networks output by finding a subset of secondary users. The authors introduced the power distribution and joint control algorithm, and then evaluate their performance. The results give an advantage over the traditional algorithms.

For device-to-device (D2D) communications, a higher data rate must be achieved in wireless networks. Authors in Azam et al. (2015) examine the challenges faced by cellular users with D2D associated with the energy allocation process for the purpose of improving overall productivity. The authors used the OAA method based on linear approximation to fix the joint access control, power allocation, and the mode selection problems. The results show that the method gives an optimum content and high efficiency in achieving service quality.

A study presented in Gallardo and Jakllari (2018) reviews mechanism to solving the problem of internet acceptance control in multi-hop CRNs. In the proposed scheme, the channel access is organized through a simple TDMA and PU activity designed as an on/off operation. The authors used a random scheduling algorithm to mitigate the problem of online acceptance control and analyzed it. They calculate the average available bandwidth with scheduling between sources in cognitive radio networks.

Authors in Kim et al. (2008) investigate on the dynamic spectrum-sharing between PUs and SUs in a CRN. They provide a solution to the fair spectrum sharing among SUs subjected to QoS constraints related to minimum SINR and transmission ratio, in addition to PUs interference constraints. Moreover, authors develop a framework for joint admission control and power allocation for secondary user. Through the analysis, the researchers concluded that the developed framework has efficacy in terms of primary and secondary user throughput in network.

In Xing et al. (2006), the authors put forward the study of the similar problem in prosthetic receivers with one PU and several SUs. The authors introduced a Distributed Constrained Power Control (DCPC) algorithm to achieve maximum yield with the aid of a potential game. However, this study assumed only a single PU in the system. In Xiang et al. (2008) the study proposes a JAPC-MRER. Researchers ignored the SUs, which removed and only focused in the secondary revenue of submitted SUs. In Roy and Kundu (2011), authors explored the performance of the all joint admission and power control algorithms used in CR networks based CDMA in shaded medium. However, this study also ignored the SUs, which removed and only focused in the secondary revenue of submitted SUs.

In Piran et al. (2020), authors review the quality of service and experience provisioning systems in multimedia communications over CR networks. They highlight the concepts related to QoS and QoE in CR multimedia communication. The authors also presented a number of characteristics of using multimedia services for customer records as well as critical challenges related to QoS requirements and QoE. In addition, they discussed the spectrum sensing features, resource allocation management, a network, and energy consumption management, with discussion of many solutions for each of them.

The authors in Gulzar et al. (2021) proposed an algorithm to address the power control problem of CR networks, where the spectrum utilization problem in the wireless system can be solved by using a non-cooperative game. The non-cooperative game works according to the theory that each player increases his advantage in a competitive environment. The results show that the proposed algorithm improves network performance in terms of high SINR rate and low power consumption.

In Rahim et al. (2020) researchers introduced the concept of Gale Shapley match algorithm to get a better match with suitable channels from the free spectrum, so that it can improve the level of QoS intended for SUs. The study determines the SUs tasks from a channel perspective and allocating the spectrum to them with the adoption of calculating the PUs appearing probability on channel again. The proposed algorithm examine the possibility of using objective functions in the development of favorite lists of secondary users and passive channels by means of Gale Shapely matching theory to choose a suitable SU channel pairs. Through evaluation, results showed a considerable enhancement in terms of overall satisfaction of SUs compared to other technologies.

Authors in El-Saleh et al. (2021) proposed a multipurpose Joint Admission and Power Control scheme (JAPC) optimization to increases the CR network throughput and decreases power consumption. They used an improved swarm intelligence algorithm to optimize the multipurpose JAPC. The study improves the convergence speed and stability of swarm intelligence used in multipurpose JAPC. Results prove that the optimized swarm intelligence algorithm enhanced both overall throughput and power consumption for CR network consists random PUs and SUs.

3 Power Control Algorithms for Cognitive Radio Cellular Network

Cognitive radio (CR) concept dictates unlicensed unused spectrum (Alsolami et al. 2021). In CRN, secondary users (SUs) support CR by sensing available spectrum and then effectively sharing that spectrum with primary users (PUs) (Saeed et al. 2009a; Zhang 2008). However, the process of spectrum sharing between PUs and SUs is considered an important issue, especially since it is exposed to large interference between the Pus (Hasan et al. 2013). Several previous studies addressed the interference problem using control power algorithms to reduce the impact of the above problem (Saeed et al. 2009a; Saeed 2011). We investigated on using the self-organizing algorithm (SOA) based on JAPC algorithm and minimal SINR removal algorithm (MSRA) approaches to improve CR spectrum and minimizing the SINR.

