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An Enhanced Cognitive Radio Spectrum Sensing Method for 4G Technologies

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Abstract: Due to increasing number of wireless communications and devices, the limited radio spectrum is heavily congested. So, the spectrum crowding problem is occurred. To avoid the spectrum crowding problem, we have to utilize the limited radio spectrum in an efficient way. The cognitive radio is an attractive solution for the spectrum crowding problem. The Orthogonal Frequency Division Multiplexing is selected as a physical layer for transmission in cognitive radio. This paper proposes the cognitive radio technology for OFDM for efficient utilization of radio spectrum.

KEYWORDS: Cognitive Radio, OFDM, Spectrum sensing, Dynamic spectrum access, spectrum scarcity, Software defined radio.

I. INTRODUCTION

Increasing number of wireless devices, the radio spectrum is highly congested. But simultaneously the measurements show that the most of the spectrum are rarely used at most of the time, when other frequency bands are heavily used. The use of the spectrum is depending on the geo location, time and the frequency bands. Though the unused portions of the spectrum are licensed and thus cannot be used by systems other than the licensed owners. So, there is a need for a new technology to use licensed and unlicensed spectrum in an efficient way. Cognitive radio is the enhanced solution for the spectral crowding problem by using the opportunistic usage of the frequency bands that are occupied by the licensed users (LUs).

The cognitive radio[1] can be defined as a radio that is aware of its environment and the internal state and with knowledge of these elements and any stored pre-defined objectives can make implement decisions about its behavior. The important feature of the cognitive radio is the autonomous exploitation of the locally unused spectrum. The features also included that the interoperability across several networks, devices and protocols, the capacity of roaming across borders, capacity of the adapting the system[2], transmission, and reception parameters without user interference, as well as the ability to understand and follow action taken and choices made by users that become more responsive over time. The focus of this article is the ability of CR to change its spectrum parameter according with the user requirements. The focus also includes that not making interference to the occupied or the licensed user by make use of the free available spectrum. For CR to achieve this objective, the physical layer should be highly flexible and adaptable. The OFDM is a special case of multi carrier transmission technique that already most widely used in many current wireless technologies and standards. So, OFDM[3] is selected as a suitable candidate for CR to overcome the spectrum crowding problem. We trust that OFDM also will play an important role in realizing the concept of Cognitive radio by providing a proven, scalable, and adaptive technology for air interface. Cognitive radio features and requirements are discussed in detail, and the ability of OFDM to satisfy[4] these requirements is also explained. Cognitive radio is viewed as a new approach for improving the utilization of a precious natural resource: the radio electromagnetic spectrum. The cognitive radio and OFDM approaches have two primary objectives[5] in mind, that are highly reliable communication whenever and wherever needed and efficient utilization of the radio spectrum

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II. Radio Technology Evolution

Before cognitive radio few software radio technologies[6] have been arrived. Those are software capable radio, software programmable radio, software defined radio, aware radio and adaptive radio. The software capable radio has the ability to handle the data under software. SINCGARS(Single Channel Ground Airborne Radio System) is an example for software capable radio. It can transmit or receive only voice and data and the frequency rages between 30MHz to 88MHz. The figure 1 shows the evolution of the radio technology.

The software programmable radio has the ability to add new functionalities through software. The network capability is added through software. ARC 210 is an example for the software programmable radio. It is a fully digital secure communication system. The frequency range of the software programmable radio is 30MHz to 400MHz. It can interoperate with SINCGARS. The software defined radio[7] having the complete adjustability through software of all radio operating parameters. The software models of the radio operating parameters are predefined in case of software defined radio.

