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A SURVEY ON COGNITIVE RADIO USING SPECTRUM SENSING

Sumit Singh[1], Mrs. Mandeep Kaur[2]

M.Tech Student[1] (ECE), Assistant Prof.[2] (ECE), CEC Landran, Mohali

sumeetmultani26@gmail.com

Abstract: The developing interest of wireless applications has put a great deal of imperatives on the utilization of accessible radio spectrum which is restricted and valuable asset. Nonetheless, a settled spectrum task has lead to under usage of spectrum as a great portion of authorized range is not adequately used. The greater part of the accessible spectral resources have as of now been authorized, so it gives the idea that there is almost no space to include any new administrations, unless a portion of the current licenses are ceased. Moreover, recent studies and estimations have demonstrated that tremendous allotments of the authorized spectra are seldom utilized because of the unyielding spectrum regulations. The entire thought behind cognitive radio (CR) utilization is that it ought to incite compelling spectrum use, since intelligence and learning procedures support the radio framework to get to the spectrum effectively. Cognitive radio is generally anticipated that would be the following Big Bang in wireless communications. Spectrum sensing, that is, distinguishing the vicinity of the primary users in a authorized spectrum, is a principal issue for cognitive radio. In this paper, spectrum sensing techniques are reviewed. The difficulties and issues concerned in usage of spectrum sensing methods are examined in detail giving relative study of assorted methodologies

Keywords: Cognitive Radio, Dynamic Spectrum Access (DSA), Primary User (PU), Secondary User (SU), Software Defined Radio (SDR)

1. INTRODUCTION

The accessible electromagnetic radio spectrum is a restricted common asset and getting gathered step by step on account of expansion in wireless devices and applications[1]. On the other hand it's been additionally found that the allotted spectrum is underutilized owing to its static allocation that is that the standard approach of spectrum management and is incredibly inflexible to work in a certain frequency band. Given the constraints of the natural frequency spectrum, it becomes obvious that this static frequency allocation schemes can't accommodate the requirements of an increasing number of higher information rate gadgets. Therefore, creative strategies that may offer new ways of exploiting the offered spectrum are required. The problem of spectrum underutilization in wireless communication are often solved in an exceedingly higher approach mistreatment utilizing *Cognitive radio (CR)* technology. Cognitive radios are outlined so that extremely reliable communication will be supplied to all users of the network, wherever and whenever required and to encourage viable usage of the radio spectrum[2].

The CR enables the usage of temporally unused frequency bands which are commonly known as spectrum holes. Usually spectrum holes are generally categorized into temporal spectrum holes and spatial spectrum holes. A temporal spectrum hole is unoccupied by the PU during the time of sensing. Hence, this band can be used by SUs in the current time slot. Spectrum sensing of this kind does not require complex signal processing[3]. A spatial spectrum hole is a band which is unoccupied by the PU at some spatial areas; and therefore can be occupied by SUs. If the band is used more by a PU, the CR moves to another spectrum hole as shown in figure 1.

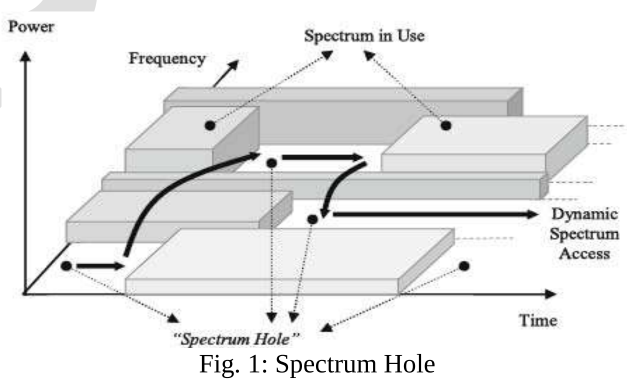

Fig. 1: Spectrum Hole

A standout amongst the most essential parts of the cognitive radio concept is the capacity to sense, learn, measure and be aware of the parameters identified with the radio channel characteristics, accessibility of spectrum and power, radio's working surroundings, user prerequisites and applications, accessible networks (frameworks) and nodes, local policies and other working restrictions[4]. Cognitive radio includes spectrum sensing, spectrum management, and spectrum sharing and spectrum mobility.

