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Major Challenges in Spectrum Sensing for OFDM Based Cognetive Radio Systems

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Abstract— now a day the usage of wireless devices has increased to a certain level, which leads to increase the efficiency of spectrum usage. Cognitive radio (CR) is a basic concept which helps to improve the communication capacity and quality on the basis of previous experiences. In this paper, requirements of CR systems are described and OFDM technique is used for CR as a transmission technology. The review study of this paper provides the overview of the challenges that evolves using OFDM in CR system are identified and discussed.

Index Terms— Wireless, Cognitive radio, OFDM

1 INTRODUCTION

As per the consumers the interest in wireless services is increasing day by day, which demands for the enhanced increased in the level of radio spectrum. Because of this requirement, new wireless devices and applications of broadband wireless are used. Due to the location, day – time and frequency bands, sometimes the spectrum band can only be utilized by a licensed owner. Therefore, there is a need for a basic technology that can be benefited from these opportunities. As per this, cognitive radio (CR) evolves to be the most eligible solution, as it can use those unused frequency band that are not heavily occupied by licensed user (LU) [1]. As still now cognitive radio is not properly defined yet, the concept has evolved recently to include in various aspects [2]. The definition given by FCC (Federal Communication Commission), " CR is a intelligent wireless system that can observe its environment and can dynamically adjust its operating parameters so that it can adapt to improve the communication capacity and quality" [3]. To achieve this objective, the physical layer should be adaptable and highly flexible.

In present wireless communication network, one of the most widely used technique for multicarrier transmission is called as orthogonal frequency division multiplexing (OFDM). OFDM has a ability to fulfil the requirement of CR with some modifications. Due to its salient features, OFDM has been widely used innumerable wireless standards and technologies.

Spectrum sensing is used to identify white spaces with the help of direct sensing of licensed bands. Because of its capability and low infrastructure cost, spectrum sensing has gained enough attention rather than other candidates. In addition to these points, we will go through all the challenges that arise after using OFDM technology in CR. In particular, in this paper, we will also discuss the major challenges in reliable identification of white spaces with its technical solutions.

2 OFDM-BASED CR SYSTEM

OFDM provides the method of transmitting multiple data streams over a common broadband medium. From wire line to wireless communication, multicarrier is used compared to single carrier modulation due to their efficiency cope capability with selective fading channels. OFDM is able to reduce both intersymbol interference (ISI) and interchannel interference (ICI) by using suitable cyclic prefix. By employing this method, OFDM can overcome the dispersion effect of multipath channel experienced with high data rate communications. OFDM has been proposed for multicarrier based CR system as a good candidate technology because of its flexible spectrum utilization and multiple user access skills [4]. In future wireless communication system, cognitive radio (CR) [5] is acknowledged as an intelligent solution for efficient spectrum utilization. OFDM provides spectrum sensing, high spectrum efficiency, interoperability, scalability, multiple accessing and spectrum allocation using Fast Fourier Transform (FFT) technique, which requires for CR system .

Available and unused portion of the spectrum is recognize and exploit by the CR system. A block diagram of OFDM-based CR system is shown in figure 1. The cognitive engine is used to take intelligent decisions and design parameters for the radio and physical layer. Policy engine and local spectrum sensing data is responsible for transmission opportunities which are recognize by the decision unit, based on the information.

By changing the configuration parameters of the OFDM, CR system can upgrade quality of communication based on the environmental characteristics. To offer the best transmission technology for CR system, OFDM provides sensing and spectrum shaping abilities together due to its flexibility and scalability property.

3 SPECTRUM SENSING

The most important feature of CR is its ability to learn, measure and sense the spectral environment operating conditions and accomplish this message for wireless channels to provide best communication requirements [6]. This comprises some specifications related to characteristics of radio channel, spectrum availability, radio's operating conditions and interference temperature. A high level of flexibility needs for the spectrum sensing under highly variable radio environment [7]. Cognitive radio define primary users, which have highly priority or rights for the usage of a particular portion of the spectrum and secondary users , who have lower priority or rights to exploit this spectrum which do not originator of interference with primary users.

