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Spectrum Sensing Techniques and Dynamic Spectrum Allocation

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Abstract: One of the fundamental problems for the future wireless systems is where to find suitable spectrum bands to fulfil the demand of future services. While basically all of the radio spectrum is allocated to different services, applications and users, observation provide proof that utilization of the spectrum is actually quite low. In order to overcome this problem and enhance the spectrum utilization, cognitive radio concept has been proposed, an application with this radio is spectrum sensing which is the biggest issue that can detect the spectrum holes or detects the presence of primary users. Cognitive radios works on dynamic spectrum allocation method where any spectrum hole detected by spectrum sensing is then allocated to the secondary user without interfering the primary users. This paper gives a summary of spectrum sensing techniques and dynamic spectrum allocation methods**.**

Keywords: Cognitive Radio, Spectrum Sensing, Dynamic Spectrum allocation, Primary user, Secondary user.

I. INTRODUCTION

The increasing demand in wireless communication has introduced economical spectrum utilization challenge and to deal with this challenge the psychological feature radio came into existence. Cognitive radio was formally given by Joseph Mitola in 1999 and this idea has been fashionable analysis in numerous fields like telecommunication ,according to him it's outlined as " a radio that employs model-based reasoning to realize a selected level of ability in radio-related domain[1] ".CR could be a type of wireless communication that has transceiver that discover which communication channels area in use or those are vacant, and instantly go into vacant channels whereas avoiding occupied ones. Cognitive radio will modify numerous parameters autonomously for the communication functions while not the necessity for the user intervention. The goal is to beat the matter by proposing opportunist spectrum usage approach [2], whenever the frequency bands those are not employed by the primary users is utilized by secondary users without interfering the primary user. Cognitive radio is incorporated with following functions [3]:

- Spectrum Sensing
- Spectrum Management
- Spectrum Sharing
- Spectrum Mobility

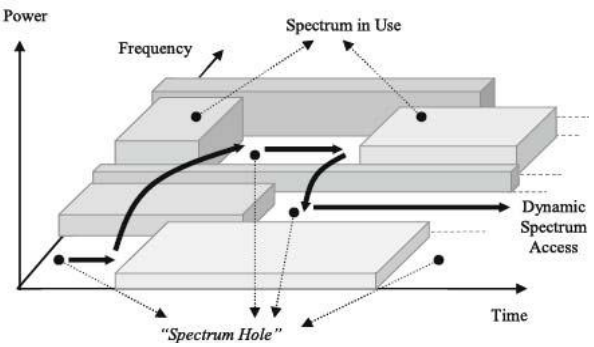

Fig 1. Spectrum Holes

Among these, spectrums sensing is that the most important and thought of because the major challenge that acts to discover the presence or absence of primary user signal in cognitive radio system. Overall spectrum utilization will be improved considerably by permitting secondary users to dynamically access spectrum holes temporally unoccupied by the first user within the countryside of interest as shown in fig 1. The Cognitive radio works on dynamic spectrum management principle which solves the issue of underutilization of spectrum in wireless communication.

II. SPECTRUM SENSING TECHNIQUES

This is one of the major issues with the cognitive radio. This is the first stage in cognitive radio where the radio scans the entire frequency band for an active signal [4]. There are 2 main application of spectrum sensing 1. Scanning for white spaces (spectrum holes) 2. Scanning for primary user signal. First one is typically for the transmitter design where system looks at a range of frequency spectrum and uses some algorithm to decide if there is any white space and if so, where is it on the spectrum and will allow the system to transmit without interfering another existing signal at the same frequency. And second is found in receiver system where the purpose is to detect any active signal both part form a complete transceiver system. Spectrum sensing techniques are classified as follows [5]-[6]:

They are broadly classified into three main types, cooperative sensing, non-cooperative sensing and interference based sensing.

1. Non –Cooperative Techniques: In this technique the each CR senses its data and uses that data to identify whether the channel is idle or busy. This technique includes primary transmitter detection where in the detection of signal from the primary transmitter based on the received signal at the CR users is done to detect the presence of the primary users, this kind of approach

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includes energy detection, matched filter detection and cyclostationary feature detection.

2. Cooperative Detection Techniques: Unlike the Non-Cooperative CR shares its sensing data with other users and utilize the sensing outcomes of others to give the decisions about the detections, here the primary signal for spectrum are detected by cooperating among the coexisting users .This method can be implemented as either centralized access to the spectrum coordinated by spectrum or the decentralized or distributed approach.