•Spectrum sensing: Detecting unused spectrum and imparting the spectrum without harmful impedance to different users.

•Spectrum management: Capturing the best accessible spectrum to meet user correspondence prerequisites.

•Spectrum mobility: Maintaining consistent correspondence necessities amid the move to better spectrum.

•Spectrum sharing: Providing the reasonable spectrum scheduling method among existing together xG users.

I. Dynamic Spectrum Access

Radio Spectrum has many dimensions such as: space, time, frequency, polarization, power of signal and interference. The static spectrum management has many challenges to provide spectrum utilization to different users in different areas. So the concept of DSA developed in CR's. It is rightly observed that spectrum scarcity was the byproduct of the antiquated spectrum management and though a large part of prime spectrum was assigned, allocated, it remained highly underutilized [5]. The static spectrum has barrier to access in many spectrum or multi dimensions to provide services to rapidly increasing demand of spectrum. The wireless networks of today can be classified into two broad classes: (1) cellular, infrastructure based networks characterized by a entity called base station providing a centralized switching point for communication from devices in a geographical area. (2) peer-to-peer or ad hoc networks where communicating nodes do not rely on a centralized node [5]. The Standing for the opposite of the current static spectrum management policy, the term dynamic spectrum access has broad connotations that encompass various approaches to spectrum reform. The diverse ideas presented on New Frontier in Dynamic Spectrum Access Networks (DySPAN) at the first IEEE symposium suggest the extent of this term [6]. The band spectrum of TV Broadcast is very widely unused and to utilize it efficiently, the DSA is implemented on it. And it is an unlicensed bans known as "White Space". In order to fully utilize the spectrum, the dynamic spectrum allocation using auctions has become a promising approach that allows SU's to lease unused bands by the PU's [7].

II. Dynamic Spectrum Allocation and sharing

When the communication over a cognitive network is established then it is not possible for the cognitive network to continue that communication very smoothly because the channel over which the communication is occurring might belong to some other primary user and that primary user may demand it back. Such a situation is bound to arise in cognitive network. The secondary network then has no choice but to return the borrowed spectrum and then switch to some other vacant spectrum to avoid the delaying or termination of the communication. Returning the borrowed spectrum and switching over to other channels is termed as SPECTRUM HANDOFF. For a successful spectrum handoff we require efficient mechanisms of spectrum handoff. Some theories are also proposed which states that for a continuous communication the secondary networks should access the spectrum from not only one primary user but other primary sources and other licensed sources also. This approach seems to be more pragmatic than other approaches as in others, there has to be a tradeoff among some important parameters.

III. Motivation: Spectrum Sensing For Spectrum Sharing

Spectrum sensing is the ability to measure, sense and be aware of the parameters identified with the radio channel characteristics, accessibility of spectrum and transmit power, obstruction and noise, radio's working surroundings, user prerequisite and applications, accessible systems(framework) and nodes, local policies and other working restrictions[7]. It is done across Frequency, Time, Geographical Space, Code and Phase. Among all different functions, Spectrum sensing is accepted as the most vital errand to establish cognitive radio systems. It can be characterized as "action of a radio measuring signal feature".

4.1 Principle of Spectrum Sensing

Fig. 2 demonstrates the standard of spectrum sensing. In the fig. the PU transmitter is sending information to the PU receiver in an authorised spectrum band while a couple of SUs intends to get to the spectrum. The SU transmitter needs to perform spectrum sensing to recognise to guarantee the PU transmission, whether there is a PU receiver in the scope of the SU transmitter.

