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Review

Fairness in Cognitive Radio Networks: Models, measurement methods, applications, and future research directions

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ABSTRACT

Fairness means to maintain the property of equity or equivalence. It is the distribution, sharing, allocation, and supply of different working metrics fairly such as bandwidth, throughput, power, utilization, resources, frequency, rate, time slot, and spectrum in any wireless network. For every network including Cognitive Radio Networks (CRNs), fairness plays a significant role. In fact, CRNs provides an intelligent, autonomous and dynamic sensing environment performing different operations, through which unlicensed users get the benefit to use licensed spectrum. In CRNs, the operations performed on spectrum includes sensing, mobility, sharing and management. However, the existence of fairness maintains the equilibrium in these different operations of CRNs. Similarly, the stability of Cognitive Radio (CR) system or network rely on fairness. So, it has a great importance in the performance of CRNs. The performance of CRNs depends on the parameters like throughput, efficiency, utilization, power consumption, bandwidth, Quality of Service (QoS), scheduling, and some other aspects related to channel and spectrum in CRNs. In this article, fairness is discussed in the context of CRNs. We provide a comprehensive survey of fairness including measuring parameters, fairness models, fairness issues, and discussion on different schemes proposed in the literature. We furthermore present common issues, challenges and future research directions for CRNs in fairness perspective.

Contents

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1. Introduction

1.1. Motivation and background

Cognitive Radio technology is a new emerging field. It has considerable value in communication services as it has the capability to utilize the spectrum, and provide benefit to the users by detecting available channels in its vicinity. The concept of Cognitive Radio (CR) technology was first presented by Joseph Mitola in 1999 (Mitola and Maguire, 1999). According to the Federal Communication Commission (FCC) (Federal communications commission, 2005), it has the ability to adjust dynamically and autonomously the radio operating parameters such as power, frequency, and modulation and sense its radio environment. CR is an intelligent software defined radio sensing its surrounding and aims to efficiently utilize resources (Haykin, 2005). It is the capability of CR to collect information like transmission frequency, bandwidth, power, modulation, frequency band, modulation mode, and transmission power in real-time and on-line manner (Preet et al., 2014). It provides an intelligent wireless communication devices which performs operations over spectrum such as spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility. CR permits wireless devices to use radio frequencies in better way and improve spectrum utilization. As new wireless devices and applications are developing quickly, demand for radio spectrum grows (Wang and Liu, 2011). Thus, CR can play a vital role in addressing the spectrum scarcity problem (Akhtar et al., 2016). Considerable work on radio resource allocation techniques for efficient spectrum access in Cognitive Radio Networks (CRNs) is discussed in Tsiropoulos et al. (2016). A detailed overview on spectrum decision in CRNs with its functions like spectrum characterization, spectrum selection and CR reconfiguration is presented in Masonta et al. (2013).

CRNs have wide range of applications like CR based Smart Grid (Khan et al., 2016), CR based Femtocells (Kpojime and Safdar, 2015), CR based Sensor Networks (Ahmad et al., 2015; Bukhari et al., 2016), and Green Powered CR networks (Huang and Ansari, 2015). Detailed discussion on CRNs security issues, threats, counter measures, attacks (Byzantine attack), and defense are presented in Sharma and Rawat (2015) and Zhang et al. (2015).

CRNs consist of CR nodes and two types of users namely, Primary Users (PUs) and Secondary Users (SUs). PUs have their own licensed spectrum and high priority than SUs, while SUs may dependent on the spectrum of PUs. Primary radio user activity modeling for CRNs has been addressed in Saleem and Rehmani (2014) and Chen and Oh (2016). The performance of CRNs is measured in different ways like interference to PUs, spectrum utilization, and fairness. These utility functions helps in solving the optimization problems as well. Similarly Quality of Service (QoS), power, frequency, time slot, spectrum availability, throughput and bandwidth are also considered as the performance metrics for CRNs.

However, fairness plays an important role in the performance of CRNs. Fairness issue is related with different aspects and characteristics of CRNs. A lot of efforts have been done previously for different issues in CRNs including fairness. In CRNs, the nodes are required to gain bandwidth, rate, power, resources and QoS fairly. In the same way, performance parameters like throughput, cost, and link quality have to be fair. Similarly, each user is required to gain same data rate as others. The efficient utilization of all these parameters are approaching to a fair network in result. Noticing these concerns fairness shows a significant need in CRNs Fig. 1.

Fairness is an important property in wireless networks. It is the equal or equivalent distribution, allocation and supply of different performance parameters in wireless networks such as bandwidth, throughput, power, efficiency, utilization, resources and spectrum. Fig. 2. shows a general concept of fairness and difference between equality and equity. Fig. 3. shows the concept of fairness in terms of bandwidth allocation in CRNs. Three nodes (A, B and C) are allocated the bandwidth ($b=20$). This shows the fair allocation of bandwidth to nodes. On the other hand, node A receives a bandwidth ($b=40$), while node B and node C has a bandwidth ($b=10$) which shows an unfair allocation of bandwidth. Fairness is defined according to different design criteria in Wang (2014): “If the available spectrum resources evenly distributed at the given time, the spectrum resources allocation is fair”. “Allocating equal percentage of power from the available power to each user”. In Zhu et al. (2007), “Fair” means the achievement of utility equally. It is noticed that fairness issue is mostly related to resource allocation. It has much importance in terms of performance for CRNs. In this article, we focus and discuss fairness in CRNs.

All the acronyms with their definitions have been listed in