Accordingly, secondary users require capabilities of CR to sense the spectrum accuracy for analysis that it

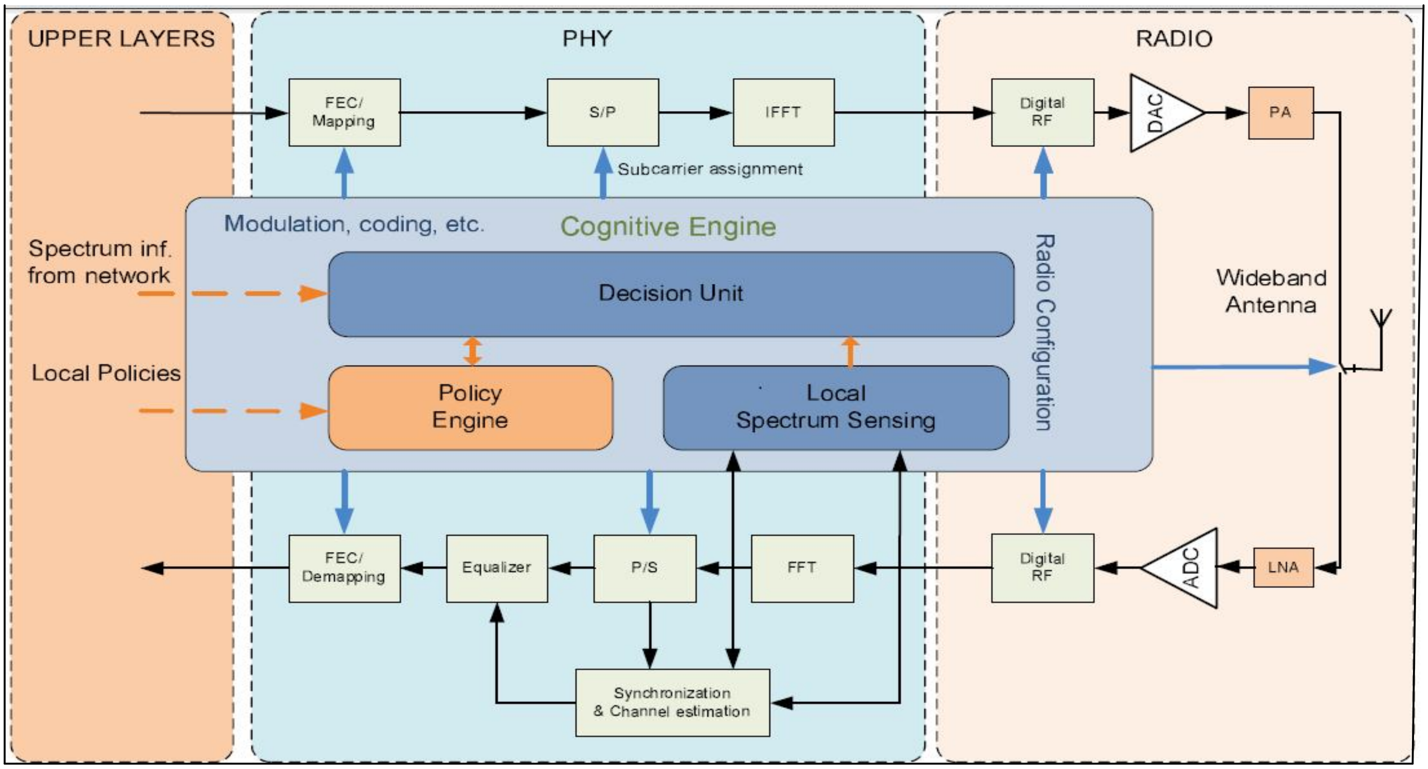


Figure 1. Block diagram of OFDM-based CR system . All of the layers can interact with the Cognitive engine. OFDM parameters and radio are configured by the Cognitive engine

is usage by the primary user and to exploit the remaining portion of the spectrum. Here, some constraints to sense and use spectrum in wireless communication link for requirement of OFDM-based CR system.

3.1 Awareness

For the organization of CR's, spectrum sensing [8] is the best substantial function because they require to sense and use the unused spectrum band. By using FFT, OFDM system converts information from time domain to frequency domain. FFT is used for the received signal in [9, 10]. The receiver identifies an existence of a primary user in the spectrum band by using FFT. In a cooperative spectrum sensing environment [11], the number of FFTs is used to upgrade the efficiency. To achieve a greater performance, the output of FFT is filtered for reducing noise [12].

