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SURVEY ON OPTIMUM WIRELESS COMMUNICATION BY COGNITIVE RADIO SPECTRUM SENSING TECHNIQUE

Prof. Prashant Bhati*1, Atul Singh Kushwah*2
**1(lecture of Patel college of science and technology, indore, india)*
**2(student of Patel college of science and technology, indore, india)*
*prashant bhati@yahoo.com*1,atulsingh41189@gmail.com*2*

ABSTRACT

Dynamic spectrum access and cognitive radio (CR) are emerging technologies to utilize the limited frequency spectrum in an efficient and opportunistic manner. Spectrum sensing helps to identify the spectrum holes in underutilized bands of the spectrum which provide high spectral resolution capability. In this paper, survey of spectrum sensing and spectrum management techniques is presented. One of the challenging problems in dynamic spectrum access for cognitive radios is to sense the spectrum in wide band system to identify the spectrum opportunities. In this paper is to present the survey of various signal processing techniques for spectrum sensing in Cognitive Radio network to make automatic and wise decision by unlicensed secondary users to adapt their transmission parameters according to their operating radio frequency environment and with respect to primary users.

Keywords-

Cognitive Radio, Dynamic Spectrum Access, Spectrum Sensing methods, Signal Processing Techniques

1. INTRODUCTION

Due to gradual increase in requirement of migration to new technology in wireless communication like 2G/3G and again for beyond 3G (B3G) with the main aim for high data rate transmissions and provide adequate capacity, cost efficiency and highly sophisticated services, comparable to those offered by wired networks, for a variety of applications, such as interactive multimedia, VoIP, network games or videoconference. As the currently known Radio Access Technologies (RATs) are not enough to satisfy the aforementioned criteria in a standalone manner, so major contribution towards this convergence are the cooperative networks concept and the evolution of cognitive-reconfigurable networks which is adaptive in nature, because a fixed spectrum assignment has lead to under utilization of spectrum as a great portion of licensed spectrum is not effectively utilized. Dynamic spectrum access and cognitive radio are emerging technologies to utilize the limited frequency spectrum in an efficient and opportunistic manner.

The available electromagnetic spectrum is limited natural resource and crowded day by day due to increase in wireless devices and applications. Firstly, it has been also found that the allocated spectrum is underutilized because of the fixed allocation of the spectrum. Secondly, the conventional approach to spectrum management is very rigid in the sense that each one wireless operator is assigned a restricted license to operate in a certain frequency band. Lastly, most of the useful radio spectrum is already allocated and it is difficult to find free bands to either set up new services or to improve existing ones. In order to overcome this situation, we need to move toward with a means for better utilization of the spectrum creating opportunities for dynamic spectrum access.

The problem of spectrum underutilization in wireless communication can be solved in a better way by using Cognitive radio technology. Cognitive radios are designed in order to provide highly consistent communication for all users of the network and to facilitate effective utilization of the radio spectrum. Figure 1[1] and 2[2] show relatively low utilization of the licensed spectrum due to incompetent fixed frequency allocations rather than any physical scarcity of spectrum. This observation has forced the regulatory bodies to seek out a method where secondary or unlicensed systems are allowed to opportunistically use the unused primary or licensed bands commonly called as white spaces. Cognitive radio can be capable to change its transmitter parameters based on interaction with environment in which it operates. The term “Cognitive Radio” was firstly introduced 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 based on the needs and user requirements. Depending on the parameters considered a difference can be made between Cognitive Radios as firstly, fully cognitive radio, which takes into account every possible parameter and secondly, Spectrum Sensing radio, which only concerned with the Radio Frequency spectrum. Cognitive Radio has four main functions which are-Spectrum Sensing, Spectrum Sharing, Spectrum Management and Spectrum Mobility. **Spectrum sensing** aims to determination of spectrum availability and the presence of the licensed users which also known as primary users. For spectrum sensing various spectrum sensing techniques includes primary transmitter detection, cooperative detection and interference detection are used. **Spectrum management** predicts how long the spectrum holes are possible to remain available for the used by unlicensed users which also called cognitive radio users or secondary users. **Spectrum sharing** for the distribution of the spectrum holes fairly among the secondary users referring to usage cost. **Spectrum mobility** for sustain seamless communication requirements during the transition to better spectrum.

