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IJIEMR Transactions, online available on 30th Jul 2022. Link :http://www.ijiemr.org/downloads.php?vol=Volume-11&issue= Spl Issue 06

DOI: 10.48047/IJIEMR/V11/SPL ISSUE 06/32

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Volume 11, SPL ISSUE 06, Pages: 171-178

Paper Authors

Naveen Kumar Bodukuri, Tinesh Krishna, Arshiya , B Prathyusha , K Gouri Shanker , Gattu Sai Pavan

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Simulation of Cooperative Spectrum Sensing Using Cognitive Radio

Naveen Kumar Bodukuri[1], Tinesh Krishna[2], Arshiya [3], B Prathyusha [4], K Gouri Shanker [5], Gattu Sai Pavan[6]

[1]*Assistant Professor, Dept. of Electronics & Communication Engineering, Balaji Institute of Technology and Science, Warangal, Telangana, India*

[2,3,4,5,6]*UG Student, Dept. of Electronics & Communication Engineering, Balaji Institute of Technology and Science, Warangal, Telangana, India*

Abstract— **The primary objective of IEEE 802.22 standard is to determine vacant spectrum bands available in Digital television channels (DTV) and to utilize them for wireless rural broadband connectivity. Cognitive Radio (CR) aims at maximizing the utilization of the limited radio bandwidth while accommodating the increasing number of services and applications in wireless networks. For cognitive radio networks to operate efficiently, secondary users (SU) should be able to exploit radio spectrum that is unused by the primary network. A critical component of cognitive radio is thus spectrum sensing. In this report, we propose simulation methodology for spectrum sensing technique to meet the requirements of IEEE 802.22 standard. This report describes several simulation scenarios that can be used to evaluate spectrum sensing by single unit (local sensing) and multiple SU's (collaboratively). The detection performance is described through extensive simulation using the MATLAB simulation tool. In most of the existing work,the simulation scenario of the CSS algorithm has been based on common theoretical assumptions rather than to meet the operational requirements of WRAN standard.**

Index Terms—**Cognitive radio, Energy Detection, False Alarm Probability, Missed Detection Probability.**

I. INTRODUCTION

Cognitive radio has been under active consideration in recent years to deal with the conflict between the steady spectrum demand of unlicensed users (cognitive users) and the inefficient spectrum utilization of the licensed users (primary users). A cognitive radio is an intelligent radio that can be programmed and configured dynamically [1]. Its transceiver is designed to use the best wireless channels in its vicinity. Such a radio automatically detects available channels in spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location [2]. This process is a form of dynamic spectrum management. In response to the operator's commands, the cognitive engine is capable of configuring radio-system parameters. These parameters include "waveform, protocol, operating frequency, and networking". This functions as an autonomous unit in the communications environment, exchanging information about the environment with the networks it accesses and other cognitive radios (CRs). A CR "monitors its own performance continuously", in addition to "reading the radio's outputs"; it then uses this information to "determine the RF environment, channel conditions, link performance, etc.", and adjusts the "radio's settings to deliver the required quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints". Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which ones are not [3]. The transceiver then instantly moves into vacant channels, while avoiding occupied ones [4].

Spectrum sensing must be performed before the cognitive users access the licensed spectrum in order to limit the interference to the primary user. However, due to the fading of the channels and the shadowing effects, the sensing performance for one cognitive user will be degraded [5]. To enhance the sensing performance, cooperative spectrum sensing has been proposed, which is usually conducted in two successive stages: sensing and reporting. In the sensing stage, every cognitive user performs spectrum sensing independently using some detection methods and gets an observation [6]. In the reporting stage, all the local sensing observations are reported to a common receiver and then a final decision will be made to indicate the absence (H0) or the presence (H1) of the primary user.

