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Improving Spectrum Efficiency by Cognitive Radio Network Using Scheduling Method

J.Beulah Mary[1], Jasmine*[2]

Assistant Professor, Dept. of ECE, Jerusalem College of Engineering, Chennai, Tamil Nadu, India[1]

Assistant Professor, Dept. of ECE, Bharath University, Chennai, Tamil Nadu, India[2]

* Corresponding Author

ABSTRACT: Recent studies show that the fixed spectrum assignment policy enforced today results in poor spectrum utilization. To address this problem, the concept of cognitive radio is proposed to address the issue of spectrum efficiency and has been receiving an increasing attention in recent years, since it equips wireless users the capability to optimally adapt their operating parameters according to their interactions with the surrounding radio environment. Cognitive radio is widely regarded as one of the most promising technologies for future wireless communications as it addresses the spectrum scarcity problem that is encountered in many countries. It is done by allowing unlicensed (secondary) users to coexist with the licensed (primary) users under the condition of protecting the latter from harmful interference. The cooperation performance of a primary user and a secondary user is evaluated and the throughput maximization is analyzed via simulations for both the frameworks of active, inactive Primary User (PU) and Secondary User (SU).

KEYWORDS: Cognitive radio, Dynamic Spectrum Access, Cognitive radio networks, Wireless Communications, Spectrum Efficiency.

I. INTRODUCTION

The usage of radio spectrum resources and the regulation of radio emissions are coordinated by national regulatory bodies like the Federal Communications Commission (FCC). Most existing wireless networks and devices follow legacy fixed spectrum access (FSA) policies to use the radio spectrum, which means the spectral bands are licensed to dedicated users and services, such as TV, Cellular networks and vehicular ad hoc networks. The FCC assigns spectrum to licensed holders, also known as primary users on a long-term basis for large geographical regions. The inefficient usage of the limited spectrum necessitates the development of dynamic spectrum access techniques, where users who have no spectrum licenses, also known as secondary users are allowed to use the temporarily unused licensed spectrum.

It is recognized that the licensed spectrum is underutilized by the license holders [1]. To improve the spectrum utilization and efficiency, the cognitive radio networking is enabled which opportunistically share and reuse the licensed spectrum and has drawn a greater attention [2-4]. A network consisting of CR users is termed as secondary network or cognitive radio network (CRN). The main requirement is primary user transmission must be free from interference by the secondary user transmission [3]. An SU can obtain transmission opportunities from the PU in exchange of services provided to the PU by relaying the PU’s traffic [5-6] or by leasing a spectral band from an inactive PU [7] an acceptable leasing price has been set and focuses on structuring and analyzing cooperation among SUs [8]. In CCRN, cooperative communications and spectrum leasing between PU and SU are investigated separately in [9].

II. COOPERATIVE COMMUNICATION IN COGNITIVE RADIO NETWORKS

Cooperation introduces the need for a control channel and has been known recently as a way to overcome the limitation of wireless systems [10]. The cognitive radios are allowed to cooperate for sensing the spectrum, so that the hidden terminal issues are addressed [10].

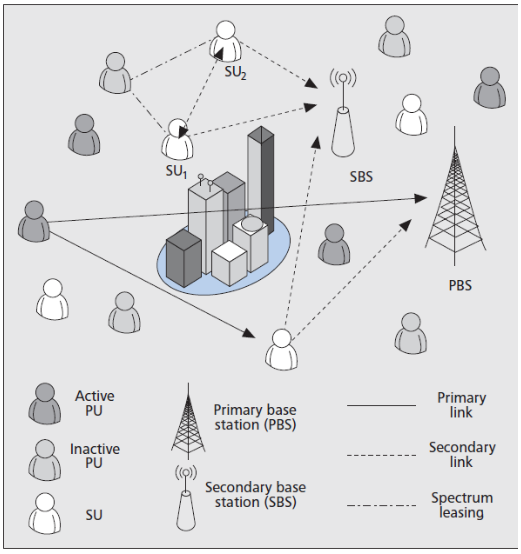

Figure 1. *Networking architectures in CCRN.*

A CCRN environment consists of a primary network (PN) with a primary base station (PBS) and multiple PU's and a secondary network (SN) with a secondary base station (SBS) and multiple SU's. In the PN, PU can occupy the licensed spectrum for a continuous time slot with duration T+ΔT allocated by the PBS on a noninterference basis [11]. If a PU is far away from its intended PBS or the link between the PU and PBS is a blocked buildings, so that the direct transmission of PU cannot support the primary service, the PU selects a SU as a relay. Now the PU communicates with its PBS and a SU communicates with the SBS and is involved in cooperative communications.

