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Performance Improved Graph Based Scheduling Algorithm for Infrastructure based Cognitive Radio Networks

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ABSTRACT

This paper focuses on cognitive radio network (CRN), in which a group of nodes communicate over a shared wireless medium with a limited bandwidth. Here frequency channel for transmission of primary radio network (PRN) which is the legacy network will be shared to the secondary users (SU). Whenever resources are shared there exist a strong need of scheduling and this guarantees maximum spectrum utilization of the serviced SUs. In addition to this we need power control too to keep transmission power in the network at the minimum level required to achieve SINR for reliable communications and restrict the co-channel interference to other transmissions there by it guarantees only acceptable interference to the primary user (PU). So we need an approach to have a maximum utilization of the frequency channel without affecting the active primary users. In other words in a CRN, a joint scheduling and power control is necessary to achieve maximum down-link sum capacity in the whole network. An algorithm defining joint scheduling and power control can be formulated to determine the admissible set of users that can safely transmit in the current slot without disrupting each other's transmission. The analysis includes single and multi-parameter interactions and effects. Since in a spectrum sensing CR the frequency channel for the transmission of PRN is to be shared to the SUs this work proposes an approach to have a maximum utilization of the frequency channel without affecting the active PUs. Eventually in this approach a new graph based scheduling algorithm is proposed, ensuring that the channel assignment satisfies the constraint and generates a graph for the given network. Thus the scheduling algorithm can be proposed by combining the graph-generation and the coloring scheme by guaranteeing that each link achieves its required rate. Finally the proposed approach that satisfies the channel assignment constraint can be evaluated and a graph for the given network can be generated and the experimental result can also be compared with the existing work

Key words : cognitive radio network, primary radio network, secondary users, primary users

1. INTRODUCTION

We are at the threshold of a wireless paradigm reVolution where new technologies promise to replace scarcity with abundance and dumb terminals with smart radios that are able to adapt to their surroundings. When the wireless communication systems are making the transition from wireless telephony to interactive internet data and multi-media type of applications, for preferred higher data rate transmission, more and more devices go wireless. So it is not hard to imagine that future technologies will face spectral crowd, and coexistence of wireless devices will be a major issue. Considering the demand for higher capacity and data rates, we require innovative technologies that can offer new ways of exploiting the available radio spectrum.

Cognitive radio is the exciting technology that offers new approaches to the spectrum usage and it has been gaining significant interest among the academia, industry, and regulatory bodies as it provides solution for spectral multitude. Cognitive Radio (CR) is a novel paradigm for efficient utilization of scarce spectrum. Hence forth CR is considered as the reVolutionary candidate for the 5th generation of wireless communication that can help to solve underutilization of a precious natural resource: the radio spectrum and other spectrum adaptation issues and is envisioned as a chief hybrid enabler for Dynamic Spectrum Access (DSA), a mechanism for allowing secondary spectrum users (SUs) to share spectrum with primary spectrum users (PUs).

A CRN can be deployed in two ways. Either as an infrastructure -based CRN or as an ad-hoc -based CRN as shown in Figure 1[16]. Irrespective of the structure, both the ways need to coexist with a PRN. The Cognitive Users (CUs) or SUs that belongs to the Cognitive Radio Network (CRN) - an interconnected set of cognitive radio devices that share information, can generally co-exists with PUs that belong to the Primary Radio Network (PRN) such as GSM, WiMAX etc in two ways. Either on a non interference basis leading to opportunistic or commons model CRNets, Or on an interference tolerant access basis leading to concurrent or property rights model CRNets.

In the first model, spectrum holes or un utilized frequency bands of the PRN are detected and are accessed opportunistically where as in concurrent CRNets, SU is allowed to operate along with the PU which utilizes the overall spectrum more effectively and hence this work deals with the study of concurrent CRNs. But the underlying challenge is to avoid excessive interference to the PU operating on the same frequency band in terms of acceptable transmitting power. The objective is twofold: first, to determine the set of users who can attempt transmission simultaneously in a given slot and second to specify the set of powers needed in order to satisfy SINR constraints at their respective receivers. Maximum down-link sum capacity can be targeted subjected to the QoS constraints of PU and SU.

