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CO-OPERATIVE RESOURCE ALLOCATION ON MULTICHANNEL COGNITIVE RADIO NETWORKS

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Abstract

The objective of this project is to illustrate the benefits of cooperation in cognitive radio. The cognitive radios are being allowed to operate in the same band to cooperate. So detection time can be reduced by increasing their ability. Two cognitive users (Primary User, Secondary User) are considered and show how the inherent asymmetry in the network can be exploited to increase the probability of detection. We extend our work to multiple cognitive user networks. We also propose a practical algorithm which allows cooperation in random networks.

Keywords: routing, cognitive radio network, route discovery reliability, MDR, Cooperative resource allocation.

1. Introduction

The ever increasing service demand poses new challenges in future wireless communication systems. One of the most prominent challenges in meeting the demand is the scarcity of radio resources. In the past decade, a number of techniques have been proposed in the literature for efficiently utilizing the radio resources-e.g., cognitive radio [1-7], cooperative communication [8-10] and multi antenna communication [11]. Cognitive radio is an emerging technology intended to enhance the utilization of the radio frequency spectrum. Cooperative communication and multi antenna systems, with the same total power and bandwidth of legacy wireless communication systems, can increase the data rate of the future wireless communication systems. A combination of cognitive radio with cooperative communication and/or multiple-antennae can further improve the future wireless systems performance. However, the combination of these techniques raises new issues in the wireless systems that need to be addressed. First, we will briefly describe the basics and terminology of cognitive radio and cooperative communication.

Formally, a cognitive radio is defined as a radio that changes its transmitter parameters based on the interaction with its environment [3, 12]. The cognitive radio has been mainly proposed to improve the spectrum utilization by allowing unlicensed users to use under-utilized licensed frequency bands. In reality, unlicensed wireless devices are already in use [13, 14]. The IEEE 802.22 standard for Wireless Regional Area Network (WRAN) addresses the cognitive radio technology to access white spaces in the licensed TV band. In North America, the frequency range for the IEEE 802.22 standard will be 54- 862 MHz, while the 41-910 MHz band will be used in the international standard [1].

The central controller of the secondary users has the access to the location database. With the knowledge of primary and secondary user locations, the central controller can efficiently manage its resources so that there will be minimum interference to the primary users. The main functions of cognitive radio to support intelligent and efficient utilization of frequency spectrum are as follows:

1.1. Spectrum sensing

Spectrum sensing determines the status of the spectrum and activity of the primary users. An intelligent cognitive radio transceiver senses the spectrum hole without interfering with the primary users. Spectrum holes are the frequency bands currently not used by the primary users. Spectrum sensing is implemented either in a centralized or distributed manner. The centralized spectrum sensing can reduce the complexity of the secondary user terminals, since the centralized controller performs the sensing function. In distributed spectrum sensing, each mobile device senses the spectrum independently. Both centralized and distributed decision-making are possible in distributed spectrum sensing. The central controller, based on the spectrum sensing information, allocates the resources for efficient utilization of the available spectrum. One major role of the central controller is to prevent overlapped spectrum sharing between the secondary users.

1.2. Dynamic Spectrum Access

Dynamic Spectrum Access (DSA) is defined as real-time spectrum management in response to the time varying radio environment -e.g., change of location, addition or removal of some primary users, available channels, interference constraints [1, 2]. There are three DSA models in the literature, namely, exclusive-use model, common-use model and shared-use model [2]. The exclusive-use model has two approaches, spectrum property rights and dynamic spectrum allocation.

In spectrum property rights, owner of the spectrum can sell and trade spectrum; and is free to choose the technology of interest. Dynamic spectrum allocation improves spectrum efficiency by exploiting the spatial and temporal traffic statistics of different services. The European Union-funded DRiVE (dynamic radio for IP services in vehicular environments) project is a classical example of dynamic spectrum allocation. It uses cellular and broadcast technologies to enable spectrum efficient vehicular multimedia services [6]. The common-use model is an open sharing regime in which spectrum is accessible to all users. The ISM (Industrial, Scientific and Medical) band and Wi-Fi are examples of the common-use model. Spectrum underlay and overlay approaches are used in the shared-use model.