Spectrum sensing is a key function of cognitive radio to prevent the harmful interference with licensed users and identify the available spectrum for improving the spectrum's utilization [7]. However, detection performance in practice is often compromised with multipath fading, shadowing and receiver uncertainty issues [8]. To mitigate the impact of these issues, cooperative spectrum sensing has been shown to be an effective method to improve the detection performance by exploiting spatial diversity. While cooperative gain such as improved detection performance and relaxed sensitivity requirement can be obtained, cooperative sensing can incur cooperation overhead [9]. The overhead refers to any extra sensing time, delay, energy and operations devoted to cooperative sensing and any performance degradation caused by cooperative sensing [10]. Specifically, the cooperation method is analyzed by the fundamental components called the elements of cooperative sensing including cooperation models, sensing techniques, hypothesis testing, data fusion, control channel and reporting, user selection and knowledge base [11].

The paper is organized into seven sections. Section I give the introduction and purpose for making this system. Section II describes the Spectrum sensing model and information related to cooperative spectrum sensing. Section III contains the explanation of the energy detection technique. The process of the energy detection technique is shown in Section IV. Section V includes the simulation results of the proposed system. We draw our conclusions in section VI and have the future scope in section VII.

II. SPECTRUM SENSING MODEL

Spectrum sensing is one of the most important processes performed by cognitive radio systems. It allows the SU's to learn about the radio environment by detecting the presence of PU signals using one or multiple techniques and decide to transmit or not in its frequency band.

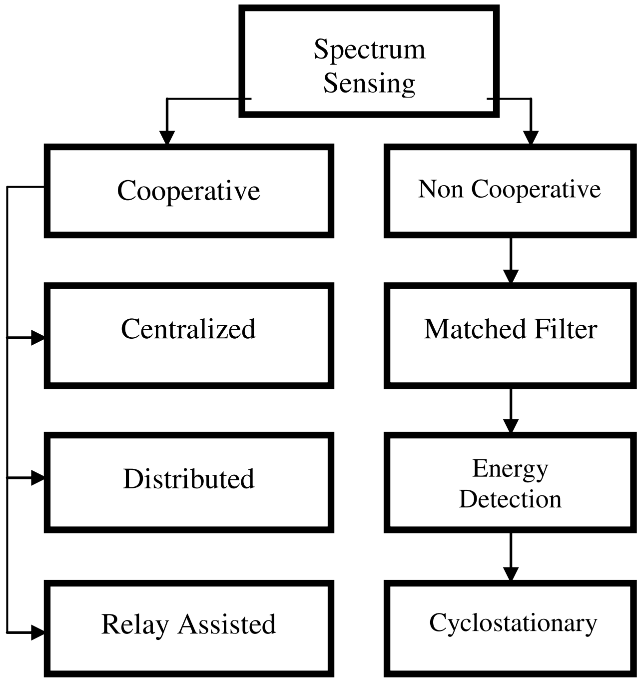

Fig 1. Spectrum Sensing Model

Under the cooperative spectrum category the SUs collaborate and coordinate with each other taking into account the objectives of each user to make the final common decision [12]. This cooperation between the different SUs can be divided into two schemes: centralized and distributed schemes. For the distributed scheme, SUs exchange their local observations and sensing results. Each SU takes its own decision taking into account the received results from the other SUs sensing the same frequency band [13]. This approach does not require any common infrastructure for the final decision and the detection is controlled by the SU's. For the centralized scheme, all the SU's send their sensing results to a central unit called fusion center [14]. The fusion center decides about the spectrum access based on the received observations. The decision can be soft or hard combining decision with AND/OR rules. Under both spectrum sensing categories, SU's can perform the sensing using a spectrum sensing technique [15]. Under the non-cooperative sensing category, also called local sensing, each SU seeks for its own objectives and does not take into account the decisions of other SU's.

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reception at primary user receiver. However, due to spatial diversity it is unlikely for all spatially distributed CR users in a CR network to concurrently experience

As there is no communication or collaboration between the different SU's that sense the same frequency band, the spectrum sensing decision is performed locally [16]. The non-cooperative techniques are simple and do not require high processing time and hardware cost. However, they are subject to errors due to shadowing, fading, interferences and noise uncertainty. They are mainly adopted when only one sensing terminal is available or when there is no possible communication between the SU's.