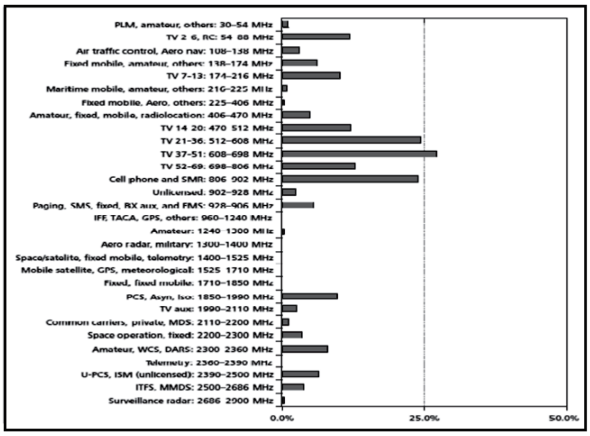

Figure1: Spectrum concentration

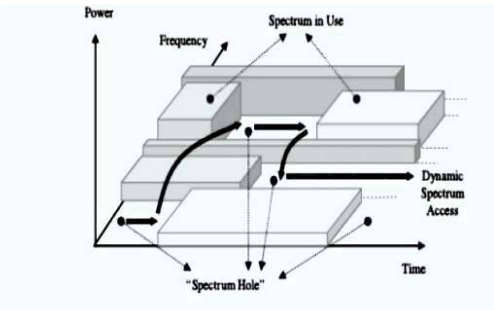

Figure 2: Illustration of spectrum white space

2. CHALLENGES AND ISSUES IN SPECTRUM SENSING

For solving the issue of spectrum sensing in cognitive network several sources of uncertainty like channel uncertainty, noise uncertainty and sensing interference limit need to be addressed. Channel uncertainty refers to uncertainties in received signal strength caused due to channel fading or shadowing which may incorrectly interpret that the primary system located out of the secondary user's interference range as the primary signal may be experiencing a deep fade or being heavily shadowed by obstacles. Cognitive radio should have to be more sensitive to differ between a faded or shadowed primary signal through white space. Any uncertainty in the received power of the primary signal requires higher detection sensitivity. The tradeoff among spectrum sensing time and user throughput is shown in Figure 3[5]. A single cognitive radio relying on local sensing may be unable to achieve this increased sensitivity under severe fading since the required sensing time can exceed the sensing period. This issue can be controlled by cooperative sensing called group of cognitive radios, which share local measurements and jointly decide on the occupancy state of a licensed band [3][4].

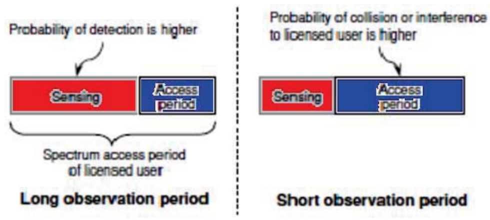

Figure 3: Trade off between spectrum sensing time and user throughput

For noise uncertainty firstly the detection sensitivity can be defined as the minimum SNR at which the primary signal can be accurately detected by the cognitive radio is given by:

$$\gamma_{min} = P_p L(D+R)/N_p \quad (1)$$

Where N_p is the noise power, P_p is transmitted power of the primary user, D is the interference range of the secondary user, and R is distance between primary transmitter and receiver. For calculating required detection sensitivity, the noise power N_p has to be known, which is not available in practice, and required to be estimated by the receiver. The noise power N_p estimation is limited by calibrating errors as well as change in thermal noise caused by temperature variations. Cognitive radio cannot satisfy the sensitivity requirement due to an underestimate of N_p, γ_{min} must be calculated with the worst case noise assumption, thereby requiring more sensitive detector.

For aggregate interference uncertainty, in future, due to the extensive deployment of secondary systems, there will be possibility of multiple cognitive radio networks operating over the identical licensed band. By which spectrum sensing will be affected by uncertainty in aggregate interference by which, a primary system is out of interference range of a secondary system, the aggregate interference may lead to incorrect detection. This uncertainty required more sensitive detector, as a secondary system may destructively interfere with primary system located beyond the interference range, so it should be required to detect them.