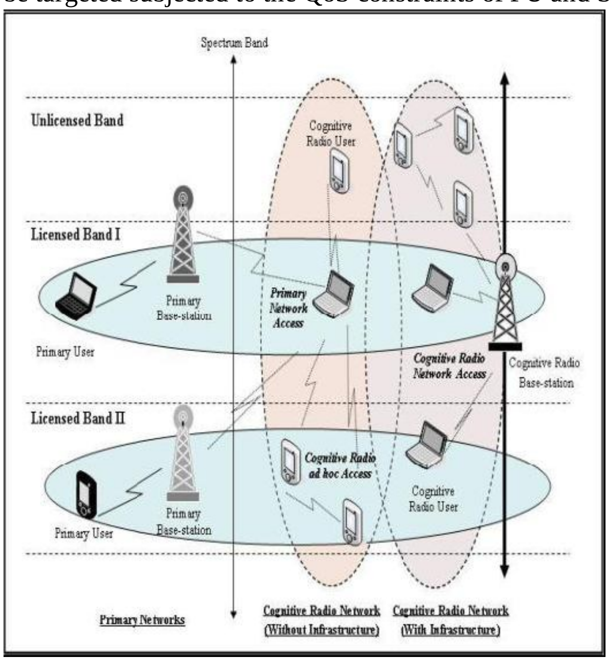

Figure 1. The CRN Architectural Diagram

QoS of PU is defined by FCCs new interference metric named Interference Temperature Limit (ITL) described in spectrum policy task force by Federal Communication Commission in [5], where the total interference power received at each primary user must not exceed ITL value. QoS of SU can be ensured by keeping the SINR value above a predefined threshold value. In this context there is a great need for a joint scheduling and power control problem for the down-link transmission in the infrastructure-based CRN to maximize the spectrum utilization while still protecting active PUs from excessive interference power caused by serviced SUs and guaranteeing reliable communications for cognitive radio users. The main issue of the proposed approach is a joint scheduling and power control for an infrastructure-based cognitive radio network in coexistence with a cellular primary radio network. This work applies a new graph based scheduling algorithm with sum-interference in the cognitive radio network. This algorithm takes into account the sum-interference, instead of resorting to the simplified pair wise-interference model. Thus, this algorithm guarantees the required rate for any arbitrary cognitive radio network.

2. RELATED WORKS

Until a decade before the problem of joint scheduling and power control was solved as a mixed-integer linear programming (MILP) with an NP-hard complexity which is complex in itself. Later a suboptimal heuristic greedy algorithm that can be obtained at a much lower complexity based on the coloring interference graph among un served SUs affected by serviced SUs and active PUs was proposed in the literature. Unfortunately this resorts to the simplified pair wise-interference model.

Work related to concurrent CRNs is discussed in [6]. The CU can coexist with a PU on an interference tolerant access basis. Such CRNs are known as concurrent CR Networks where the SU is also allowed to operate along with the PU concurrently at the same time without causing excessive interference to the PUs. S.Haykin [6] deals with such an access rather than the opportunistic access in his work, which utilizes the overall spectrum more effectively and the same is used in this project work also. In other words this project is restricted to interference tolerant-based CRNs where the utility is appreciably better than the other access method. Works on multichannel multi cell PRN is detailed in [7] and [8]. Lee et al. [7] proposes an improved orthogonal resource allocation algorithm (IORAA), which is designed to incorporate with the OFDMA-based cellular wireless system architecture using relays (OCWSAR) in order to reduce the inter-cell interference (ICI) significantly for mobile stations (MSs), especially, cell-edge MSs in his investigation: "An Orthogonal Resource Allocation Algorithm to Improve the Performance of OFDMA-Based Cellular Wireless Systems Using Relays", which recommends the usage of relays to cover the cell-edge areas and a robust algorithm with priority resource allocation, the inter-cell interference of the system is significantly reduced. Lee- Nguyen- Lee [8] presents a novel orthogonal resource allocation algorithm (ORAA) for their proposed system architecture, named the OFDMA-based cellular wireless system architecture using relays (OCWSAR) in their work: "A Resource Allocation Algorithm and System Architecture to Extend the Cell Coverage and Alleviate the Inter-Cell Interference". The performance of their proposed algorithm is valuated in a multicell/multi-user environment, where the effect of the IORAA is also evaluated precisely.

