A Review on Spectrum Sensing Approaches in Cognitive Radios

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***Abstract*—** The frequency spectrum is limited resource to accommodate the large number of users. Therefore it is necessary to efficiently utilize it so that the demands of upcoming generation can be fulfilled. In ordinary system, fixed spectrum accessing technique is used hence it cannot lead to optimum utilization of spectrum. So in order to efficiently utilize the scarce resource i.e. frequency band the new technique is introduced i.e. dynamic spectrum access (DSA) method. To attain the dynamic access to the spectrum the Cognitive radio can be use. The CR can reuse those frequency bands which are already occupied by the licensed user. In this paper the Cognitive radio is studied with different sensing techniques that can be used by CR. CR comprises of smart trans-receiver that can sense the state of channel whether in idle state or used state. When the idle channel is detected then it acquires the free channel. Cognitive radio permits the creation of infrastructure less network.

Keywords— *Opportunistic spectrum access (OSA), Spectrum sensing (SS), Cognitive radio (CR), Dynamic spectrum access (DSA), Inter-symbol interference (ISI).*

I. INTRODUCTION

Usually in wireless transmission system, the right to acquire the particular frequency band given on the basis of different parameters like power required for transmission, owner of spectrum or licensee, type of use, and time period of license. Generally, single license is provided to one licensee and the type of use of particular frequency band which is assigned to licensee must be specified in the license. In ordinary spectrum licensing method, features like change in type of use and facility to transfer the rights to another licensee was not provided. Furthermore, the license is provided for larger frequency bands. All the features which are mentioned above used in spectrum allocation technique may lead to inefficient utilization of spectrum. As the newly developed applications require high transmission capacity with enhanced transmission rate, therefore it is required to create the new methods that can improve the spectrum utilization. In order to obtain the optimum utilization of spectrum it is necessary to overcome the limitations that are mentioned above by adding the new features in ordinary spectrum licensing technique and by implementing the dynamic spectrum allocation model. The main objective is to make access to particular frequency band flexible by permitting the secondary users to acquire the radio spectrum under some conditions. As the ordinary wireless transmission system was created to operate on particular frequency band, hence this spectrum licensing technique cannot use the flexible features of new spectrum licensing method. Hence, the idea of Cognitive Radio was introduced whose main objective is to provide flexibility to wireless communication system by using dynamic spectrum accessing technique so that the spectrum can be effectively utilized and also the benefits associated with static spectrum allocation technique will remain un altered.

II. COGNITIVE RADIO

The Cognitive Radio may be described as "intelligent radio" as it can sense the channels that comprise of different types signals. Based on this sensing mechanism, the CR will use different paradigms so that the frequency allocated to primary users can be reused by secondary users in such a way that it will not create any type of interference with the primary or licensed user. Therefore, the Cognitive radio uses the concept of multiple accesses through different devices in different radio spectrum and by implementing the various radio transmission methods. The cognitive radio can determine its operational EM environment and therefore can adjust its parameters accordingly to alter the system operation such as increasing the output, eliminate interference, provide interoperability and can access secondary market.

Various functions of cognitive radio are as follow: **Spectrum sensing and Analyzing**: The Cognitive radio identifies the spectrum which is currently in use by the primary user or licensed user.
Spectrum management and Handoff: choose the optimum channel that can be used for transmission of data.

- **Spectrum sharing and Allocation:** the fair means of access to the spectrum is coordinated with the selected channel.
- **Spectrum mobility:** Relieve the channel if the primary user is detected and simultaneously maintain the continuous communication by searching another available channel.

Approaches for accessing Licensed Spectrum
To access the licensed spectrum by the secondary or unlicensed users, three types of methods are generated and are described below:

- **Opportunistic spectrum access (OSA):** It is also referred as interweave technique. If any frequency band is detected which is idle that means not used by licensed user then only the secondary user will access it [14].

- **Spectrum sharing (SS):** It is also referred as underlay technique. In this method both the primary user and secondary user simultaneously using the same frequency under the condition that they will not interfere with each other [15-16].
- **Hybrid approach**: This technique was recently proposed. In this technique the above mentioned techniques are integrated and this has resulted in optimum utilization of spectrum. In hybrid approach firstly the unlicensed user sense the status of frequency band (whether idle or active) and then decision taken by radio in such a way that the interference should not takes place [19].

In Cognitive radio the spectrum sensing plays vital role. Therefore, it is very important to develop an efficient spectrum sensing technique. Different spectrum sensing techniques are described below along with their merits and de-merits.