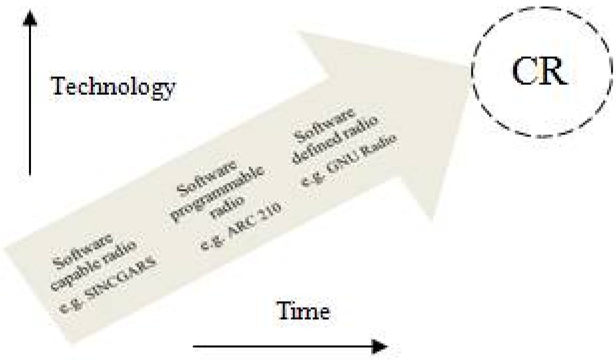

Figure 1. Radio Technology Evolution

The CR is built on the software defined radio only. GNU radio is an example for the software defined radio. It is Linux based software. Aware radio is a simple protocol decision radio. It may provide network information to maintain a radio's status as aware. It provides the information like geo location, time of the day, etc. GPS (Global Positioning System) is an example for aware radio. It gathers information, but provides only on request. In adaptive radio the radio operating parameters that may be adapted[8].

The operating parameter may be the frequency, bandwidth, error correction coding, data rate and modulation scheme. But these radio models having drawbacks of fixed modulation capabilities, less number of frequencies, limited data rate capabilities and very important is inefficient use of the radio spectrum. The IEEE 802.22 is a new working group[9] for the wireless regional area network (WRAN) and cognitive radio.

III. Cognitive Radio Functions

The main functions[10] of Cognitive Radios are:

A) SPECTRUM SENSING:

Detecting the unused part of the spectrum[11] and sharing it without making harmful interference with other licensed and occupied users. It is an important requirement of the Cognitive Radio network to sense spectrum holes. Detecting primary users is the most efficient and intelligent way to detect spectrum holes. Spectrum sensing techniques can be classified into three categories. Transmitter detection, Cooperative detection and interference based detection.

In transmitter detection the 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 approaches proposed for the transmitter detection. These are matched filter detection, energy detection and cyclostationary feature detection.

The cooperative detection is refers to spectrum sensing methods where information from multiple Cognitive radio users are incorporated for primary user detection.

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B) SPECTRUM MANAGEMENT:

Capturing the best available free spectrum to meets the user communication requirements, while not creating interference to other (primary) users. Cognitive radios should decide on the best spectrum band to meet the Quality of service requirements over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios. These management functions can be classified into spectrum analysis and spectrum decision.

The practical implementation of spectrum management functions is a very complex and multifaceted issue in itself, given that it has to address a combination of technical and legal requirements. An example of the former is choosing appropriate sensing threshold to detect other users, while the latter is exemplified by the need to meet the rules and regulations set out for radio spectrum access in international (ITU Radio Regulations) and national (Telecommunications Law, etc.) legislation.

C) SPECTRUM MOBILITY

It is defined as the process when a cognitive radio user exchanges its frequency of operation. Cognitive radio networks targets to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during the transition to better spectrum.

Dynamic Spectrum Access: Dynamic spectrum access (DSA) models[12] for cognitive radio can be categorized as exclusive-use, shared-use, and commons models. In the exclusive-use model, a licensed user can grant an unlicensed user the right to have exclusive access to the spectrum. In a shared-use model, an unlicensed user accesses the spectrum opportunistically without interrupting a licensed user. In a commons model, an unlicensed user can access the spectrum freely. DSA can be implemented in centralized or distributed cognitive network architecture. DSA can be optimized globally in a cognitive radio network if a central controller is available. On the other hand, when a central controller is not available, distributed algorithms would be required for dynamic spectrum access. Issues related to spectrum trading such as pricing will also need to be considered for dynamic spectrum access, especially with the exclusive-use model. For DSA-based cognitive radio networks, MAC protocols designed for traditional wireless networks have to be modified to include spectrum sensing and spectrum access, as well as spectrum trading between licensed and unlicensed users. The figure 2 shows the functions of the cognitive radio.