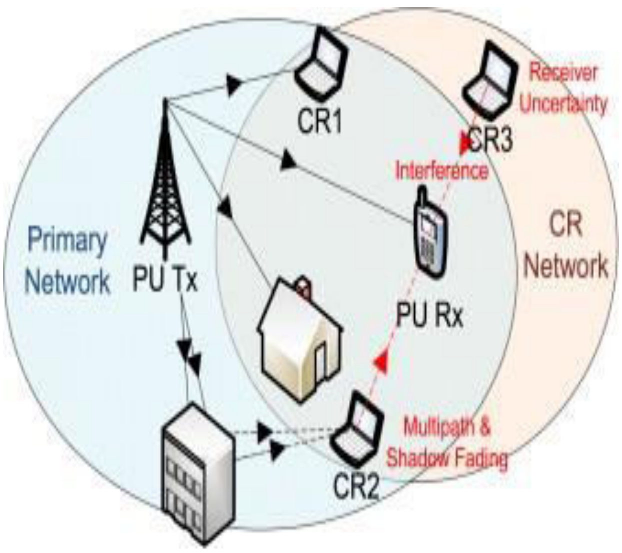

Fig 2: Receiver uncertainty and multipath/shadow fading.

Figure 2 explains that many factors in practice such as multipath fading, shadowing and the receiver uncertainty problem may significantly compromise the detection performance in spectrum sensing. CR1 and CR2 are located inside the transmission range of primary transmitter while CR3 is outside the range. Due to multiple attenuated copies of the PU signal and the blocking of a house, CR2 experiences multipath and shadow fading such that the PU's signal may not be correctly detected. Moreover CR3 suffers from the receiver uncertainty problem because it is unaware of the PU's transmission and the existence of primary receiver. As a result, the transmission from CR3 may interface with the

the fading or receiver uncertainty problem. If CR users, most of which observe a strong PU signal like CR1 can cooperate and share the sensing results with other users, the combined cooperative decision derived from the spatially collected observations can overcome the deficiency of individual observations at each CR user. Thus the overall detection performance can be greatly improved [17].

Cooperative sensing is a solution to enhance the detection performance, in which secondary users collaborate with each other to sense the spectrum to find the spectrum holes. The process used by secondary users (SU) to confirm the state of the channel (idle or busy) through cooperation with other SU's or a fusion center. A technique where the cognitive radio share their individual sensing information to improve the overall sensing information about the primary user. An approach proposed to enhance the reliability of the spectrum sensing process. It implies sharing the local sensing results of several users at a central entity, aiming at improving the reliability of the process decision. Spectrum sensing is almost a continuous process during the life cycle of CR communications. Sensing must be done initially to find an idle channel, and then it must be done periodically to protect the PU when he decides to use his licensed channel again. In this case, sensing is invoked again to find a different idle channel. Therefore, reducing sensing time increases the room left for transmission and consequently achieves the main goal of CR in increasing the utilization of the wireless spectrum. As a matter of fact, sensing does not only allow CR nodes to use the idle licensed channels. Thus, sensing has received a lot of attention in CR in the research community. In cooperative spectrum sensing a fusion center collects the sensing results from different CRs and makes a decision about the presence of absence of PU. This decision is then broadcasted to all CR nodes. Apparently, this communication process adds

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to the energy consumption requirements in CR networks. The energy is consumed during CSS in two stages: sensing and reporting.

Firstly, the CR is required to sense the presence of the PU under very low signal-to-noise ratio (SNR) that prolongs the sensing time. Secondly, some CR nodes may suffer from deep fading and shadowing effects, which may produce false sensing results. Cooperative spectrum sensing (CSS) is supposed to overcome these challenges but at the expense of extra energy consumption due to sensing and reporting the results to the fusion center (FC). This energy is dependent on the sensing time of CR nodes, the selection of the FC and the number of CR sensing nodes. The CSS performance is evaluated by the detection accuracy of the global decision. A combination of the detection probability and false alarm probability contribute to the detection accuracy. Additionally, the achievable throughput and total energy consumption represent important metrics in any communication network.

