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Utilization Methods of Frequency Spectrum and It's Dynamic Allocation

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

Keywords— Cognitive radio, spectrum sensing, dynamic spectrum access.

I. INTRODUCTION

The increasing demand in wireless communication has introduced efficient spectrum utilization challenge and to address this challenge the Cognitive radio came into existence. Cognitive radio was officially presented by Joseph Mitola in 1999 and this concept has been popular with research in different fields such as telecommunication ,according to him it is defined as " a radio that employs model-based reasoning to achieve a specific level of competence in radio-related domain[1] ".CR is a form of wireless communication in which a transceiver can detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. Cognitive radio can modify various parameters autonomously for the communication purposes without the need for the user intervention. The main goal is to overcome the problem by proposing an opportunistic spectrum usage approach [2], where in the frequency bands that are not used by the primary users can be utilized by secondary users without interfering the primary users. Cognitive radio is incoorpated with following functions [3]

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

Among these, spectrums sensing is the most crucial and considered as the major challenge which acts to detect the presence or absence of primary user signal in cognitive radio system. Overall spectrum utilization can be improved significantly by allowing secondary unlicensed users to dynamically access spectrum holes temporally unoccupied by the primary user in the geographical region of interest as shown in Fig 1.

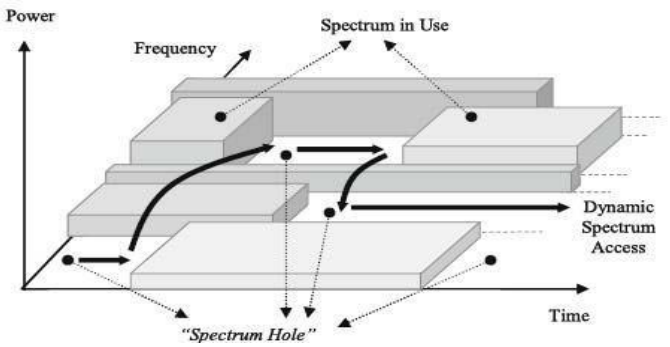

Fig 1. Spectrum holes

The Cognitive radio works on dynamic spectrum management principle which solves the issue of underutilization of spectrum in wireless communication.

II. SPECTRUM SESNING 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.

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Spectrum sensing techniques are classified as follows [5]-[6]:

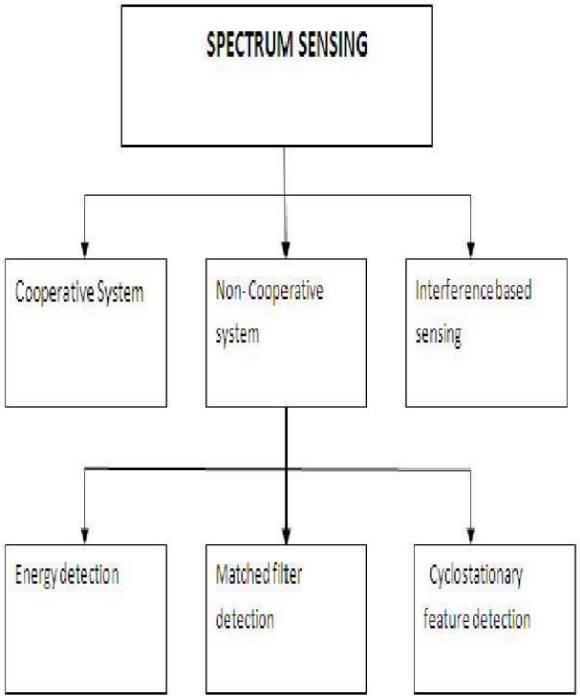

Fig 2. Spectrum sensing Techniques

They are broadly classified into three main types, transmitter detection or non cooperative sensing, cooperative sensing and interference based sensing. Transmitter detection technique is further classified into energy detection, matched filter detection and cyclostationary feature detection.

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

2. Coopertaive Detection Techniques: Unlike the Non-Cooperative CR shares its sensing data with others users and utilize the sensing outcomes of others to give the decisions regarding 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 spectrum coordinated by spectrum or the decentralized or distributed approach.

3. Interference Based Sensing Technique: CR system works as in the UWB technology where SUs will exit along with PUs and are allowed to transmit with the low power and restricted by the interference temperature so as not to cause the primary users.