D) SPECTRUM SHARING

It can able to provide a fair spectrum scheduling[13] method. One of the major challenges in open spectrum usage is the spectrum sharing. It can be regarded to be similar to generic media access control MAC problems in existing systems

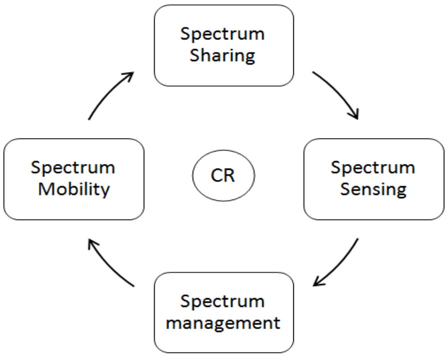

Figure 2. functions of cognitive radio

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IV. PROPOSED METHOD

Cognitive radio is a new concept that enables wireless systems to sense the environment, adapt, and learn from previous experience to improve the quality of the communication. CR may achieve this objective through the use of OFDM. OFDM[14] has gained popularity and is used in many current wireless communications system nowadays, e.g., Wireless Metropolitan Area Network (WMAN), Wireless Local Area Network (WLAN), and Digital Video Broadcasting (DVB) that is already proven as an adaptive, flexible and reliable transmission method. In spite of this,

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identified challenges (adaptation[15], awareness, etc.) need to be researched further to find firm solutions[16]. It is predicted that OFDM will be an attractive PHY technology for CR systems.

A) COGNITIVE RADIO BASED OFDM

OFDM is a multi-carrier modulation technique[17] that can overcome many problems that arise with high bit-rate communications, the most serious of which is time dispersion problem. The data-bearing symbol stream is split into several lower-rate streams, and these streams are transmitted on many different carriers. Because this splitting increases the symbol duration by the number of orthogonally overlapping carriers (subcarriers), the multipath echoes affect only a small portion of the neighbouring symbols. The remaining inter-symbol interference (ISI) is removed by extending the OFDM symbol with a cyclic prefix (CP).

This method, OFDM reduces the dispersion effect[18] of multipath channels encountered with high data rates and reduces the requirement for complex equalizers. Other advantages of OFDM include high spectral efficiency, robustness against narrowband interference (NBI), scalability, and easy implementation using fast Fourier transform (FFT). In this project, we assume a CR system operating as a secondary user in a licensed band. The CR system identifies available or unused parts of the spectrum and exploits them. The goal is to achieve maximum throughput while keeping interference to a minimum for primary/licensed users. The figure 3 shows the block diagram of the cognitive radio based OFDM. Example of a CR system could be the IEEE 802.22 standard-based system where the spectrum allocated for TV channels is reused. In this case, the TV channels are the primary users, and the standard-based systems are the secondary users. The cognitive engine is responsible for making intelligent decisions and configuring the radio and PHY parameters.

The transmission opportunities are identified by the decision unit based on the information from the policy engine, as well as local and network spectrum sensing data.

As far as the PHY layer is concerned, CR can communicate with various radio-access technologies in the environment, or it can improve the quality of communication depending on the environmental characteristics, by simply changing the configuration parameters of the OFDM system and the radio frequency (RF) interface. Note that coding type, coding rate, interleaver pattern, and other medium access control (MAC) and higher layer functionalities, and so on, should also be changed accordingly.

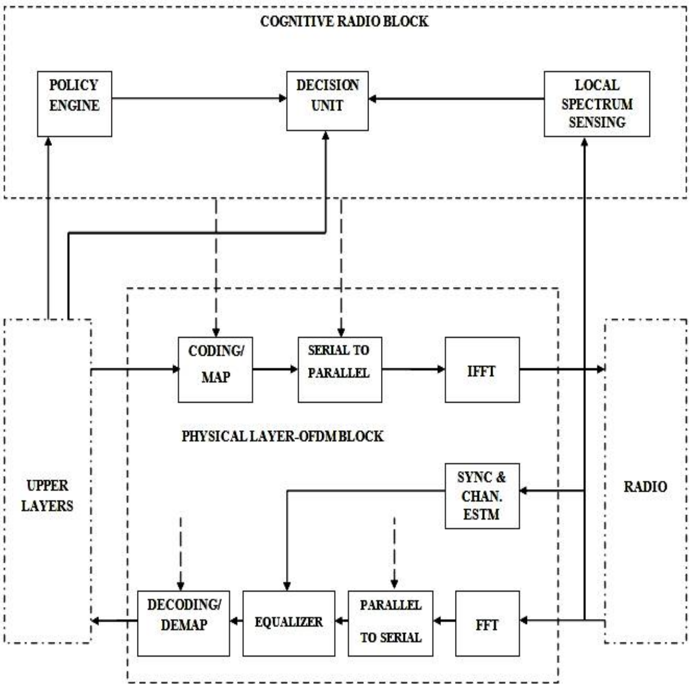

Figure 3. The block diagram of Cognitive Radio based OFDM

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B) ALGORITHM FOR SPECTRUM SENSING