The self-organizing algorithm is working after removed SUs with the less value of SINR. Usually, these SUs located at the edge of cell, and the received power from SUs to the BS is not satisfied (Mokhtar et al. 2021). The SOA checks the safety zone and going to inform the SU to increase the SINR by sending command to removed SUs. Then SOA searching for the SUs with maximum SINR and sending a

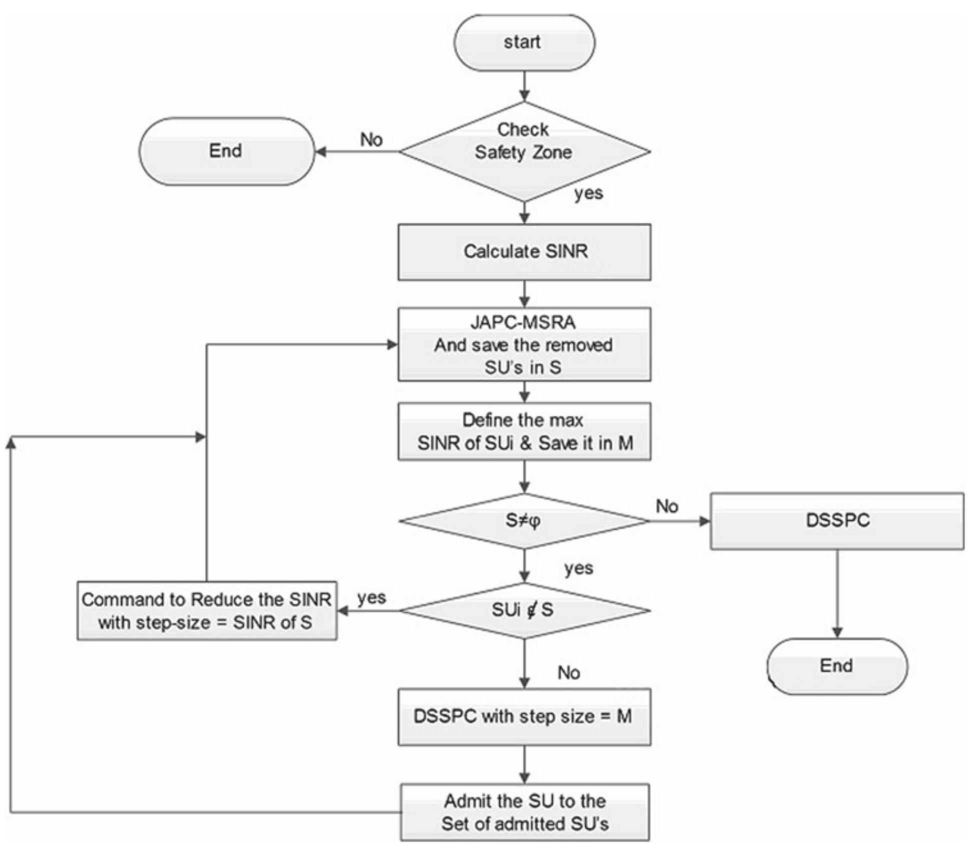

Fig. 1 Self-organization algorithm

command to inform these SUs to reduce their SINR. The removed SUs will be admitted, and the SUs with maximum SINR will be removed. It is look like replacing them as shown in Fig. 1.

The method used in this study will utilize the use of dynamic step-size power control commands (DSSPC), the SIR/power, and mobile site help data. Accordingly, the concept presented an update to the dynamic interface process of controlling the energy, admission and delivery, which helps to improve the convergence between the proposed energy control mechanisms.

4 Simulation Model and Parameters

The system model consists of a general scenario consisting of a number of SUs and PUs. The base station can accept SUs is used if the PUs interference is less than the previous ones, according to certain thresholds (see Fig. 2). The base station (BS) is assumed to be located at the cell center. It's operated to provide services to SUs with the existence of PUs distributed around the cell. The model shows that SUs enable to access the same spectrum and try to send data to the BS at the same time while the PUs were in receiving mode. This scenario can leading to that PUs to be interfered to SUs.

The calculations related to the evaluated model are focusing to study the performance of the three JAPC schemes with the performance of SOA. The simulation parameters illustrated in Table 1, which provides estimation for interference related to the SUs interference, in addition to values of calculated SINR corresponding to the number of SUs. The simulation calculations are depends to evaluate the self-organization algorithm (SOA) in terms of SUs interference.