In sensing interference limit, main goal of spectrum sensing is to sense the spectrum status i.e. whether it is idle or busy, so that it can be accessed by an unlicensed user. The problem arises in the interference measurement at the licensed receiver caused by transmissions from unlicensed users. Firstly, an unlicensed user could not recognize exact location of the licensed receiver which is required to compute interference caused due to its transmission. Secondly, if a licensed receiver is a passive device, the transmitter might not be aware of the receiver. So these factors require attention while calculating the sensing interference limit.

3. SPECTRUM MOBILITY ISSUES

Dynamic Spectrum Access function performed by spectrum mobility functions in a cognitive radio network which allows an unlicensed user to change its operating spectrum dynamically dependent on the spectrum conditions .This issue can be described in following ways.

Best frequency band searching: A cognitive radio must keep record of available frequency bands so that it can switch immediately to other frequency band. During transmission through unlicensed user frequency band condition has to be observed. Similarly for spectrum sensing, this would of course acquire some overhead. The observation can be done in proactive manner or on demand basis. In proactive approach, the condition of the available channels is observed periodically and channels are continuously updated. In on demand approach, channel observation can be performed by an unlicensed user require to switch the channel.

Protocol stack adaptation: Since the latency caused by spectrum handoff possibly will be high, the modification and adaptation of other components in the protocol stack is required for which a cross layer optimized framework for protocol adaptation has to be developed to manage spectrum mobility.

Synchronization and Self coexistence: When an unlicensed or secondary user performs spectrum handoff, two issues are possible firstly, the target channel should not presently be used by any other secondary user called the self coexistence requirement, and secondly the receiver of the corresponding secondary link must be aware of the spectrum handoff called the synchronization requirement. For the self coexistence, a spectrum broker may be used to manage spectrum allocation. For synchronization, the MAC protocol should be designed with provision for spectrum handoff information exchange.

4. SPECTRUM SENSING

Sub bands of the radio spectrum might be categorized as follows. a) White spaces, for free of RF interferers. b) Gray spaces, for partially occupied by interferers as well as noise. c) Black spaces, for completely full due to the combined presence of communication and interfering signals plus noise. A cognitive radio is designed to be responsive to the changes in its surrounding or in environment. The spectrum sensing technique enables the cognitive radio to be responsive for its environment by detecting spectrum holes. The efficient way to detect spectrum holes is to sense the primary users those are receiving data within the communication range. It is difficult for a cognitive radio to have a direct dimension of a channel between a primary receiver and a transmitter. So the most recent work focused on primary transmitter detection based on local observations of next generation users.

We can categorize spectrum sensing techniques into direct method also called frequency domain approach, where the estimation is carried by signal and the indirect method also known as time domain approach, where the estimation is performed by autocorrelation. Categorization will also based on the spectrum sensing and estimation methods by making group into model based parametric method and periodogram based non-parametric method.

Another way of classification according to the need of spectrum sensing as stated below:

For Spectrum Opportunities

a. Primary transmitter detection: The detection of primary users is dependent on the received signal at cognitive radio users. This approach contains matched filter (MF) based detection, energy based detection, waveform based detection, covariance based detection, cyclostationary based detection, radio identification based detection and random Hough Transform based detection.

b. Cooperative and collaborative detection: In this detection approach, the primary signals are detected reliably by interacting or cooperating with other users, and the method can be implemented as centralized access to spectrum synchronized by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection.

For Interference Detection

a. Interference temperature detection: In this detection approach, cognitive radio system works in ultra wide band (UWB) technology where the secondary users coexist with primary users and permissible to transmit at low power and constrained by the interference temperature level so as not to cause destructive interference to primary users.

b. Primary receiver detection: In this detection method, the interference or spectrum opportunities are depend on primary receiver's local oscillator leakage power.

The detailed classification of spectrum sensing techniques is shown in Figure 4 [5]. They are generally classified into three main categories, transmitter detection or non cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection technique is further divided into energy detection, matched filter detection and cyclostationary feature detection.