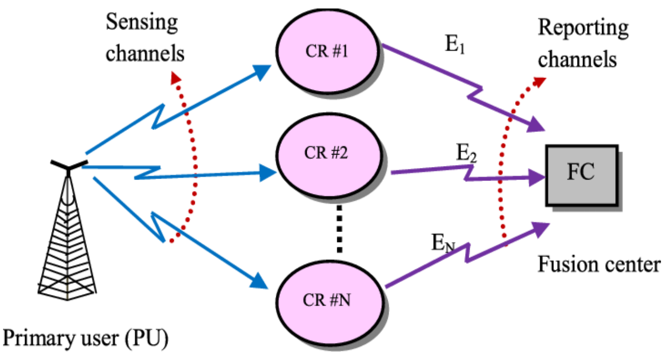

Fig 3: Cooperative spectrum sensing scenario

The process of cooperative sensing starts with spectrum sensing performed individually at each CR user called local sensing. To facilitate the analysis of cooperative sensing, cooperative spectrum sensing is classified into three categories based on how cooperating CR users share the sensing data in the network: centralized, distributed, and relay-assisted. In centralized cooperative sensing, a central identity called fusion center (FC) controls the three-step process of cooperative sensing. By cooperation, CR users can share their sensing information for making a combined decision more accurate than the individual decisions. The performance improvement due to spatial diversity is called cooperative gain.

III ENERGY DETECTION TECHNIQUE

From the various types of spectrum sensing techniques we use Energy Detection (ED) method to resolve the occurrence of primary signals. Energy Detection is a spectrum sensing method that detects the presence/absence of a signal just by measuring the received signal power. The signal detection approach is quite easy and convenient for practical implementation. Energy detector is most widely used technique in radiometry. The energy detector detects the received signal's energy to compare with the threshold and then deduce the status of the primary signals. The disadvantage is that a threshold we used will be easily influenced by unknown or changing noise levels, so the energy detector will be confused by the presence of any in-band interference. Another disadvantage of the energy detector is that perfect noise variance information is required. When there is noise uncertainty, there is an SNR threshold below which the energy detector cannot reliably detect any transmitted signal.

The disadvantage can be overcome by estimating the noise variance as accurately as possible. Different algorithms exist that can be used to estimate the noise variance, which when combined with input signal information can give the signal length at that point. The noise is generally estimated to be "Additive White Gaussian Noise" or AWGN. Three main algorithms are required for this job. They are periodogram, threshold detection and channel availability detection.

$$s(\omega) = \frac{1}{N} \left| \sum_{n=1}^{N} x(t) e^{-j\omega t} \right|^2$$

The Fast Fourier Transform (FFT) is an efficient method for transforming signal from time domain to the frequency domain. The Periodogram is based on the Fourier transform - and most often the Fast Fourier Transform (FFT), which is an efficient way of calculating the Discrete Fourier Transform. The difference between the two is that the Periodogram takes the FFT of evenly spaced segments of the data rather than the entire data at once. Periodogram method is superior because it provides a better variance for the set of input data. Energy detection is a sub – optimal detector, it can help us detect the presence of unknown signals. The advantage of this technique is it is independent of the type of signal to be detected which means that it does not require any knowledge about what type of signal we want to detect. A key requirement is to set the detection threshold we need to know what is the noise power in the frequency band that we are trying to sense. It can be performed in both time domain and frequency domain. In time domain we have to channelize the spectrum to find out whether each band is occupied or not which would require filter bands and in frequency domain the fast Fourier transform automatically does the channelizing of the band. The energy detection is based on PSD, we calculate a power cycle density and compared to a detection threshold and then make a spectral decision. Energy detection is easy to implement and does not require any prior knowledge about the PU signal, which makes it one of the most used techniques. However, it is very sensitive to the noise and cannot distinguish between the signal and the noise when the signal power is low. In addition, the sensing threshold for energy detector is an important parameter.