In both these papers authors add some practical fixed-location edge-cell relays to optimize spectrum utilization in a multichannel multi cell PRN. An investigation on transmit power control is discussed in [9]. "Integrated Power Control and Base Station Assignment," work by the authors R. Yates and C. Huang [9] integrates power control and base station assignment. In the context of a CDMA system, they consider the minimization of the total transmitted uplink power subject to maintaining an individual target CIR for each mobile. This minimization occurs over the set of power vectors and base station assignments. In short this focuses mainly on transmit power control. Unfortunately, they just concern for single-channel scenarios. Since all above studies are just addressed for a PRN, they cannot be applied for a multichannel CRN where the protection of PUs must be guaranteed from the aggregated interference caused by multiple cognitive transmissions. Power scheduling is investigated in [10] and [11]. Kulkarni et al. [10] uses the minimum incremental power allocation (MIPA) algorithm to address the problem of assigning subcarriers to wireless links in the presence of co channel interference with the objective to minimize the total transmitted power over the entire network while satisfying the data rate requirement of each link in their work: “Subcarrier Allocation and Bit Loading Algorithms for OFDMA-Based Wireless Networks”

The power control scheduling algorithm (PCSA) proposed by A. Behzad and I. Rubin [11] has another approach to maximize the number of supported transmissions by greedy selecting the transmissions causing minimal interference to others which is explained in “Multiple Access Protocol for Power-Controlled Wireless Access Nets,” The mentioned algorithm, in contrast to other employed conventional graph-based scheduling algorithms, satisfies the requirement that a minimum signal-to-interference and noise ratio (SINR) is met at all intended receivers of the PRN. Both the MIPA in Kulkarni et al. [10] and the PCSA in Behzad et al. [11] are based on the construction of interference graphs. However, both two schemes are not for CR, protection of PUs is not of concern. Works on scheduling in multi channel CRNs is discussed in [12]. Here the relationship between the available channels, the location, and the traffic load of the PUs is studied by W. Wang and X. Liu [12] in their investigation: “List-Coloring Based Channel Allocation for Open-Spectrum Wireless Networks”. Then, the channel allocation problem is formulated as a list-coloring problem and a distributed greedy algorithm is proposed to maximize the total spectrum utilization. They studied the dynamics in the available channels caused by the location and traffic load of the primary users and proposed several distributed algorithms to exploit the available channels for secondary users. But it is to be noted that the above said work is also restricted to the opportunistic access of idle spectrum. Thus this survey indicates that there is sufficient room for the optimization of a multi cell CRN overlaid with a multi cell PRN. In this context there is a great need for a joint scheduling and power control problem for the down-link transmission in the infrastructure-based CRN to maximize the spectrum utilization while still protecting active PUs from excessive interference power caused by serviced SUs and guaranteeing reliable communications for CR users.

3. PROPOSED SYSTEM

3.1 System Model

Each hexagonal cell is sectorized in to three sectors & let the frequency band be divided equally for the three sectors as in Figure 2. At the center of each PRN cell and CRN cell, there are a P-BS and a CR-BS to serve PUs and SUs in the corresponding cells, respectively. The 4 basic elements [16] of the primary and unlicensed networks are:-Primary User (PU), Cognitive User (CU), Primary Base-Station and Cognitive Radio Base-Station.

1. Primary User: Primary user has a license to operate in a certain spectrum band. This access can be only controlled by its base-station and should not be affected by the operations of any other unauthorized user.

2. Primary Base-Station: Primary base-station is a fixed infrastructure network component which has a spectrum license. In principle, the primary base-station does not have any cognitive radio capability for sharing spectrum with cognitive radio users. However, primary base-station may be required to have both legacy and cognitive radio protocols for the primary network access of cognitive radio users.

