A Survey on Spectrum Sensing Techniques for Cognitive Radio

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Abstract

Natural frequency spectrum is scared resource; the efficient use of it can only accommodate the need of future computing world. But efficient use of it is not possible within the existing system, where the allocation of spectrum is done based on fixed spectrum access (FSA) policy. Many surveys show that it leads to inefficient use of spectrum. For efficient utilization of spectrum innovative techniques is needed. Using Dynamic spectrum access (DSA) policy, available spectrum can be exploited. For given purpose Cognitive radio arises to be a tempting solution which introduces opportunistic usage of the frequency bands that are not heavily occupied by licensed users. This paper presents the study of different spectrum sensing techniques of cognitive radio networks. As matter of fact Cognitive radio is a form of wireless communication where radio transceiver intelligently detects which spectrums are free which are not. After this it occupies the vacant one while avoiding busy one. Cognitive radios promote open spectrum allocation which is a clear departure from traditional command and control allocation schemes for radio spectrum usage. In short, it allows the formation of "infrastructure-less" collaborative network clusters which is called Cognitive Radio Networks (CRN). However spectrum sensing techniques are needed to detect free spectrum. In this paper, different spectrum sensing techniques are analyzed with their respective pros and corns

Keywords- CRN, FSA, DSA, SU, PU

1. Introduction

Wireless and mobile technologies are growing so fastly, that leads to a complex spectrum usage along with inefficient utilization of radio electromagnetic spectrum. Wireless technology will be the backbone of the future computing world one in which a large number of communicators, mobile devices and sensors are connected to the global Internet and serve as the basic block for many new classes of applications. As we know that natural frequency spectrum is scared resource, the efficient use of it can only accommodate the spectrum demand of future computing world. The existing fixed spectrum access (FSA) policy is not suitable for it as it uses spectrum in very inefficient way because most of the time the channel bandwidth is remained unutilized due to less subscribers load on a Certain channel and only 6% (approx) of the radio electromagnetic spectrum is utilized. Graph based on Resent survey regarding partial use of spectrum in FSA scheme is show below in Figure1.

Finding of this serve suggest that for efficient utilization of spectrum innovative techniques is needed. One can offer new ways of exploiting the available spectrum by using Dynamic spectrum access (DSA) policy. For given purpose Cognitive radio may be a Tempting solution to the spectral congestion problem by introducing opportunistic usage of the frequency bands that are not heavily occupied by licensed users as we can see in figure 1.

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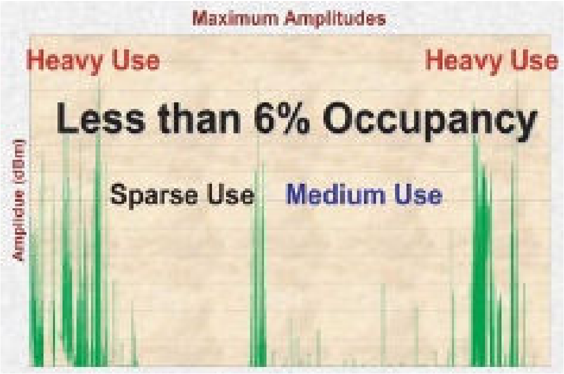

Figure 1 Spectrum usage [1]

Therefore cognitive radios are designed on the technique of Dynamic Spectrum access that allows cognitive user to detect the white space of licensed user to transmit its data on transmission link without destructive interference. So to construct the reliable and robust model there are two basic issues. First is, to device a efficient channel sensing algorithm and second is efficient utilization of detected spectrum holes.

Cognitive radio networking is a new concept in wireless communication in which the network or cognitive radio themselves changes their parameters to do their task efficiently without disturbing the other cognitive radio node. The cognitive radio system therefore used to define the efficient use of spectrum by allowing the Unlicensed user (secondary user) SU to access the spectrum allocated to licensed user (primary user) PU.

The channel efficiency is given as ratio of data rate and bandwidth.

$$Efficiency = \frac{Data\ Rate}{Bandwidth} \qquad (1)$$

To improve the channel efficiency there are two possible ways either increase the data rate or decrease the bandwidth. Given the limitations of the natural frequency spectrum, it becomes obvious that the current static frequency allocation schemes cannot accommodate the requirements of an increasing number of higher data rate devices .so cognitive radios came in to scene as in this sharing also take place and spectrum is efficiently utilized.