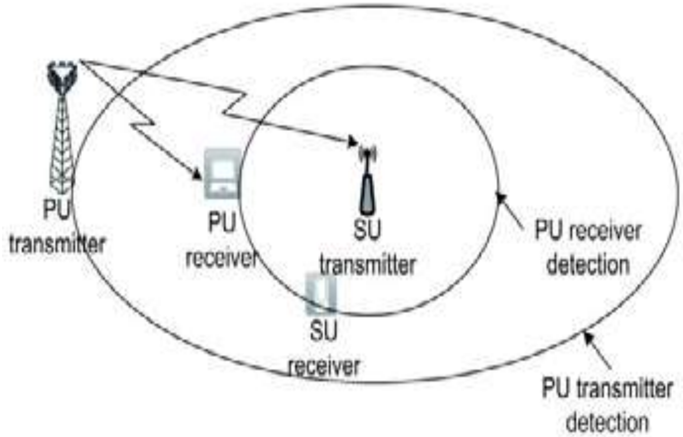

Fig. 2: Principle of Spectrum Sensing

IV. Spectrum Sensing Detection Methods

Spectrum sensing (a.k.a.spectrum detection technique)is the main task in cognitive cycle and the main challenge to the CRs. In spectrum sensing studying the spectrum and find the unused bands and sharing it while avoiding the spectrum that is occupied by PU. Figure 3 demonstrates the itemized arrangement of spectrum Sensing techniques. They are extensively characterized into three fundamental sorts, transmitter identification or non cooperative sensing, cooperative sensing and obstruction based sensing. Transmitter identification procedure is further ordered into three types i.e. energy detection, cyclostationary feature detection and matched filter detection. In this section, some of the most common spectrum sensing techniques in the cognitive radio literature are explained.

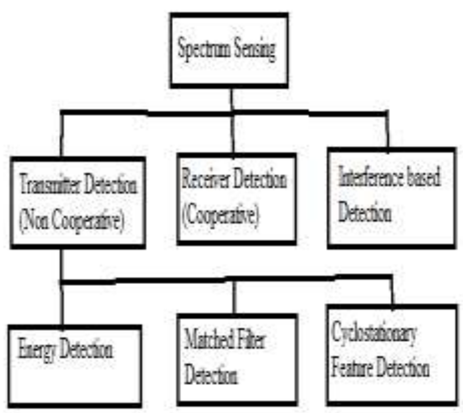

Fig. 3: Spectrum sensing Techniques

4.2 Matched Filter Detection

The matched filter detector that can use as CR has been initially proposed in [8]. The matched filter, it can think about as a best sensing method if CR has information of PU waveform. It is extremely exact since it maximizes the received signal-to-noise ratio (SNR).Matched filter compares between the final output of matched filter and predetermined threshold will determine the PU vicinity. Thus, if this data is not exact, then the matched filter works feebly.

4.2.1 Advantages

Matched filter detection needs less discovery time in light of the fact that it requires only O (1/SNR) tests to meet a given likelihood of identification limitation. When the cognitive radio user knows the data of the primary user signal, matched filter detection is optimal detection in stationary Gaussian noise.

4.2.3 Disadvantages

i) Matched filter detection obliges an earlier information of each essential signal.
ii) For Matched filter detection CR would require a committed recipient for every sort of primary user.

4.3 Cyclostationary Feature Detection

Implementation of a cyclostationary feature detector, has been initially introduced in [9], as spectrum sensing which can seperate the modulated signal from the additive noise. If the mean and autocorrelation are a periodic function, then, a signal is said to be cyclostationary. Feature detection signifies to seperating features from the received signal and performing the detection based on the extracted features. cyclostationary feature detection can recognize PU signal from noise, and utilized at very low Signal to Noise Ratio (SNR) detection by utilizing the data implanted as a part of the PU signal that are not present in the noise. primary disadvantage of this technique is the intricacy of calculation. Additionally, it must manage all the frequencies keeping in mind the end goal to create the spectral correlation function, which makes it an extensive calculation. The benefit of feature detection is that it typically allows different among dissimilar signals or waveforms[9][10].

4.3.1 Advantages

i) It performs better than energy detection in low SNR regions and Robust to noise vulnerabilities.
ii) In cyclo stationary though we need priori knowledge of the signal characteristics anyway it is equipped for recognizing the CR transmissions from different sorts of PU signals.
iii) Synchronization prerequisite of energy detection in cooperative sensing wiped out utilizing this procedure.
iv) Improves the overall CR throughput.

