The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 3 || Pages || 57-62 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Review on Resource Efficient Relay Selection Scheme for Cognitive Radio Network

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ABSTRACT
Cognitive radio is a very promising area of research today. It increases spectral efficiency and hence applicable to many area where spectrum is a scare resource. However, it posses the main challenges like the interference and the false alarm probabilities. Research community is engaged in finding the proper solution in such cases. In some cases it happens that primary transmitter (licensed user) and secondary receiver (unlicensed user) are far apart and direct communication is not possible. In such cases relay nodes are used to establish communication. However to select the best relay among many is quite challenging task. This paper presents the overview of cognitive radio, importance of relaying network, relay selection algorithm and resource allocation in cognitive radio.

Keywords - Cognitive Radio, Cooperative communication, relaying network, Resource Allocation

Date of Submission: 14 March 2014 Date of Publication: 30th March 2014

I. INTRODUCTION

As wireless communication techniques develop rapidly, heterogeneous wireless communication system need to be accommodated in limited frequency bandwidth. Traditional orthogonal spectral separation of heterogeneous system is not efficient enough to support the continuous growth of wireless device deploying requirement, which makes spectrum sharing among heterogeneous system more and more important. There are two major challenges for the future of wireless systems: wireless spectrum availability and the high data rate demand of increasing number of users. Cognitive Radio (CR) is a novel aspect of telecommunication systems to solve the problem of spectrum availability by reusing underutilized licensed frequency bands. In a cognitive radio system, unlicensed wireless users (secondary users) are allowed to access the licensed bands dynamically under the constraint of acceptable interference to the Primary Users (PU's). Spectrum overlay and underlay are the existing techniques which can facilitate the spectrum sharing among Secondary Users SUs and PUs [8]. In the overlay approach, the SU shares part of its power resources with the PU to provide a relay assisted transmission. Therefore, the secondary network compensates the imposed interference by increasing the signal to interference plus noise ratio (SINR) of primary receivers. Then the basic idea of overlay approach is to allocate power and channel resources to whole network, while utilizing the requirements of PUs. Recently, to overcome the spectral efficiency loss of one-way half duplex, two-way relaying has been implemented [1]. In the underlay approach, the SU uses the same spectrum concurrently with the PU while maintaining or improving the transmission of the PU by applying signal processing and coding [8]. Cooperative communications and networking is another new communication technology paradigm that allows distributed terminals in a wireless network to collaborate through some distributed transmission or signal processing so as to realize a new form of space diversity to combat the detrimental effects of fading channels [20]. Cooperative Communication (CC) can offer high channel capacity and reliability in an efficient and low-cost way by forming a virtual antenna array among single-antenna nodes that cooperatively share their antennas.

This paper is organized as follows. The fundamental of cognitive radio are discussed in Section II. Different proposed relay selection algorithms are described in Section III. Section IV discusses concept of Resource Allocation. Finally, paper is concluded by Conclusion in Section V and future work in Section VI.

II. COGNITIVE RADIO

Cognitive Radio (CR) is the enabling technology for supporting dynamic spectrum access: the policy that addresses the spectrum scarcity problem that is encountered in many countries. Thus, CR is widely regarded as one of the most promising technologies for future wireless communications [17]. CR differs from conventional radio devices in that a cognitive radio can equip users with cognitive capability and reconfigurability. Cognitive capability refers to the ability to sense and gather information from the surrounding environment, such as information about transmission frequency, bandwidth, power, modulation, etc. With this capability, secondary users can identify the best available spectrum. Reconfigurability refers to the ability to rapidly adapt the operational parameters according to the sensed information in order to achieve the optimal performance. By exploiting the spectrum in an opportunistic fashion, cognitive radio enables secondary users to sense which portion of the spectrum are available, select the best available channel, coordinate spectrum access with other users, and vacate the channel when a primary user reclaims the spectrum usage right.