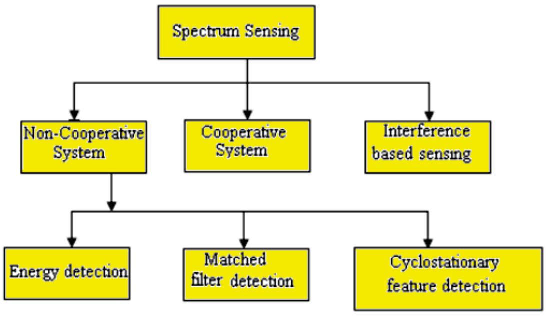

Figure 4: Classification of spectrum sensing techniques

5. SPECTRUM SENSING TECHNIQUES CLASSIFICATION :

Primary Transmitter Detection

Energy Detection: This method is regarded as the general method of signal detection because of its low computational and implementation complexities. It is regarded as non coherent detection method that detects the primary signal depends on the sensed energy. Due to its simplicity and no prior knowledge of primary user signal is required, energy detection (ED) is the main sensing technique in cooperative sensing.

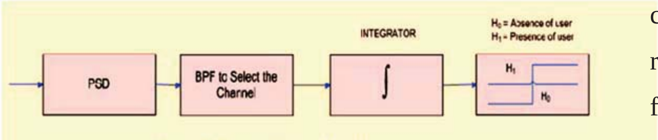

Figure 5: Energy detector block diagram

Figure 5 [1] shows the block diagram for the energy detection technique. In this method, signal is passed through band pass filter of the bandwidth W and is integrated. The output from the integrator block is then compared to threshold. This comparison is used to find the existence of absence of the primary user. The threshold value can be fixed or variable depend on the channel conditions.

The energy detector is also called the Blind signal detector because it ignores the structure of the signal, It also estimates the presence of the signal by comparing the energy received by threshold ν derived from the statistics of the noise. Signal detection can be reduced to a simple identification problem analytically, formalized as a hypothesis test,

$y(k)=n(k)$ for H_0 (2)

$y(k)=h*s(k)+n(k)$ for H_1

here y (k) refers to sample to be analyzed at each instant k and n (k) is the noise of variance σ^2. Let y (k) refers to a sequence of received samples k Є {1, 2….N} at the signal detector, then a decision rule can be stated as below,

H_0 if $\varepsilon < \nu$ (3)

H_1 if $\varepsilon > \nu$

Here ε is $E\,|y(k)|^2$ called the estimated energy of the received signal and ν is chosen to be the noise variance σ^2.

Following disadvantages of energy detection are, firstly, sensing time may be high, secondly, detection performance due to the uncertainty of noise power, thirdly, energy detection cannot be used to distinguish primary signals from the cognitive radio user signals due to which CR users required to be strongly synchronized and refrained from the transmissions during an interval referred as Quiet Period in cooperative sensing, lastly energy detection cannot be used to detect spread spectrum signals.

Matched Filtering Based Signal Detection: When the transmitted signal is known at receiver, the optimal method for detecting primary users is matched filtering (MF) which maximizes received signal-to-noise ratio (SNR), and matched filter (MF) is a linear filter designed to maximize the output signal to noise ratio for a given input signal. When secondary user has a prior knowledge about primary user signal, matched filter detection is applied. Matched filter operation is corresponding to correlation in which the unidentified signal is convolved with the filter whose impulse response is the mirrored and time shifted description of a reference signal.

Figure 6: Block diagram of matched filter

The matched filter detection operation is expressed as:

$y[n]=\sum_{k=-\infty}^{\infty} h[n-k]x[k]$ (4)

Where 'x' refers to unknown signal vector and is convolved with the 'h', which refers to impulse response of matched filter which is matched to the reference signal for maximizing the SNR.

Detection by using matched filter is useful for the cases where the information from the primary users is known to the cognitive users, technique is shown in fig. 6 [1]. **Advantages** of this method involves less detection time because it requires only O (1/SNR) samples to meet a given possibility of detection constraint. When the primary user signal information is known to the cognitive radio user, matched filter detection is optimal technique for stationary Gaussian noise. **Disadvantages** of this method involves requirement of prior knowledge of every primary signal. If the information is not exact, matched filtering performs poorly. Second, MF implementation difficulty of detection unit in cognitive radio devices is very high because cognitive radio system needs receivers for all signal types of wide band system. Lastly, large power will be consumed for execution of such several detection processes as cognitive radio device sense the wideband system. Therefore the disadvantages overshadow the advantages of MF based detection. MF based technique may not be a good choice for real cognitive radio system because of its above-mentioned disadvantages.