4.3.2 Disadvantages

i) High computational complexity
ii) Long sensing time.

4.4 Energy Detection

Energy detection (also denoted as non-coherent detection), is the signal detection mechanism utilizing an energy detector (also known as radiometer) to indicate the vicinity or absence of signal in the band. Energy Detection (ED) is one of the most basic sensing schemes. It is optimal if both the signal and the noise are Gaussian, and the noise variance is perfectly known. However, its performance degrades rapidly when there is uncertainty in the noise power value and is also incapable to differentiate between signals from different systems and between these signals and noise. This energy detection method is optimal for detecting any zero-mean constellation signals. In this energy detection approach, the received signal strength indicator (RSSI) or radio frequency (RF) energy in the channel is measured, in order to determine whether the channel is occupied or not. Firstly, in order to select the bandwidth of interest; the input signal is filtered by a band pass filter. After getting the square of the output signal, it is integrated over the observation interval. At the end, the output from the integrator is compared to a predetermined threshold value to conclude the presence or not of the PU signal. Fast Fourier transforms (FFT) based methods are used when the spectral is analyzed in the digital domain. Then the peak of this power spectrum is located and after windowing the peak of spectrum we obtain. Then the signal energy in the frequency domain is collected.
We also call Energy detection technique as BLIND SIGNAL DETECTION because it disregards the structure of the signal and evaluations the vicinity of the signal by contrasting the energy received with a known threshold derived from the statistics of the noise.

4.4.1 Disadvantages

i) High sensing time taken to attain to a given likelihood.
ii) Detection performance is liable to the uncertainty of noise power.
iii) Using Energy Detection technique it is hard to recognize primary signals from the CR user signals.
iv) ED not suitable to identify spread spectrum signals.

V. Challenges

Some of few Challenges associated with the spectrum sensing for cognitive radio are given in this section.

5.1 Hardware Requirements

Spectrum sensing for cognitive radio applications obliges high sampling rate, high resolution analog to digital converters (ADCs) with large dynamic range, and high speed signal processors. Noise variance estimation techniques have been prominently utilized for optimal receiver designs like channel estimation, soft information generation *etc.*, as well as for improved handoff, power control, and channel allocation techniques [11]. Thus, cognitive radio ought to have the capacity to catch and analyze a relatively larger band for identifying spectrum opportunities. The large operating bandwidths impose additional requirements on the radio frequencies (RF) components such as antennas and power amplifiers as well. These components should be able to operate over a range of wide operating frequencies. Furthermore, high speed processing units (DSPs or FPGAs) are required for performing computationally demanding signal processing tasks with relatively low delay.

6.2 Hidden Primary User Problem

The hidden primary user problem is similar to the hidden node problem in Carrier Sense Multiple Accessing (CSMA). It can be caused by many factors including severe multipath fading or shadowing observed by secondary users while scanning for primary users' transmissions. Fig. 4 shows an illustration of a hidden node problem where the dashed circles show the operating ranges of the primary user and the cognitive radio device. Here, cognitive radio device causes unwanted interference to the primary user (receiver) as the primary transmitter's signal could not be detected because of the locations of devices.

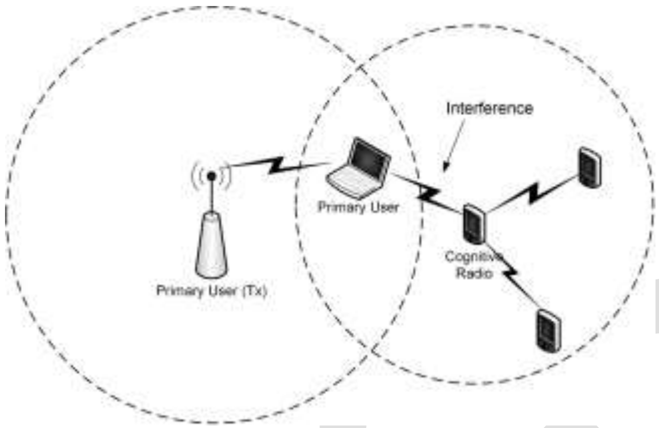

Fig. 4: Illustration of hidden primary user problem in cognitive radio systems

VI. Fault-Tolerance

A sensor node may fail due to physical damage or lack of energy (power). If some of the nodes fail, the protocols that are working upon must accommodate these changes in the network[12]. As an example, for routing or aggregation protocol, they must find suitable paths or aggregation point in case of these kinds of failures.