i. Divide the sampled signal into 'T' Frames. Each frame containing 'N' samples. $x_t(n)$,
Where n = 1,2,3, . . N-1

ii. Multiply each frame with Window function, 'w'.

$$x_{w,t}(n) = x_t(n)w(n) \quad (1)$$

iii. Compute PSD of each frame. $P_t(k) = abs(fft(x_{w,t}(n)))^2$

iv. Find the average PSD of 'T' frames.

$$P_{avg}(k) = (1/T)sum(P_t(k)), \text{ for } k = 0,1,2, . .(N/2) \quad (2)$$

v. Then, define mean of $P_{avg}(k)$ as mean power P_m.

vi. Decision variable r(k) is given by the ratio of

$$r(k) = P_{avg}(k)/P_m , k = 0,1,2, .. (N/2) \quad (3)$$

vii. Apply thresholding to get the channel or Primary user states.
PU_status = Occupied('1') if r(k) > α and Free('0') if r(k) <= α Where, α is the preset threshold.

V. CO OPERATIVE SPECTRUM SENSING

Cognitive radio spectrum sensing[12] techniques have been developed considerably as a variety of cognitive radio network systems technologies have increased. While non-cooperative spectrum sensing is applicable for many applications, it has a number of drawbacks for many applications. In cognitive radio applications where a cognitive radio network is present, cooperative spectrum sensing is not only advantageous, it becomes essential if the network as a whole is to avoid interference with any primary users. Cognitive radio cooperative spectrum sensing occurs when a group or network of cognitive radios share the sense information they gain. This provides a better picture of the spectrum usage over the area where the cognitive radios are located.

There are broadly two approaches to cooperative spectrum sensing:

A) CENTRALISED APPROACH:

In this approach to cognitive radio cooperative spectrum sensing, there is a master node within the network that collects the sensing information from all the sense nodes or radios within the network, It then analyses the information and determines the frequencies that can cannot be used. The cognitive radio central node or controller can also organise the various sensor nodes to undertake different measurements at different times. In this way it is possible to undertake a number of different sense actions at the same time. For example, some nodes may be instructed to detect on channel signal levels, while others may be interested to measure levels on adjacent channel to determine suitable alternatives in case a channel change is required.

B) DISTRIBUTED APPROACH

Using the distributed approach for cognitive radio cooperative spectrum sensing, no one node takes control. Instead communication exists between the different nodes and they are able to share sense information. However this approach requires for the individual radios to have a much higher level of autonomy, and possibly setting themselves up as an ad-hoc network.

C) ADVANTAGES:

While cognitive radio cooperative spectrum sensing is obviously more complicated than a single non-cooperative system, it has many advantages that outweigh the added complexity. Naturally cooperative spectrum sensing is not applicable in all applications, but where it is applicable, considerable improvements in system performance can be gained.

i. Hidden node problem is significantly reduced
ii. Increase in agility:
iii. Reduced false alarms[17]:

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VI. Simulation Results

The complexity of modern communication systems is driving force behind the widespread use of simulation. Digital communication, especially wireless communication system is required to operate at a high data rate with constrained power and bandwidth. The simulation results often guide analysis, since a property developed simulation provides insights into system behaviours. The simulation is done in MATLAB and the output graph is obtained between frequency and power level.

