Review Paper on Various Modulation Techniques Used in Cognitive Radio Network

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Abstract— CR that is cognitive radio organizes a smart radio system that is capable of identifying the existing unoccupied frequency channels or slots without any human interventions, where the two most important methods for CR network are spectrum sensing and energy detection. Energy detection and spectrum sensing technique performance depends upon system complexity, quality of service, cost effectiveness, power control and Bandwidth efficiency. Various modulation techniques evolved in cognitive radio network are OFDM, PSK, DPSK, GMSK, BPSK, FM, and AM etc. It is so obvious that all primary users utilize a single modulation technique or some other technique to transmit the signal over the wireless medium; so, to identifying the modulation technique would substantiate the occurrence of the signal of primary user in the wireless medium. The selection of a particular modulation technique relies on Symbol Error Rate, Signal to Noise Ratio, Bit Error Rate.

Keywords— *cognitive radio (CR), Software defined radio (SDR), modulations techniques, spectrum sensing, energy detection, cognitive radio environment (CRE), mobile network (MN) cognitive radio (CR), Software defined radio (SDR), modulations techniques, spectrum sensing, energy detection, cognitive radio environment (CRE), mobile network (MN)*

I. INTRODUCTION

In today's world, the structure of cognitive radio has capabilities of learning and understanding to achieve the required goals. CR is a smart wireless communication system that is aware of its surrounding environment and utilizes that understanding by its capability of learning from the environment. CR network automatically adjusts according to its inner states to variations in incoming RF stimuli by varying certain functioning parameters in order to achieve highly reliable communication and efficient usage of the radio system. The prime requirement of the system is to avoid interference for PU (Primary User) in their region. There is a need to identify the PU's signal existence in the wireless surroundings to assure that the primary users will not be interfered by the cognitive radio users (that is secondary users). This process of identification is attained by means of recognizing the wireless environment, and is known as spectrum sensing.

Since the key idea of CR depends upon identifying the actions of primary user, hence for the proper functioning of CR systems spectrum sensing is the foremost function. On the other hand, the challenge arises to identify the occurrence of primary user with a high stage of speed and reliability. It occurs due to the frequent significant impairments prior reaching the CR sides. Moreover CR has limited computational abilities. Therefore the challenge is to attain a fast and reliable sensing, particularly where environment has low signal to noise ratio.

Many different techniques were proposed to sense the spectrum conventionally those are, Matched-Filter Detection, Cyclostationary Feature Detection, and energy detection. Significant awareness has been paid to use Modulation Classification for sensing the spectrum in CR systems. This allows the devices of CR radio to consistently recognize and identify the entire signals of primary radio in the spectrum surrounding and upgrade the performance of systems that is cognitive radio.

II. COGNITIVE RADIO FUNCTIONS

The four main operations or functions of CR are as follows: To avail the ability to efficient utilize and share the spectrum. Fig 1 shown below demonstrates the CR radio cycle which includes parts of it like sensing the spectrum, spectrum sharing, spectrum decision, and spectrum mobility.

A. Spectrum Sensing

Spectrum sensing **is** explained as the "task of identifying the spectrum holes by recognizing the radio spectrum in the nearby surroundings of the CR receiver in an unsupervised manner". Therefore, the main objective of spectrum sensing is to provide sample chances to Cognitive Radio end users those may acquire the vacant spectrum on temporary basis to transmit the signal to the licensed user's (also known as primary users) without any interference.

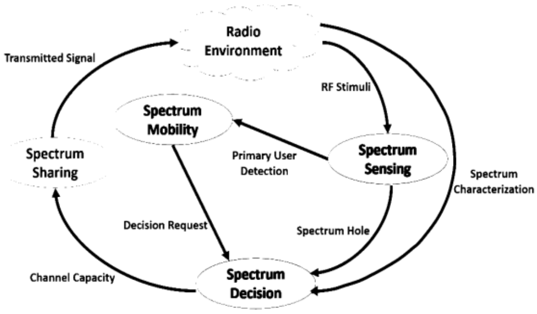

Fig.1 Cognitive Radio Cycle

B. Spectrum Decision

Spectrum Decision is a function that caters the information to the cognitive radio, operating frequency and its related technical parameters on spectrum identification bases. In order to upgrade the service quality lacking any overhead disturbance the CR can use the facts and statistics from strategic directory. Hence CR makes a decision which is appropriate for spectrum bands and can be utilized by secondary user.