VII. **Scalability**

Depending upon the application, the number of sensor nodes deployed could be in order of hundreds, thousands or more[13]. The protocols must scalable enough to respond and operate with such large number of sensor nodes.

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VIII. SDR and its relationship with Cognitive Radio

The Software Defined Radio (SDR) was presented for taking care of more than one communication technology such that with respect to the software, the terminals can change their operation. In recent times different signalling methods have been proposed and utilized in different communication technologies everywhere throughout the world. Prior to the development of cognitive radio, SDR was centered around multi-mode and multi-standard devices. To avoid analog circuits and components, SDR gives variable radio functionality. The cognitive radio is essentially a SDR which already knows the condition, state, position and consequently adjusts its functions according to the desired objectives.

The connection between the SDR and the cognitive radio can be exhibited in Fig 5. It is clear from the diagram that the cognitive radio envelops the SDR. The SDR is based on Digital Signal Processing and developed in software with the modifiable Radio Frequency components. Subsequently, the SDR is a generic radio platform which has the capacity to work in different bandwidths over an oversized variety of frequencies furthermore as using different modulation schemes and waveform formats. As a results of this, the SDR can support multiple standards such as GSM, WCDMA, WIMAX etc., and multiple access schemes such as TDMA, OFDM and SDMA etc.

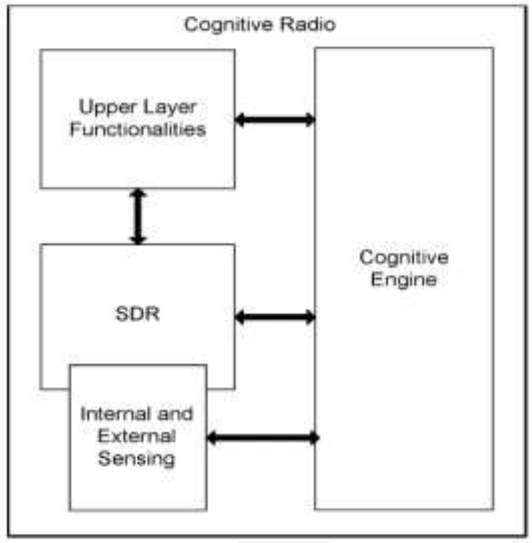

Fig. 5: Illustration of the relationship between the SDR and the cognitive radio

IX. Spectrum Sensing in Current Wireless Standards

Recently developed wireless standards have started to include cognitive features. Even though it is difficult to expect a wireless standard that is based on wideband spectrum sensing and opportunistic exploitation of the spectrum, the trend is in this direction. In this section, wireless technologies that require some sort of spectrum sensing for adaptation or for dynamic frequency access (DFA) are discussed. However, the spectrum knowledge can be used to initiate advanced receiver algorithms as well as adaptive interference cancellation.

10.1 IEEE 802.11k

A proposed extension to IEEE 802.11 specification is IEEE 802.11k which defines several types of measurements [14]. Some of the measurements include channel load report, noise histogram report and station statistic report. The noise histogram report provides methods to measure interference levels that display all non-802.11 energy on a channel as received by the subscriber unit. AP collects channel information from each mobile unit and makes its own measurements. This data is then used by the AP to regulate access to a given channel. The sensing (or measurement) information is used to improve the traffic distribution within a network as well. WLAN devices usually connect to the AP that has the strongest signal level. Sometimes, such an arrangement might not be optimum and can cause overloading on one AP and underutilization of others. In 802.11k, when an AP with the strongest signal power is loaded to its full capacity, new subscriber units are assigned to one of the underutilized APs. Despite the fact that the received signal level is weaker, the overall system throughput is better thanks to more efficient utilization of network resources.