A . Non cooperative techniques

- *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]. The total energy of the received signal is first detected and threshold value is set that is then compared with the energy if the energy of the signal found to be greater than the threshold then the decision will be made in the favour of presence of primary users else it will be the favour of absence of primary users. Block diagram for energy detection is shown as Fig 3.

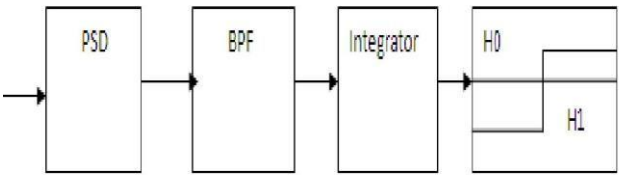

Fig 3. Block diagram for energy detection

Where H0 = absence of PU, H1= Presence of PU.

In this method the signal is passed through band pass filter of bandwidth of W and integrated over time period and output of integrator block is 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 each 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:-

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1. Sensing time taken to achieve a given probability of detection may be high.
2. This cannot be used to detect spread spectrum signal.

- *Matched filter Detection Technique*

A matched filter (MF) is a linear filter that is designed to obtain maximum the output signal to noise ratio for a given input signal. When secondary user has a priori knowledge of primary user signal, matched filter detection is applied. Matched filter operation is same as correlation in which the unknown signal is convolved with the filter whose impulse response is the mirror and time shifted version of a reference signal. Block diagram for matched filter is as shown in Fig 4.

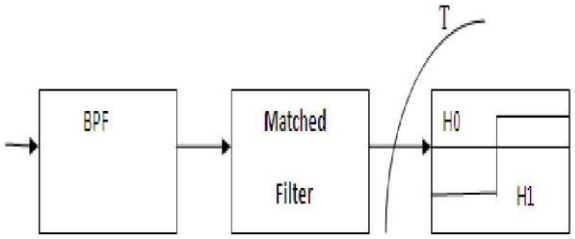

Fig 4. Block diagram for matched filter detection

Where H0 = absence of PU, H1= Presence of PU.

Matched detection can be expressed as following

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

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

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

Disadvantages: Matched filter detection requires a prior knowledge of every primary signal. If the information is not accurate, MF perform poorly, another important disadvantage of MF is that a cognitive radio would need a dedicated receiver for every type of primary user.

- *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 these periodicity can be easily detected by obtaining its correlation. Fourier transform of the correlated signal results in peaks at frequencies which are specific to a signal and searching for these peaks helps in determining the presence of the primary user. Block diagram for cyclostationary feature detection is as shown in Fig 5.

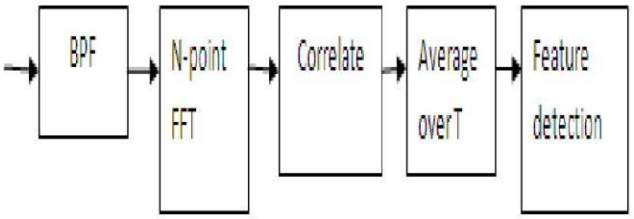

Fig 5. Block diagram for cyclostationary feature detection

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 and noise.

Disadvantage:

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

2. Cooperative techniques

- *Decentralized Uncoordinated Technique*

In the uncoordinated technique the cognitive radio will be independently detects 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.

- *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.

- *Decentralized Coordinated Technique*

This type of coordination techniques implies in building a cognitive radio network without having a controller in it.

Advantages of Cooperative techniques**:** The CR users cooperating to sense the channel have lot of benefits among which various sensitivity requirements - channel impairment like multipath fading, shadowing 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 as the sensed

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information became fast due to factors like mobility , channel impairment etc.

3. 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.