When the PU does not communicate it leases the spectrum to the SU so that the spectrum is utilized efficiently and also the PU is profitable. This is referred to as spectrum leasing. Cognitive radio can be used for cooperative communications with active PU, SU and spectrum leasing with inactive PU, SU [12].

III. PROBLEM FORMULATION

As multiple SUs compete with each other to cooperate with the PU, each SU is motivated to provide a large cooperation gain to PU such as meeting the transmission requirement and power constraint. SU uses additional transmit power to obtain the transmission opportunity, the parameters SU needs to optimize are P_s and α [13].

Weighted sum throughput maximization for the SU has to be evaluated for the performance of cooperative communications. The optimization problem can be formulated as

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$$\max_{\alpha, P_s} C_{WSum} = (1-\zeta)C_P + \zeta C_S,$$

$$\text{Subject to:}$$

$$C_P > KC_{Pd},$$

$$C_S \geq C_{ST},$$

$$P_S \leq P_{SM},$$

$$0 < \alpha < 1,$$

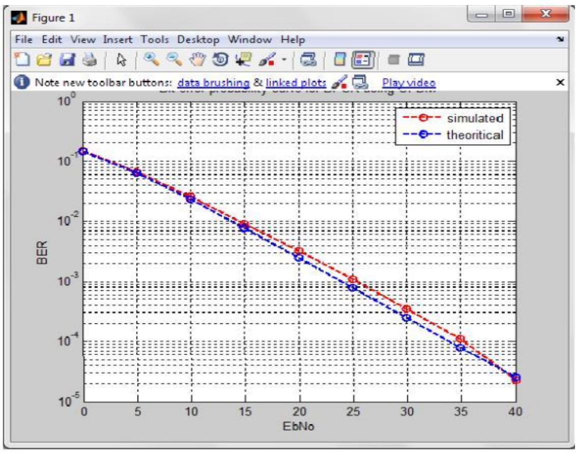
Where C_{WSum} is a weighted sum of the PU's cooperating throughput, $C_{P,}$ and SU's throughput $C_{S,}$ with the weighting parameter ζ. The generalized metric in terms of throughput are as ζ=0, it maximizes PU's throughput, when ζ=1, it maximizes SU's throughput and ζ=1/2 which strikes a balance between PU and SU [14].

If the link from PU to the PBS is blocked by buildings, the SU provides multihop service to the PU and SU may ask for larger ζ for cooperation. C_{Pd} denotes the direct transmission throughput of PU without cooperating SU. The constraints are cooperation with SU, achievable throughput of SU to meet its minimum throughput requirement denoted as C_{ST} and SU's transmit power should be bound by P_{SM} [15].

The optimization problem can be solved by using primal-dual subgradient algorithms such as the method of Lagrange multipliers and the Karush-Kuhn-Tucker conditions. By solving the problem, the SU knows whether itself and PU can obtain benefits. If so it responds else keeps silent. Based on the response of SU, PU selects the SU that can provide the largest C_P as the relaying node.

IV. SIMULATION RESULTS

An ideal channel is selected and simulation results for the bit error probability for the BPSK signal using OFDM modulation with the theoretical and simulated performance is compared.



Based on the On-Off Based Scheduling algorithm the User Signal-to-Noise Ratio rates and the acceptable users SNR are simulated for the bandwidth with minimum and maximum number of users.