X. Bluetooth

A new feature, namely adaptive frequency hopping (AFH), is introduced to the Bluetooth standard to reduce interference between wireless technologies sharing the 2.4GHz unlicensed radio spectrum [15], [16]. In this band, IEEE 802.11b/g devices, cordless telephones, and microwave ovens use the same wireless frequencies as Bluetooth. AFH identifies the transmissions in the industrial, scientific and medical (ISM) band and avoids their frequencies. Hence, narrow-band interference can be avoided and better bit error rate (BER) performance can be achieved as well as reducing the transmit power. Fig. 5 shows an illustrative Bluetooth transmission with and without AFH. By employing AFH, collisions with WLAN signals are avoided in this example. AFH requires a sensing algorithm for determining whether there are other devices present in the ISM band and whether or not to avoid them. The sensing algorithm is based on statistics gathered to determine which channels are occupied and which channels are empty. Channel statistics can be packet-error rate, BER, received signal strength indicator (RSSI), carrierto- interference-plus-noise ratio (CINR) or other metrics [15]. The statistics are used to classify channels as good, bad, or unknown [16].

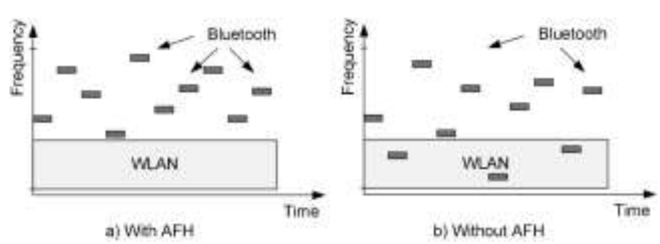

Fig. 5. Bluetooth transmission with and without adaptive frequency hopping (AFH). AFH prevents collusions between WLAN and Bluetooth transmissions.

XI.IEEE 802.22

IEEE 802.22 standard is known as cognitive radio standard because of the cognitive features it contains. The standard is still in the development stage. One of the most distinctive features of the IEEE 802.22 standard is its spectrum sensing requirement [17]. IEEE 802.22 based wireless regional area network (WRAN) devices sense TV channels and identify transmission opportunities. The functional requirements of the standard require at least 90% probability of detection and at most 10% probability of false alarm for TV signals with - 116 dBm power level or above [18]. The sensing is envisioned to be based on two stages: fast and fine sensing. In the fast sensing stage, a coarse sensing algorithm is employed, *e.g.* energy detector. The fine sensing stage is initiated based on the fast sensing results. Fine sensing involves a more detailed sensing where more powerful methods are used. Several techniques that have been proposed and included in the draft standard include energy detection, waveform-based sensing (PN511 or PN63 sequence detection and/or segment sync detection), cyclostationary feature detection, and matched filtering. A base station (BS) can distribute the sensing load among subscriber stations (SSs). The results are returned to the BS which uses these results for managing the transmissions Another approach for managing the spectrum in IEEE 802.22 devices is based on a centralized method for available spectrum discovery. The BSs would be equipped with a global positioning system (GPS) receiver which would allow its position to be reported. The location information would then be used to obtain the information about available TV channels through a central server. For low-power devices operating in the TV bands, *e.g.* wireless microphone and wireless camera, external sensing is proposed as an alternative technique. These devices periodically transmit beacons with a higher power level. These beacons are monitored by IEEE 802.22 devices to detect the presence of such low-power devices which are otherwise difficult to detect due to the low-power transmission.

XII. Conclusion

Spectrum is an extremely profitable asset in wireless communication systems, and it has been a point of convergence for innovative work endeavors throughout the most recent quite a few years. Cognitive radio, which is one of the endeavors to use the accessible spectrum more efficiently through shrewd spectrum usage, has turned into an energizing and guaranteeing idea. One of the imperative components of cognitive radio is sensing the accessible spectrum opportunities. In this Paper, Various aspects of the spectrum sensing task are explained in detail. Considering the difficulties raised by cognitive radios, the utilization of spectrum sensing strategy shows up as a urgent need to accomplish acceptable results as far as proficient utilization of accessible spectrum and restricted interference with the authorized primary users.