Cyclostationarity-Based Detection: The cyclostationarity based signal detection technique is also regarded as a good candidate for spectrum sensing in cognitive radio systems. This technique takes the advantage of cyclostationarity properties of the received signals to detect primary user transmissions. The basic idea in this method is to use the cyclostationarity features of the signals. Generally, the transmitted signals are stationary random process also the cyclostationarity features, that are the periodicity in signal statistics such as mean and autocorrelation which are induced because of modulation of signals by sinusoid carriers, cyclic prefix in OFDM, and code sequence in CDMA. Contradictory, the noise is considered as Wide-Sense Stationary (WSS) with no correlation. So this method can differentiate primary user's signals from noise. In this scheme, cyclic spectral correlation function (SCF) is used for detecting the signals as shown in fig. 7 [1].

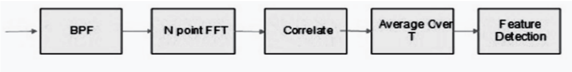

Figure 7: Cyclostationary feature detector block diagram

It exploits the periodicity in the received primary signal to classify the presence of primary users (PU). The periodicity is commonly implanted in sinusoidal carriers, spreading code, pulse trains, hopping sequences or cyclic prefixes of the primary signals. Due to periodicity, cyclostationary signals reveal the features of periodic statistics and spectral correlation, which is not found in stationary noise and interference. So, cyclostationary feature detection is tough to noise uncertainties but better than energy detection in low SNR regions. It requires a prior knowledge of the signal characteristics; cyclostationary feature detection can distinguish the cognitive radio transmissions from various types of primary user's signals. This eliminates the synchronization necessity of energy detection in cooperative sensing. Cognitive radio users could not be required to keep silent during cooperative sensing so improving cognitive radio throughput. This method has its own shortcomings remaining to its high computational complexity and long sensing time. Due to these, this detection technique is less common than energy detection in cooperative sensing.

Figure 8 shows the assessment of different transmitter detection techniques for spectrum sensing and the spectrum opportunities. It is evident from the figure, that matched filter depends on detection is complex to implementation in cognitive radio's, but has highest accuracy. Likewise, the energy based detection is least complex to employ in cognitive radio system and least precise as compared to other approaches.

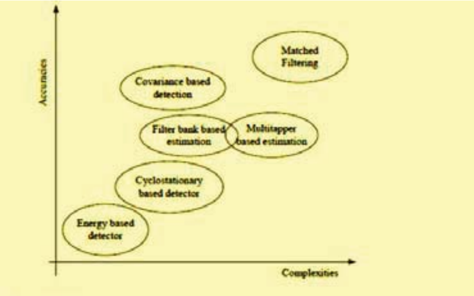

Figure 8: Sensing accuracy and complexity of various sensing methods

Cooperative Detection Technique: In cooperation dependent spectrum sensing, cognitive radio users can use appropriate method for primary spectrum sensing and collaborate for the sensed information among participating users in order to increase the consistency of sensing. In this detection, the spectrum estimation can be done by interacting with other users for getting reliable and accurate information of spectrum opportunities. In wireless system there is primary user or hidden terminal problem due to path loss or network coverage and due to shadowing or blocking of transmission [6]. This hidden terminal problem used in detecting primary user with outcome in increase in false alarm, which is objectionable for spectrum sensing in cognitive radio systems. So in order to face this problem with increase in reliability of sensed information, the cognitive radio user can cooperate with other cognitive radio users to share the information. So this method can solve the hidden terminal (primary user) problem with the solution of many problems in spectrum estimation; it reduces the probability of miss-detection as well as false alarms. High sensitivity necessities on the cognitive user can be improved if multiple cognitive radios cooperate in sensing. Various topologies are presently used and are generally classifiable into three categories based on their level of cooperation are shown in fig. 9 [10][11] and described as follows:

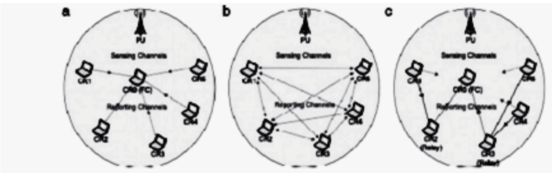

Figure 9: Cooperative sensing techniques: a-Centralised Coordinated, b- Decentralised Coordinated, and c-Decentralised Uncoordinated .