2. Related Work

Ghada Hatem et al. [15] have done a resource allocation algorithm where each secondary user can transmit and receive variable number of packets at each time slot. The scheduling algorithm implemented in this increases the throughput and decreases the average packet delay of the secondary user. In this, the primary user suffers a small delay and spectrum underlay model is used. In [16], the cross-layer design is done by jointly optimizing spectrum sensing, access decision, physical layer modulation and coding scheme and data link layer frame size in cognitive radio networks. In this, the lower layer design parameters are jointly optimized to maximize the TCP throughput in centralized cognitive radio network.

A cross-layer distributed control algorithm (DCA) in [17] jointly optimizes routing, medium access and physical layer functions to yield reliable and high capacity links for wireless communication in smart grids. The DCA maintains service guarantees in terms of reliability, latency and data rate for each flow, according to the priority of classes.

Lei Ding et al. [18] have proposed routing and dynamic spectrum allocation (ROSA) algorithm. This algorithm dynamically allocates spectrum resources based on locally collected information to maximize the network throughput. In a multi hop path, the available spectrum band is different for each relay node because spectrum occupancy is location dependent. In ROSA algorithm, nodes adjust their transmission power to maximize the link capacity. In [19], the dynamic spectrum access protocol is centralized. With local information and low complexity, ROSA algorithm gives 75% performance of the centralized solution in [19].

To minimize wastage of resources used by packets in their previous hops, the authors in [20] proposed a cross-layer design between data link and network layer. The link layer resource allocation is done by considering the hop-count information from the network layer module. To overcome this, after channel reservation, packets travelling for maximum number of hops, the power is distributed among packets and transmitted through the best available channel without any degradation in throughput and outage performance.

A cooperative communication is achieved between primary users and secondary users. Christo Ananth et al. [21] proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs). The group signature scheme is widely used in VANETs for secure communication, the existing systems based on group signature scheme provides verification delay in certificate revocation list checking. In order to overcome this delay this paper uses a Hash message authentication code (HMAC). It is used to avoid time consuming CRL checking and it also ensures the integrity of messages. The Hash message authentication code and digital signature algorithm are used to make it more secure . In this scheme the group private keys are distributed by the roadside units (RSUs) and it also manages the vehicles in a localized manner. Finally, cooperative message authentication is used among entities, in which each vehicle only needs to verify a small number of messages, thus greatly alleviating the authentication burden.This work is carried out for single-hop cognitive network and analyses have to be done for multi-hop network.

3. Proposed Co-operative Resource Allocation Technique

Recently several works have dealt with cooperation based spectrum sensing because this utilizes the inherent diversity in the network and it has been shown to provide much better detection of the primary user. This diversity arises because of the independence of the factors like noise, variable channel gain that affect the signal received by a secondary user. Diversity exists in various forms like spatial diversity, temporal diversity and frequency diversity. In a cooperation based spectrum sensing scheme, the measurements of several secondary users are combined and examined together in order to determine the presence of the primary user. The probability that all the cognitive users fail to detect the presence of the primary user, when present, is much smaller as compared to the case when each of them fails independently.

Several cooperation schemes have been suggested to increase the robustness of the detection process. Cooperative schemes can be subdivided mainly into two types: 1) those using hard decisions and 2) those using soft decisions. Hard decision making is the one in which the individual cognitive radios make the decisions regarding the existence of the primary user and the final decision is made by fusing together these decisions from individual cognitive users. In the case of soft decisions, the decision is made by correlating the measurements made by the individual users rather than the decisions of the individual users. It has been shown in [10] that soft decision making has much better results when compared to hard decision making.

3.1. Multipath Diversity Routing

The multipath routing is proposed as an alternative to single shortest path routing to distribute load and alleviate congestion in the network. In multipath routing, traffic bound to a destination is split across multiple paths to that destination. In other words, multipath routing uses multiple "good" paths instead of a single "best" path for routing. Two key questions that arise in multipath routing are how many paths are needed and how to find these paths. Clearly, the number and the quality of the paths selected dictate the performance of a multipath routing scheme. There are several reasons why it is desirable to minimize the number of paths used for routing. First, there is a significant overhead associated with establishing, maintaining and tearing down of paths. Next the complexity of the scheme that distributes traffic among multiple paths increases considerably as the number of paths increases.

4. Performance evaluation

In this section, we will describe basic elements of resource allocation in CRN with cooperative communication and/or multiple-antenna capability.

4.1. Relay assignment/selection

The use of relays in a CRN can benefit in two ways. First it can increase the transmission rate and, secondly the use of relays can reduce the overall transmission power of the systems. The use of multiple relays simultaneously can further increase the performance of a cognitive radio network. A well designed multiple relay assignment and power allocation scheme can be helpful in two ways. It reduces the interference induced to the primary users in multiuser CRN and increases the connectivity of the wireless network. In a multiple relay system, if any relay is dead or in deep fade the receiver can still get data from other relays.

4.2. User scheduling

In multiuser CRN, due to resource limitations and interference constraints, user scheduling in intelligent way can achieve high throughput. User scheduling schemes select the best group of users at each time slot to maximize the total throughput. The complexity of an exhaustive search for user scheduling increases exponentially with the number of users. For example, if K is the total number of users, then the number of possible ways of scheduling/selecting k users is $\binom{K}{k}$. Enumerating all possible combinations to find the one that gives the best performance is computationally inefficient. Due to the high computational complexity of the optimal selection (e.g., exhaustive search algorithm), efficient user scheduling in cooperative CRN is an active area research.

4.3. Routing

Most of the research on CRN to date has focused on one or two-hop scenarios. With the advancement on ad hoc networks, recently, researchers have started to realize the importance and potential of multi-hop CRN. To get the benefits of multi-hop transmission, new challenges must be addressed and solved. In particular, efficient routing techniques and solutions must be integrated into the ad hoc cooperative CRN.

4.4. Quality of service (QoS)

QoS is a general term used for much user satisfaction related requirements. It comprises response time, throughput loss, rate requirements, outage and blocking probabilities. The main aim of QoS in CRN is to guarantee a minimum rate, reduction in latency jitter and packet errors.

4.5. Delay

Delay is an important metric in any wireless network especially for real-time applications such as voice and multimedia. Delay in cooperative CRN is a still an unexplored area of research.

4.6. Subcarrier allocation

Subcarrier allocation and pairing play a significant role in future cooperative CRN which employs OFDM technique in physical layer; One can increase the throughput of cooperative CRN with the intelligent utilization of subcarriers.

4. Experimental Results

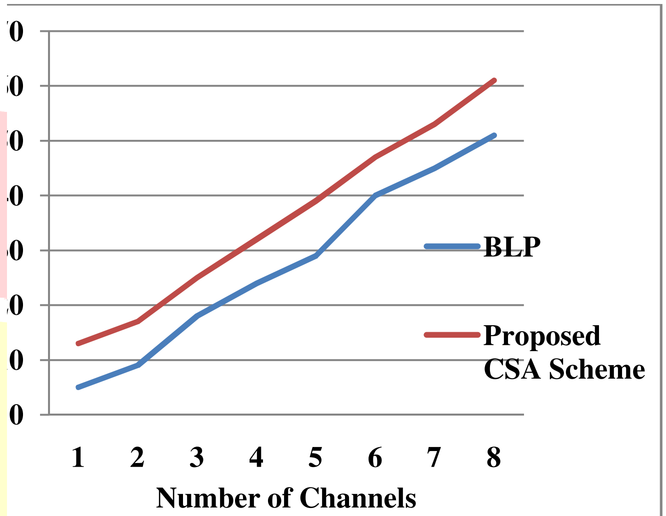

Figure 1: Number of Channels vs. Network Throughput

Figure 2, compares the Number of Channels and Network Throughput of Binary Linear Programming (BLP) and proposed CSA scheme. The red line indicates the performance of the proposed cooperative scheme and blue line shows the BLP performance. When Number of Channels increases the performance of Network Throughput is also increased gradually. Through the comparison graph it is clearly show that proposed CSA scheme provides better performance when compared to BLP.

5. Conclusion

In cognitive radio networks, due to the variable factors except the node location, energy and more working frequency band, make real-time dynamic control network circumstance is very complicated. At present most of the research is based on static modeling optimization calculation, practicality is not high. To solve these problems, this paper put forward the routing strategy is based on the color chart of cross-layer routing algorithm, the algorithm of network topology coloring to differentiate between the number of available frequencies, and through the update rules to dynamically adjust the network topological structure, at the same time of increase network throughput can ensure minimal interference of neighbor nodes.

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