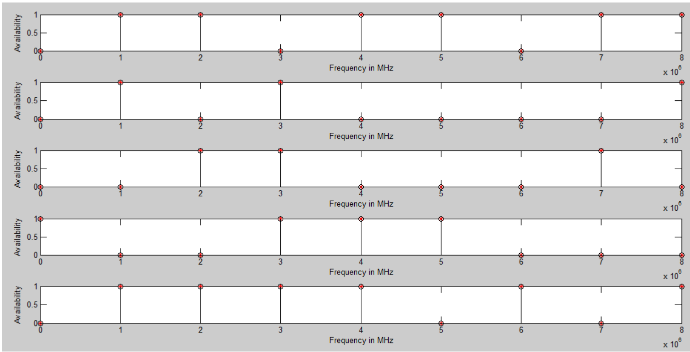


Figure 4. MATLAB output for spectrum sensing

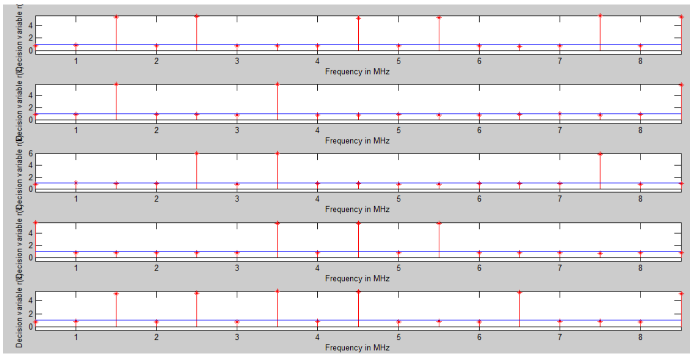
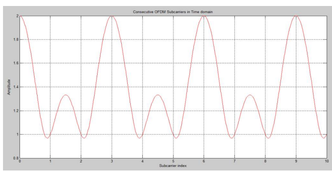
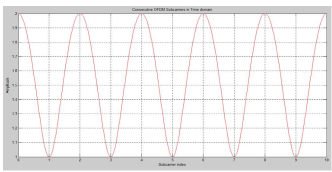


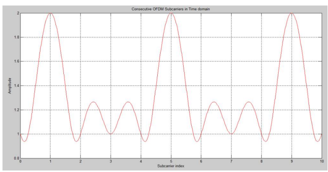
Figure 5. Secondary user using free spectrum



(a)



(b)



(c)

Fig 6. Sub Carrier of (a) First Signal, (b) Second Signal and (c) Third Signal

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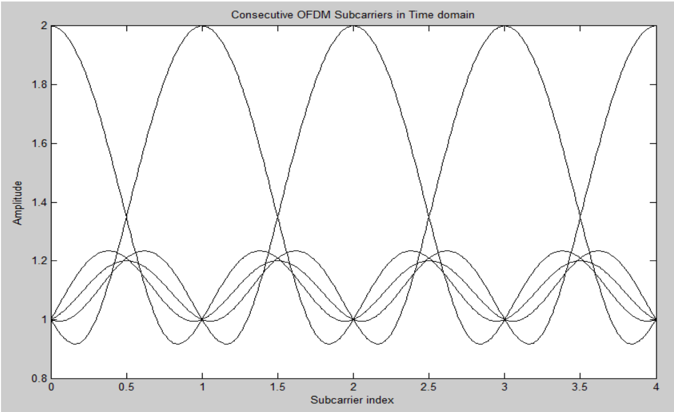

Fig 7. Sub Carrier of the Free Spectrum

The output figure 4 represents the availability of the free spectrum. In the figure 5 the output is obtained between the frequency and the decision variable. In figure 4 and 5 the dots presence in the vertical line should be considered as the occupied or licensed user. The dots presence in the horizontal line shows the available free spectrum or spectrum hole. The figures 6 and 7 represent the subcarrier of the free spectrum.

VII. CONCLUSION AND FUTURE WORK

CR is the promising technology that offers a solution to the spectrum crowding problem. In this article the various spectrum sensing methods were discussed and the cooperative spectrum sensing method was proposed. The Matlab simulation also has been done for the cooperative spectrum sensing. The current implementation of the cooperative spectrum sensing for cognitive radio is valid only for the simulation purpose. For the real time purpose the simulation method is to be extended by using new arriving technologies for cognitive radio and the orthogonal frequency division multiplexing technique.

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