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Spectrum Aware Mobility Management in Cognitive Radio-A Survey

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Abstract

Cognitive radio (CR) enables the efficient utilization of the limited radio spectrum, network resources and an unlicensed user can communicate in licensed spectrum without interfering a licensed user. In CR expected to address several operational challenges such as spectrum access in dynamic manner, providing Quality of Service (QOS) between end-to-end and spectral heterogeneity. Hence it become an all-encompassing term for a wide variety of technologies and emerges as a promising solution to improve current spectrum utilization efficiently. In this paper we proposed spectrum mobility management in cognitive radio.
Keywords: Cognitive Radio, Dynamic Spectrum Access, spectrum polling, spectrum handoff, spectrum mobility management

I. INTRODUCTION

Due to the ever-increasing demand for new wireless services and applications for anytime and anywhere connectivity in our daily businesses and lives, we expect to face a shortage of available wireless spectrum in the near future. However, this spectrum-shortage problem is known to be rooted in the conventional static spectrum-allocation policy where only licensed devices can operate on a designated spectrum band. For example, according to a recent measurement report, an average of only 5.2% of wireless spectrum under 3GHz was being actively used, indicating that a large fraction of spectrum bands are unutilized or underutilized at any given location and time.

The cognitive radio (CR) network refers to the wireless network using CR technology. The key functionality that enables the efficient utilization of the limited radio spectrum and network resources, which provides the ability to share the wireless channel with primary users in an taking immediate advantage manner. The term "Cognitive Radio" was first coined by Joseph Mitola III in his article with Gerald. Q. Maguire, Jr., in 1999 describing it as a software defined radio which can change its parameters depending on the need and user requirements. The importance of Cognitive Radio is that it operates in both licensed band and also in unlicensed band. In the licensed band the functions of CR are mainly aimed to avoid the interference with the licensed users. During the ongoing communication if the primary user is detected then secondary user should vacant current spectrum and move to other unused spectrum by the process called spectrum handoff. If there are no license users in the band then entities of all networks in unlicensed band have equal rights to access the spectrum.

In upcoming sections we will discuss cognitive radio technology, CR architecture, functions of CR, spectrum mobility for CR, and spectrum polling concept.

II. COGNITIVE RADIO TECHNOLOGY

Two main characteristics of network architecture can be defined as follows:

A. Cognitive Capability:

Which is the ability to acquire the radio parameters from its surroundingsThe.CR should be able to determine the frequency occupancy by identifying the spectrum holes (or spectrum opportunities). The spectrum hole is defined as the frequency bands which are allocated but not utilized in some location and at some times by the licensed system Moreover, depending on the system, CR might have information about the modulation and coding as well as the geo-location of the licensed system devices.

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B. Re Configurability:

Which is the ability to rapidly adapt the transmit parameters, i.e. operating frequency, modulation and coding, transmit power and communication technology, according to the radio environment in order to achieve the optimal performance.

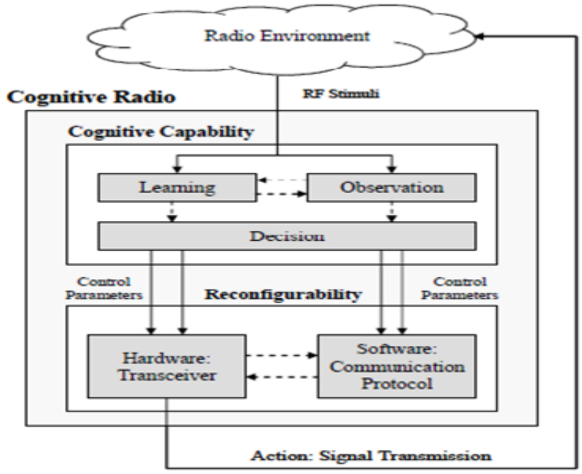

Fig .1: cognitive radio concept

Figure 1 depicts how the cognitive radio concept can be realized through cognitive capability and re configurability. First, the cognitive radio identifies radio information through observation and learning processes and makes proper decisions accordingly. Based on these decisions, the cognitive radio reconfigures its software (e.g., communication protocols) and hardware (e.g., an radio frequency (RF) front-end and an antenna).