3.2 Spectrum Utilization

By simply turning off some subcarriers, waveform can easily be shaped where primary users exist. Spectrum shaping is a next step after scanning and identifying the spectrum. In order to achieve minimum interference to primary users (PUs), a key feature of CR system is to perform spectrum shaping, operating in the used band. In current wireless communication systems, OFDM fulfil the requirement of CR by providing flexible spectrum efficiency and control over waveform elements which are power level, signal bandwidth and centre frequency. The spectrum of signals can be shaped by attenuate some subcarriers to fit into the desired spectrum band.

Spectrum sensing and shaping procedures are used in OFDM-based CR system is shown in figure 2[13]. By using the output of the FFT, the two Pus are identified and disabling a subcarriers that can cause interference towards these PUs. The unused part of the spectrum is used by the transmitter for transmission of signals.

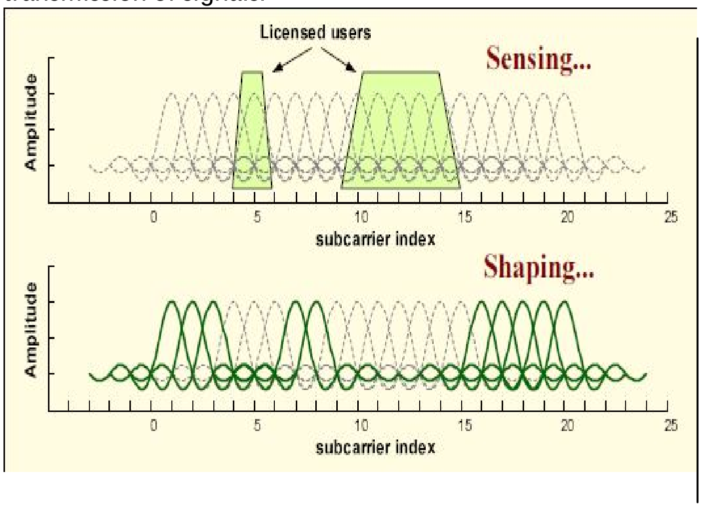


Figure 2. Spectrum sensing and shaping in OFDM-based CR

3.3 Environmental Adaptation

One of a key point for the requirement of CR is the adaptivity. CR can accomplish many tasks by integrating collected information by using the limitations and capabilities of the modern wireless system. For available resources and various transmission environments, OFDM systems can be used. FFT size, CP size, subcarrier powers, coding, subcarrier spacing and modulation are few adaptable parameters. To compensate channel fading and reduce interfering signal, the system waveform can be adapted. In this concern, OFDM system provides great flexibility for quite large adaptation [14].

On the basis of user requirement, an OFDM can adaptively modify the transmission parameters such as coding, modulation and transmit power of every subcarrier [15]. This adaptively is used to obtain various objectives like maximizing the throughput, minimizing bit error rate (BER), increasing coverage range and reducing interference to PU's. To achieve same objectives, in multiple-user OFDM systems, allocation of subcarriers can be performed adaptively [16].

In addition to reduce ISI and increasing the system throughput, an OFDM based CR system can adaptively adjust the length of the CP based on channel parameters [17]. An OFDM-based system can be done adaptivity using either algorithm level or parameter level. In OFDM-based CR systems to achieve interoperability with optimize system performance, usually require algorithm parameters e.g. channel coding type can be adapted.

4 MAJOR CHALLENGES IN SPECTRUM SENSING

In future wireless communication system, CR offers solutions of various communication problems by employing some key features like awareness, adaptivity or scalability, interoperability, efficient spectrum utilization, spectrum sensing, and learning. Our main focus in this paper is challenges that arise due to spectrum sensing when OFDM technique is employed by CR system.

Spectrum sensing in OFDM-based cognitive radio networks is challenged by various factors of uncertainty [18]. Such uncertainty in terms of the necessary detection of spectrum sensitivity, as mentioned below

4.1 Uncertainty due to channel

OFDM-based system uses either multi-band or single-band. Selecting the number of bands under given shape of spectrum depends on various elements. CR system could be affected by throughput, hardware limitations, mathematical complexity, level of interference and bandwidth. The challenges that arise in multi-band OFDM system includes the requirement of wide range synthesizers, broadband circuits and switched used in low power amplifier (LNA) and fast band hopping for neglecting interference to used bands [19].