Decentralized Uncoordinated Techniques: It is also called external detection technique; in this method all cognitive radio users obtain the spectrum information from external detection agent. An external agent performs the spectrum detection or sensing since the external agent is prepared with sensing capability with spectrum sensors. The cognitive users in the network doesn't coordinated which means that each cognitive radio user will independently detect the channel, and if a cognitive radio user detects the primary user it may leave the channel without informing to other users. So cognitive radio users experiences bad channel realizations detect the channel incorrectly causing interference at the primary receiver.

Centralized Coordinated Techniques: It is also called centralized server based detection in such networks, a central unit called a server that collects all the sensed information related to spectrum occupancy from cognitive radio devices, collect the available information centrally, and then disseminates or broadcasts the collected information related to spectrum status to all cognitive radio users. The cognitive radio controller notifies all the cognitive radio users in its range by sending broadcast control message. Centralized method can be further classified as: Partially cooperative where network nodes cooperate for sensing channel. Cognitive radio users detect the channel independently and inform the cognitive radio controller which then informs all the cognitive radio users; and finally called totally cooperative Schemes where nodes cooperate in dependent on each other's information with cooperatively sensing the channel.

Decentralized Coordinated Techniques: It is also called centralized and external detection distributed cooperative detection, this coordination implies building up a network of cognitive radios without a controller. Various algorithms have been implemented for the decentralized techniques among which are the clustering schemes, where cognitive users assembled to clusters, auto synchronize them. The cooperative spectrum sensing raises the need for a control channel, which can be implemented as a dedicated frequency channel or as an underlay UWB channel.

Advantages of Cooperation: channel impairments like multipath fading, shadowing and building penetration losses, impose high sensitivity requirements inherently limited by cost and power requirements, reduce the sensitivity requirements up to -25 dBm, also reduction in sensitivity threshold, reduce detection time compared to uncoordinated networks

Disadvantages of Cooperation: Increases in data overhead; large sensory data: resulting in large amounts of data, inefficient with respect to data throughput, delay sensitivity requirements and energy consumption and gives less information about.

Interference Based Detection Technique

In this section, the cognitive radio users would operate in spectrum underlay (ultra-wideband like) approach.

Primary Receiver Detection: In general, local oscillator (LO) leakage power emitted from primary receiver while receiving the data from primary transmitter. It has been suggested that in order to detect the local oscillator power leakage power emitted by the RF front end of the primary user's receiver within the communication range of cognitive radio system users. It reports the sensed information to the cognitive radio users helps to identify the spectrum occupancy. This method can also be used to identify the spectrum opportunities to operate cognitive radio users in spectrum overlay.

Interference Temperature Management: For dynamic spectrum access or spectrum utilization, this approach considers the spectrum underlay approach. When primary and secondary user transmit their data simultaneously, for that the best approach is interference temperature management to protect primary users from the interference caused by secondary users by imposing some constraints (like, low transmit power) to secondary cognitive radio users to prevent exceed specified interference limit. The interference temperature based approach is shown in Figure 10 [5].

This approach set up an upper limit in interference power for known frequency band in specific geographic location such that cognitive radio users will not create harmful interference while using the specific band in specific area. This approach works as an ultra-wideband technology where the secondary users' are permitted to transmit simultaneously with primary users at low transmit power, and are restricted by the interference temperature level so as not to cause destructive interference to primary users. In this approach, cognitive radio users start communication without sensing and waiting for spectrum opportunities but they are restricted by some operating constraints, as they have to respect the serving primary users.

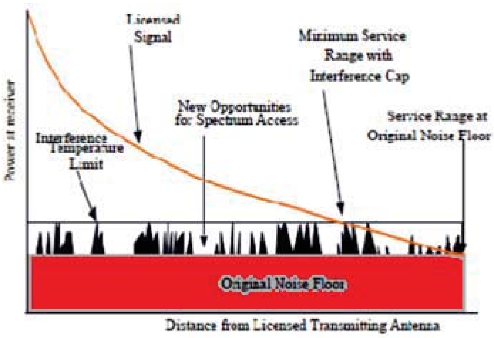

Figure 10: Interference temperature model

However, due to low transmit power and interference temperature limit if the licensed system is completely idle for given time and location to secondary cognitive radio users which cannot transmit their data with higher power that can be seen as a disadvantage of this approach.