REFERENCES:

[1] Wael Guibene, Monia Turki, Bassem Zayen and Aawatif Hayar, "Spectrum sensing for cognitive exploiting spectrum discontinuities detection", Guibene et al. EURASIP Journal on Wireless Communication and Networking 2012, 2012:4, pp. 1-9, (SPRINGER).
[2] Lu Lu, Xiangwei Zhou, Uzoma Onunkwo and Geoffrey Ye Li, "Ten years of research in spectrum sensing and sharing in cognitive radio", [3] Lu et al. EURASIP Journal on Wireless Communication and Networking 2012, 2012:28, pp. 1-16, (SPRINGER).
[4] Peter Steenkiste, Douglas Sicker, Gary Minden, Dipankar Raychaudhuri, "Future Directions in Cognitive Radio Network Research" , NSF Workshop Report, March 9-10, 2009, pp. 1-39.
[5] Milind M. Buddhikot "Understanding Dynamic Spectrum Access: Models, Taxonomy and Challenges" , IEEE DySPAN 2007, Dublin, April 17-21, 2007.
[6] Qing Zhao and Brian M. Sadler, "A Survey of Dynamic Spectrum Access", IEEE Signal Processing Magazine, May 2007, pp. 79-89.

[7]Badr Benmammar[1] Asma Amraoui[1], Francine Krief2, "A Survey on Dynamic spectrum Access Techniques in Cognitive Radio Networks", International Journal of Communication Networks and Information Security (IJCNIS), Vol. 5, No. 2, August 2013, pp. 69-79.
[8] A. Sahai, N. Hoven, and R. Tandra, "Some fundamental limits in cognitive radio," in Proceedings of the Allerton Conference on Communication, Control, and Computing, Monticello, Ill, USA, 2004.
[9] D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation issues in spectrum sensing for cognitive radios," in Proceedings of the 38th Asilomar Conference on Signals, Systems and Computers, vol. 1, pp. 772–776, 2004.
[10] A. Garhwal, and P. P. Bhattacharya "A Survey on Dynamic Spectrum Access Techniques for Cognitive Radio," International Journal of Next-Generation Networks, vol. 3, no. 4, pp. 15-32, 2012.
[11] T. Y¨ucek and H. Arslan, "MMSE noise plus interference power estimation in adaptive OFDM systems," IEEE Trans. Veh. Technol., 2007.

[12] R. Chen and J.-M. Park, "Ensuring trustworthy spectrum sensing in cognitive radio networks," in Proc. IEEE Workshop on Networking Technologies for Software Defined Radio Networks (held in conjunction with IEEE SECON 2006), Sept. 2006.
[13] C. N. Mathur and K. P. Subbalakshmi, "Digital signatures for centralized DSA networks," in First IEEE Workshop on Cognitive Radio Networks, Las Vegas, Nevada, USA, Jan. 2007, pp. 1037–1041.
[14] Draft Supplement to STANDARD FOR Telecommunications and Information Exchange Between Systems - LAN/MAN Specific Requirements- Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications: Specification for Radio Resource Measurement, The Institute of Electrical and Electronics Engineering, Inc. Std. IEEE 802.11k/D0.7, Oct. 2003.
[15] N. Golmie, N. Chevrollier, and O. Rebala, "Bluetooth and WLAN coexistence: challenges and solutions," IEEE Wireless Commun. Mag., vol. 10, no. 6, pp. 22–29, Dec. 2003.
[16] Specification of the Bluetooth system, Master Table of Contents & Compliance Requirements, Bluetooth, SIG Std. Bluetooth Standard, Nov. 2004.
[17] Standard for Wireless Regional Area Networks (WRAN) – Specific requirements - Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and procedures for operation in the TV Bands, The Institute of Electrical and Electronics Engineering, Inc. Std. IEEE 802.22.
[18] C. R. Stevenson, C. Cordeiro, E. Sofer, and G. Chouinard, "Functional requirements for the 802.22 WRAN standard," IEEE 802.22- 05/0007r46, Sept. 2005