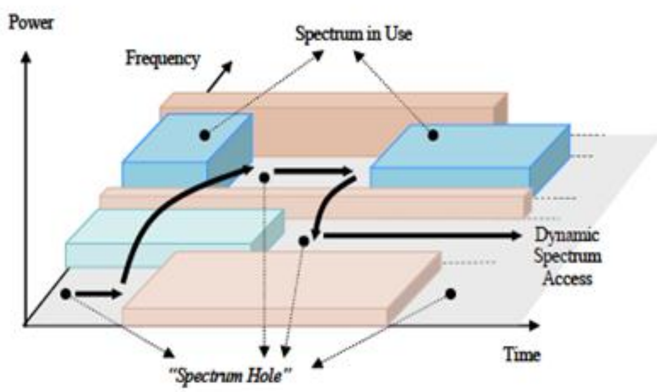

Fig. 2: spectrum hole and dynamic spectrum access

The cognitive radio enables the usage of temporally unused spectrum through cognitive capability and re configurability which is referred to as a white space or spectrum hole .when this band is further used by a primary user, the cognitive radio user uses other spectrum hole to avoid interference to the primary users, as shown in Figure 2. This new research area foresees the development of CR networks to further improve in efficiency of spectrum.

III. COGNITIVE RADIO NETWORK ARCHITECTURE

Figure 3 shows the CR network architecture components. This architecture can be classified as primary network and Cognitive Radio network .The primary users of a primary network have a license to operate in a specific spectrum band. If the primary network has an infrastructure, primary user (PU) activities are controlled through the primary base-stations. Because of their priority in spectrum access, primary users operation should not be affected by any other unlicensed users.

The Cognitive Radio network does not have a license to operate in a desired band. Hence, in order to share licensed spectrum with the primary network additional functionalities are required for CR users.CR networks can be deployed as either an infrastructure based network or an ad hoc network. CR infrastructure based networks can be equipped with a central

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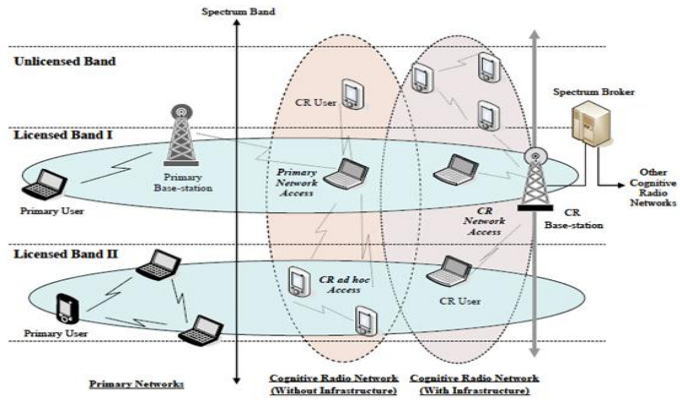

Fig. 3: cognitive radio network architecture

network entity such as a CR base-stations, which provide a single-hop connection to CR users. On the other hand, in the CR ad hoc network have infrastructure less backbone. Thus, user of a CR can communicate with users of other CR through ad hoc connection on both unlicensed spectrum and licensed spectrum bands. Furthermore, CR networks may use spectrum brokers that can be functioned as role in sharing spectrum resources with different CR networks.

IV. FUNCTION OF COGNITIVE RADIO(SPECTRUM MANAGEMENT)

Spectrum management captures the best available spectrum to meet the needs of the communication requirement among users. CR users should select the best spectrum band to satisfy the quality of service (QoS) requirements over all available bands, which necessitate the spectrum management functions such as spectrum sensing, spectrum sharing, spectrum decision and spectrum mobility for cognitive radio users.

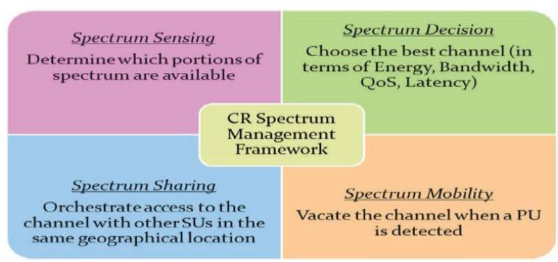

Fig. 4: functions of cognitive radio (spectrum management)

A. Spectrum Sensing:

Spectrum sensing detects and shares the available spectrum without interfering with other users severely. The key of cognitive radio networks to find spectrum holes. Primary users are detected in an most efficient and effective way from detecting spectrum holes.