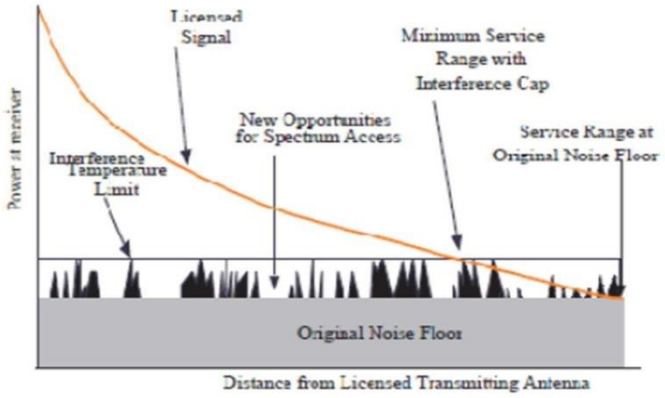

Fig 6. Model for interference temperature

The working principle of this technique is like an UWB technology, when the CR users are allowed to coexist and transmit simultaneously with primary users (PU) using low. The basic idea behind the interference, the interference temperature management is to set up an upper interference limit for given frequency band in specific geographic location such that the CR users are not allowed to cause harmful interference while using the specific band in specific area Transmit power is restricted by the interference temperature level as a result no harmful interference to primary users does not occur.

III. DYNAMIC SPECTRUM ACCESS

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 comparison 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 environment when spectrum access provides the ways to use the available spectrum opportunities for reuse efficiently.

2. Cognitive processing: It is the intelligence and decision making function that performs several subtasks like learning of radio environment designing sensing efficient and access polices which manages interference for coexistence of secondary user network with primary user network.

A. Different approaches of Dynamic spectrum access

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

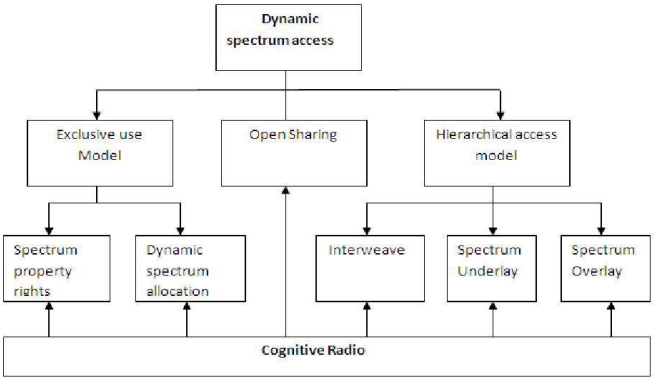

Fig 7. Dynamic spectrum access approaches

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

1. Exclusive Use Model

The basic structure of the current spectrum regulation policy is maintained in this model: Spectrum bands are licensed to services for exclusive use. The main concept is to improve spectrum efficiency by introducing flexibility. Two approaches have been considered under this model: i) Spectrum property rights and ii) dynamic spectrum allocation. Spectrum property rights approach allows licensees to sell and trade spectrum and to choose technology freely. Dynamic spectrum allocation approach aims to improve the efficiency of spectrum through dynamic spectrum assignment by using the spatial and temporal traffic statistics of different services.

2. Opening Sharing Model

Open sharing model is also called spectrum commons model. In spectrum commons model, every user has equal rights to use the spectrum. This is also known as open spectrum model, has been successfully applied for wireless services which operates in the unlicensed industrial scientific and medical (ISM) radio band (e.g., WLAN). Open sharing among users as the foundation for

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managing a spectral region used by this model. There are three types of spectrum commons models:

- Uncontrolled –common: When a spectrum band is managed and uses thus uncontrolled commons model, no entity has exclusive license to the spectrum band.
- Managed- common: Managed-commons represent an effort to avoid the tragedy of commons by imposing a limited form of structure of spectrum access. This is resource which is owned or controlled by a group of individuals or entities and it characterized by restrictions 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 development of Secondary markets for spectrum. This concept grew on allowing use of advanced technologies which enable multiple users to access the spectrum.

3. Hierarchical Access Model

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

- Inter-weave: The inter-weave model is based on the idea of on opportunistic re-use the spectrum in the spatial domain i.e., the primary spectrum is utilized by CRs in the geographical areas where primary activity is absent. Exploitation of the so called "spatial spectrum holes" is attracting an interest, since many current licensed systems like, e.g., TV broadcasting and cellular systems.
- Underlay: Underlay technologies operate in the used spectrum at a very low power level for other licensed or license exempt uses but does not impair the users. Underlay use is not licensed. Underlay access ideated CRs to operate below the noise floor of the PUs, involving an undercurrent of Cognitive Radio communications without PUs being aware of.
- Overlay: An overlay approach allows higher powers that could result interference to existing users but overcomes this possibility by only permitting transmissions at 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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