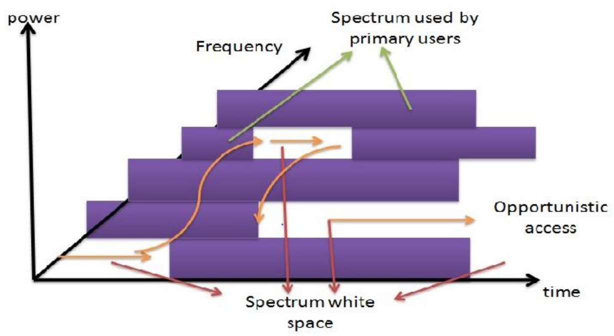

Fig. 1 Illustration of spectrum white space

Through spectrum sensing and analysis, CR can detect the spectrum white space (see Fig. 1), i.e., a portion of frequency band that is not being used by the primary users, and utilize the spectrum. On the other hand, when primary users start using the licensed spectrum again, CR can detect their activity through sensing, so that no harmful interference is generated due to secondary users' transmission. Thus spectrum management is done efficiently[20].
Because CRs are able to sense, detect, and monitor the surrounding RF environment such as interference and access availability, and reconfigure their own operating characteristics to best match outside situations, cognitive communications can increase spectrum efficiency and support higher bandwidth service. Moreover, the capability of real-time autonomous decisions for efficient spectrum sharing also reduces the burdens of centralized spectrum management. As a result, CRs can be employed in many applications. The main functions of cognitive radios are[19]:

1. Spectrum sensing
2. Power Control
3. Spectrum management

Spectrum sensing

Detecting unused spectrum and sharing it, without harmful interference to other users; an important requirement of the cognitive-radio network to sense empty spectrum. Detecting primary users is the most efficient way to detect empty spectrum. Spectrum-sensing techniques may be grouped into three categories such as Transmitter detection, Cooperative detection, Interference-based detection.

Transmitter detection

Cognitive radios must have the capability to determine if a signal from a primary transmitter is locally present in a certain spectrum. There are several proposed approaches to transmitter detection namely Matched filter detection, Energy Detection, Cyclo-Stationary feature Detection.

Cooperative detection

Refers to spectrum-sensing methods where information from multiple cognitive-radio users is incorporated for primary-user detection.

Power Control

Power control is used for both opportunistic spectrum access and spectrum sharing CR systems for finding the cut-off level in SNR supporting the channel allocation and imposing interference power constraints for the primary user's protection respectively. In a joint power control and spectrum sensing is proposed for capacity maximization.

Spectrum management

Capturing the best available spectrum to meet user communication requirements, while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band (of all bands available) to meet quality of service requirements; therefore, spectrum-management functions are required for cognitive radios. Spectrum-management functions are classified as:

- Spectrum analysis
- Spectrum decision.

The main requirement of these new radios is that they posses the ability to sense and quantify interference on or from other radio systems and that they be capable of establishing collaborative sharing of spectrum. Automatic Modulation Classification (AMC) is the automatic recognition of the modulation format of a sensed signal. For an intelligent receiver, AMC is the intermediate step between signal detection and demodulation. AMC plays an important role in civilian and military applications, especially in dynamic spectrum management and interference identification. It has also been an important topic for electronic surveillance for over two decades.

Following are the issues of Cognitive Radio

- Advance spectrum management
- Unlicensed spectrum usage
- Spectrum sharing strategies
- Hidden node and sharing issues
- Trusted access and security
- Complexity issue
- Cross-layer design
- Hardware and software architecture

Some of the above mentioned issues can be overcome with the use of relaying network.

Some of the main advantages of relaying network are explained below:

Good Signal Strength: In long distance communication interference and noise is present, thus sensing is not good, so if relay is introduced in it noise is removed and interference is beyond certain limit.

Increased Coverage: With multi-hop relays the macro cell coverage can be expanded to the places where the base station cannot reach.

Increased Capacity: It creates hotspot solutions with reduced interference to increase the overall capacity of the system.

Lower CAPEX & OPEX: Relays extending the coverage eliminates the need of additional base stations and corresponding backhaul lines saving wireless operators deployment costs and corresponding maintenance costs. The relays can be user owned relays provided by operators and can be mounted on roof tops or indoors.

Better Broadband Experience: Higher data rates are therefore now available as users are close to the mini RF access point

Reduced Transmission Power: With Relays deployed there is a considerable reduction in transmission power reducing co-channel interference and increased capacity

Faster Network Rollout: The deployment of relays is simple and quickens the network rollout process with a higher level of outdoor to indoor service and leading to use of macro diversity increasing coverage quality with lesser fading and stronger signal level.