Generally, spectrum sensing techniques can be categorized into three groups: Detection of primary transmitter, detection of primary receiver, and management of interference temperature as described below.

1) *Detection of Primary Transmitter:*

In this approach, primary transmitter is detected based on the weak signal received at the CR user, from this approach we define whether present or absent of primary user. Three methods are generally used for transmitter based detection are matched filter based detection, energy based detection, and feature detection [11]

a) Matched filter detection:

In this approach, a matched filter is a linear filter designed to maximize the output SNR for a given input signal. Matched filter detection is applied when secondary user has a priori knowledge of primary user signal.

b) Energy detection:

In this approach, the energy detection method compares the energy of a received signal with a threshold signal to noise ratio (SNR) value to determine the presence or absence of a PU signal and it does not require a priori knowledge of PU signal specific features. The energy detector is one of the most widely used because of its low complexity and simple design and lower delay.

c) Feature detection:

In this approach, modulated signals are signals are characterized as cyclostationarity since their mean and autocorrelation exhibit periodicity. It needs excessive processing task and does not require transmitter information. Robustness to uncertainty in noise power is the main advantage of feature detection. However, it requires significantly long observation times and implementation is complex.

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2) *Primary Receiver Detection*

In this approach, based on the local oscillator leakage power of primary receiver's, the interference and/or spectrum opportunities are detected. However, implementation of a reliable detector is not trivial because of the LO leakage signal is typically weak. Currently, this approach is only suitable in the TV receiver's detection.

3) *Interference Temperature Management:*

In this approach, at the transmitter interference can be controlled through the radiated power and location of individual transmitters. However, interference only present at the receivers, Therefore, recently a new method is proposed by Federal Communication Commission (FCC) for measuring interference, called as interference temperature [13]. The interference which is present at the receiver which can be controlled through interference temperature method, which is the new amount interference that receiver could tolerate. The spectrum band is allowed to use until the user of the cognitive radio should not exceed this limit. Although this method is the best suitable for the spectrum sensing objective, the difficulty with this method lies in exactly finding the interference temperature limit.

a) *Interference Temperature Management:*

In this approach, generally user of a Cognitive Radio cannot be aware of the primary receiver's exact locations because of the lack of interactions between Cognitive Radio networks and primary networks. Thus, at nearby primary receivers new methods are needed to estimate or measure the interference temperature.

4) *Spectrum Sensing Challenges*

a) *Spectrum sensing in multi-user networks:*

Spectrum sensing technique must be developed for the multi-user environment this is because the multi-user environment consisting of primary users and multiple CR users. Result in more difficult to estimate interference and sense spectrum holes.

b) *Spectrum-Efficient Sensing:*

CR users should stop transmitting while sensing, because Sensing cannot be performed while transmitting packets. Hence, this reduces efficiency of spectrum. For this reason, sensing accuracy and balancing spectrum are the two important factors. Moreover, because sensing time directly effects on performance of the transmission. To overcome form this novel spectrum sensing techniques must be developed so that the sensing time is reduced within a particular sensing accuracy.

B. Spectrum Sharing:

Spectrum sharing provides the fair spectrum scheduling mechanism. It exhibits some similarities of the classical media access control issues in current wireless systems. Spectrum sharing can be classified as centralized and distributed; non-cooperative and cooperative; overlay and underlay in terms of different criteria such as architecture, allocation behavior and access technique respectively.

1) *The first types of spectrum sharing methods are centralized v/s distributed based on the architecture:*

a) *Centralized spectrum sharing:*

A central entity that controls the access procedures and spectrum allocation. Moreover, at the central entity a distributed sensing procedure can be used to forward measurements of the spectrum, and from this spectrum allocation map is constructed. Furthermore, users access the spectrum based on lease from central entity for a specific duration of time in an limited geographical region. A central spectrum policy server is used to handle the competition for the spectrum, and competition for users [12].

b) *Distributed spectrum sharing:*

Each node independently follows local (or possibly global) procedures for Spectrum allocation and access [17]. Distributed solutions are required between Different networks of each base station (BS) competes with its interferer BSs to satisfies the requirements of QOS of its users to allocate a spectrum portion. The recent research on comparison between centralized solutions and distributed solutions, provided that through the message exchanges cost between nodes, distributed solutions generally adopted to the centralized solutions[18].