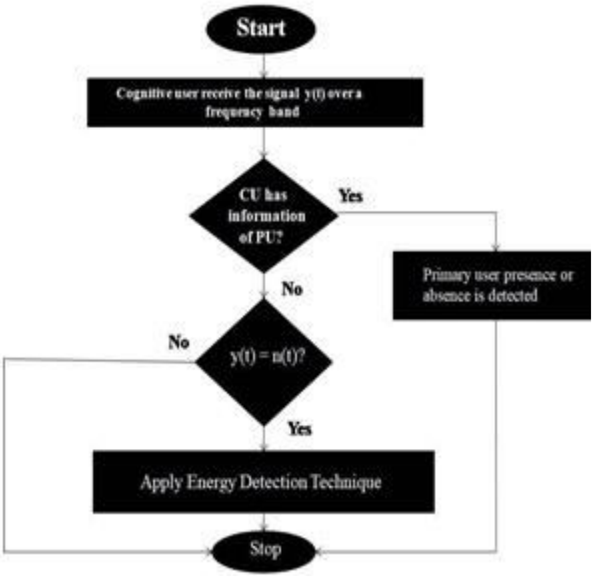

Fig 4. Flow Chart

IV PROCESS OF ENERGY DETECTON

The process of energy detection can be briefly described as follows:

1.The frequency range over which the secondary user is to transmit is decided (r1-r2).

2. The spectrum is scanned to find any holes in the given range.

3. Energy detection is done at every frequency in the range by using a periodogram.

4. Decision metric is calculated from the received signal.

5. The decision metric is compared with a calculated threshold based on the statistical interference of a hypothesis regarding a signal's presence

The received signal can be either only noise w(n) or signal together with noise (s(n)+w(n)).

$$RS(n) = w(n)$$

$$w(n) + s(n)$$

Energy detection is the simplest sensing technique, which does not require any information about the PU signal to operate. It performs by comparing the received signal energy with a threshold. The threshold depends only on the noise power. The decision statistic of an energy detector can be calculated from the squared magnitude of the FFT averaged over N samples of the SU received signal. Energy detection is easy to implement and does not require any prior knowledge about the PU signal, which makes it one of the most used techniques. However, it is very sensitive to the noise and cannot distinguish between the signal and the noise when the signal power is low. In addition, the sensing threshold for energy detector is an important parameter. When a detector does not adjust its threshold properly, it suffers from some performance degradation of the spectrum sensing. Various approaches were suggested for energy detection technique. As the sensing performance is highly affected by the estimation error of the noise power, a dynamic estimation of the noise power is recommended.

In the energy detection, energy of an averaged signal is subjected to two hypothetical test functions.

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H0 (PU is absent)

H1 (PU is present)

Under H0

x[n] = w[n] (presence of noise only)

Under H1

x[n] = s[n] + w[n] (presence of signal with noise)

H_0 is the hypothesis which means that the received signal consists of the noise only. If H_1 is true then the received signal has both signal and noise, the decision value will be larger than the threshold. So, the detector concludes that the vacant spectrum is available. The fusion center's decision is calculated by a logic AND of the received hard decision statistics. Cooperative decision performance fusion rule can be obtained. AND rule decides H_1 while every CR user ahead their bit-1 local detections. In AND rule every local detections of CR users must be H_1 to decide the existence of PU signal.

The detector output is the received signal energy as given by:

$$T_{ED} = \sum_{n=0}^{N} y(n)|^2$$

where n=1…. N, N is the sample number, and y(n) is the SU received signal, and TED is the test statistic. Thus, the decision-based energy detection can be expressed as:

$$\begin{cases} T_{ED} \geq L, & \text{PU signal present} \\ T_{ED} < L, & \text{PU signal absent} \end{cases}$$

$$P_d = \sum_n \binom{M}{k} P^k_{d,i} \left(1 - P^{M-k}_{d,i}\right)$$

Where Pd,i is the probability of detection for individual node.

V. SIMULATION RESULTS

In our project, we simulated the cognitive radio network spectrum sensing using MATLAB. We used "Cooperative spectrum sensing" technique where individual nodes use "Energy Detection" to come to a local decision about the presence of Primary User (PU). Based on the local decisions, the Fusion center comes to a final decision about the presence of the primary user.

