GRD Journals | GRD Journal for Engineering | National Conference on Emerging Research Trend in Electrical and Electronics Engineering (ERTE'19) | May 2019
e-ISSN: 2455-5703

Cognitive Radio Architecture: A Survey

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Abstract

Cognitive Radio (CR) is a recent technology to improve the spectrum availability. Cognitive radio scenario is well explained in this paper. When secondary users fail to realize the white space, either it will cause a serious interference with primary user or a failure to reuse the unoccupied band. Various sensing scheme for the cognitive radio are reviewed and the challenges associated with it. This paper describes signal sensing techniques and their various forms. Further identified issued and research challenges to overcome in future.

Keyword- Spectrum Sensing, Cognitive Radio, Spectrum Hole, Spectrum Sensing Techniques

I. INTRODUCTION

According to the Federal Communications Commission (FCC) spectrum occupancy is less than 15 percentages. There is a spectrum Scarcity through fixed spectrum assignment policy .Possible solution is opportunistically reusing portions of the licensed spectrum (known as DSA) Primary users(Licensed) and the secondary users (Un licensed) can work in cooperation in this. A key enabling technology of DSA is the Cognitive Radio(CR).The Cognitive Radio Network (CRN)is traditional network + Cognitive Radio .CR capabilities are DSA, Changeable Frequency, Power, Modulation order other transmission parameters .The components of CR Architecture is shown in figure1.Design of CR involves many aspects like Spectrum management which is a core aspect of CRN. Spectrum Sensing is an inevitable and prime important function of a cognitive radio that helps to sense the environment and locate vacancy of frequency bands. There are different methods available for spectrum sensing and each has its own advantages and disadvantages.

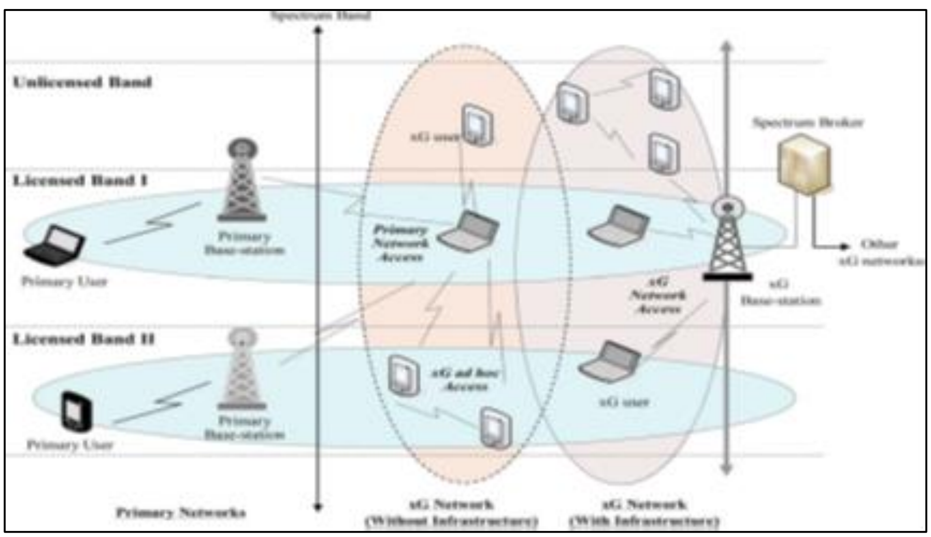

Fig. 1: cognitive radio architecture [10]

CR has two most important characteristics, Cognitive capability and Reconfigurability. Cognitive capability is according to the change in spectrum environment, CRs are able to identify the unoccupied spectrum band which are currently unused by the primary user .The vacant band can share it with other CRs, and use this spectrum without interference on primary users. Reconfigurability is a character which allows cognitive radio to adapt the variation in the operating parameters while already in action without any alteration in the hardware components. The Reconfigurability parameters are frequency, Modulation techniques, Transmission power, and Communication technology [1]. CR networks can utilize unlicensed as well as licensed band but currently unoccupied spectrum [2]. In Licensed band operation Primary users have priority to use licensed band. CR must vacate this spectrum band and leave suddenly when primary user appears. In Unlicensed band operation for a certain free spectrum abandoned by PU; all CRs have the same rights to access it. Consequently, effective spectrum sharing method is important for CR networks to develop.

II. LITERATURE SURVEY

Cognitive radio (CR) is considered as a new technology to overcome the scarce RF (radio frequency) spectrum in opportunistic way to improve the spectrum efficiency. Main challenge to a efficient CR system is the identification and capturing of primary user signals in the wide spectrum band to realize the spectrum opportunities efficiently.

F. Akyildiz et al. (2006) Cognitive radio technology is well explained and the xG network concepts also introduced in paper .4 spectrum management function like spectrum sensing, spectrum mobility and spectrum sharing, spectrum hand over are explained in detail.[1]

Sindhubargavi et al. (2014) In this paper they found an improved energy detection technique that detect the exact value of threshold voltage and it is confirmed with the use of accurate noise power by this proposed method. The energy detection method compare with the threshold value with the energy of the signal. The spectrum hole is detected if the threshold value is higher than the energy of the signal.

Niranjan Muchandi et al. (2017) They gives a survey conducted on 2 types of sensing method which are signal processing and cooperative sensing techniques. Signal processing technique are matched filter detection, energy detection, cyclostationary feature detection. Energy detection technique is simple and most popular but it cannot perform well in low SNR. Matched filter detection takes fever sensing time and has an increased SNR but it requires higher power and more complex.

Nasser et al .(2017) In this paper they found For Half-Duplex mode, a new Spectrum Sensing detectors depend on the Cumulative Power Spectral Density (CPSD). Their proposed method confirms the linearity of the CPSD shape of the signal. This figure is almost linear if and only if the PU is not present .Hard and soft decision methods are there to combine the CPSD measures, which are found, based on the 2 symmetric parts of the Power Spectral Density.

Chaari, Fakher et al. (2014) organized this book in two parts. The first part will be dedicated to pure theory on cyclostationarity. Applications are presented in the second part.

Padya et al. (2015) Energy detection technique well explained in this paper .Energy detection technique is the most popular technique due to its simplicity so far. Also they examined the performance of energy detection technique in detecting the vacant band [3]

III. WHY COGNITIVE RADIO

According to the Federal Communications Commission (FCC) spectrum utility is less than 15%. Fig.2 shows spectrum utilization diagram. It shows that some frequency bands are intensely occupied and some are medium used. Remaining frequency bands are not occupied. The Dynamic Spectral Access has been introduced as a solution to improve the spectrum usage, and to overcome the problem of the scarcity in the frequency resources due to the high demand on the wireless networking. The Cognitive Radio (CR) technology is as a best method for applying the Dynamic Spectral Access. According to FCC, CR is an aware system that can analyze its own electromagnetic environment, so it can intelligently detect which communication channels are available and which are not, and immediately move into vacant band while neglecting occupied ones. This increase the use of available radio-frequency (RF) spectrum at the same time removing interference [1][3].

FCC definition for Cognitive radio is "A 'Cognitive Radio' is radio that can change its transmitter parameters based on interaction with the environment in which it operates"[11].

The CR shares o spectrum between Primary Users (PU) and Secondary Users (SU). SU can occupy the channel only when PU is absent. It's the SU responsibility to monitor all the sensing and mobility activities in this process. Primary user is not aware of this.

Cognitive radio can use the spectrum efficiently and can overcome the scarcity in radio spectrum. Without interfering with the primary user they can use the un occupied spectrum. Cognitive radio will avoid jamming by and opportunistically y change to higher quality channels .By change to protocols that use lower power consumption for lower information measure cognitive radios conserve power. Cognitive radio increases communication quality once and wherever the information is requires d most. Quality of service (QoS) given by sensing environmental and accidental synthetic radio interference s also cognitive radios will choose frequency channels with higher Signal to Noise ratio (SNR) [5].

IV. SPECTRUM HOLE

The cognitive radio allows the usage of currently unused frequency bands that mostly referred to as spectrum holes. Sometimes spectrum holes are typically categorised into temporal spectrum holes and spatial spectrum holes. A temporal spectrum hole is unoccupied by the primary user throughout the time of sensing. Hence, this band is utilized by secondary user within the current interval. Spectrum sensing of this type doesn't need advanced signal processing .A spatial spectrum hole could be a band that is unoccupied by the element at some spatial spaces; and thus is occupied by secondary user moreover as outside this area. In terms of power spectra of incoming RF are classifying the spectrum holes into 3 .Black spaces, gray spaces, and white spaces. Black spaces that are advanced by high-power "local" interference .Gray spaces that are partial y advanced by low-power interference. White spaces that doesn't have RF interference aside from AWGN. White spaces and gray spaces is utilized by unauthorized operators if proper sensing method is meant, and Black areas can't be used as usage of this area can cause interference [6].

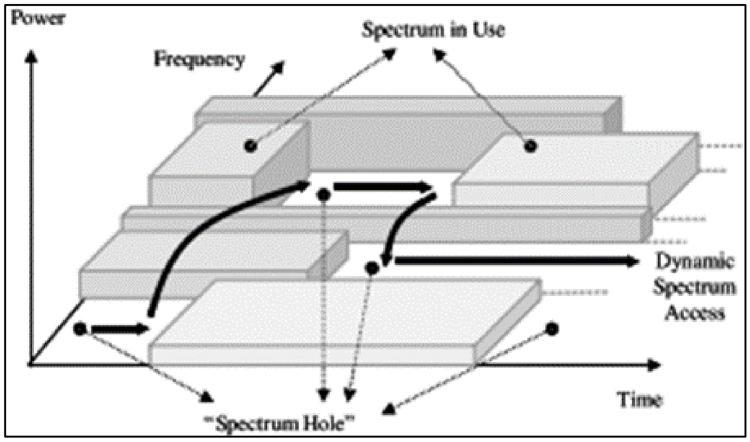

Fig. 2: Spectrum hole concept [7]

CR technology is a new paradigm that allows the spectrum to be utilized by the SU in an opportunistic way by sensing the unoccupied band, also known as spectrum holes or white spaces. If the PU arrives it vacates the band without causing interference to the other users using DSA technique as shown in Fig2.

The tasks performed by the CR are referred as cognitive cycle. The 3 main steps of cognitive cycle are Spectrum sensing, Spectrum analysis, Spectrum decision .In Spectrum sensing cognitive radio investigate the radio spectrum environment, captures their information and identifies the spectrum availability. In Spectrum analysis cognitive radio find characteristics of the detected spectrum hole and Spectrum decision is the capability to select the best acquired channel for the communication of the Secondary user. Figure 4 explain the cognitive cycle [1].

V. COGNITIVE NETWORK ARCHITECTURE

In a detailed description of the next generation network architecture (cognitive radio architecture) all possible scenarios have to discuss. The elements of the xG network architecture, as shown in figure1. This can be mainly divided in two groups as the primary network and the xG network. Primary network is the excising network, which has a prime right to a access certain specified spectrum band. Examples include the mobile and TV networks. The components of the primary network are Primary user, Primary base-station. Primary user access the licensed spectrum which should not be affected by secondary users and controlled only by primary base station. Primary base station does not have any cognitive capability for sharing spectrum with secondary users. xG network doesn't have license to work in a desired band. Hence, the spectrum access is allowed solely in an opportunistic way [7].

The elements of cognitive network are as follows xG user, xG base-station, spectrum broker. xG user use additional functionalities for accessing the unused spectrum . xG base-station has cognitive capabilities through which an xG user can access other networks. Spectrum broker is a central network entity that plays a role in sharing the spectrum resources among different xG networks.

VI. SPECTRUM SENSING

One of the main aims of Cr is to utilize of the spectrum holes opportunistically. The SU ought to sense the arrival of the primary user and move to a different unused space while not inflicting interference to the PU. In spectrum sensing cognitive radio examines the obtainable spectrum, captures their data and identifies the spectrum holes and move to another unused space without causing interference to the PU. In spectrum sensing cognitive radio examines the available radio spectrum find their characteristics and identifies the spectrum hole [8].

A. Performance Analysis

Spectrum sensing is the technique to find the available spectrum hole in bandwidth of interest (BoI). Availability and non-availability can be expressed in a classic Bayesian detection problem: Under H0, the PU is not present, whereas under H1 PU present.

$$H0 : y(n) = w(n) \text{ (null hypothesis)}$$

$$H1 : y(n) = h\, s(n) + w(n) \text{ (alternative hypothesis)}$$

w(n) is the noise where H0 represents the hypothesis corresponding to "no signal transmitted" and H1 to "signal transmitted". In this to type of error may be there, False alarm, missed detection. False alarm means we decide H1, were as actual case is H0.Missed detection means we decide H0 were actually it is H1 .A incorrect decision about the channel status can affect either the PU transmission or the efficient use of the channel. Missed detection can cause a unnecessary interference which is due to the transmission of the SU in the same band of the PU. A false alarm, however, decreases efficiency of spectrum sensing [11]

VII. SPECTRUM SENSING TECHNIQUES

Channel choice and spectrum hole finding are the most functions of spectrum sensing. Cognitive radio ought to be aware of the surroundings. Normally, CR senses the spectrum so as to cognitive cycle realize the appearance of primary user. Additional the sensing time, the gathered data are more correct. However it decreases the transmission time. In cooperative sensing, the sensing time is reduced because of the cooperation between the users. Spectrum sensing is classified into two as narrow band spectrum sensing and wideband spectrum sensing which also known as cooperative spectrum sensing [3].

Narrowband spectrum sensing (non cooperative spectrum sensing) access one channel at once. There are mainly 3 type of narrow band spectrum sensing .Energy detector based spectrum sensing. Matched filter based spectrum sensing. Cyclostationary feature detection based spectrum sensing.

Energy detection also Known as radiometry or periodogram is the most common technique of spectrum sensing. Its advantage is its computational complexity is low. In this Sensed energy which is compared with a threshold to detect the presence of the signal. Disadvantage is this technique is inefficiency at low SNR and high power consumption. Block diagram f energy detection is in figure 3[9]

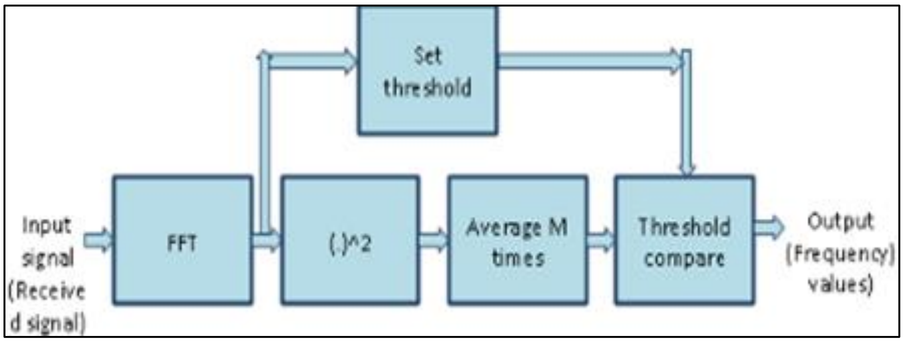

Fig. 3: Block diagram of energy detection

The matched filter maximizes received SNR in communication systems, so it can be considered as optimal detector. Matched filter has a demerit, that it should have the knowledge of PU signal characteristics, i.e., packet format, pulse shaping and type of modulation.

By exploiting the second order periodicity inherent in most modulated signals [5, 6] cyclostationary detection can be used for reliable spectrum sensing. Cyclostationary sensing has been suggested in the past and combined with other approaches like neural networks and is a more reliable method of spectrum sensing at low SNR. It exploits the built-in periodicity of the modulated signal such as sine wave carriers, pulse trains, repeating spreading, hoping sequences or cyclic prefixes. Basic bock diagram shown in figure 4[10].

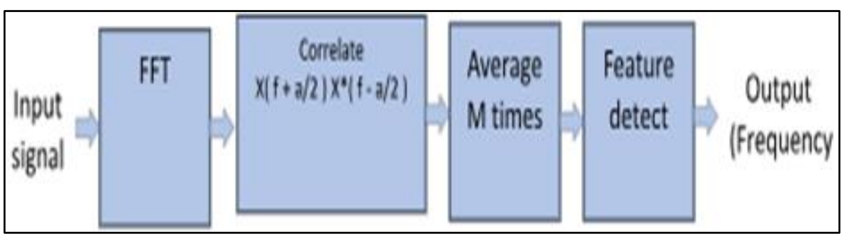

Fig. 4: Block diagram of Cyclostationary feature detection

The most important part of cooperative sensing is to increase the detection execution by exploiting spatial differences in the vicinity of spatially found CR users. CR cooperative spectrum sensing occur when a system of CRs share the gained data. This gives accurate spectrum sensing around the area where the CRs are operating. In Cooperative detecting it decreases issues because of fading, shadowing and noise instability. The Cooperative Sensing divided in to centralize sensing, Distributed Sensing, Relay Assisted Sensing [3].

VIII. ISSUES AND CHALLENGES

When considering the problems Hardware requirements like terminals and high speed process units (DSPs or FPGA) are required for comparatively low dela y process .The Hidden Primary User drawback is there because of intense multipath fading and shadowing g observed by secondary users. A CR terminal desires a high detection sensitivity that may be a difficult demand for wireless communications .Another issue is primary user that use spread spectrum signaling are troublesome to discover so as to stop interference to and from authorized owners,

Cognitive radio ought to be ready to determine the presence of primary users as quickly as attainable and may vacate the band Straightaway .Hence sensing strategies ought to be ready to determine the presence of primary users among certain period.

Compared with traditional radio, CR is additional versatile and exposed to the wireless network. Therefore security problems also conjointly there [13].

In Challenges related to spectrum sensing techniques most needs of cognitive networks is that the detection of authorized users in a very short time. it's too much necessary to develop an interference detection model by effectively measure the interference temperature also specified SNR for detection could also be very low. Multipath fading and time dispersion of the wireless channel complicate the sensing. Multipath attenuation could cause the signal power to a maximum of thirty dB, whereas unknown time dispersion in wireless channels could flip the coherent detection unreliable. The noise or interference level could change with time and placement that yields the noise power uncertainty issue for detection. For choosing a sensing technique some trade-offs ought to be considered like accuracy, computational quality, sensing duration requirements, network needs.Table1 gives a overview of different spectrum sensing techniques.

Spectrum sensing	Methods Advantages	Disadvantages
Matched Filter	Best in Gaussian Noise requires less sensing time	Requires prior information of PU transmission characteristics high complexity
Energy Detection	Low computation simple Longer sensing time	Low SNR High power consumption
Cyclostationary detection	Most resilient to the variation in noise levels	Requires prior knowledge of PU transmissions
Wavelet detection	Effective for wideband signals	Does not work for spread spectrum signals High computational cost

Table 1: Overview (Signal processing technique)

IX. Conclusion

CR technology s the next generation technology as demand of spectrum source is increasing. CR technology is well explained and the concept of spectrum hole and next generation architecture is described in this paper .Different sensing techniques also explained. Energy detection technique. Matched filter detection, cyclostationary detection also explained. It is observed that each sensing technique has its own advantages, and disadvantages so that they can use according to the problem in hand .We further identified the research challenges and found that there are lots of prospect to this new research area.

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