C. Spectrum Mobility

Spectrum mobility is defined as: "preserving flawless communication necessity throughout the duration of evolution to superior spectrum". Moreover, in order to lodge this task, in CR networks the spectrum mobility can be diversified into two categories as:

- **Spectrum handoff -** It means transfer uninterrupted transmission from recent spectrum to unoccupied spectrum. As a result when the Primary User arrives, then the Secondary User should quit the licensed spectrum right away.
- **Connection management-** It is a one of the important protocol used in CR network.it has information regarding spectrum handoff duration

D. Spectrum Sharing

The spectrum holes can be utilized by numerous SU's. The major confront of the CR's is "to attain stability among its self-goal of fetching information efficiently and a selfless objective to allocate the existing assets with remaining cognitive and non-cognitive users." Therefore it can be stated that arranging the utilization of spectrum holes among the CR users will contribute to avoid overhead interference to PU's and among SU's.

III. SPECTRUM SENSING METHOD

Different types of the spectrum sensing techniques like, MFD, energy Detection, CFD methods etc. are discussed as follow

A. Matched filter detection

Data concerning to the Primary User must be collected by Secondary User and at each point of time it identifies the prior collected data regarding Primary User. Therefore PU and SU are mutually connected so that they occur at the same time or rate.

B. Energy detection

To conquer the insertion of matched filter so that both the users' functions at the same time, another method used is energy detection. Here in this procedure, spectrum is transformed to separate samples and each sample is précised with energy and mean value of all the energies is taken into consideration

C. Cyclostationary Filter Detection

Cyclostationary signals are prone to noise and interference due to their repeated characteristics and spectral inter-relation. The primary users can be detected by the repetitive property of received signals that is further examined from the sinusoidal carriers, spreading code and pulse trains utilizing the spectral correlation function. Such characteristics are required to determine the primary user in the scanned band, and their absence indicating an unoccupied band. Figure shown, determines the outline of the process taking place during the cyclostationary detection.

The Benefits and limitations of various spectrum sensing schemes are as shown in table 1.

SPECTRUM SENSING METHOD	METHOD ADVANTGES	METHOD DISADVANTAGES
MATCHED FILTER	1. Computational time is very less 2.Optimal detection	1 differentiates the signal according to its types. 2. Noise level adjustable
ENERGY DETECTION	1. no Information regarding primary user is needed before detection process 2. Computational time is very less.	1. Signal cannot be Differentiates according to its types. 2.Effortlessly Susceptible to noise which rises the value of mean energy beyond threshold
CYCLOSTATI-ONARY DETECTION	1 differentiates the signal according to its types. 2. Noise level adjustable.	1. very expensive computational time 2. complex circuit

IV. CR UTILIZING VARIOUS MODULATION TECHNIQUES

Spectrum sensing has been the considerable area of research over past few years for CR systems utilizing categorization of modulation. Numerous procedures can be seen in the literature [2-7]. In literature [10-12] methods of spectrum sensing for CR systems utilizing the categorization of modulation are proposed, for various sets of modulation under different conditions of transmission, by implementing cyclo stationary signatures of the signals received. It was proven that above procedures can attain a superior execution in case of low SNR [13]. On the other hand, attributes utilized in procedures have elevated computational complexity; hence, these are inappropriate methods for actual and real-time cases. Modulated signals with cyclostationary signatures cannot categorize the QAM (quadrature amplitude modulation) until the time tedious excessive sequence cyclostationary investigation is achieved.

In literature [8], a method of sensing the spectrum using classifications of modulation is presented by implementing time-frequency attributes resulted from the PWVD that is Pseudo Wigner–Ville Distribution of the signals obtained as major attributes for categorization of modulation and the DBSCAN that is Density Based Spatial Clustering of Applications with Noise method as a categorization scheme. The crux was given by author's research that procedure responds sound within the scrutinized scale of Signal to Noise Ratio's. Contrary, the attributes implemented in this technique needs extensively numerous review samples to obtain extreme quality approximations [9].

In literature [15], spectrum sensing methods utilizing modulation categorization with low-complexity is presented by implementing partial lower array data of the signal received as major attribute for modulation categorization and the predictable Euclidean distance classifier as a categorization system. It is proficient and an easy method to employ.

In [17], spectrum sensing method is applied by using QPSK and BPSK modulation scheme and also compared the result with Eigen value and other modulations techniques. Performance analysis of spectrum sensing CR network has been done based on signal to noise and probability of detection and probability of false alarm. It was proven that at low signal to noise ratio QPSK and BPSK gives better probability of detection as compared to AM.

In literature [18], method of identifying the spectrum utilizing classifications of modulation presented by means of implementing cyclostationary signatures of the signals received as major attribute for classifications of modulation and a superior casual forest classifier as a system of classification. It was presented that procedure could offer a tremendous classification performance in case of low SNR environments. Whereas, such methodology comprises a minute set of modulation strategies as stated in literature [19].