2. Dynamic Spectrum Access

Spectrum allocation policy allows a fix spectrum band to licensed user for a long term use. In this allocation of frequency spectrum a huge amount of allocated spectrum is remained unutilized .These unutilized frequency band is known as spectrum hole or white spaces. Dynamic spectrum access (DSA) is a new spectrum sharing technique that utilizes the spectrum holes and hence removes the spectrum scarcity problem as well as increases spectrum utilization. There are two basic elements of cognitive radio as analog RF front-end antenna and Digital processing engine, which may be a general-purpose processor, a digital signal processor (DSP), or a customized field programmable gate array (FPGA) board.Figure2 shows the different model for DSA as stated below:

2.1 Interweave DSA model: Interweave DSA Model is also known as opportunistic spectrum access [4] in which SU are required to utilized the white space .In this approach SU uses the cognitive radio to sense the radio environmental changes and Figure 2 illustrates the dynamics of spectrum availability and how SUs search and access idle spectrum bands with the interweave DSA model.

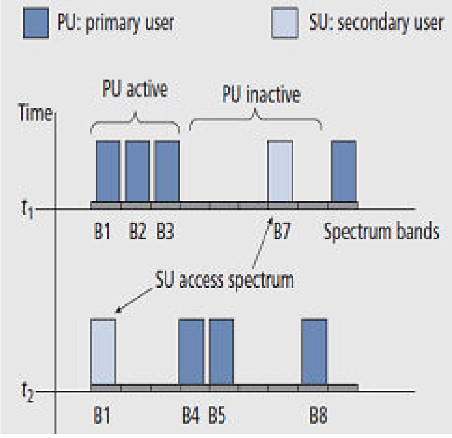

Figure 2 Interweave DSA Model [2]

2.2 Underlay DSA model**:** The underlay DSA model allows SUs to transmit their data on a licensed spectrum band regardless of the PU accessing the band or not, subject to a constraint that the accumulated interference from all SUs is tolerable by the PU, i.e., below some threshold. There are two ways to meet this constraint are as

In the first approach, the SU transmit power spreads over a wide range of spectrum such that the interference to the (narrowband) PU on each licensed band is well below the threshold. This is the approach used in the ultra-wide band (UWB) technology. This approach is basically for short range communications. The second approach is called interference temperature. With this approach, SUs can transmit with a higher power on a licensed spectrum band, as long as the total interference from all SUs on the band is below a threshold.

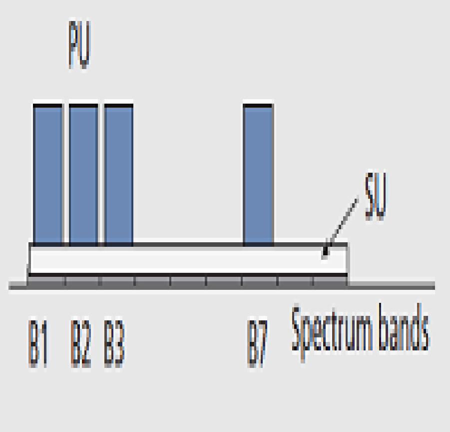

Figure 3 Underlay DSA Model [2]

2.3 Overlay DSA Model**:** This model is recently developed and it also allows the SU to transmit on licensed band regardless of whether PU is transmitting or not but constrains are different. The overlay DSA model targets maintaining the PU performance. SUs are allowed to transmit simultaneously with PUs as long as there is no performance degradation for PU. In the first approach for the overlay DSA model is to use channel coding. Particularly, when a PU transmitter is transmitting a PU packet that is known to an SU transmitter, the SU transmitter can split its transmit power into two parts, one to transmit its own (SU) packet, and the other to transmit the PU packet to enhance the total power received at the PU receiver, such that the signal to interference and noise ratio (SINR) [5] at the PU receiver does not degrade.

Second approach for the overlay DSA model is to use network coding. With this approach, an SU is used a relay node between disconnected or weakly connected PU nodes. While relaying a PU packet, the SU may encode an SU packet onto the PU packet through network coding, and hence the transport of the SU packet does not incur separate spectrum access, without affecting the PU performance.

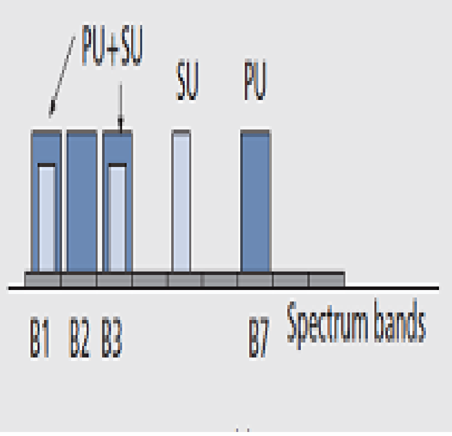

Figure 4 Overlay DSA Model [2]

3. Cognitive Radio System Architecture

There are three main components in the cognitive radio network as:

- ***Spectrum authorities*****:** These are the spectrum right owners, such as government who gives the right to the network operators for long term use.
- ***Primary Networks*****:** These are primary base stations and primary end users.
- ***Secondary Networks*****:** The secondary base stations dynamically request and access available spectrum of PU.

For using the spectrum of PU, SU make payments to primary users as an incentive for the primary users to borrow the licensed spectrum.

”A Cognitive radio is a system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets.” [6-8]

The basic cognitive radio network architecture [4] is shown in Figure 5which shows that spectrum authority gives permission to the network operators (primary users) to use the spectrum for a long period .Different secondary users (known as cognitive user) senses the spectrum that the PU is transmitting or not. Depending on availability that if not then SU sends request to secondary base station to use the spectrum of PU only if it is not transmitting.

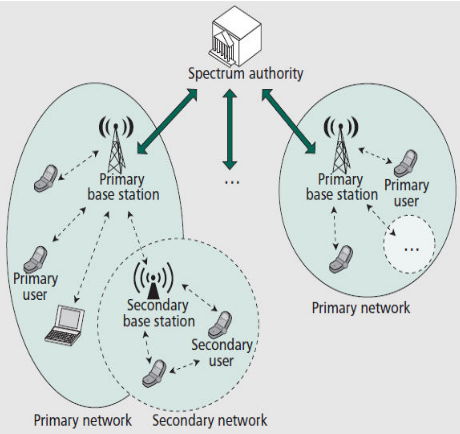

Figure 5 Cognitive Radio System Architecture [8]

> ***Cognitive radio** is "a type of radio in which communication systems are aware of their environment and internal state and can make decisions about their radio operating behavior based on that information and predefined Objectives" [9]-[11]*

4. Cognitivity

As the secondary user requests to primary network the reconfiguration of parameter takes place. The different steps under parameter reconfiguration and three *on-line* cognitive tasks are as stated:

- ***Radio-scene analysis***: It includes the estimation of interference temperature of the radio Environment and Detection of spectrum holes.
- ***Channel identification***: It includes the estimation of channel-state information (CSI) and prediction of channel capacity for use by the Transmitter
- ***Transmit-power control and dynamic spectrum management***: It includes the control of transmitted power and the management of dynamic spectrum. The two steps are done in the receiver, and last step is carried out in the transmitter. By the interaction with the RF environment the three tasks makes Cognitive cycle [11-16]**.** Figure 6 shows the cognitive cycle. Basically it is a closed cycle which actually controls the power required for transmission and also manages the dynamic spectrum.

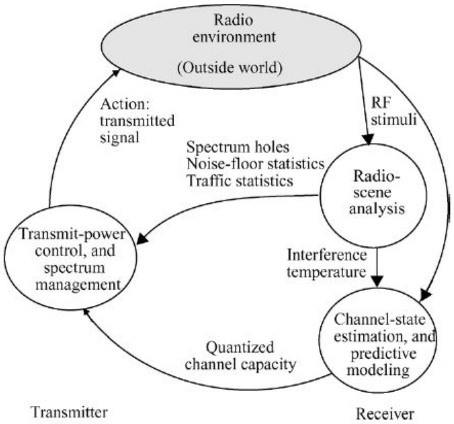

Figure 6 Cognitive Radio Cycle [6]

5. Basic block diagram of cognitive radio networks

The change in the technology of radios is shown in the Fig7. The cognitive radio has a extra block on comparing with software radio as named intelligence block which is having three main sub algorithms for sensing the spectrum learn the parameters and finally optimizing the system parameters for opportunistic reconfiguration[17] .

Due to the use of intelligent algorithm these automatically senses the parameters when comes in contact of radio environment and reconfigures the system parameters to adopt the spectrum of primary user[18-20].Figure7 shows the stepwise improvements of traditional radio.

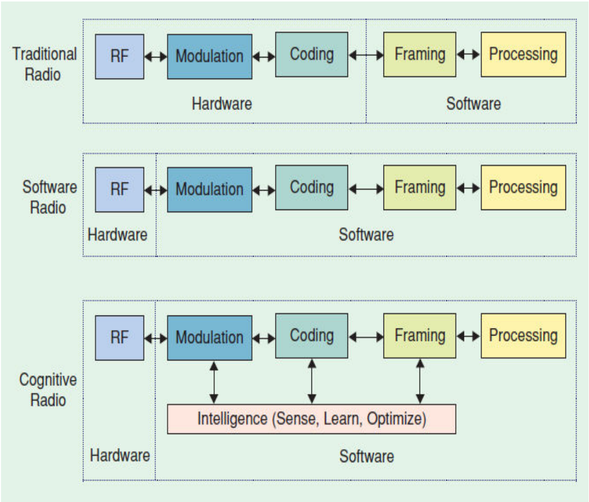

Figure 7 chain- wise improvement of cognitive radio [17]

6. Approaches for accessing Licensed Spectrum

Three main approaches have been developed for cognitive radio, regarding the way a secondary user accesses the licensed spectrum:

- ***Through opportunistic spectrum access*** **(OSA)**: It is also known as interweave scheme, according to which a secondary user accesses a frequency band only when it is detected not being used by the primary users [21-26]

- ***Through spectrum sharing (SS):*** It is also known as underlay scheme, based on which the secondary users coexist with the primary users under the condition of protecting the latter from harmful interference [27-28]

- ***Hybrid Technique:*** *A* new hybrid approach was proposed, aiming to increase the throughput of the two aforementioned schemes, in which the secondary users initially sense for the status (active/idle) of a frequency band (as in the OSA) and adapt their transmit power based on the decision made by spectrum sensing, to avoid causing harmful interference (as in SS) [29].