Matrix laboratory is a proprietary multi-paradigm programming language and numeric computing environment developed by math works. Matlab allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces and interfacing with programs written in other languages.

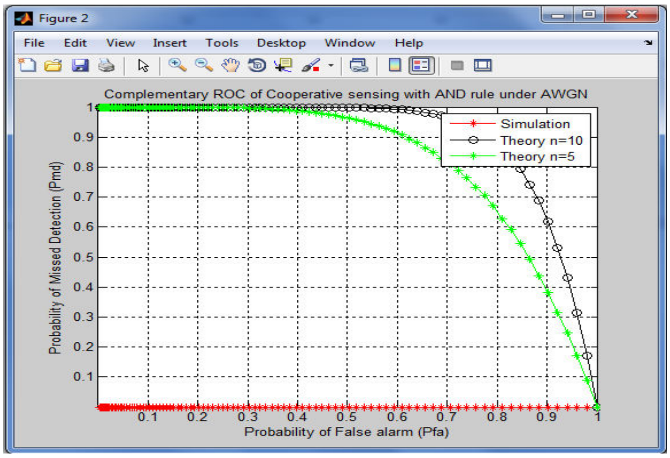

Fig 5: Complementary ROC of Cooperative sensing with AND rule under AWGN

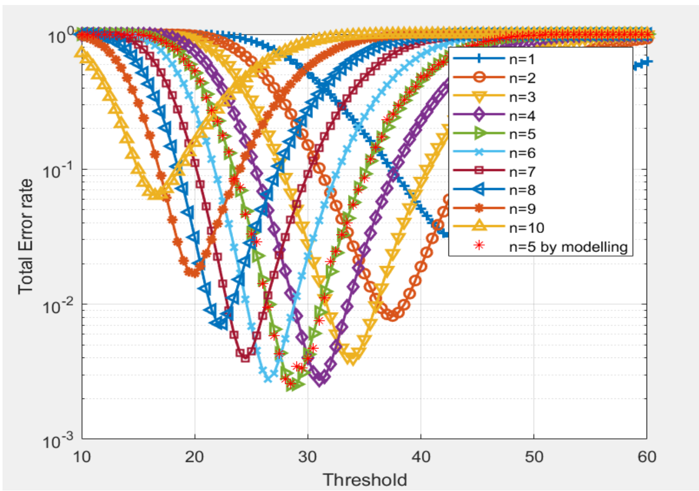

Fig 6: Total Error Rate

The Energy Detection (ED) compares the ratio obtained by the probability of missed detection

(Pmd) and probability of false alarm rate (Pfa). The probability of missed detection is simply the probability that the test statistic will not exceed the threshold under hypothesis. The probability of false alarm is the probability of falsely detecting the primary signal when the primary user is actually silent in the scanned frequency band.

These are the two important parameters for finding the spectrum holes in the cognitive radio networks.The concept of Probability of Detection (POD) is used in various industry sectors to establish the capability of an inspection to detect flaws. This is generally expressed as a POD curve, which relates the likelihood of detection to a characteristic parameter of the flaw, usually its size. In cognitive radio networks spectrum sensing plays a vital role to identify the presence or absence of the primary user. In conventional spectrum sensing one secondary user will make a correct decision about the presence of the primary user if he is in fading environment and it causes interference to the licensed users. Therefore to avoid the interference to the licensed users and to make correct detection cooperative spectrum sensing has been proposed.

