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Spectral efficient and Interference free spectrum sharing in Cognitive radio using Signal Space Diversity

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Abstract – The development of the new technologies in the field of communication has created an explosive demand in terms of high quality services. In this study paper, spectrum sharing protocol is introduced which is based on signal space diversity (SSD) for cognitive radio networks. Spectrum scarcity and underutilization in wireless networks, arising day by day due to traditional static spectrum allocations which have been into consideration from last decades. The proposed network consist of one primary transmitter and primary receiver pair and one secondary transmitter and secondary receiver pair which help in coordination before transmitting its own signal on the primary user's spectrum. In our research work transmission is done in three signalling intervals which avoid any mutual interference between users and the SSD which is provided by coordinate interleaved orthogonal design (CIOD) whose purpose is to increase the transmission rate of the primary users. The output probabilities of both primary and secondary users are mathematically derived and analysed using MATLAB simulations. The results will show that significant performance improvement is provided by the proposed protocol.

Keyword- Cognitive radio, Spectrum efficiency, Spatial diversity, Cooperative communication, Spectrum sensing, coordinate interleaved orthogonal design (CIOD).

1.INTRODUCTION

Since the soonest times, man has found it essential to communicate with others. To meet these requirements and to ensure high quality of services to users, the spectrum sharing protocol is used in cognitive radio. Within the current spectrum regulatory framework, however, all of the frequency bands are exclusively allocated to specific services, and no violation from unlicensed users is allowed. A recent survey of spectrum utilization made by the Federal Communications Commission (FCC) has indicated that the actual licensed spectrum is largely underutilized invast temporal and geographic dimensions [1]. For instance, a field spectrum measurement taken in New York City has shown that the maximum total spectrum occupancy is only13.1% from 30 MHz to 3GHz [2], [3]. For a long term use for large scale geographical regions the FCC assigns spectrum to licensed holders which is known as primary users. However, this assigned spectrum remains under utilized as shown in Figure1. 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 which are allowed to use the temporarily unused licensed spectrum. In recent years, the FCC has been considering more flexible and comprehensive uses of the available spectrum [1], through the use of cognitive radio technology [2]. Cognitive radio is the key technology that is the next generation communication networks which is known as dynamic spectrum access (DSA) networks, whose purpose is to utilize the spectrum more efficiently without interfering with the primary users. It is the radio that operates with change in transmitter parameters according to the environment [4]. Cognitive radio differs from conventional radio device as it has cognitive capability and reconfigurabililty [3] [5]. Cognitive capability refers to the ability to sense Spectrum usage [3] and gather information from the surrounding environment, such as information about performance

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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. Thus, 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. Considering the more flexible and comprehensive use of the spectrum resources, especially when secondary users coexist with primary users, traditional spectrum allocation schemes [6] and spectrum access protocols may no longer be applicable. New spectrum management approaches need to be developed to solve new challenges in research related to cognitive radio, specifically, in

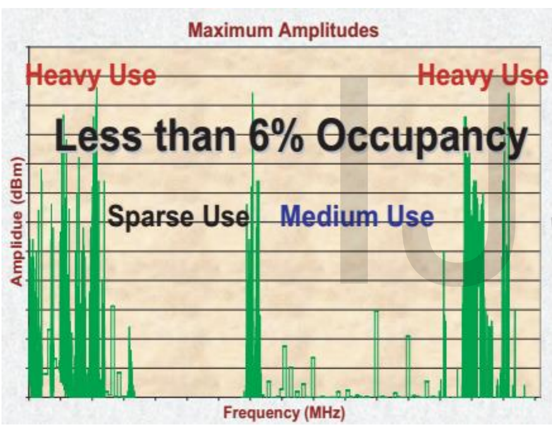

Fig. 1.Spectrum usage

Spectrum sensing and dynamic spectrum sharing of BWA. As primary users have priority in using the spectrum, when secondary users coexist with primary users, they have to perform real-time wideband monitoring of the licensed spectrum to be used. When secondary users are allowed to transmit data simultaneously with a primary user, interference temperature limit should not be violated [7]. If secondary users are only allowed to transmit when the primary users are not using the spectrum, they need to be aware of the primary user's reappearance through various detection techniques, such as energy detection, feature detection, matched filtering and coherent detection. Due to noise uncertainty, shadowing, and multipath effect detection of single user sensing is pretty limited. However, Cognitive Network (CN) is a network with a cognitive process that can perceive current network conditions, plan, decide, act on those conditions, learn from the consequences of its actions, all while following end-to-end goals. Cooperative communications represent a new class of wireless communication techniques in which network nodes help each other in relaying information to realize spatial diversity advantages. In cooperative spectrum sensing, how to select proper users for sensing, how to fuse individual user's decision and exchange information, and how to perform distributed spectrum sensing are issues worth studying.