Relay assisted wireless communication techniques can provide benefits like improvement in link quality and reliability, and increase in coverage. In conventional two way relaying, the selection of the best relay, among a set of available relaying nodes depends on the transceiver to relay and reverse channel gains. The presence of the PU restricts the power of the relayed signal so that the interference to the PU receiver does not violate the specified limits. Thus, joint relay selection and power allocation algorithms are used in this paper [14]. The advantage of relay network lies in reducing the overall path loss achieved by using a relay between a source and a destination. Inspired by cognitive radio and relay networks, Cognitive relay networks (CRN) have recently been adopted to improve secondary user throughput using one of the two approaches: cooperation between primary and secondary users, and cooperation between secondary users [8]. Generally, there are mainly two paradigms for the operation of CR: opportunistically spectrum access (OSA) and spectrum sharing (SS) . OSA allows SUs to transmit only when a frequency band is detected to be idle, while SS allows SUs to transmit simultaneously with the PU over the same frequency as long as the quality of service of PU is guaranteed. In order to improve CR network performance, resource allocation in CR networks has been extensively researched . The optimal power allocation strategies which aim at, respectively, maximizing the ergodic delay limited and outage capacities of the SU were studied under different combinations of transmit power constraint and interference power constraint. In the case of severe channel conditions in direct links, cooperative relay has been introduced to forward the data from source to destination in CR networks. Recent works have studied the resource allocation for cooperative relay in CR networks. Relay selection and power allocation with amplify and forward (AF) relaying protocol was investigated in cooperative CR systems. The power and channel allocation with decode and forward (DF) relaying protocol was proposed to maximize the overall end to end throughput in the cooperative relay CR network. Here, the relay and power allocation schemes with decode and forward (DF) relaying protocol were presented for cooperative relay in the CR network [4].

III. RELAY SELECTION

Relay selection is a very challenging task for optimum performance of any communication. Following are the different relay selection algorithms.

1) Firstly, relay is selected randomly, then selected relay for primary and secondary transmission verifies the channel gain selection, followed by relative channel gain selection by the selected relay. Finally, average relative channel gain selection is done by selected relay [3].

2) A variety of criteria for relay selection have been proposed as a way of maximizing capacity or minimizing outage probability in conventional relay networks. The max-min criterion, which maximizes the minimum of signal-to-noise ratios of the source-relay link and relay-destination link, has proven optimal for this purpose. Relay is chosen based on the channel gains of the relaying link [8].

3) Two half-duplex relaying protocols are Amplify-and-forward (AF) and Decode-and-forward (DF). AF relaying protocol: The relay SU receives and amplifies the transmitted data from source SU in the first phase, and retransmits the data to destination SU in the second phase. DF relaying protocol: The relay SU receives and decodes the transmitted data from source SU in the first phase, and re-encodes and forwards the data to destination SU in the second phase [11]

4) Relay selection is done by Artificial Bees Colony (ABC), a relatively new global optimization algorithm. It works on non-convex problems. ABC emulates honey bees intelligent behaviour of searching for quality food source with highest nectar (i.e., the best solution) and sharing that information with their fellows in the hive. Thus, the goal of the whole Bee Colony is to maximize the amount of nectar (SNR) [16].

5) Adaptive cooperation diversity algorithm is proposed for relay selection in which the best relay selection considers not only the channel state information (CSI) of two-hop relaying link, but also the condition of the link from secondary relay to primary destination. Here, an interference criterion is considered which should be below certain limit. The relay which can successfully decode the secondary transmitters signal and can achieve the highest SINR at Secondary Destination is selected [13].

6) Optimal relay assignment (ORA) algorithm is proposed to maximize the minimum data rate among multiple source- destination pairs. Optimization algorithms and techniques which can be applied to non-linear constraints and give the feasible optimal solution [6].

7) A comparative heuristic relay selection algorithm was proposed in [5]. Its main objective is t\o select relay and to assign the best channels for selected RE-CPE (relay nodes for customer premise equipments). Since the bandwidth of each component carrier is large and each relay requires high transmit power for multi-carrier transmission, it is assumed that each cognitive relay can only amplify-and-forward via one component carrier. To overcome the above mentioned issue comparative heuristic relay selection algorithm is proposed that finds the best total gain for considered order of maximum gain.

