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Cognitive Radio as Encouraging Technology for Efficient Spectrum Resource Utilization

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ABSTRACT

In order to accommodate more number of users and to get better throughput, requirement of advance radio system is increasing. Due to this demand, usage of radio spectrum which is a limited resource and allocated to various number of users based of fixed assignment policy, is increased. However, latest studies and researchers found that most of the time frequencies which are assigned to particular users are not fully utilized. To mitigate the issues of spectrum underutilization and spectrum scarcity, an encouraging technology i.e. Cognitive radio has been proposed, where spectrum sensing and dynamic spectrum access technique provide better resource utilization

1. INTRODUCTION

As requirement of higher data rate, throughput and efficiency is getting increased in almost all advance communication system and applications, which are based on wireless communication. Demand of available spectrum resource is rapidly change toward the peak. On the other hand, it has been observed that within the available and allocated spectrum most of the frequencies are not properly used all the time and most of the valuable spectrum lies idle. Following issues took attention of various researchers to start their work to overcome and mitigate the conflict among spectrum scarcity and spectrum under-utilization [1], which is shown in figure 1.

There are mainly two types of users in communication system exist. First one is primary users also known as licensed users because they purchased spectrum and having full access to use it, depending on their requirement. On the other side second type of users are secondary users or cognitive users, which are not having licensed but can utilize spectrum resource of primary user without creating interference and interruption to primary user. Cognitive radio has been proposed as a promising technology which allows the secondary users i.e. cognitive users to communicate over the spectrum allocated to the primary users when they are not utilizing it.

In order to achieve utilization of spectrum in efficient manner cognitive radio provides dynamic spectrum access (DSA) [2]. In this access mechanism, the unlicensed users sense the presence of license users by various spectrum sensing techniques [3]-[5]. Based on the result collected by sensing techniques, cognitive users start communication whenever they found that there is no communication going on in that unoccupied spectrum. At that time, when primary users want to start communication, then secondary users have to check the availability of primary users based on high probability and leave the channel or to overcome the interference by changing the level of transmit power of secondary users.

As shown in figure 2, cognitive radio [3], is an intelligent wireless transceiver, which sense the availability of unoccupied spectrum also called as spectrum holes [4], in operational environmental world by dynamic access and adjust their parameters which are required for proper communication in wireless world such as operating carrier frequency, power required for transmission and modulation techniques, accordingly.

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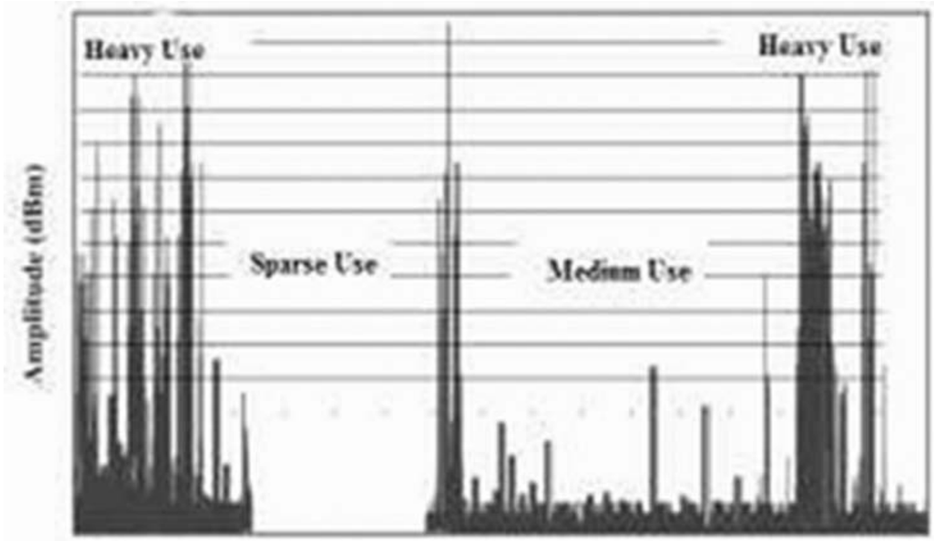

Figure 1: Spectrum Utilization

This paper is organized as follows: In section II, Cognitive radio defined. Section III describes the physical architecture followed by network architecture of cognitive radio in section IV. Then in section V and VI, working of cognitive radio using cognition cycle and various function of it, are explained respectively. Finally, in section VII conclusions are given.