2) *The second types of sharing methods are cooperative v/s non-cooperative based on allocation behavior:*

a) *Cooperative spectrum sharing:*

The measurements of interference of each node such that one node communication effect on other nodes is considered through exploit of Cooperative (or collaborative) solutions. A general method used in this technique is interference information can be shared locally by means of forming clusters. This localized function results in an effective balance between a distributed scheme and fully centralized scheme.

b) *Non-Cooperative Spectrum Sharing:*

Non-cooperative (or non-collaborative, selfish) solutions consist only a single node[19] and without considering interference in other CR nodes. This result in reduced spectrum utilization. However, frequent message exchanges between neighbors are not required in this solution.

3) *The third type of spectrum sharing is based on the access technology [20]:*

a) *Overlay Spectrum Sharing:*

The secondary user is allowed to access bands only where and when no primary communication is available. if a portion of the spectrum not used by licensed users then Nodes access the network. In primary network this method reduces interference.

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b) Underlay Spectrum Sharing:

Where the primary user accepts the possibility of interference up to a predefined (and agreed) threshold. The techniques of spread spectrum are exploited such that the Cognitive Radio node transmission is regarded as noisy from licensed users.

C. Spectrum Sharing Challenges:

In CR networks, there are many open research factors for the realization of seamless and efficient open spectrum operation, given as follows:

a) Common control channel:

Many spectrum sharing functionalities facilitated by a common control channel (CCC). However, implementation of a fixed CCC is unfeasible, because a channel must be vacated when a licensed user selects a channel. Moreover, in CR networks all users have a common channel. This common channel is highly topology dependent and varies over time [21]. Consequently, either for local clusters of nodes CCCs must be exploited or CCC techniques of mitigation must be devised.

b) Dynamic radio range:

Because of the interdependent between range of radio and frequency of operating, the neighbors of a node may change as the operating frequency changes. this is difficult task in CR networks, and we advocate frequency aware spectrum sharing methods.

c) Spectrum unit:

In developing algorithms, the definition of a channel as a spectrum unit is crucial one because almost all sharing techniques and spectrum decision consider a channel as the basic spectrum unit.

d) Location information:

An important assumption about the existing work is that interference calculations can be performed easily if unlicensed users know the transmit power and location of licensed users. However, this assumption may not always be true in CR networks.

D. Spectrum Mobility:

Spectrum mobility is defined as a technique that a secondary user vacates or switches to other channels than the one it is using when the primary user appears or conditions of current channel become worse. In CR networks, spectrum utilization can be achieved through a dynamic manner by making the radio terminals to operate in the best available frequency band.

V. SPECTRUM MOBILITY FOR COGNITIVE RADIO

Users of Cognitive Radio are generally referred as ‘visitors’ to the spectrum. Hence, if the desired spectrum portion in use is required by a Primary User, the communication needs to be carried in another vacant spectrum portion called as spectrum mobility. In CR networks, Spectrum mobility leads to a other handoff types called as spectrum handoff, in which, the secondary users moves their connections to an unallocated spectrum band. In CR network, spectrum handoff occurs for the following reasons:

- On detection of Primary User.
- Because of the mobility of users involved in an current communication which in turns user is disconnected from connection.
- If degradation in current spectrum band for the Quality of Service requirements.

In spectrum handoff, temporary communication break is inevitable due to the process for discovering a new available spectrum band. Since available spectrums are discontiguous and distributed over a range of wide frequencies, CR users may require the reconfiguration of operation frequency in its Radio Frequency front-end, which gives rise to longer switching time. In Cognitive Radio the purpose of the spectrum mobility management is to ensure the fast and smooth transition leading to a degradation of minimum performance during a spectrum handoff.

A. Spectrum Mobility Main Functionalities:

1) *Spectrum Handoff:*

Based on two different strategies, spectrum handoff can be implemented as proactive spectrum handoff and reactive spectrum handoff. In proactive spectrum handoff, CR users predict future activity in the current link and determine a new spectrum while maintaining the current transmission, and then perform spectrum switching before the link failure happens. Since proactive spectrum handoff can maintain current transmissions while searching a new spectrum band, the spectrum switching is faster but requires more complex algorithms for these concurrent operations. On the other hand, in reactive spectrum handoff, CR users perform spectrum switching after detecting link failure due to spectrum mobility. This method requires immediate spectrum switching without any preparation time, resulting in significant quality degradation in on-going transmissions. Depending on the events that trigger the spectrum mobility, different handoff strategies are needed.