In order to fully utilize the spectrum resources, efficient dynamic spectrum allocation and sharing schemes are very important. Novel spectrum access control protocols and control channel management should be designed to accommodate the dynamic spectrum environment while avoid collision with a primary user. Although to manage the interference to the primary users and the mutual interference among themselves, secondary users transmission power should be carefully controlled, and their competition for the spectrum resources should also be addressed. There have been many advantageous developments in past years on cognitive radio. Thus, this study paper shows significance of research related to cognitive radio and spectrum sensing. In Section II, overview of cognitive radio technology, architecture of a cognitive radio network and its applications is focused. In Section III, review existing works in spectrum sensing, including interference free atmosphere, and cooperative spectrum sensing is discussed. In Section IV several important issues in dynamic spectrum allocation and sharing is explained.

I. FUNDAMENTALS

A. Cognitive Radio Characteristics

In the last few decades, communication over a distance is focused and scalability of radio access technology is taken into an account, thus provides a great flexibility in network deployment options and offer better services. The dramatic increase of service quality and channel capacity in wireless networks is severely limited by the scarcity of energy and bandwidth, which are the two fundamental resources for communications. Therefore, researchers are currently focusing their attention on new communications and networking paradigms that can intelligently and efficiently utilize these scarce resources. Cognitive radio (CR) is one

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critical enabling technology for future communications and networking that can utilize the limited network resources in a more efficient and flexible way.

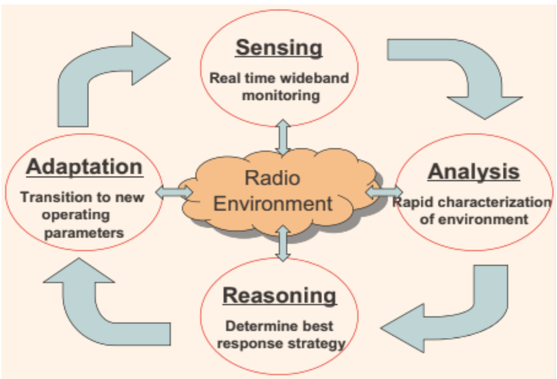

Fig. 2. Cognitive cycle

In dynamic spectrum access, a secondary user may share the spectrum resources with primary users, other secondary users, or both. Hence, a good spectrum allocation and sharing mechanism is critical to achieve high spectrum efficiency. Since primary users own the spectrum rights, when secondary users co-exist in a licensed band with primary users, the interference level due to secondary spectrum usage should be limited by a certain threshold. When multiple secondary users share a frequency band, their access should be coordinated to alleviate collisions and interference.

B. Network Architecture and Applications

With the development of CR technologies, secondary users who are not authorized with spectrum usage rights can utilize the temporally unused licensed bands owned by the primary users. Therefore, in CR network architecture, the components include both a secondary network and a primary network, as shown in Figure 4.

A secondary network refers to a network composed of a set of secondary users with/without a secondary base station. Secondary users can only access the licensed spectrum when it is not occupied by a primary user. If several secondary networks share one common spectrum band, their spectrum usage may be coordinated by a central network entity, called *spectrum broker* [8]. A primary network is composed of a set of primary users and one or more primary base stations. Primary users are authorized to use certain licensed spectrum bands under the coordination of primary base stations. Their transmission should not be interfered by secondary networks.

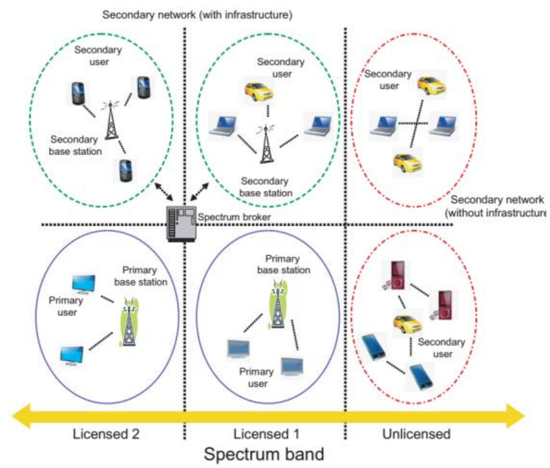

Fig. 3. Network architecture of dynamic spectrum sensing

II. SPECTRUM SENSING

Spectrum sensing enables the capability of a CR to measure, learn and be aware of the radio's operating environment, such as the spectrum availability and interference status. When a certain frequency band is detected as not being used by the primary licensed user of the band at a particular time in a particular position, secondary users can utilize the spectrum i.e., there exists a spectrum opportunity. Therefore, spectrum sensing can be performed in the time, frequency, and spatial domains. With the recent development of beam forming technology, multiple users can utilize the same channel/frequency at the same time in the same geographical location. Thus, if a primary user does not transmit in all the directions, extra spectrum opportunities can be created for secondary users in the directions where the primary user is not operating, and spectrum sensing needs also to take the angle of arrival into account.

Spectrum analysis discovers the different functionalities of the spectrum bands, to make productive use of the spectrum band according to the requirements. Each spectrum hole (Band of frequencies assigned to the primary user, but at a specific time and geographic location, these bands is not fully utilized by that user) should be defined according to the time varying environment and the information of the band like frequency and bandwidth. To represent the quality of the spectrum band, parameters are

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defined such as interference, holding time, path loss, link layer delay, wireless link errors etc.