Table 1 Parameters for simulation

Parameter	Values
Number of admitted SU in SOA	120
Number of max. replaced SU	30
Number of available channels	120
Interference threshold	1.5
Optimized SINR	1.4–1.9

5 Simulation Result and Discussion

The result in Fig. 3 shows the calculated interferences corresponding to the amount of SUs with and without using the self-organization algorithm (SOA). The calculation of SUs interferences observing that, the interference constraints in to the PU and SU set before using the SOA, obviously shows the increases in SUs numbers will increase the interference. However, after use of the SOA, the system making fairness to the system by re-adding and removing "replacement" of SU by making maximum number of SU in system and replace the other SU which reduces the interference constraints in the system.

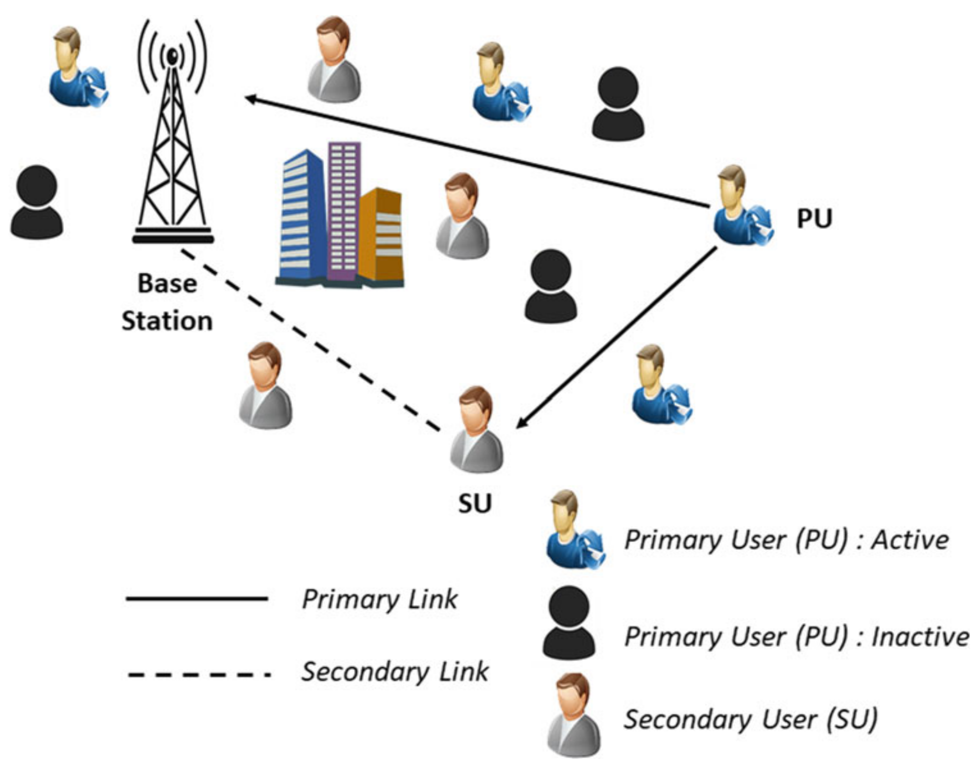

Fig. 2 Simulation system model

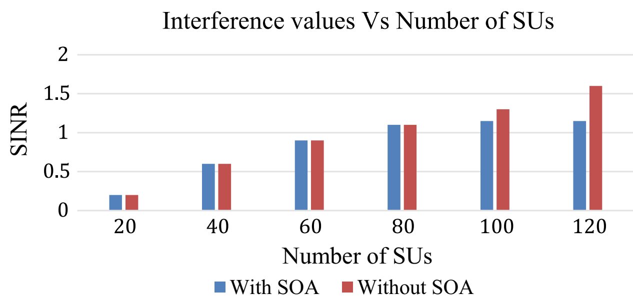

Fig. 3 Performance evaluation of using SOA in term of interference values versus number of SUs

6 Conclusions

The hasty wireless applications growing over the last few decades have initiated a massive demand for wireless network services. Due to the scarcity of the wireless spectrum especially below 10 GHz, wireless industry is unable to catch the fast growing and it becomes quite challenging to grow their revenue. There are many ideas have been proposed by researchers to overcome this problematic issue. One of the potential solutions was to increase the utilization rate of the existing spectrum by using cognitive radio. In this paper, the problem of interference that directs the use of the common spectrum and the increase of the secondary spectrum studied to improve the quality of service. Where the algorithm SOA performance is analyzed to ensure that interference between PUs minimized. The proposed self-organizing algorithm for fairness in joint admission and power control gives more efficient and fairly improvement when compared to other schemes. The self-organizing algorithm enables to improve the system performance in term of power interference on Pus. Moreover, it ensures that system making fairness by limits the maximum number of SU and replace them in order to reduce the interference constraints, in addition to minimize the SINR by 45% in network consists more than 120 SUs.

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