Proactive spectrum handoff is suitable for the spectrum quality degradation or user mobility events. On other hand reactive spectrum handoff is generally used in the Primary User appearance event. These events do not require immediate spectrum switching, and can be easily predicted. Even in event of the Primary User appearance, the proactive spectrum handoff may be used instead of the reactive method, but requires an accurate model for PU activity to avoid an adverse influence on communication performance [6].

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2) *Connection management:*

If CR user current operational frequency becomes busy in the middle of a communication then applications running in this node have to be replaced to other suitable frequency band. More ever, this may take time for the selection of new operational frequency. An connection management protocols important requirement is the information about a spectrum handoff duration. Once the latency information is available, the CR user can predict the influence of the temporary disconnection on each protocol layer, and accordingly preserve the ongoing communications with only minimum performance degradation through the reconfiguration of each protocol layer and an error control scheme. Consequently, to accomplish the spectrum mobility functionalities multi-layer mobility management protocols are required. For different types of applications these protocols support mobility management function.

B. Spectrum Mobility Challenges:

1) *Spectrum mobility in the time domain:*

Based on the available bands CR networks adapt to the wireless spectrum. Because these available channels change over time, maintaining a QoS in this environment is difficult task.

2) *Spectrum mobility in space:*

As a user place changes takes from one to another, result in a change in the available bands. Hence, continuous allocation of spectrum is a major task.

VI. SPECTRUM POOLING CONCEPTS

A. Spectrum Pooling:

Spectrum pooling, firstly introduced in [2] by Mitola, enables public access to those already licensed spectrum bands. It aims to enhance the spectrum utilization efficiency by allowing new wireless networks to work overlapped with an existing licensed system without requiring any changes to the existing system. The basic concept of spectrum pooling is to merge the unoccupied spectrum gaps owned by different owners into one common pool, which can be allocated to cognitive radio users for temporary use. Through this way, the under-utilized licensed spectrums can be further allocated to some new users when they are not occupied by the licensed users, so that the spectrum utilization can be improved. The basic requirement for the new networks is that they need to be highly flexible in order to efficiently fill the available spectrum gaps.

B. Spectrum Sharing with Spectrum Pooling:

In a spectrum pooling strategy, there are two key factors. They are the time interval of updating the spectrum gaps stored in the pool and how to allocate the available resources. The selection of updating interval differs based on different scenarios. For example, when the traffic density of the primary network is heaver, shorter update period should be used in order not to influence the primary transmissions. If the primary transmissions are sparse, then the updating can be performed infrequently. It has been studied in [3] that the update time of spectrum pool varies according to spectrum characteristics and user's quality of service demands. It is also shown that tradeoff is needed between many factors in spectrum pooling, such as access time delay, system efficiency, costs of software and hardware resources, and complexity in establishing multi-dimensional cost function.

In practical spectrum pooling scenarios, multiple networks may be deployed by different operators. This indicates that it is difficult to have a central control point, and thus spectrum sharing is preferred to work in a distributed manner. In [4, 5], how to optimally allocate spectrum among the networks with spectrum pooling in a distributed and cooperative way is investigated. In them, the dynamic inter-network spectrum sharing among multiple networks is formulated as a model-based optimization system, where the multiple networks cooperate with each other to share the spectrum dynamically, and therefore no central control point is needed. It is shown that the proposed scheme in [4, 5] maximizes the utilities of the networks sharing the spectrum pool, where a utility is defined based on the price and spectrum efficiency.

VII. CONCLUSION

The Cognitive Radio technology can solve the spectrum underutilization problem by dynamically accessing the spectrum and making most out of the limited spectrum. In Cognitive Radio Network problem of Spectrum scarcity can be reduced. The Cognitive Radio devices need to have incorporated a function of spectrum management in it. In this survey paper, CR networks important properties and current research spectrum management challenges are presented. In particular, we analyzed spectrum sensing, spectrum sharing, and spectrum mobility as functions of spectrum management. Based on predicted data and signaling trends of mobile users and usage pattern, mobility management and signaling management in future next generation networks will be a challenging task and research works needs to be addressed towards mobility management and signaling for further development of cognitive radio networks..

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