The literature [20] presents the various multicarrier schemes for CR that is cognitive radio network by using OFDM that is orthogonal frequency division multiplexing modulation technique, it is widely used for higher speed data transmission and also a low complexity demodulation and modulation scheme which can better performed by fast Fourier transformation and inverse fast Fourier transformation respectively. In this research work , author also discussed advantages and applications of OFDM cognitive radio network and also discussed benefits of DFTS-OFD that is DFT-spread OFDM, CEODFM that is Constant Envelope and FBMC that is Filter Bank Multicarrier over OFDM cognitive radio. In this research paper conclusion was given by author that FBMC will be the best suitable modulation technique for Cognitive radio network as Cyclic Prefix is excluded in it and can simply meet the firm necessities of CR that is low adjacent channel leakage ratio and low Out of band radiation.

In [23], method of identifying the spectrum utilizing classifications of modulation presented by using PSK that is phase Shift keying modulation scheme for cognitive radio network. Now in these days, PSK widely used in CR wireless communication systems as it provides higher capacity and data security. In digital communication system, it is also provides more compatibility and better Quality communication system. Author examined that PSK provides better BER data error and effective signal to noise ratio using coding mechanism hence it can also provide very less probability of error at the destination side.

In literature [25], a method of sensing the spectrum using classifications of modulation is presented by implementing typical measures obtained via immediate data of the signals obtained as major attribute for modulation categorization and SVM that is Support vector management as an arrangement of classification. A latest immediate characteristics measure was developed by authors with the total significance of the zero-center normalized immediate energy as an average value so as to obtain superior identification performance. On the other hand, even though the attributes utilized in this procedure are simple to employ and appropriate for actual-time functions, still these are very sensitive to noise effects particularly in small and medium SNR regions.

In literature [29], method of identifying the spectrum using classifications of modulation is presented by the AMC task in cognitive radio. Two forefront methods were compared: cyclostationarity and CSS. The forefront of CSS pooled with the linear kernel SVM classifier attained superior outcomes for the adopted set of modulations, and proved to be viable for implementation in a Field Programmable Gate Array, processed in real time. Moreover, a synthesizable architecture of CSS SVM was introduced, that offered suitable outcomes for AMC with a comparatively proficient usage of the available FPGA assets.

In literature [32], method of sensing the spectrum using classifications of modulation is discussed benefits and limitations of most of the recent identification algorithms proposed in literature. After a cautious, unbiased and productive investigation of the majority of the recent identification methods in literature proves that none of the methods can sufficiently and reliably identify all kinds of primary radio signals in a CR surrounding. This contributes to the method known as novel detection that was presented in this research area using an autonomous modulation detection method.

In literature [35], a method of sensing the spectrum using classifications of modulation is discussed. Two applicants for responsive modulation in CR transceivers also examined and implementing cognitive radio transceivers with SC-FDMA and MC-CDMA that is carrier frequency division multiple access and multicarrier code division multiple access. Author analysis that Bit error rate that is BER performance of Single carrier frequency division multiple access optimum than to Multicarrier code division multiple access system.

In [47], a method of sensing the spectrum using classifications of modulation was presented by cyclostationary Cooperative spectrum sensing technique which involves numerous cognitive delay nodes. It is one of the most optimum techniques to increase the performance of spectrum sensing detection with many relay nodes. In this research paper, result shown that spectrum sensing detection performance is improved with various number of cognitive relay nodes.

V. FUTURE WORK RECOMMENDATIONS

There is a need to talk about future scope as how to incorporate a proficient and flexible medium admittance strategy that could maintain both dynamic channel preference and power distribution in CR environment to the established CRE. In order to attain this, as an alternative to the random allocation of the radio spectrum band by MN in this search, game theory for spectral assets like power and spectrum bands, allocation can be included into the established CRE. The usage of game theory was particular due to its inherent ability to examine users those perform in a selfish behavior by looking for a benefit of performance over separate users at the cost of network implementation on the whole.

Various references in the field of cognitive radio for future research are: Femtocells in the place of Television white spaces, CR in the 5th generation, long Term Evolution in the place of Television white spaces and Multimedia services over CR system.

VI. CONCLUSION

This review paper presents the general idea on sensing the spectrum for CR networks using different categorizations of modulation has been given. A significant analysis of the accessible spectrum identification methodologies for CR schemes utilizing categorization of modulation, extending their benefits along with limitations. Whereas, limitations or drawbacks basically rely upon the utilization structure, subsequent standardization and much on their carrier to noise ratio necessary to decode the signal and its bandwidth. Various literature surveys and development of reliable analytical models tackle major CR concepts. Whereas to substantiate the theoretical results for the purpose of unbiased and precise results, numerical simulations must be practiced. The active and the rapid growth of research in this particular field can be seen in this review paper. Actually, enhancing consistent and quick spectrum sensing method for CR structure using categorization of modulation is yet a huge challenge, particularly over multiple path fading channel and recently non-Gaussian impulsive noise, where obtained signal encounters a serious fade. The predictable methods of spectrum identification for CR scheme have been discussed. Further research is to be required to make efficient system.

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a.

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