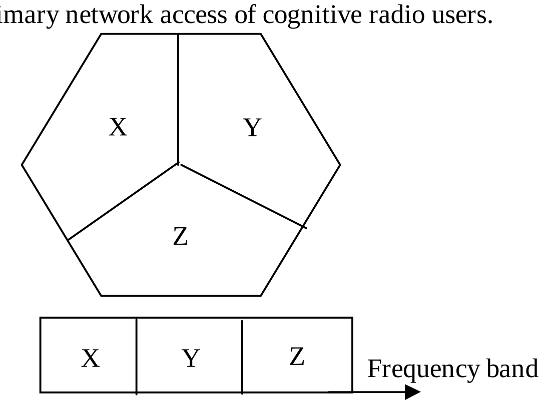

Figure 2. Hexagonal Cell Sectorization

3. Cognitive Radio User: Cognitive radio user has no spectrum license. Hence, the spectrum access is allowed only in an opportunistic manner. Capabilities of the cognitive radio user include spectrum sensing, spectrum decision, spectrum handoff and cognitive radio MAC/routing/transport protocols. The cognitive radio user is assumed to have the capabilities to communicate with not only the base-station but also other cognitive radio users.

4. Cognitive Radio Base-Station: Cognitive radio base-station is a fixed infrastructure component with cognitive radio capabilities. Cognitive radio base-station provides single hop connection to cognitive radio users without spectrum access license. The CRN cell is placed at the junction of three adjacent PRN cells and thus the position of CRN cell is fixed with respect to PRN cells. Now we want to locate the positions of SU and PU. By means of dedicated control channels between secondary base station and SU, the position of SU can be found out. But cognitive base station (C-BS) has no

knowledge about the PUs and during the uplink transmission periods PUs behaves as transmitters enabling C-BSs to estimate their location by triangulation principle and angular measurement from three base stations. Finally the channels used by PU are sensed using well renounced spectrum techniques such as matched filter technique, cyclo-stationary feature detection technique etc to detect whether they are free or not. Thus the system can be modeled by knowing the location of PU, SU and by collecting the channel state information. The channel power gain on any channel from P-BS or C-BS to a PU or SU= power gain due to shadowing × power gain due to multipath fading × path loss on the channel under consideration.

3.2 Problem Formulation

The main aim is to maximize the down link sum capacity in the service area of the SU, while satisfying two important QoS requirements.

1. QoS requirement of PU is defined in terms of interference temperature (ITL). Total Interference power received at each PU should not exceed ITL or should be less than ITL represented as λ_0 .The interference power from all cognitive transmissions on each PU can be represented as $P^c{}_i G_{c,i\to I}$ and is $\leq \lambda_0$.

2. QoS requirement of SU is defined in terms of signal to interference plus noise ratio (SINR). SINR must exceed a predefined threshold value or should be greater than the threshold value represented as γ_0 .For reliable down-link communication the received SINR must be $\geq \gamma_0$ the minimum required SINR. If Ci is the down link capacity then Ci can be expressed as Ci= log(1+ γ_c^i) where γ_c^i is the SINR at SUi. Since our main aim is to maximize the down link sum capacity the objective function can be formulated by maximizing this Ci as

$$\max \sum_{i=1}^{v} C_i = \max \sum_{i=1}^{v} \log(1+ \gamma_c^i) \qquad (1)$$

while satisfying the QoS requirements of PU as well as SU and regulating the down-link transmit power at each CR-BS and by restricting only one channel to one SU. Thus equation (1) is subjected to these four restrictions [13] as:

$$\gamma_c^i = \frac{P_i^c G_{c,i\to i}^{CR\to SU}}{N_0 + \sum_{P\varepsilon\Omega} P_m^P G_{c,p\to i}^{P\to SU} + \sum_{j\varepsilon\Gamma cj\neq i} P_j^c G_{c,j\to i}^{CR\to SU}} \geq \gamma_0$$