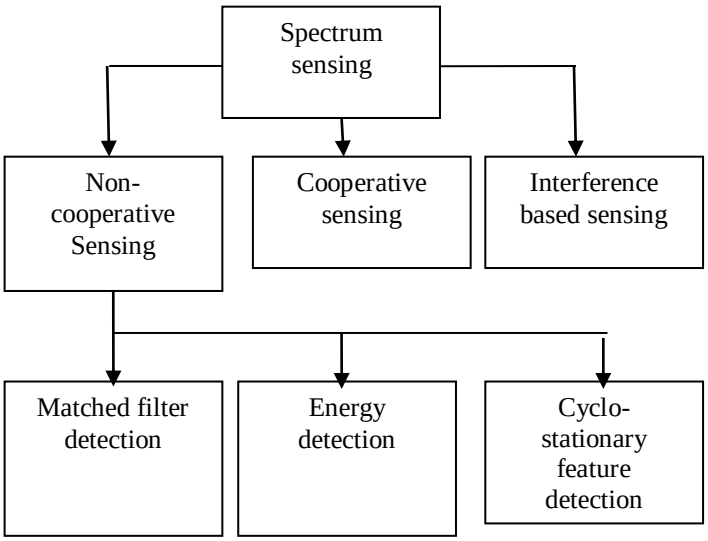


Fig.1: Spectrum Sensing Techniques

III. CLASSIFICATION OF SPECTRUM SENSING TECHNIQUE

The spectrum sensing technique can be categorized into two parts:
1. Cooperative Detection Technique.
2. Non-cooperative Detection Technique.

1. Cooperative Detection: In this technique different Cognitive radios exchange their information regarding the spectrum sensing so that more efficient data can be collected to get optimum results. Now this information about channels state collected by unlicensed users and represents this data in bit vector form on spectrum map. The unlicensed users transmit this data after regular interval of time to central coordinator. The data received by central coordinator in form of bitwise-OR, to identify the set of ultra high frequency channels available at each node. Then the Coordinator chooses the optimum channel and transmits it back to primary users. This method implements the spatial diversity technique in multi user environment and this can be done in two ways: centralized and distributed way. [5]

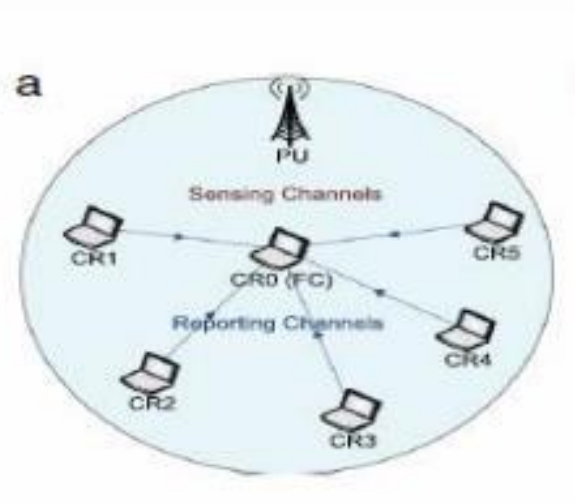
Cooperative sensing approach can be divided into further three parts:

a**) Centralized approach:** In this type of cooperative spectrum sensing technique the information regarding the channels from all the sense nodes is gathered by the central processor also known as fusion centre. After this it evaluates the gathered information and identifies the frequency that can be utilized. [8]

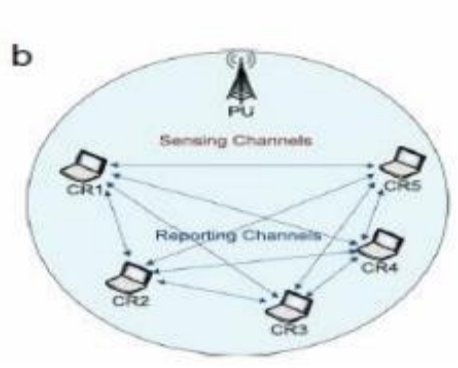
b) Distributed approach: In this type of spectrum sensing technique there is no requirement of fusion centre or central processor. Here the data transmitted among various nodes and exchange the information related channels state. Although this technique requires that each radio has high level of autonomy [9]

c) Relay-assisted cooperative: Along with the above mentioned cooperative sensing techniques, there is one more technique that is relay assisted cooperative sensing. As both sensing and report channel are not ideal, therefore the Cognitive Radio user identifies weak sensing channel and strong report channel or vice versa. It can complement each other in order to enhance the operation of cooperative sensing in cognitive radio. If it is required to transmit the data gathered after sensing through multiple hops to reach the destination node, then all the in between hops are relays. Hence, the centralized approach and distributed approach uses one hop for transmission and relay assisted approach uses multiple hops for transmission of information to reach the required node.

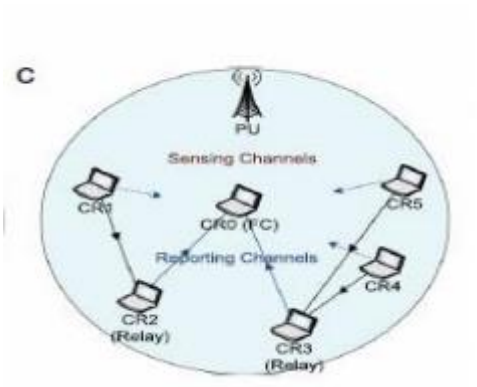
2. Non-Cooperative Detection: In this Detection method, all the radios are self responsible to perform spectrum sensing in order to collect the information regarding channels state [10].



a) Centralised cooperative sensing technique[30]



b) Distributed cooperative sensing technique[30]



c) Relay-assisted cooperative sensing technique [30]

Fig.2: classification of cooperative sensing technique

a) **Blind Sensing**: this technique there is centralized controller called as fusion centre. The whole sensing information of network is stored in it. After that it determines the appropriate frequency that can be utilized.

1. **Energy Detector based sensing**: In case if receiver unit is not able to collect the required amount of data related to licensed users and only the power information of random Gaussian noise is gathered by receiver, then the optimal detector used here is energy detector. It is very easy to determine the amount of energy by implementing the Fast Fourier Transform paradigm. Although, various de-merits are also associated with this technique. First one is that the value of signal to noise varies due to decision threshold. The second disadvantage is that it cannot determine the interference signal. Now the third one is that it cannot be implemented on those signals whose is not optimum for signals whose power has been spread over whole bandwidth [17].

2. **Eigen value based Sensing**: In the received signal, the Eigen value obtained from the covariance matrix can be used for the initial detection. By implementing random matrix theory, the ratio of the max to min Eigen value can be quantized and one value out of various obtained values can be selected as detection threshold level. [3, 4]

3. **Covariance based Sensing:** the statistical covariance matrices of received signal and matrix obtained from noise signal are usually different. By implementing this difference, it is possible to find out the difference between the desired value of signal and noise in background. [6, 7]

b) **Signal Specific:** In this sensing technique, information related to licensed user is pre-requisite.

1. **Waveform based Sensing**: This technique is only applied to those systems that have known signal shape and that can be preambles, periodically transmitted pilot patterns; spreading sequences and etc. this type of sensing technique can also be described as waveform based sensing technique or coherent sensing. This sensing technique is highly efficient as compare to the detector based sensing technique in terms of reliability and time required for convergence. Moreover, it can be observed that efficiency of sensing paradigm is directly proportional to the length of the signal pattern [11-13].

2. **Transmitter Based Sensing**: This technique uses the CR attempts to distinguish between the free or used areas frequency spectrum by identifying whether the licensed user is transmitting in its surrounding area. This technique is based on the determination of the weakest signal in the surrounding instead of strongest signal. The basic concept used in it is that the weakest signal generating device probably be distant away from CR, but yet vulnerable to interference from the signal generated by Cognitive radio. H0 depicts null hypothesis, it describes that in a particular band the licensed users does not exist. H1 depicts alternative hypothesis, it states that in particular channel few primary users exist. This type of sensing technique can be further divided into three types and that is explained below:

- Energy sensing
- Matched filter sensing
- Cyclostationary based sensing

3. Radio Identification Based Sensing: This technique modifies the ordinary way to study interference which generally moves around the transmitter. Generally, the interference is controlled by the regulating the amount of power produced by transmitter, by preventing the transmission of signal beyond the limits from transmitter unit. In CR based identification the main focus is at the analysis of interference at the receiver end. The novice method of analyzing the interference introduced by FCC is referred as interference temperature. In this technique, the cumulative energy acquired from large number of transmissions and set the limit at the level obtained after adding different energy levels. Now this obtained threshold level is used by the secondary users. If the transmission power of CR within the limit of threshold then secondary users can use the particular frequency band. Main problem associated with this technique is that the interference cannot be analyzed effectively unless the users of CR are aware of accurate position of surrounding licensed users.

IV. RELATED WORK

Lu Yang (2014), "OPPORTUNISTIC USER SCHEDULING IN MIMO COGNITIVE RADIO NETWORKS"[7] In uplink transmission with MIMO cognitive radio network had been studied in this paper for various users. Under scheduling paradigm, two stages had been presented in this paper. Take the first stage: the shape generated by the CR beam in such a way that the interference due to unwanted signals can be removed effectively from the part of spectrum which had been taken by the licensed MIMO system. After that, various unlicensed users that create least interference leakage with primary users are already chosen as candidate of the system. After this considers the second phase, various candidate users that generate utmost sum secondary rate have been chosen for scheduling in uplink. The technique which had been projected in this paper had initiated the secondary link so that multiple users can operate simultaneously and also ensured that intervention in primary link was minimum. After analysis the results had shown that the proposed method is optimum.

Suzan Bayhan (2012), "Scheduling in Centralized Cognitive Radio Networks for Energy Efficiency"[10] As the problems related to environment has been increasing on large scale, so it is required to have an green communication algorithm and for that the cognitive radios need to be implemented. The main aim of this paper to focus on Cognitive Radio Networks, in this type of networks the cognitive BS used to assign the frequencies to the different cognitive radios when the frame is initiated. While scheduling, the variation in channel capacity of cognitive radios should take into consideration by the cognitive. Channel capacity of CR should be measured in number of bits. After looking at all these parameters, the scheduling algorithm was created to utilize the energy efficiently, the problem associated with it is nonlinear and also contain integer programming and therefore it was difficult to resolve. Another simpler technique was developed to make the calculation easy and simple. Focused at this objective, the polynomial time heuristic paradigm was projected in this paper. In other words, energy efficient heuristic scheduler (EEHS) had been introduced in this paper work; this assigned each unused frequency to cognitive radio which had achieved the maximum energy efficiency. After all this, the actual problem was taken as output increasing problem aimed at minimum energy consumption and after this the minimum energy consumption problem had been consider for guarantee for maximum rate of output. The above mentioned two types of schedulers helped in utilization of fair means for allocation of resource. At last the analysis had been done to examine the energy efficiency and optimum probability of communication of the projected schedulers and these had been consider for both continuous and fragmented situations. After analysis, form results it had been observed that the projected scheduler can acquire the required output and utilize very small amount of energy.

Vamsi Krishna Tumuluru, " A Novel Spectrum Scheduling Scheme for Multi-channel Cognitive Radio Network and Performance Analysis "[11] An opportunistic spectrum scheduling paradigm for multiple channel CR network had been described in this research work. The licensed user activity and signal to noise ratio at the receiver changes with the slot in the projected technique. When the frame is initiated then only scheduling is performed and this frame contains large number of slots. By this scheduling paradigm the approximate count of packets can be estimated that need to be forward over the frame by all unlicensed users for all licensed channel. The Markov chain formulation was presented over here in order to compute the probable count of packets that can be forwarded over the frame for an unlicensed user for all licensed channels. The central scheduler had assigned the licensed channels to the unlicensed user on the basis of this probable packet transmission. Main idea behind scheduling paradigm was to assign the licensed channels to improve the total output rate of unlicensed users. The proposed paradigm was differentiated with pre-defined dynamic spectrum access paradigms. The paradigm which had been suggested in this paper induce minimum overhead while scheduling and therefore maximum output can be obtained. The projected paradigm had been examined by implementing the Markov chain examination technique. The efficiency of projected scheduling paradigm had been estimated in terms of different parameters that were: average user output rate and blocking possibility

Rahul Urgaonkar ,(2008) ,"Opportunistic Scheduling with Reliability Guarantees in Cognitive Radio Networks"[12] In this research work, the scheduling technique for CR network had been proposed in this paper, which had increased the output rate of unlicensed users that had highest probability to collide with primary users. The CR network had been used here with fixed licensed users and varying unlicensed users. To create an online flow manager, scheduling and resource assigning technique which can attain the required demands and can provide optimum performance, the Lyapunov Optimization paradigm was implemented.

Danijela ýabriü, " A Cognitive Radio Approach for Usage of Virtual Unlicensed Spectrum"[13] It was observed that the practically the spectrum available for use is actually limited when all the frequency bands are assigned for particular applications and especially those frequency bands are limited which are above 3 GHz. Cognitive Radio technique for utilization of Virtual Unlicensed Spectrum (CORVUS). This method was based on a technique in which the CR had used the already assigned frequency bands in an effective way to formulate virtual band for secondary users in such a way that it should not create any type of interference with licensed users. Therefore, this technique was helpful in utilization of limited bandwidth in optimum way and large number of users can accommodate simultaneously. The Dynamic spectrum management approaches had been

implemented to utilize the local free spectrum. Here in this paper the basic necessities of CORVUS had been described along with basic architecture and physical layer operation.

V. CONCLUSION

For optimum utilization of limited bandwidth resource, the Cognitive radio with Dynamic spectrum allocation techniques can be used in wireless networks. It is a dynamic and promising approach that can improve the optimum use of spectrum. Cognitive Radio implement the opportunistic channel usage technique, it senses the available channel that can be allocate to secondary user. So, both secondary user and primary user are sharing the same frequency band simultaneously without creating any ISI inter-symbol interference. Hence in this way large number of users can be accommodated in limited spectrum. This technique of using the same frequency band simultaneously by different users is referred as Dynamic Spectrum Access (DSA).

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