• **Interference:** The interference characteristics of the channel can be determined from the spectrum band in used. The permissible power of a CR user can be calculated, from the amount of interference which is use for the calculation of the channel capacity.

• **Holding time:** Holding time is an expected time, from which the CR user occupy the licensed band before its interruption. For better quality holding time should be as long as possible.

• **Path loss:** If the operating frequency increases, the path loss will also be increased. If the cognitive users have the constant transmission power then at higher frequencies their transmission range decreases. In order to compensate the increased path loss if we increase the transmission power this yields in higher interference to the other users.

• **Wireless link errors:** This error rate of the channel changes according to the change in modulation scheme and interference level of the spectrum band.

• **Link layer delay:** Different link layer protocols are required to address path loss, interference and wireless link errors.

III. SPECTRUM SHARING

Spectrum sharing is the major challenge which open spectrum usage faces. Spectrum sharing is related to medium access control (MAC) problems in the current system. However, there are different challenges for the spectrum sharing in cognitive radio. Spectrum sharing consists of five steps which are:

• **Spectrum sensing**: The CR can allot a specific part of the spectrum if it is not used by the licensed user. When a CR wants to transmit data, it will first sense its surrounding spectrum usage.

• **Spectrum allocation:** When spectrum is available, a channel is allocated. This allocation depends on the availability of the channel and also internal/external policies.

• **Spectrum access**: When the nodes are trying to access the available spectrum, spectrum access helps to prevent colliding and overlapping of the spectrum.

• **Transmitter-receiver handshake:** The transmitter-receiver handshake is essential for effective communication in cognitive radio, after the determination of the spectrum.

• **Spectrum mobility:** The spectrum mobility is important in the communication between the nodes. If a particular part of the spectrum is required by the licensed user, communication should be continued by utilizing another free part of the spectrum.

A. Classification of spectrum sharing

Spectrum sharing can be classified into three main parts, i.e. architecture, spectrum allocation behaviour and spectrum access techniques which is illustrated in Fig2.5.

• **Centralized spectrum sharing:** In centralized spectrum sharing, spectrum allocation and access procedures are controlled by a centralized entity [7].Each entity in the CR network forwards the measurements of spectrum allocation to the central entity.

• **Distributed spectrum sharing:** when the construction of an infrastructure is not suitable, then distributed solutions are proposed.

• **Cooperative spectrum sharing:** The interference measurements are distributed among other nodes, the centralized solution is also referred as cooperative.

• **Non-cooperative spectrum sharing:** Non-cooperative solutions only think about the nodes in hand that's why also called selfish solutions. The Non-cooperative solutions are reduced spectrum utilization and minimal communication requirements.

• **Overlay spectrum sharing:** This overlay spectrum sharing is also known as the spectrum access technique. The node accesses the network by using that portion which is not under usage of the licensed user (LU).

• **Underlay spectrum sharing:** The underlay spectrum sharing technique take advantage of the spread spectrum techniques which are specifically developed for cellular networks [8]. The underlay spectrum sharing requires such

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spread spectrum technique from which it can utilize high bandwidth.

B. Spectrum sharing challenges

There is a huge amount of ongoing research issues in spectrum sharing, which should be properly investigated for the efficient use of the spectrum. A few challenging issues in CR along with their possible solutions are [7]:

• **Common control channel (CCC):** In spectrum sharing solutions,when the primary user has selected a channel, this should be vacated without any interference. As a result, implementation is not feasible in fixed CCC CR networks. When we are not using CCC,the handshaking between the transmitter and the receiver becomes a challenge.

• **Dynamic radio range:** In CR networks, huge amounts of spectrum are used. Node neighbours change with respect to the variation of the operating frequency. The changing in the neighbour node affects the interference profile and the routing decisions. For minimum interference, control channels will be selected from the lower portion (high transmission range and selection of data channels in the high part of the spectrum.) and data channels will be selected from the higher portion.

• **Spectrum unit:** The channels can be defined with respect to the frequency dimension,as frequency bands [9]. Spectrum sharing is a challenge in advanced algorithms with respect to the definition of the channel behaving as a spectrum unit. The properties of the channel are not constant due to the influence of the operating frequency. The cognitive radio spectrum can be designed based on the generic spectrum unit. In a cognitive radio network it is difficult to find a common spectrum for efficient utilization.

IV. CONCLUSION

Spectrum is an incredibly precious reserve in wireless communication systems, and it was an important point of discussion, research and development efforts over the last many decades. CR which is one of the hard works to employ the available spectrum more ingeniously through opportunistic spectrum usage has turned into an electrifying and talented concept. The available spectrum opportunities are one of the significant elements of sensing in CR. In this paper, concepts related to spectrum sensing and its opportunities are re-evaluated by taking into account different proportions of the spectrum space. Diverse aspects of the spectrum sensing assignment are explained in detail. A number of sensing methods are considered and collaborative sensing is well thought-out as an answer to some frequent problems of spectrum sensing.

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