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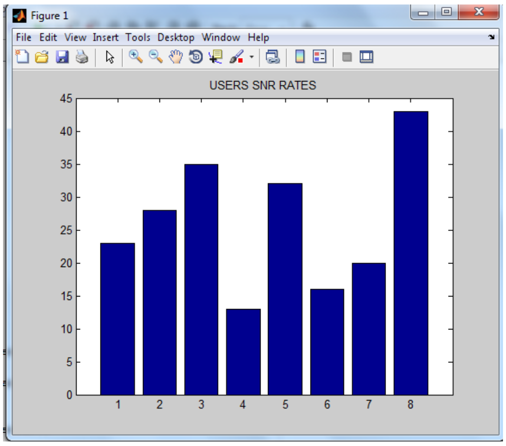
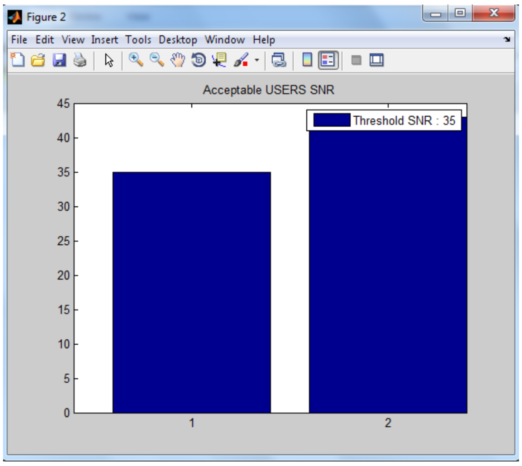
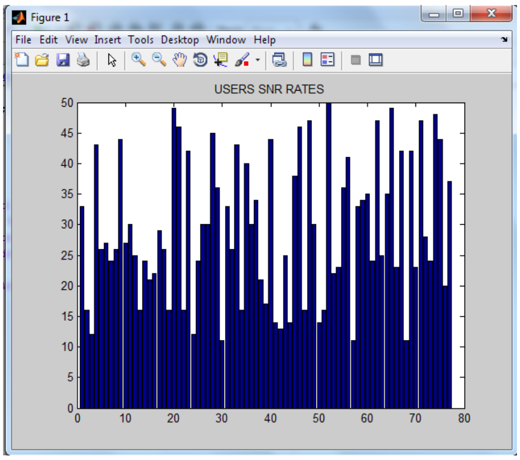




Based on the Switched Based Scheduling algorithm the User Signal-to-Noise Ratio rates and the acceptable users SNR are simulated for the bandwidth with minimum and maximum number of users.



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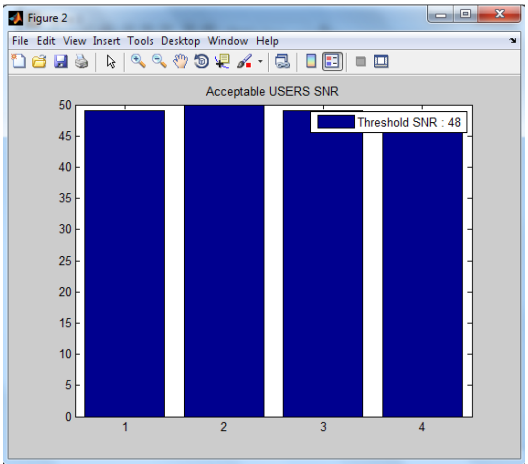
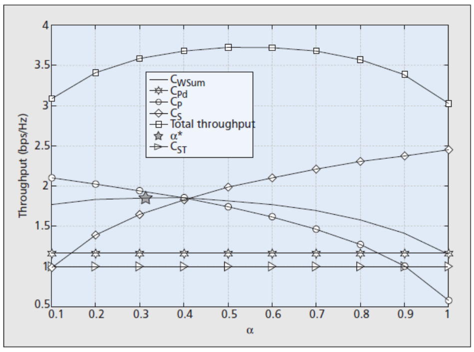


Throughput of cooperative communications between primary users and secondary users is simulated.



V. CONCLUSIONS AND FUTURE WORK

User-Cooperation based CRN is an excellent approach for improving the spectral efficiency and utilization. The different scheduling algorithms are applied for the acceptable users SNR Rates for the effective utilization of the spectrum. The throughput maximization for PU and SU is evaluated for cooperative communications. The future work for improving spectral efficiency is encountering the challenging issues in the Physical layer, MAC layer and Co-Channel interference.

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