VI. CONCLUSION

The primary objective of cooperative spectrum sensing (CSS) is to determine whether a particular spectrum is occupied by a licensed user or not, so that unlicensed users called secondary users (SUs) can utilize that spectrum, if it is not occupied. For CSS, all SUs report their sensing information through reporting channel to the central base station called fusion center (FC). During transmission, some of the SUs are subjected to fading and shadowing, due to which the overall performance of CSS is degraded. We have proposed an algorithm which uses error detection technique on sensing measurement of all SUs. Each SU is required to re- transmit the sensing data to the FC, if error is detected on it. Our proposed algorithm combines the sensing measurement of limited number of SUs. Using proposed algorithm, we have achieved the improved probability of detection (PD) and throughput. To improve the performance of spectrum sensing, cooperative sensing is proposed to exploit the spatial diversity of spatially located SUs. The cooperative spectrum sensing is carried out by three steps. First, cooperating SUs sense the channel state independently. Then, each SU reports their results to fusion center. The fusion center may be a CR base station for centralized cooperative sensing, or any sensing SU for distributed cooperative sensing.Finally, the fusion center determines the channel state according to the reports from SUs by using a certain fusion scheme. Though cooperative sensing enhances the sensing performance, it is influenced by several factors which mainly include sensing techniques, cooperative models, data fusion and user selection etc. Energy detection is a spectrum sensing method that detects the presence or absence of a signal just by measuring the received signal power. This signal detection approach is quite easy and convenient for practical implementation. Energy detection is the most widely used technique in radiometry.

VII. FUTURE SCOPE

Cognitive radio provides a cutting edge solution to the problem of spectrum crunch and represents a new paradigm for designing intelligent wireless networks to mitigate the spectrum scarcity problem and provide significant gain in spectrum efficiency. We anticipate that cognitive radio technology will soon emerge from early stage laboratory trials and vertical with regard to a theoretical approach and emerge as a multi-purpose spectrum stretching programmable radio that will serve as a universal platform for wireless system development, much like microprocessors have served a similar role for computation. There is however a big gap between having a flexible cognitive radio, effectively a building block, and the large-scale deployment of cognitive radio networks that dynamically optimize spectrum use. Building and deploying a network of cognitive radios is a complex task. Major research themes being pursued include spectrum policy alternatives, system models, and spectrum sensing algorithms, cognitive radio architecture as software abstractions, cooperative wireless communications, DSA technology, Protocol Architectures for CRNs, and algorithms for network security for CRNs etc. CRN research must be relatable to the physical world and it is more than important to test the same for real-world situations.

Radios work. A CRN research program must develop the tools and techniques to easily move information from field experiments (test beds) to abstract models that confirm to real life issues and move questions from the models to experiments in the field. A range of capabilities such as a flexible physical platform that supports diverse front-ends and a range of programming tools is required. Spectrum sensing within the wireless sensor technology- the essential concept for wireless technology today depends on the cognitive features. Spectrum sensing has a future in several existing and novel situations and applications. Those include crisis situations, local and indoor networks like wireless local area networks (WLAN) and battery-oriented applications. One among the foremost future scope of cognitive radio within the application of mobile communication and internet technologies using fast spectrum sensing features to reduces the time and therefore the traffic jam, WLANs are connected to FC that has a very high signal level.

REFERENCES

[1] Karthik Kumar Vaigandla, Dr.N.Venu, " Survey on Massive MIMO: Technology, Challenges, Opportunities and Benefits," YMER, VOLUME 20 : ISSUE 11 (Nov) - 2021, Page No:271-282.

[2] Karthik Kumar Vaigandla and Dr.N.Venu, "A Survey on Future Generation Wireless Communications - 5G : Multiple Access Techniques, Physical Layer Security, Beamforming Approach", *Journal of Information and Computational Science*, Volume 11 Issue 9, 2021, pp.449-474.

[3] Karthik Kumar Vaigandla and Dr.N.Venu, "BER, SNR and PAPR Analysis of OFDMA and SC-FDMA," GIS SCIENCE JOURNAL, ISSN NO : 1869-9391, VOLUME 8, ISSUE 9, 2021, pp.970-977.

[4] Dr.Nookala Venu, Dr.A.ArunKumar and Karthik Kumar Vaigandla. Review of Internet of Things (IoT) for Future Generation Wireless Communications. International Journal for Modern Trends in Science and Technology 2022, 8(03), pp. 01-08.

[5] A.V.L.N.Sujith, R.Swathi, R. Venkata subramanian, Nookala Venu, S. Hemalatha, Tony George, A. Hemlathadhevi, P. Madhu, