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A Review on Spectrum Sensing Approaches in Cognitive Radio Networks

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Abstract— *The frequency spectrum is a 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. Thus, to efficiently utilize the scarce resource i.e. frequency band, various techniques are introduced.*

This study provides an overview to the concept of cognitive radio and spectrum sensing in cognitive radio. There are large numbers of techniques that are used for spectrum sensing in cognitive radio and some of them are discussed in this work. The work that has been done in this domain is also reviewed by the author.

Keywords—*Wireless Communication, Cognitive Radio, Spectrum Sensing.*

I. INTRODUCTION

Cognitive Radio (CR) is a form of wireless communication that is utilized to automatically determine the channels allocated in frequency range. It performs modification to the factors that are responsible for data transmission. These alterations are done to perform efficient utilization of spectrum. CR is an adaptive, intelligent network tool [1]. CR utilizes various technologies comprising Adaptive Radio and Software Defined Radio. To create the cognitive radio, the techniques of Software Based Radio, DSP and AI are utilized [2]. The major objective of CR is to properly utilize the various resources such as frequency, energy, time slots etc. It did not create interference to allocated users regarding available frequency bands [3]. The requirements of CR are as follows:

- Main user
- Consistent Spectrum Hole
- Connection
- Frequency Control Mechanism
- Power Control Mechanism

The availability of above defined components assures transmission reliability with zero interference by the user [4]. CR is flexible in nature and it configures itself as per the requirement of the users. Theoretically the frequency band has no limits but in practical life for transmission and communication purpose it is limited due to demand for only specific part of spectrum. The allotted frequency band cannot be used completely [5]. In present scenario, to utilize the spectrum effectively is the major concern. Cognitive radio can automatically identify the frequency band which is currently in use and then cognitive radio use this frequency band without creating any type of interference [6]. Various other capabilities of CR are: identifying the position, determine the frequency band in use by devices in surroundings, varying frequency, regulate output power, changing the factors and features responsible for transmission [7]. All these above mentioned features yet to be obtained. This facilitates the user to work in real time environment in order to properly utilize the available frequency bandwidth [8].

II. SPECTRUM SENSING

In the beginning of spectrum sensing, the primary user is identified on the frequency band. After detection of primary users, the CR can share the consequence of its detection among different CR after determining the spectrum [9]. Main aim of frequency range is to determine the status of frequency band by automatically sensing the required spectrum after short interval of time [10]. Specifically a CR transmitter and receiver unit identifies the spectrum which is not presently in use as well as it also identifies techniques to access the spectrum irrespective to the primary users. The two types of spectrum sensing are given below:

1. Centralized
2. Distributed.

III. APPROACHES FOR SPECTRUM SENSING

In spectrum sensing, the spectrum is examined first and then it establishes an unemployed fraction and allocation of the spectrum. To promote the position likelihood frequent spectrum classification actions can be operated [11].

3.1 Narrow band spectrum sensing

The narrowband spectrum sensing approach has an ability to sense a spectrum [12]. In this technique, due to the incomplete regularity collection, the reply from channel intensity is treated as intensity. The achieved bandwidth is not accurately used for efficient channel data relocation. The procedure of this narrowband computation requires varied circumstances. Mainly, there are three computations for contracted band spectrum sensing which are as follows:

1. Force detector based spectrum sensing.
2. Harmonized riddle based spectrum sensing.
3. Cyclostationary characteristic recognition based spectrum sensing.

The exceeding spectrum sensing approaches are also called as Transmitter discovery or Non- accommodating exposure spectrum sensing method.

3.2 Energy detection based spectrum sensing

The energy detection method is not only the superlative procedure used for distinguishing every indicator but it is similar to recognized spectrum exploitation in cognitive radio system. In energy detection procedure, recognized signal is stated through surveillance and the flouting after the spectrum's signal superiority [13]. The primary user available data can be used for spectrum sensing using energy detection method and it is widely used method due to less effort required for actualization.

The evaluation i.e. absence and presence of the primary user is done by comparing the energy output with the threshold value using following equation i.e.

$$\text{H0, if } \sum_{n=1}^{N} |y[n]|^2 \leq \lambda \ldots\ldots..(1)$$
$$\text{H1, Otherwise}$$

In the above equation, λ is referred as the threshold value lies on the receiver noise.

3.3 Matched filter based spectrum sensing

The matched filter strategy is a superlative methodology for spectrum sensing because it enhances the Signal to Noise Ratio (SNR) within the vision of additional stabilizer noise. The acknowledged signals are invoked in this preferred perspective method that is configured for well known received signal incidence recognition [14]. The inflection type, bandwidth, pulse influential and occurrence like traditional signal previous information are employed in matched filter detector method.

At this point, the expected and conducted signals are associated to each other. The conduct signal has a previous knowledge of attendance of the primary signal and distinguishes the communicated signal. The illustrious signal gives the data about the incidence of primary signal.

In order to evaluate the presence or absence of the primary user's signal, the received and pilot signal is combined. The obtained results are compared with threshold value to obtain the output.

$$\text{H0, if } \sum_{n=1}^{N} y[n]x\,[n]^* \leq \lambda \ldots\ldots\ldots(2)$$
$$\text{H1, Otherwise}$$

In the above equation, λ is defined as threshold.

The cognitive radios and PU existing information are considered in Matched filter method that are equipped with delivery service harmonization, instating devices and punctuating extended comprehensive nature.

3.4 Cyclostationary feature detection based spectrum sensing

In this method, an auto association signal is considered as returning function which is known as cyclostationary signal. Cyclostationary quality detector is one of the techniques of spectrum sensing that disconnect the amended signal from the preservative noise [15]. The spectral distorted signal is then associated to evaluate the Spectral Correlation Function (SCF). The spectrum detection can be done through cyclic frequency matching or SCF that also helps in deciding that signal applicability. The FFT which is used to calculate the spectral mechanisms of the input signals is defined as:

$$R_x^{\alpha}(\tau) = \lim \lim_{T\to\infty} \frac{1}{T} \int_{=\frac{T}{2}}^{\frac{T}{2}} x\left(t + \frac{\tau}{2}\right) x\left(t - \frac{\tau}{2}\right) e^{-j2\pi\alpha t} dt \quad \ldots\ldots..(3)$$

After the calculation, spectral correlation is performed on the spectral component in order to estimate the SCF i.e. Spectral Correlation Function.

$$S_x^{\alpha}(f) \int_{-\infty}^{+\infty} R_x^{\alpha}\,(\tau) e^{-j2\pi f\tau} d\tau \ldots\ldots\ldots\ldots\ldots(4)$$

In starting phase, PU signal noise is considered in cyclostationary feature detector method. After that the squat SNR detection is done using distinguished signal then a new data is added in it which shows that there is no noise left in the PU signal. The estimation difficulty is the main limitation of this technique.

3.5 Wide band spectrum sensing

It is one of the vital usefulness of the cognitive radio systems which enable the cognitive radios to differentiate between the outrageous openings and wideband channel. Moreover, it also allows usage of under-used frequency groups without considering the security of primary systems. The narrowband detecting systems are not suitable for wideband spectrum sensing systems as the narrowband system performs on a single binary decision for the whole spectrum [16]. Consequently, narrowband spectrum sensing cannot differentiate the individual spectrum that may lies in the wideband spectrum. Number of techniques and procedures have been used for wide band but the use of only single strategy is prove to be efficient for wideband detection.

IV. RELATED WORK

Prem Prakash Anaand, et al. (2016), proposed the method for detecting white spaces in the spectrum employed in communication process involved in Cognitive Radio Networks (CRN). The work demonstrates the usage of Spectrum Sensing function for issue solving purpose. This spectrum sensing was operated in two stages in noisy environment. The major concern involved in the proposed technique was the robustness of uncertain noise power which influenced the detection of primary users (PU) that led to reduced efficiency of method. This spectrum sensing operates over the functionality provided by two other techniques, namely Energy Detection (ED) and Akaike's Information Criteria (AIC). The estimation of power average was performed by ED method over the received signal which constitutes the first stage. This was followed by Information Theoretic Criteria (ITC) used by AIC technology. The ED offered better efficiency with less time consumption for high Signal to Noise Ratio (SNR) on the other hand in case of low SNR, reduced throughput is achieved. At low SNR, AIC offered high performance. The limitation of AIC was high complexity levels involved in it. The drawback on false alarm probability was overcome by considering two stage threshold parameters. Through this, the detection probability along with time required for detection could be maximized.

Mengwei Sun, et al. (2016), presented the reviewed study over the spectrum sensing involved in Cognitive Radio Networks along with varying dynamic noise. The detection of primary frequency occupancy was provided by Bayesian solution. It was also capable of simultaneous recovering of the dynamic noise variance. Through particle filtering, the state of each primary user was identified. The noise parameters were found using adaptive particle filtering for each particle. The results of this work depicts that the performance rate of the efficient spectrum sensing was directly linked with the dynamic noise variance of the spectrum.

Enwei Xu, et al. (2015), proposed the need of reliable spectrum sensing for achieving efficient Cognitive Radio Networks. These CRs were required to work effectively despite of impulsive noise and noise uncertainties. This study elaborates the utilization of spectrum sensing for detectors in the domain of the Middleton class. The work was divided in various stages and the first stage includes derivation of false alarm and analytical expressions of detection probabilities. The negligible effect was produced by variance in impulsive parameters A and Γ. The noise power having value of σ2Z generated SNR Walls that hindered the detector from detecting the primary users robustly. The proposed technique is suitable for robust spectrum sensing via energy detectors.

Kanabadee Srisomboon, et al. (2015), have proposed a technique by considering the CAV, MME and ED techniques that helps in getting presence of primary user. The author had defined that the in traditional spectrum sensing techniques, the major issue was related to the noise power uncertainty. Due to this problem, degradation has been seen in the performance of spectrum detection. In this paper, a noise power is considered while proposing a new two stage spectrum sensing novel scheme. The ED technique is used for spectrum sensing in case of having less time and reliable detection can also be achieved in case of having high SNRs. But in case of having noise uncertainty, the use of ED technique prove to be not efficient so use of CAV and MME are recommended by authors. The proposed technique is tested and results shows that a reliable detection can be achieved using proposed technique even in case of having high SNRs or noise power uncertainty. The only drawback of using proposed technique is large time required for processing. Still use of proposed technique was proved to be efficient in protecting primary user from secondary user harmful interference.

Tadilo Endeshaw Bogale, et al. (2015), have proposed a test statics based on novel ratio technique that helps in sub band edges detection. The technique was proposed on the basis of the white sub bands for reference. They have proposed a novel Generalized Energy Detector (GED) technique and according to energy as one white sub band reference comparison of different approaches are conducted by them. The noise sub bands information reference was exploited by it. In proposed technique, probability of detection as well as false alarm was considered and sensing time was also optimized for CR network throughput maximization. As compared to existing techniques of signal detection, the proposed one was performed in good manner even in the presence of SNR. The information of noise variance and optimal were dependent on each other. In case of perfect scenario of noise variance, the optimal to achieved was 18.5 ms by proposed technique for frame duration of 2 sec, 20 dB SNR and total bands were 10TV.

Tadilo Endeshaw Bogale, et al. (2014), proposed a novel spectrum sensing algorithms by considering the receiver which was asynchronous as well as synchronous and pulse shaping filter for transmitter in cognitive radio networks. In this firstly combiner vector was introduced and then there was linear combination of symbol period equal total duration of signal which was already sampled. After that as problem of Rayleigh quotient optimization, a minimization as well as maximization problem of Signal to Noise Ratio (SNR) for the signal achieved in first section. In the last section a test static was proposed then for Additive White Gaussian Noise (AWGN) channel, expressions for detection probability as well as false alarm were derived. The novel sensing algorithm was tested and it was proved to be more robust and in comparison to energy detection and Eigen value decomposition algorithms, the detection probability of proposed work was better.

Kriti Chabbra, et al. (2014), have given a review on existing techniques of energy detection. By the development of CR, it becomes possible to use available wireless communication spectrum for different purpose. The spectrum holes can be detected using energy detection technique of spectrum sensing. This study was comprised of a review to the false alarm and detection probability as communication system performance parameter gets affected by factor of noise uncertainty and dynamic threshold. After that work has been done on reducing its factor on sensing technique. The MATLAB is used for performing simulation to get tabulation as well as computations results that helps in developing a relationship between SNR and sampling number.

V. CONCLUSION

To sum up, for optimum utilization of limited bandwidth resource, the Cognitive Radio with Spectrum Sensing techniques can be used in wireless networks. It is a dynamic and promising approach that can improve the optimum use of spectrum. Hence in this way, large number of users can be accommodated in limited spectrum.

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