If single-band OFDM system is used, several subcarriers can be turning off. For achieving higher performance, effective algorithm for particular OFDM-based CR should be designed [20]. Because CR has to be more sensitive to analyse a faded primary signal from a white space, hence spectrum sensing is challenged by channel uncertainty.

4.2 Uncertainty due to noise

Let, P_b denotes transmitted power of the primary user, R is the maximum distance between the primary and its corresponding receiver, and D is the interference range of the secondary user. If L is the total path loss then the detection sensitivity, Υ_{min} is defined as the minimum signal to noise ratio (SNR) at which primary signal may still be accurately detected through cognitive radio, this requirement may be indicated as:

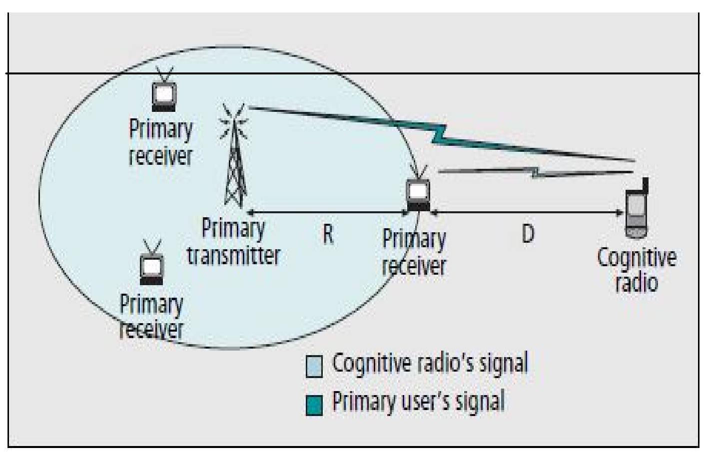
$$\Upsilon_{min} = P_b L \, (D+R) \, / \, N \qquad (1)$$

Where, N represents the noise power. The noise power should be known for calculating the required detection sensitivity in eq. 1. Variation in temperature caused changes in thermal noise by which noise power can be calculated. Spectrum sensing is challenged by uncertainty of noise when detection is used as the sensing technique. If weak primary signal SNR decreases below at a certain threshold level which is measured by the noise uncertainty if signal will be identical by noise [21].

4.3 Uncertainty due to interference

Figure 3 shows the interference range of a cognitive radio.Due to increased usage of multiple CR network, operating within the same licensed band, there will be wide spread application of secondary system in the coming time. Because of these unknown numbers of secondary systems and their present locations, spectrum sensing will turn to many complications by the aggregate interference's uncertainty. We used sensitive detectors as a replacement of secondary system and primary system located beyond their interference range, as their ability to detect uncertainty calls.

There is a maximum power leakage from OFDM signals because of the large sidelobe of modulated OFDM. The power leakage is through the adjacent channels. Several methods are used in order to minimize this leakage. For large OFDM symbol duration, modification in spectrum shaping is required for decreasing the spectrum efficiency. The best way to reduce interference to spectrum holes, keeping its efficiency high is proposed in [22] and [23], which are known as cancellation



carrier and active interference cancellation, respectively.

Figure 3. Interference range of a cognitive radio.

To reduce the leaked interference to spectrum holes, minimum number of adjacent subcarrier is used, as a replacement of attenuate adjacent subcarrier. Minimize adjacent channel interference is achieved by this technique. It has only demerit, which is enhanced system complexity as a result of calculation of cancellation carrier value for each symbol. To achieve required interference level more cancellation carrier are needed for larger spectrum holes. There are some more methods to minimize OFDM spectrum interference to adjacent channels which are presented in [24] and [25].

5 Conclusion

For spectrum clustering problem, CR is the most promising and desirable technology that can be used. On the same way the most effective and trustable multiple – carrier transmission method for wireless communication system is OFDM technique. OFDM's inherent capability makes it most widely used for realizing CR concept. Unlike to CR operation, this is the main requirement that the radio is able to detect the environment over large spectrum bands and easily adaptable to it as the radio lacks primary rights to any preassigned frequency. In this paper challenges are the main factors which observe in spectrum sensing of OFDM based CR system. Various challenges like performance limitation because of the uncertainties due to several factors of operation may be overcome by a suitable combination of user level cooperation among CR, local signal processing and system level coordination among various CR networks. As per the challenges presented in this paper, require to be research further in order to detect the evolved issues.

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