$$\sum P_i^c G_{c,i}^{CR\to PU} \leq \lambda_0$$

$$0 \leq P_i^c \leq P_m^{CR}$$

$$P_i^{cj} P_m^{ck} = 0$$

Characteristics of a interference model can be analyzed and can be used in the process of developing our algorithm. The achievable power region associated with the assumption of one unserved SU and one served SU in a CRN is considered and should be non null. The non null achievable power region is bounded by the four inequalities which are the objective constraints in section 3.For any general case we want to consider any unserved SU requesting for service while there exists some active PUs and SUs already operating on the channel. So we can formulate the joint scheduling and power control problem as a coloring graph based problem where the vertex set of the graph represents the unserved SUs so that any channel is not simultaneously assigned to nodes at the edges. However, here the modeling takes place in a pair wise manner in which the contention between two links is decided by the properties of two links only and other links do not play a role in deciding an edge between two links. Due to this critical issue it fails to achieve the required data rate as the aggregate effect of interference from all other operating links are ignored. More over the coloring problem still remain as a NP hard problem. So we propose a new graph based scheduling algorithm which guaranteed the required rate or any arbitrary CRN.

4. PERFORMANCE IMPROVED GRAPH BASED SCHEDULING ALGORITHM

While satisfying the two QoS constraints discussed in 3, the channel assignment is carried out by generating a graph using the following pseudo code.

```
F is an n × n all zero matrix;
for i=1 to n
    do {p[j]gi[j]}←{ pjgij/j≠i} in increasing order;
s=0,k=0
while s≤Si // The Max allowed interference
    do k←k+1,s←s+ p[k]gi[k];
for l=k to n
    do F(I,[l])←1;
return F
```

4.1 Maximum Power Control Scheduling Algorithms (MPCSA)

This algorithm while satisfying the SINR requirement maximizes the number of transmission. When number of transmissions occurs simultaneously a subset of maximal independent set is found out so that under the influence of all cognitive transmissions, the simultaneous transmissions are allowed to allocate the channel. The algorithm stops when all the secondary users are assigned with the channel reminding the pair wise characteristics. However this algorithm can also be applied for a multichannel system too by running it for the first channel and allocating maximum SUs possible. This continues for all the subsequent channels.

4.2 Dynamic Graph Based Scheduling Algorithms (DGBSA)

This algorithm takes in to consideration the interference between pairs of unserviced SUs subjected to the aggregated interference by the serviced SUs on the channel. But this does not minimizes the total down link transmit power on channels. Only those SUs which cause least interference effect to the network are selected for service from the requesting many. The transmission power is to be controlled to prevent co-channel interference to other transmissions and hence power control is also an expected factor in this algorithm. This scheme is applied for a CRN coexisting with an ad-hoc PRN. Channel assignment stops when all the SUs have been served reminding the single color characteristics. We need to consider the interference effect of all active PUs on the SUs too.

4.3 Random Scheduling Algorithm (RSA)

In a CRN scheduling, it is necessary to maximize the spectrum utilization of the serviced SUs. Similarly transmission power is to be controlled to prevent co-channel interference to other transmissions. Thus a joint scheduling and power control is necessary to attain our principle objective of maximizing the down link sum capacity in the serviced area. This algorithm is considered under the assumption that one channel is assigned to one unserved SU at a time without degrading the performance of other competitors. While satisfying all the QoS requirements algorithm try to assign a random channel say c to a random unserved SU or the combinational trial of unserved SU and channel pair continuous until all the simultaneous channel allocation criteria are met with and this unserved SU is selected for service.

5. RESULTS AND DISCUSSIONS

For 1000 random snap shots the environment parameters considered are- number of SUs requesting for service, number of active PUs, number of channels or assignment, cell radius of both cognitive and primary cell, effective SINR and ITL values and noise power for calibrating the average performance of all these suboptimal algorithms in section 4. For a given service area the performance improved graph based scheduling algorithm is found to be the best to schedule network resources in a large scale CRN environment. In other words this scheme approaches closer to optimality than the previous techniques.

6. CONCLUSION

This work applies performance improved graph based scheduling algorithm with sum-interference while guaranteeing the required rate for any arbitrary cognitive radio network. A strong focus is given for the joint scheduling and power control problem for the down-link transmission in the infrastructure-based CRN to maximize the spectrum utilization while still protecting active PUs from excessive interference power caused by serviced SUs and guaranteeing reliable communications for cognitive radio users. A fundamental property of the cognitive radio network is the highly dynamic relationship between the primary users having an exclusive priority to their respective licensed spectrum and the secondary users representing the cognitive network devices. This creates new challenges for the network design.

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