In this algorithm the CBS (Cognitive Radio Base Station) allocates Component Carrier to i-th CPE as follows, iteration number is denoted by r and CPE index by j and initially set to 1. In the r-th iteration (r= 1.,...,R), the i-th CPE, to which no component carrier has allocated yet, compares the r-th maximum channel gain to the j-th CPE, j=1,....,M. If the given channel has the r-th best gain($Max_r(F_{c,i}*g_{c,i})$)for exactly one CPE this channel is allocated to that CPE and the next iteration starts. The channel allocation procedure continues until a channel has been allocated to N out of M CPEs. If the number of selected CPE is not equal to N, the algorithm should be applied for remaining CPEs and component carrier.

8) Relay is selected based on residual of energy and minimum distance criteria. In this algorithm two different approaches are used: strategic relay and random relay. Random relay is selected randomly on the basis of energy threshold whereas strategic relay is selected not only on the basis of energy threshold but also on minimum distance criteria. If the relay is having minimum distance and fulfilling energy criteria then that relay would be selected for further communication.

IV. RESOURCE ALLOCATION IN CR

Resources in cognitive radio imply power, channel capacity, and bandwidth. Certain algorithms are proposed according to the requirements for allocation of power, bandwidth and channel. System throughput and energy is maximized. In [8], they presented two optimal resource allocation schemes that maximize throughput and symbol correct rate (SCR). The throughput and SCR are derived. The derived throughput and SCR are optimized with respect to the sensing time, the source transmission power and the relay transmission power. Numerical results show that the optimal sensing time is dependent on the primary user's signal-to-noise-ratio (SNR). They also show that SCR increases with increase in the number of relays. The relay allocates its amplify-and-forward matrix for achievable sum-rate maximization, whereas the mobile transmitters selfishly allocate their spreading codes for individual achievable rate maximization. Convergence of the proposed algorithm is proved and its performance contrasted against a centralized approach.

They proposed a power updating scheme [9]that tries to maximize the coverage and throughputs of the secondary network, while increasing the SINR constraint of the primary transceivers. This scheme is applied to one channel at a time. For the c^{th} channel, following actions are carried out: Initialization, Power updating, Termination. After the power updating scheme is completed for each channel c, channel assignment problem is to be considered. A bipartite which can be solved by Kuhn-Munkres (Hungarian) algorithm such that the sum of secondary networks throughput is considered as the weighted matching parameter.

In [1] , power allocation scheme for relay-assisted Infra-structure system is provided so as to minimize the interference to the Ad-hoc links ,in order to maintain a specified QoS level. This resource allocation problem is formulated as a convex optimization problem. Following the duality theory, firstly for fixed dual variables then the dual problem is solved. The Karush-Kuhn-Tucker optimality conditions are applied and the problem is solved.

In [4], the problems of joint bandwidth and power allocation with AF or DF (Amplify and forward or Decode and forward) protocol are formulated. For AF and DF relaying protocol, the joint bandwidth and power allocation problem aims at maximizing the sum throughput of the CR network , minimize the total transmit power of the CR network, and maximizing the energy efficiency. In this case it is assumed that relay SU can execute the DF relaying protocol if the data rate between source SU and relay SU is greater than zero. But actually the data rate between source SU and relay SU should be higher than $r(r>0)$ to ensure reliable decoding in relay SU. This decoding rate constraint will cause some poor quality of relaying link and will require more resource. In this case, a part of resource will be wasted. Therefore, a hybrid relaying protocol to overcome the problem in which a relay SU uses the AF relaying protocol only if it cannot decode reliably the source data. Otherwise, a relay SU uses the DF relaying protocol.

V. CONCLUSION

Cognitive radio technology has been proposed in recent years as a revolutionary solution towards more efficient utilization of the scarce spectrum resources in an adaptive and intelligent way. By tuning the frequency to the temporarily unused licensed band and adapting operating parameters to environment variations, cognitive radio technology provides future wireless devices with additional bandwidth, reliable broadband communications, and Versatility for rapidly growing data applications. In this survey the fundamental concept about cognitive radio characteristics, functions, relaying concept, relay selection methods are presented, and then various research topics on cognitive radio networks are discussed. Relay selection based on cooperative diversity scheme increases the SNR at the cognitive relay destination and hence optimize the performance of the system.

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