Whatever the approach is, it is clear that spectrum sensing is the key for all of them. Thus we can say that without highly accurate and accomplished spectrum technique it is very difficult to make competent Cognitive radio system. In this paper our discussion will revolve around different spectrum sensing techniques and their advantages as well as disadvantages.

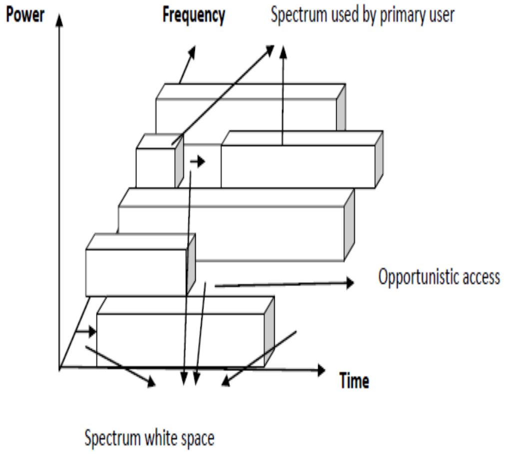

Figure 8 Illustration of spectrum white space [1]

7. Spectrum Sensing Techniques

The basic principle for spectrum sensing is shown in the figure 9, a licensed Tx sends data to its required Rx in a certain licensed spectrum band. A pair of CR users (CR Tx and CR Rx) intends to access the spectrum holes for secondary communication. [31-32]

To guarantee the protection of PUs, the CR Tx needs to perform spectrum sensing to find spectrum holes. In particular, the CR Tx is required to detect whether there is an active primary Rx inside the coverage of the CR Tx. If not, the CR Tx can safely transmit to the CR Rx using the identified spectrum hole [33-39]. Otherwise, the CR users are not allowed to use the band. Therefore, detecting the nearby primary Rx's can directly identify the spectrum hole, which is called direct spectrum sensing. [30]

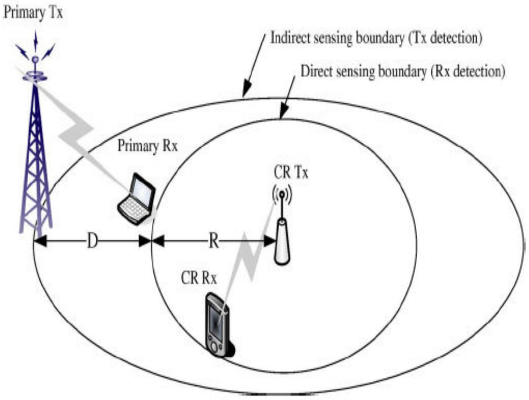

Figure 9 Principal of channel sensing [30]

Detection of a Rx is a challenging task, because the Rx usually does not transmit signals when it works. Thus, most of the existing spectrum-sensing schemes identify spectrum holes by detecting the primary Tx's . In the fig above let D be the transmission range of the primary Tx and R be the interfering range of the CR Tx. Then, the CR Tx needs to detect the presence of an active primary Tx within a distance $D + R$. If the distance between the primary and the CR Tx's is larger than $D + R$, there will be no active primary Rx inside the interfering range of the CR Tx, and then, the CR Tx can safely access the spectrum bands. Otherwise, the primary Rx may be inside the interfering range of the CR Tx and be interfered by its transmission. Therefore, detecting surrounding primary Tx's can also identify the spectrum holes, but in an indirect way, which is called indirect spectrum sensing. Indirect spectrum sensing requires a larger detection range from R to $R+D$ when compared to direct spectrum sensing technique. [39].

8. Classification of Spectrum Sensing Technique

We can broadly divide spectrum sensing techniques under two categories: Cooperative Detection Technique and Non-cooperative Detection Technique.

8.1 Cooperative Detection**:** In this method group of CR's share sensing *information* so as to get a more efficient result. In this process group of secondary user (Su) collect the information regarding channel occupancy and maintain this information into spectrum map represented by bit-vector. Su periodically transmit it to the Central Coordinator as part of control message. Central coordinator takes bitwise-OR of spectrum maps, to determine the set of UHF channels available at all of the nodes.

After that Coordinator select the best available channel and broadcast it back to SU. This technique exploits the spatial diversity intrinsic to a multi-user network. It can be accomplished in a centralized or distributed fashion. [41].There are broadly three approaches for cooperative spectrum sensing:

*8.1.1 Centralized approach***:** In this approach to cognitive radio cooperative spectrum sensing, there is a node called fusion center (FC) or central processor controls within the network that collects the sensing information from all the sense nodes or radios within the network. It then analyses the information and determines the frequencies which can be used.[42]

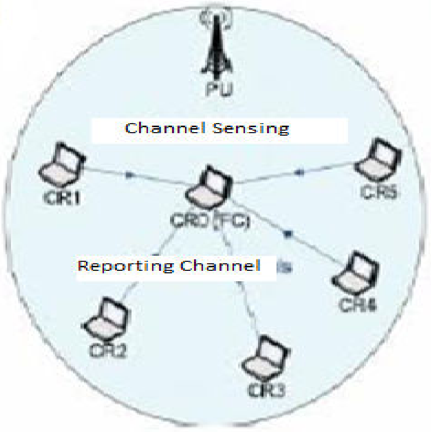

Figure 10 Centralized approach

*8.1.2 Distributed approach***:** In this approach distributed approach for cognitive radio cooperative spectrum sensing, no one node act as fusion center (FC) or central processor controls. Instead communication exists between the different nodes and they are able to share sense information. However this approach need individual radios to have a much higher level of autonomy, and possibly setting themselves up as an ad-hoc network.[43]

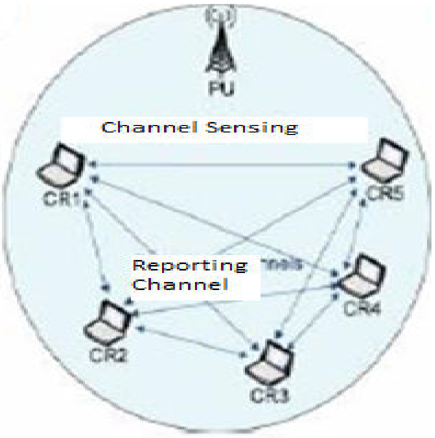

Figure 11 Distributed Approach

*8.1.3 Relay-assisted cooperative***:** Cooperative sensing techniques have been studied to remove the wireless fading and also when the multiple cognitive users sense independently the licensed primary channel using a detector algorithm and reports to the fusion center (FC).

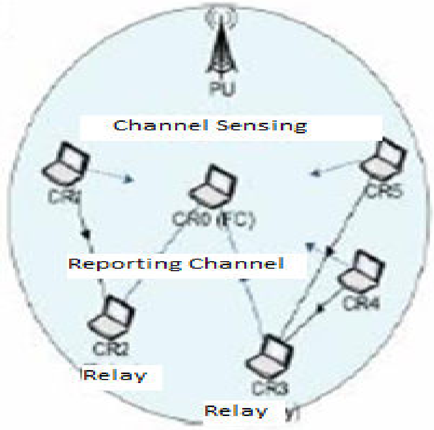

Figure 12 Relay-assisted cooperative approach

Generally two basic steps are involved in the cooperative sensing as:

- *Detection of PU*: In this phase of cooperative sensing all cognitive users' attempts to find out the primary unused channel.

- *Reporting*: In this the results of detection phase is reported back to the FC.

There is a big issue in the report phase that is when CUs send their initial results to FC there may be a interference with the PUs. To combat it selective relay based cooperative scheme came into the existence in which all CUs can send their detection results to FC without using a dedicated channel depending on a selective algorithm based on if absence of PU is detected or not..

If Kth CU detects absence of PU in its phase of detection then it starts to transmit a cyclic redundancy check (CRC)-coded indicating signal to the FC over the Lth orthogonal sub-channel of the primary channel, else nothing is transmitted from CU to avoid interfering with PU. On other side of FC, if the CRC checking is successful on the Lth orthogonal sub-channel, FC considers the absence of PU as the initial result detected by CU otherwise, it considers the presence of PU as the CU initial detection result [45-50].

U1 Tx	U2 Relay	U2 Tx	U1 Relay	------

Figure13 shows two user cooperative relay based a relay protocol [44]

8.2 Non-Cooperative Detection: In this Detection technique Individual radios act locally and autonomously to carry out their own spectrum occupancy measurements and analysis. [51]

There are broadly three approaches for non-cooperative spectrum sensing:

8.2.1Blind Sensing: In this approach to cognitive radio cooperative spectrum sensing, there is a node called fusion center (FC) controls within the network that collects the sensing information from all the sense nodes or radios within the network. It then analyses the information and determines the frequencies which can be used.

8.2.1.1 Energy Detector based sensing: If a receiver cannot gather sufficient information about the primary user's signal, such as in the case that only the power of random Gaussian noise is known to the receiver, the optimal detector is an energy detector. Energy detection is simple and can be implemented efficiently by using a Fast Fourier Transform (FFT) algorithm. However, there are some drawbacks for energy detection. First, the decision threshold is subject to changing signal-to-noise ratios (SNR's). Second, it cannot distinguish interference from a user signal. And third, it is not effective for signals whose signal power has been spread over a wideband.[52-66]

Let us assume that received signal has the form as

$$Y(n) = s(n) + w(n)$$

Where w is additive white Gaussian noise

s is signal to be detected

is index sample .

[$s(n)$; when PU doesn't transmits]

The calculation of energy is done on the basis formula

$$E = \sum_{n=n}^{N} |S(n)|^2$$

The calculated energy of interest is compared to a threshold as Eth. Based on the decision algorithm the detection takes place [67]

However, there are some drawbacks for energy detection:

- The decision threshold is subject to changing signal-to -noise ratios (SNR's).
- It cannot distinguish interference from a user signal.
- It is not effective for signals whose signal power has been spread over a wideband.

8.2.1.2 *Eigen value based Sensing*: The Eigen value of the covariance matrix of the received signal can also serve the purpose of primary detection. With the help of random matrix theory, the ratio of the maximum eigen value to the minimum eigen value is quantized, and one of the quantized values is chosen as detection threshold is [68-70].

8.2.1.3 *Covariance based Sensing*: As a matter of fact statistical covariance matrices of the received signal and that of noise are normally different. By utilizing this difference we can differentiate the desired signal component from background noise .[71] It is done based on the scheme:

8.2.1.3.1Antenna Correlation Based Sensing: Antenna correlation based detector by extending the covariance based detector from time domain to space domain via exploiting the correlation among antennas. By obtaining threshold level to achieve required probability of false alarm due to the approximate in the derivation which is helpful in order to sense spectrum.

8.2.2 Signal Specific: This sensing technique requires prior knowledge of Primary User (PU) signal.

8.2.2.1Waveform based Sensing: This method is only applicable to systems with known signal patterns which could be preambles, midambles, regularly transmitted pilot patterns, spreading sequences and etc. ***Preamble*** is a known sequence transmitted before each burst and ***Midamble*** is transmitted in the middle of a burst or slot. It is also known as waveform-based sensing or coherent sensing. It is shown that waveform based sensing outperforms energy detector based sensing in reliability and convergence time. It is shown that the performance of the sensing algorithm increases as the length of the known signal pattern increases [72-73]. And in the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself.

Waveform based sensing can be performed by the given formulation as:

$$M = \mathrm{Re}\left[\ \sum_{n=1}^{N} Y(n)\, S(n)^{*}\ \right] \qquad (4)$$

Where $S(n)^{*}$ is the conjugate of S(n).

In absence of PU the metric value is

$$M = \mathrm{Re}\left[\ \sum_{n=1}^{N} W(n)\, S(n)^{*}\ \right] \qquad (5)$$

Similarly, in the presence of a primary user's signal, the Sensing metric becomes

$$M - \sum_{n=1}^{N} |S(n)|^{2} + \mathrm{Re}\left[\ \sum_{n=0}^{N} W(n)\, S(n)^{*}\right] \qquad (6)$$

The decision on the presence of a primary user signal can be made by comparing the decision metric *M* against a fixed threshold [67]. Waveform-based sensing requires short measurement time however; it is susceptible to synchronization errors. Uplink packet preambles are exploited for detecting Worldwide Interoperability for Microwave Access. [74 -76]

8.2.2.2*Transmitter Based Sensing:* Here, the cognitive radio attempts to discern areas of used or unused spectrum by determining if a primary user is transmitting in its vicinity. This approach is predicated on detecting not the strongest transmitted signal from a primary user, but the weakest. The idea is that the weakest signal producing primary transmitter would ideally be the one furthest away from the cognitive radio, but still susceptible to RF interference from the radio. The basic hypothesis for transmitter detection as:

$$x(t) = \begin{cases} n(t)\, H_0 \\ h_s(t) \mid n(t) H_1 \end{cases} \qquad (7)$$

Here, x(t) is the signal received by the cognitive radio, s(t) is the transmitted signal of the primary user, n(t) is all white Gaussian noise (AWGN) and h is the amplitude gain of the channel. H0 is a null hypothesis, which states that there is no licensed (primary) user signal in a certain band. H1 is an alternative hypothesis, which indicates that there exists some licensed user signal. The three main detection techniques which rely on this hypothesis for transmitter detection are described below.

8.2.2.2.1 Energy Sensing: If a receiver cannot gather sufficient information about the primary user's signal, such as in the case that only the power of random Gaussian noise is known to the receiver, the optimal detector is an energy detector. Energy detection is simple and can be implemented efficiently by using a Fast Fourier Transform (FFT) algorithm.

8.2.2.2.2 Matched Filter Sensing: The matched filter works by correlating a known signal, or template, with an unknown signal to detect the presence of the template in the unknown signal. Because most wireless network systems have pilots, preambles, synchronization word, or spreading codes, these can be used for coherent (matched filter) detection. A big plus in favor of the matched filter is that it requires less time to achieve a high processing gain due to coherency. The main shortcomings of the matched filter are:

- It requires a priori knowledge of the primary user signal which in a real world situation may not be available.
- Another disadvantage of matched filter sensing is that cognitive radio requires a dedicated receiver for licensed user.

8.2.2.2.3Cyclostationary Based Sensing: Because modulated signals are coupled with sine wave carriers, repeating spreading code sequences, or cyclic prefixes all of which have a built-in periodicity, their mean and autocorrelation exhibit periodicity which is characterized as being Cyclostationary. Noise, on the other hand, is a wide-sense stationary signal with no correlation. Using a spectral correlation function, it is possible to differentiate noise energy from modulated signal energy and thereby detect if a primary user is present. Cyclostationary feature detection is a promising option especially in cases where energy detection, described next, is not so effective. However, Cyclostationary detection requires a large computational capacity and significantly long observation times. [78-88]

8.2.2.3 Radio Identification Based Sensing: This method veers from the typical study of interference which is usually transmitter-centric. Typically, a transmitter controls its interference by regulating its output transmission power, its out-of-band emissions, based on its location with respect to other users. Cognitive radio identification-based detection concentrates on measuring interference at the receiver.[67]

9. Newer algorithms for Spectrum Sensing

In Cognitive radio networks for reliable and interference free communication the SU is required to sense the spectrum of licensed user efficiently. Due to different environmental conditions like fading and multipath etc cognitive radio may not be able to detect reliably the free spectrum of PU. So the different approaches are developed to sense the spectrum reliably as well as efficiently.

- Optimal linear cooperation framework is another way for spectrum sensing in order to reliably detect the weak primary signal. Within this framework, spectrum sensing is based on the linear combination of local statistics from different individual cognitive radios [91-93].

- To improve the spectrum sensing capabilities of centralized cognitive radio (CR) networks we can use spatial diversity. The fixed relay scheme employs a relay that has a fixed location to help the cognitive network base station detect the presence of the primary user. The variable relay sensing scheme employs cognitive users distributed at various locations as relays to sense data and to improve the detection capabilities. This effectively reduces the average detection time by exploiting spatial diversity inherent in multiuser networks [94]

- Present radio frequency (RF) front-ends cannot perform sensing and transmission at the same time, which decreases their transmission opportunities, which is known as sensing efficiency problem. Both the interference avoidance and the spectrum efficiency problem can be solved by an optimal spectrum sensing framework**.**[95]Sensing framework can achieve maximum sensing efficiency and opportunities in multi-user multi-spectrum environments, satisfying interference constraints.[96]

- soft combination and detection is the scheme, in which the accurate sensing energies from different CR users are combined to make a better decision based on the Neyman-Pearson criterion [97-98]. This scheme maximizes the detection probability for a given False alarm probability.

- *Multi-antenna-Assisted Spectrum Sensing* A generalized likelihood ratio test (GLRT)[100]is developed to detect the presence/absence of the primary user *at* cognitive receiver[101].

10. Comparison of Various Sensing Methods for non-cooperative sensing

- *Waveform-based sensing* is more efficient than energy detector and *Cyclostationary* based other methods because of the coherent processing that comes from using deterministic signal component However, it is required that a pre-stored information about the primary user's characteristics and PU should transmit known patterns[67] .

- The performance of energy detector based sensing is limited when two common assumptions do not hold these are :

i. The noise may not be stationary and its variance may not be known.
ii. The energy detector includes baseband filter effects and spurious tones.

It is stated in literature that cyclostationary-based methods perform worse than energy detector based sensing methods when the noise is

However, the noise becomes non-stationary in presence of co-channel or adjacent channel interferers. Hence, energy detector based schemes fail while cyclostationarity-based algorithms are not affected.[101]

- Cyclostationary features may be completely lost due to channel fading .It is shown that uncertainties cause an SNR wall for cyclostationary based feature detectors similar to energy detectors . Furthermore, cyclostationarity based sensing is known to be immune to sampling clock [102-104] offsets.

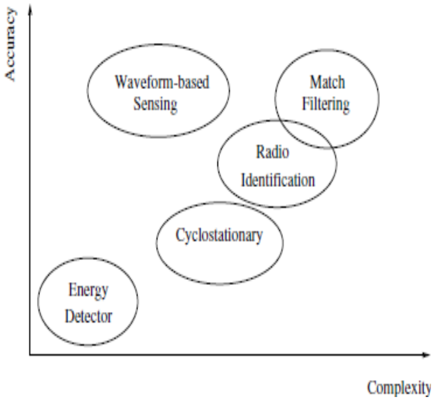

Figure 14 Main spectrum sensing Technique

11. Shortcomings of cognitive radio network

The efficient cognitive radio should be capable of utilizing the available degree of freedom in frequency, time and space. From cognitive radio point of view, if each node is having the cognitive properties then the transmission efficiency can be improved up to great extent.[30]

There are still some problems in designing a efficient and robust model of cognitive radio for effective spectrum sharing. Some of these issues are are stated as below:

- *Economical aspect and real opportunity:* We are required to measure the economic and engineering benefits of using CRN-based systems over the traditional wireless communications systems. In addition, the underlying network economy models need to be developed so that the commercial community can feel comfortable with CRNs. A number of spectrum measurements are required to understand how many of the spectrum holes are commercially viable. The low utilization does not necessarily mean that the SUs can use the opportunity in any economically sensible way.

- *Combined spectrum sensing and access*: The designing of Spectrum sensing and access are done individually, because spectrum sensing achieves certain detection performance, whereas spectrum access mainly focuses on improving the system capacity based on the identified spectrum hole[13]. However, these two aspects are inevitably coupled. For example, different transmission power levels of the CR users may require different decision thresholds in spectrum sensing, and *vice versa*. Furthermore, the joint design of multichannel sensing and distributed random access will be a challenging issue in CRN.

- *Cross layer link design*: The implementation architecture for supporting fully functioning prototypes needs a cross-layer design concept, and it becomes challenging to build. In particular, handling the coordination and control of various levels of protocol stack and enforcing cooperation among the CRs still require considerable research and development work [90].

- *Common control channel* There is a question on whether we require a common control channel for CR Operations. A common control channel will pave the path to an easier way of enabling information exchange during spectrum sensing and access in CR networks. However, unlike conventional networks, a common control channel may not be available in the initial phase when spectrum holes are not sufficiently identified. Furthermore, an identified channel may be preoccupied by the PUs at any time, which may interrupt the coordinating messages if it is used as a common control channel. How we can set up and maintain the common control channel is particularly crucial for proper operations in CRNs.

12. Replacement of Spectrum sensing in Cognitive radio networks

There are two main problems out of all as above described ,two basic problems in designing the model are spectrum sensing and hidden terminal problem.

In [105] where the spectrum sensing task is individual from the unlicensed users (secondary users). The service provider for the SU is required to put sensing devices within the networks of licensed users (primary users). These sensing devices spy on the primary users' activity. The sensing devices are also used to decide whether to admit a secondary user's transmission. A new cognitive cycle is proposed accordingly.

A low temperature handshake technique is proposed for handshakes between the secondary users and the sensing devices for the cases where a separate control channel is not available.

13. Conclusion

In this research work at first four primary functions of a cognitive radio: spectrum sensing, spectrum management, spectrum sharing, and spectrum mobility has been described followed by detail analysis of different spectrum sensing techniques. This paper can be of great help for the researchers who wish to pursue their research in this field as it provides compressive account of many spectrums sensing technique proposed so far .It can be used as base paper by many aspirants, who wish to work in this field.

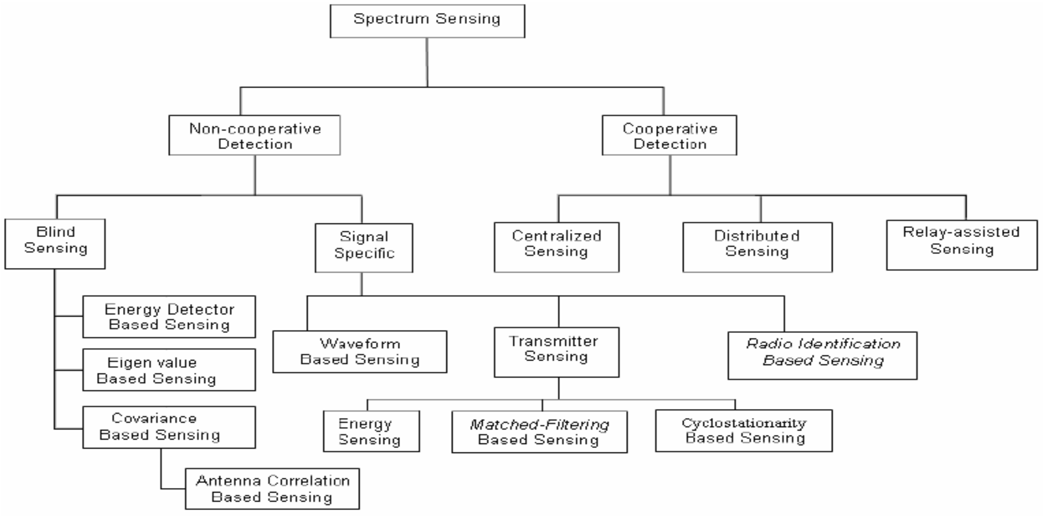

Figure15. Different Schemes of Spectrum Sensing

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