3. Interference Based Sensing Technique: The working principle of this model is as UWB technology wherein the CR and Pus are allowed to simultaneously transmit with low power and is restricted by the temperature level and hence no interference is caused to the Pus.

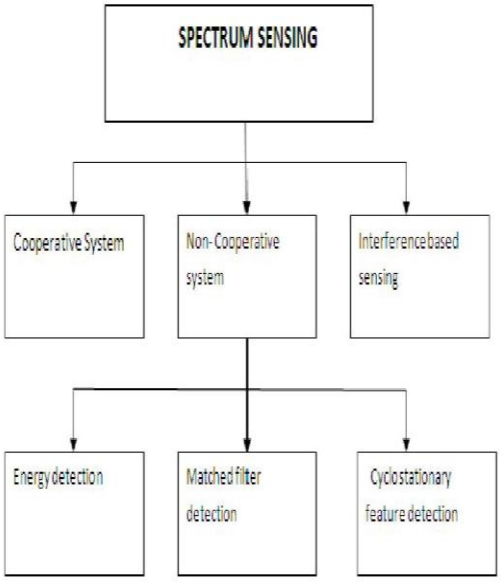

Fig 2. Spectrum Sensing Techniques

A. Non Cooperative Techniques

1 Energy Detection Technique:

It is the signal detection mechanism where it uses energy detector to specify the presence or absence of the signal in the band, this energy detector can implemented in time or frequency domain either by using simple FFT or Periodograms or it can be implemented using wavelet transforms[7]-[9].

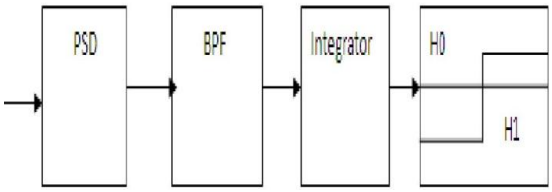

Fig 3. Block Diagram for Energy Detection

Where H0 = absence of Primary User,
H1= Presence of Primary User.

The total energy of the received signal is first detected and threshold value is set that is then compared with the energy and based on the decision if the energy of the signal is greater or less than the threshold the decision will be made in the favour of presence or absence of the primary users. Block diagram for energy detection is shown as fig 3.

In this method the signal is passed through BPF of bandwidth W and that is integrated over time period and output of integrator block is then compared with the predefined threshold and based on this comparison the presence and absence of primary users can be detected. Energy detection can be expressed as following:

$$Y(k) = n(k) \ldots\ldots\ldots\ldots H0 \quad (1)$$

$$Y(k) = h * s(k) + n(k) \ldots\ldots H1 \quad (2)$$

Where y (k) is the sample to be analyzed at every instant k and n(k) is the noise of the variance σ^2 , let Y(k) be sequence of the received samples for k={ 1,2,…..N} at the signal detector, then a decision rule can be stated as

$$H0 \ldots. \text{if } \varepsilon > V \quad (3)$$

$$H1 \ldots. \text{if } \varepsilon < V \quad (4)$$

Where, $\varepsilon = E|Y(k)|^2$ the estimated energy of the received signal and V is chosen to be the noise variance of σ^2.

Advantages:
1. No need of prior knowledge of primary signal energy.
2. It is simple technique.

Disadvantages:
1. Sensing time taken to obtain a given probability of detection will be high.
2. This cannot be used to detect spread spectrum signal.

2. Matched filter Detection Technique:

It is a linear filter that is devised to obtain maximum signal to noise ratio for a given input signal. To apply the matched filter detection technique secondary users must have a prior knowledge of primary user signal. It works alike correlation in which the unknown signal is convolved with the filter whose impulse response is time shifted and the mirror image of the reference signal. Block diagram for matched filter is as shown in fig 4

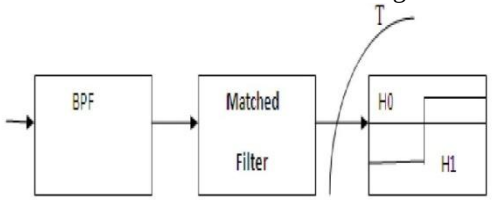

Fig 4. Block Diagram for Matched Filter Detection

Where H0 = absence of Primary User
H1= Presence of Primary User.

Matched detection can be expressed as following

$$Y[n] = \sum h[n-k]\, X[k] \quad (5)$$

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

Advantages: Matched filter detection desires less detection time as it requires only O (1/ SNR) samples to meet a given probability of detection restraint, when the knowledge of primary user signal is known to cognitive radio user.