Signal Processing Approaches

Multi -Taper Spectrum Sensing and Estimation (MTSE): Thomson proposed that in the last N samples of received signal which are collected in a vector form and represented as a set of Slepian base vectors. The Slepian base vectors are used to recognize the spectrum opportunities in the targeted spectrum band. The main idea is to utilize its fundamental property i.e. the Fourier transforms of Slepian vectors have the maximum energy concentration in the bandwidth fc-W to fc+W under a finite sample-size constraint. By analyzing this feature, cognitive radio users can find spectrum opportunity or not. This method is also regarded as proficient method for small sample spaces.

Filter Bank Based Spectrum Sensing Estimation (FBSE): It is the simplified version of MTSE which uses one prototype filter for each band and has been planned for multi-carrier modulation based cognitive radio systems by using a pair of matched root Nyquist filter. It also uses the concept of maximal energy concentration in the bandwidth fc -W to fc +W. By using this information, cognitive radio user recognizes the spectrum occupancy and the spectrum opportunities. MTSE is better for small samples and FBSE for large number of samples.

Wavelet based detection method: This technique is widely used in image processing for edge detection applications. For spectrum sensing Tian and Giannakis (2006) have proposed this approach where wavelets are used for edge detecting in the power spectral density (PSD) of a wideband channel. The edges in PSD are the edge between spectrum holes and occupied bands and it also helps to find vacant bands. Due to this cognitive radio can identify the spectrum opportunities.

Random Hough transforms based detection method: This method is widely used for pattern detection in image processing applications. For identification of presence of radar pulses in the operating channels of IEEE 802.11 wireless systems Challapali et al. (2004) have introduced Random Hough transform of received signal r(n). That can be also used for spectrum sensing in cognitive radio.

Radio identification based detection method: For extraction of various characteristics of signal like transmission frequency, transmission range, modulation technique etc these techniques are used. After extraction of these features from the received signal, cognitive radio users used those features and can select suitable transmission parameters for them.

MIMO OFDM approach for spectrum sensing: In the Spectrum sensing problem can be treated as a Composite Hypothesis test problem. To solve the problems, two algorithms can be used called Iterative & non Iterative GLRT sensing algorithms developed for slow and fast fading channels respectively. Iterative sensing algorithms having high complexities and are used for performance comparison, while non iterative algorithm is simple and best for fast fading as well as slow fading channels and also for MIMO and OFDM systems. So, non iterative method used for several other sensing methods. By implementing OFDM technique in cognitive radio systems, more adaptive, aware and flexible systems can be made. Challenges which arise due to the use of OFDM in cognitive radio are identified and for future research.

For the physical layer of cognitive radio, different multicarrier techniques have been reviewed [8]. The filter banks for multicarrier communication are introduced and performance of OFDM is analyzed. The multi-taper is an effective method for spectral analysis; OFDM suffers from leakage issues and with TDD the issues of OFDM of low importance. In FDMA/FDD operation filter-banks may be preferred over OFDM. In communication technique filter-banks provide better results than OFDM [9]. The performances of filter-banks are equal optimal multi-taper method. They are better candidates for spectrum sensing in CR systems but the understanding of OFDMA systems is simpler than filter banks.

CONCLUSION

Cognitive radio is a efficient technology which enables spectrum sensing for opportunistic spectrum usage by the means of white spaces. By considering the challenges raised by cognitive radios, the use of spectrum sensing method required satisfactory results for the efficient use of available spectrum and limited interference with the licensed users [7].

In this paper, the development of the cognitive radio network required many advanced techniques that include interference management, distributed spectrum sensing, cooperative communications and cognitive radio reconfiguration management. For complete realization the cognitive radio system in wireless communications used for efficient utilization of scarce RF spectrum, the method used for identification of the interference and spectrum sensing should be consistent. This paper presented the various signal processing methods, with advantages and disadvantages of different spectrum sensing methods, and compare various operation, accuracies, complexities and implementations. Various issues are described for primary signal detection time, hardware requirements and computational complexities. In this paper OFDM technique is discussed for spectrum sensing, but still there are various researches will be done for optimum utilization of spectrum for future. This paper also described detailed information for cognitive radio.

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