2. DEFINITIONS OF COGNITIVE RADIO

Based on the spectrum sensing side information [6] a cognitive radio can adopts transmission and reception parameters such as operating carrier frequency, power required for transmission and modulation techniques accordingly, through DSA and provide efficient and flexible usage of valuable spectrum resources. In literatures, various researchers and authors define cognitive radio in their own way. Some of them are as follows: When the term cognitive came into focus, in the year 1999, Joseph Mitola III defines a cognitive radio as [5]: "A transceiver which offers model based reasoning to achieve a specified level of competence in radio-related domains."

The Federal Communication Commissions has defined a cognitive radio as: "A transceiver that may alter transmitter and receiver parameters based on spectrum sensing side information of the operational wireless environment"

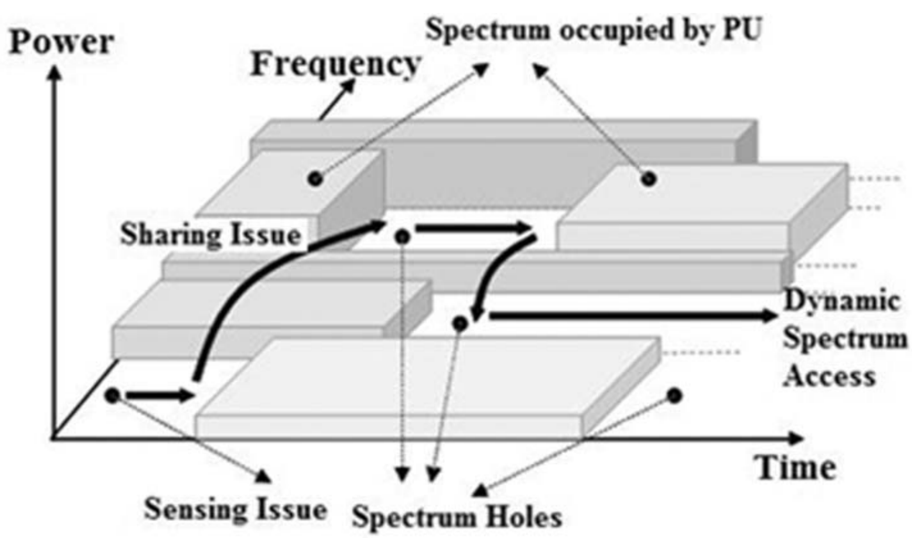

Figure 2: Functions of Cognitive Radio

According to IEEE USA [7]: "A transceiver system designed to sense spectrum availability intelligently and to switch into the temporarily-unused spectrum immediately, without disturbing the communication of other primary users."

All these definitions provide following concluding common capabilities of cognitive radio as follows:

Observation - The radio is able to sense the spectrum information directly or indirectly, in its operating wireless environment and identified available spectrum holes.

Adaptability - Capability to adapt transmission operating parameters as carrier frequency, transmit power and modulations in dynamic manner accordingly.

Intelligence – Based on gathered sensing information of operation environment, move forward towards a purposeful goal.

3. PHYSICAL ARCHITECTURE OF COGNITIVE RADIO

Figure 3 show that designing of cognitive radio transceiver includes two main components; as the radio front-end and the baseband processing unit, whose configuration can be changed via a control bus. Functions of the RF front-end are amplification of received analog signal, generation of new signal using mixing and finally convert into digital signal. Similarly the functions of processing units are to perform alteration of frequency using various modulation and demodulation techniques as well as also provide encoding and decoding operation.

In order to get these functionalities, such as wideband sensing, hardware of the RF front-end in cognitive radio should have wideband antenna, power amplifier and adaptive filter along with tuning over wide range of available spectrum. During the designing process one of the major challenge is, to identify or sense low signal to noise ratio signal of primary users in this available wide range of spectrum without misdetection.

Designing structure of the RF front-end is represented in figure 4, which is having multiple components as follows [2]:

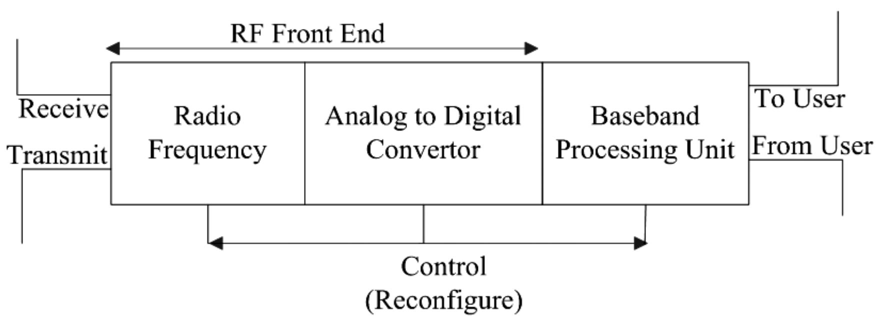

Figure 3: Cognitive Radio Transceiver

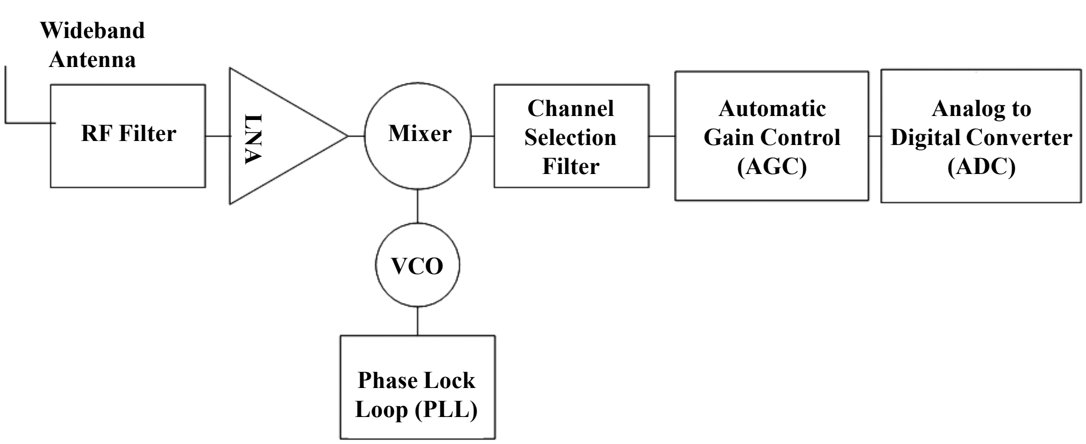

Figure 4: RF Front End Architecture of Cognitive Radio

RF filter – Main task of any filter is to pass desired signal and block others. Similarly the RF filter provides the desired band in output by bandpass filtering.

Low noise amplifier (LNA) – This amplifier increased the strength of desired signal as well as reduced the noise level.

Mixer – In this component, received signal interact with locally generated oscillator frequency and generate intermediate frequency or baseband signal.

Voltage controlled oscillator (VCO) – Based on the applied voltage, specific frequency signal to mix with incoming signal, has been generated by using VCO.

Phase locked loop (PLL) - The PLL ensures that a signal is locked on a specific frequency and can also be used to generate precise frequencies with fine resolution.

Channel selection filter – Out of the multiple adjacent channels to select the desired channel, channel selection filter is used.

Automatic gain control (AGC) – Gain and power level fluctuation in the received output signal maintains by using AGC.

Analog to digital converter (ADC) – ADC provides sampling, quantization and encoding to get digitized signal in output.

4. NETWORK ARCHITECTURE OF COGNITIVE RADIO

A smart wireless transceiver i.e. cognitive radio, which can detect presence of primary user in operating environment and adapt their transmission parameter such as carrier frequency, transmitting power and modulation schemes accordingly so that available spectrum resources can be utilized effectively and more number of user may be accommodated in allocated spectrum.

As shown in figure 5, a cognitive radio network (CRN) consist both primary user (PU) i.e. licensed user and secondary user i.e. cognitive user. A primary user is defined as a user which has a license to operate in

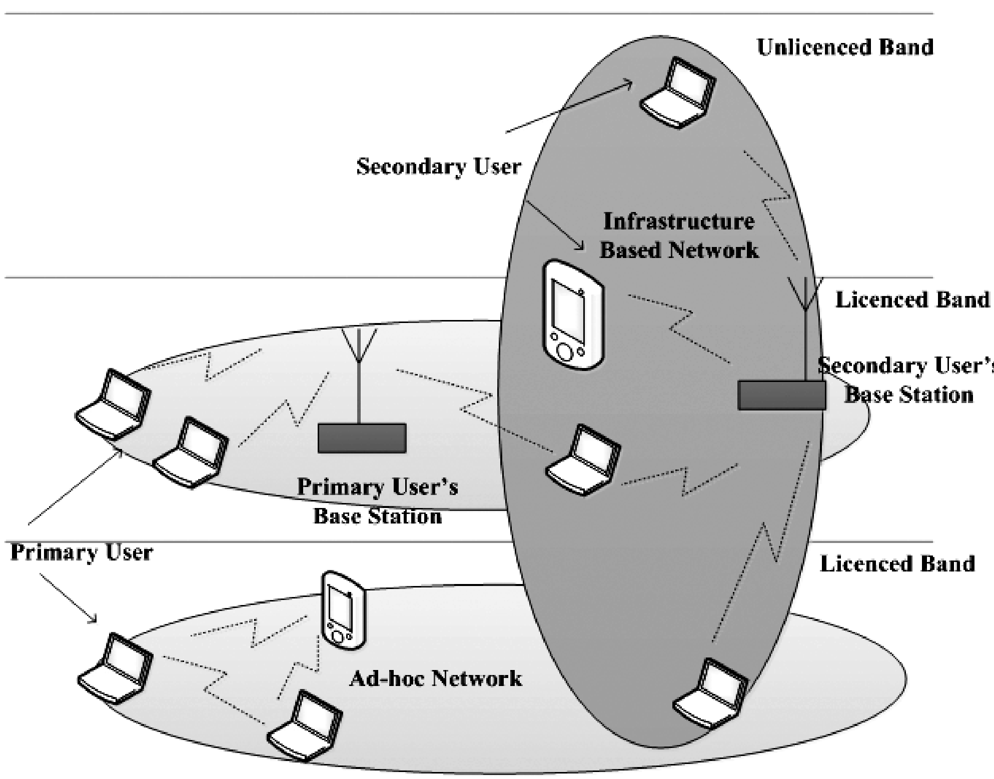

Figure 5: Cognitive Radio Network Architecture

a certain frequency band that allocated by the government agency while secondary user (SU) does not have license to operate in desired frequency band.

Hence secondary user is allowed to access spectrum only in opportunistic manner keeping certain constraints imposed by FCC as PU should experience negligible interference from SU and when PU are not required to react in any way to the needs of SU means when PU again want to use that particular frequency band it should be free. Both types of users primary and secondary can form ad-hoc network where access point is not needed and infrastructure based network in which all users are connected through a central device known as access point or base station.

5. COGNITION CYCLE

To understand the working of cognitive radio and answer of following question; "how does a cognitive radio is get so intelligent while performing multiple functions," Mitola [7] introduces cyclic representation of cognitive radio to understand interaction with the operating environment.

Figure 6 depict working of cognitive radio, how it continuously sense spectrum in the operating environment, change transmission parameters accordingly, take decision on various plans and then acts toward meaningful goal. After collecting spectrum sensing side information about its operating environment through direct observation or by using signaling technique, cognitive radio forward same into a cycle, i.e. formed by OBSERVE, ORIENT, PLAN, DECIDE and ACT states. At ORIENT state, first established priority for this information as normal, urgent or immediate, then judge it to find its importance.

Based on this estimation process, at PLAN state the radio find its options and take decision on an alternative in order to further improve the valuation at DECIDE state. Then in ACT state, the radio implements the various options by putting its resources and performing the appropriate signaling. These functions at different states are then reflected in the interference profile, presented by the cognitive radio in the operating wireless environment. Then based on these observations and decisions radio further improve the operation by including LEARN state.

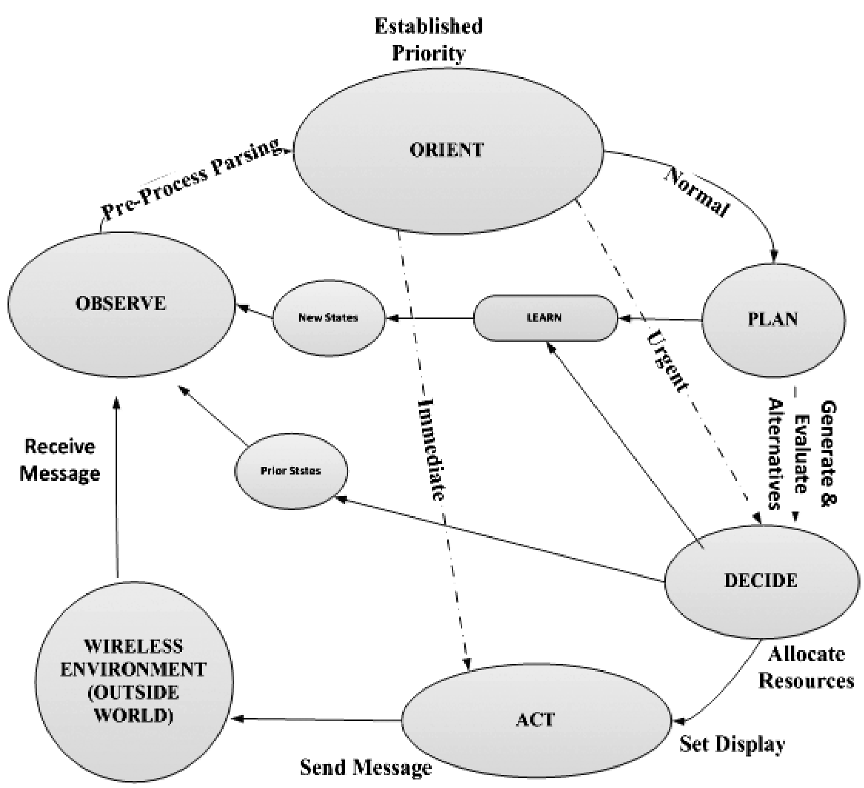

Figure 6: Cognition Cycle

6. MAJOR FUNCTIONS OF COGNITIVE RADIO

Generally, the cognitive radio would be able to perform the some of the major functions as [4] [9]:

6.1. Spectrum Sensing and Detection

Spectrum sensing and detection process provides awareness of the radio environment and gives indication on the sharing of unused spectrum i.e. spectrum holes. A spectrum hole is defined as a range of frequencies allocated to a primary user, but, based on the time and location, these ranges of frequencies are not being effectively used by respective users. Identification and detection of spectrum is one of the most critical issues in cognitive radio network as it is required at the starting to provide access to unlicensed users in under-utilized licensed band.

Figure 7 shows that spectrum sensing techniques [8] – [10] can be broadly classified into three categories:

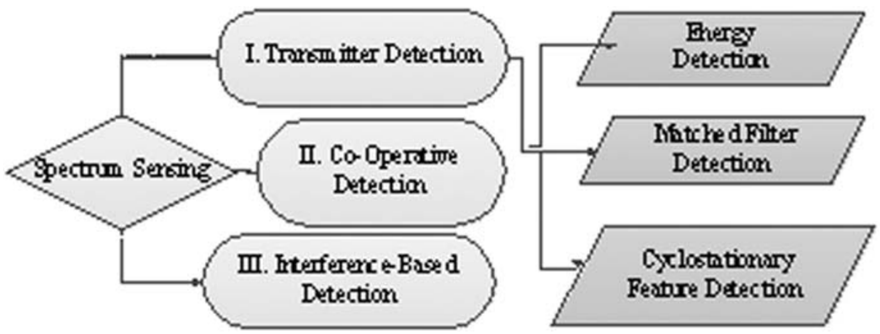

Figure 7: Classification of Spectrum Sensing

1. Transmitter detection: In this approach, Cognitive radios find the presence of primary user based on local signal which is being transmitted by primary transmitter in particular spectrum.

There are multiple approaches have been proposed to transmitter detection [10], out of these commonly used techniques are as:

1.1. Energy detection [11] [12] – This technique will provide optimal detection for any unknown zero-mean constellation signals. Due to minimum complexity and very low processing load, most of the time this techniques is used.

1.2. Matched filter – Another optimal method to detect signal is matched filter, where it maximizes the signal to noise ratio of the received signal in the presence of AWGN. Due to comparatively less time required for sensing this method provides better detection in low SNR also.

1.3. Cyclostationary feature detection – In this technique, based on the cyclic features of primary user, signal can be sensed at very low signal to noise ratio (SNR). Here by using this technique, signal of primary user and noise can be distinguished.

2. Cooperative detection: In this approach, the information gathered from various cognitive radio users can be used as detection of presence of primary user.

3. Interference based detection: Cognitive interference based detection concentrates on measuring interference at the receiver.

6.2. Spectrum Decision and Management

Cognitive radios should capture and take active decision on the best available unused frequency band to satisfy quality of service requirements, while not introducing disturbance to primary users. Therefore, spectrum decision and management functions are very important for cognitive radios.

6.3. Spectrum Sharing

Spectrum sharing allows CR users to perform channel selection to select proper channel and power allocation to adjust transmitting power, according to their quality of services. By using spectrum scheduling scheme among primary, secondary users and resource allocation, sharing of spectrum can be achieved. In order to avoid collision, it provide way to various cognitive users to share the channel determining who will access the channel or when a user may access a channel.

6.4. Spectrum Mobility

In cognitive radio network, secondary users are considered as a visitor to the frequency band. If PU wants to use any particular band that is being used by SU, the communication of the SU required to be continued in other unused frequency band. Spectrum mobility is play important role to provide uninterrupted communication during the switching to better spectrum as well as in case of the presence of licensed use

7. CONCLUSION

Conflict among spectrum scarcity and spectrum under-utilization can be overcome by dynamic spectrum access mechanism in cognitive radio which is an emerging technology. Cognitive radio users are fully capable to identify and detect the presence of primary user by using various spectrum sensing methods and then adapt its transmission parameters such as carrier frequency, power requirement of transmitted signal and modulation techniques accordingly with minimum interference at primary user. However, there are number of challenges such as; to successfully sense spectrum holes and utilize it in efficient approach, to overcome interference at primary users and to enable high level of intelligence using adaptive modulation techniques, faced by various researchers to be address in the implementation of cognitive radio network.

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