Disadvantages: Matched filter detection requires previous information of every primary signal. If the information is

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not accurate, it performs poorly; another important disadvantage of MF is that a cognitive radio requires a dedicated receiver for every type of the primary user.

3. Cyclostationary feature detection

This technique is based on periodicity of the signal. The signals that are used in several applications are generally coupled with sinusoidal carriers, spreading codes etc. which results into a periodicity of their statistics like mean and auto-correlation.

Thus, primary signals which have this periodicity can be easily detected by obtaining its correlation. Fourier transform of the correlated signal results the peaks at frequencies which are specific to a signal and presence of primary users are determined by these peaks. Block diagram for cyclostationary feature detection is as shown in fig 5.

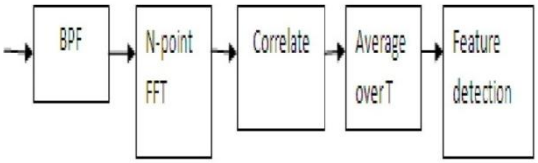

Fig 5. Block Diagram for Cyclostationary Feature Detection

The received signal is given in form of

$$Y(n) = S(n) + w(n) \quad (6)$$

Advantages:
1. Works well at low SNR conditions.
2. It can distinguish between primary users signal & noise.

Disadvantage: 1.Since all the cycle frequencies are calculated so the computational complexity is higher.

B. Cooperative Techniques

1. Decentralized Uncoordinated Technique

In the uncoordinated technique the cognitive radio will independently detect the channels and vacant the channels where it finds the primary user without informing other coexisting users.CR users will detect incorrect channels there by interfering the primary users.

2. Centralized Coordinated Technique

This technique uses a cognitive radio controller as the cognitive radio detects the presence of primary users the controller informs the other cognitive radio users using some broadcast methods.

3. Decentralized Coordinated Technique

This coordination technique helps in building a cognitive radio network without having a controller in it.

Advantages of Cooperative techniques**:** The CR users cooperate to sense the channel and have lot of benefits among which various sensitivity requirements - channel impairment like shadowing, multipath fading and penetration losses, impose high sensitivity requirement are limited by cost and power requirement.

Disadvantage of Cooperative techniques: CR users need to perform sensing at periodic intervals of time. Due to the factors like mobility, channel impairment etc the information becomes fast .

C. Interference based Technique

Interference occurs at the receivers and is controlled at the transmitter through location of individual transmitter and radiated power. A model for interference temperature is as shown in fig 6.

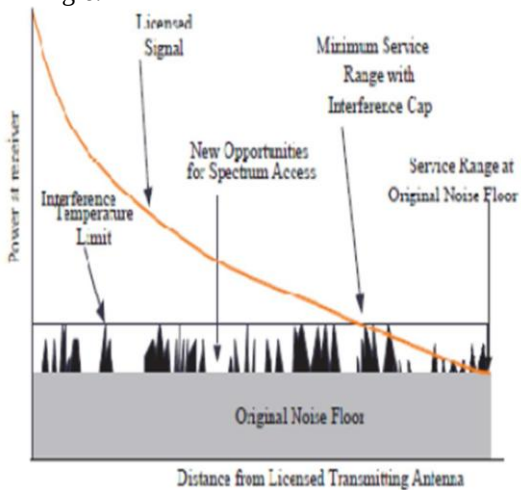

Fig 6. Model for Interference Temperature

The working principle of this technique is same an UWB technology, when the CR users are allowed to coexist and transmit at the same time with primary users (PU) exploiting low transmit power. The notion behind the interference temperature management is to set up an upper limit of interference for the given frequency band in specific geographic location such that the Cognitive Radio users are not allowed to cause harmful interferences while using the specific band in specific location. The interference temperature level restricts the transmit power that causes no harmful interference to primary users occur.

III.DYNAMIC SPECTRUM ALLOCATION

Dynamic spectrum access is the most vital application of cognitive radio, PU bands are opportunistically accessed by the SU network such that the interference caused to PUs is negligible. The methods of assigning different fixed bandwidth to different systems are not producing the full benefits of having dynamically shared bandwidth for different system only as and when they need them, when PU wants to start transmission, CR enabled device free that band and switch to another band. Main objective of dynamic spectrum access is to overcome two types of interferences [10]-[11]:

1. Harmful Interference caused by the device malfunctioning.
2. Harmful Interference caused by malicious user.

In contrast to the static spectrum access, dynamic spectrum access (DSA) is widely used in cognitive network and having various approaches and applications.

There are two main functions which are following:

1. Spectrum Awareness: Creates awareness about radio frequency surrounding when spectrum access provides the different ways to utilize the available spectrum opportunities to reuse it efficiently.
2. Cognitive processing: It's the intelligence and decision making capability which performs many subtasks like learning of radio surroundings planning sensing

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economical and access polices that manages interference for being of secondary user network with primary user network.

Dynamic spectrum access approaches can be classified as shown in fig 7.

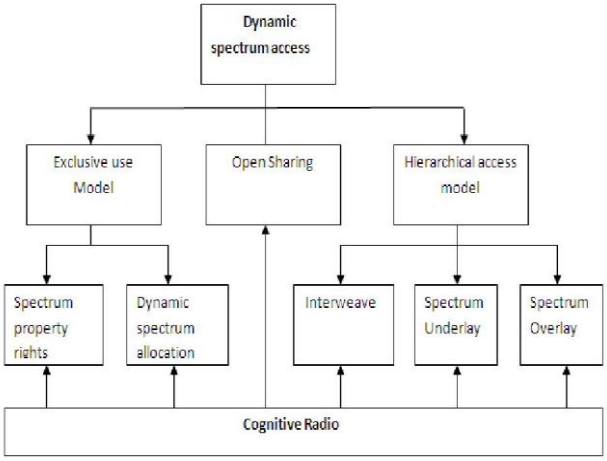

Fig 7. Dynamic Spectrum Allocation Approaches

They are broadly classified into Exclusive use model, open sharing model and hierarchical access model.

A. Exclusive Use Model

The basic structure of the present spectrum regulation policy is maintained in this particular model: Spectrum bands are authorized to services for exclusive use. The main idea here is to enhance spectrum efficiency by introducing flexibility. There are two approaches present in this model: i) Spectrum property rights and ii) dynamic spectrum allocation. Spectrum property rights approach permits license to sell and trade spectrum and to decide technology freely. Dynamic spectrum allocation approach aims to get the better efficiency of spectrum through dynamic spectrum assignment by means of the spatial and temporal traffic statistics of different services.

B. Opening Sharing Model

Open sharing model is also called as spectrum commons model. In this model, each user has equal rights to utilize the spectrum. This is also known as open spectrum model that has been successfully functional for wireless services which operate in the unlicensed industrial medical(ISM) and scientific, radio band (e.g., WLAN). There are three types of spectrum commons models:

- Uncontrolled –common: When a spectrum band is managed and uses the uncontrolled commons model, there is no entity that has exclusive license to the spectrum band.
- Managed- common: Managed-commons represent an effort to avoid the misfortune of commons by imposing a limited form of structure of spectrum access. This is resource which is controlled by a group of individuals or entities and characterized by limitations on when and how the resource is used.
- Private –common: The concept of Private Commons was introduced by FCC in its Second Report on the elimination of barriers to growth of Secondary markets for spectrum. This concept grows on allowing use of advanced technologies that enables many users to access the spectrum.

C. Hierarchical Access Model

In this model, SUs use the primary resources such that the interference to the Primary User is limited, there are 3 approaches in this model which are following:

- Inter-weave: This inter-weave model is based on the concept of re-using the spectrum in the spatial domain i.e., the primary spectrum is used by CRs in those geographical locations where primary activity is absent. Development of thus known as "spatial spectrum holes" is attracting an interest, since many current licensed systems like, e.g., TV broadcasting and cellular systems.
- Underlay: An Underlay technology operates within the used spectrum at a very low power level for other licensed or license excused users however doesn't impair the users. Underlay access allows the CRs to operate below the noise floor of the PUs, without the PUs being aware of.
- Overlay: This approach allows higher powers that results interference to existing users but overcomes this possibility by permitting transmissions at different times or areas where the spectrum is currently unused.

IV. CONCLUSION

As the usage of frequency is increasing day by day, it is becoming more valuable and necessary to utilize the spectrum efficiently and effectively, to meet this issue we have used Cognitive Radio with dynamic spectrum allocation since static spectrum allocation is no more a solution. This paper gives an overview of Cognitive Radio, its functions, different techniques for spectrum sensing which is a major challenge of Cognitive Radios, and different approach models for dynamic spectrum access for a Cognitive Radio.

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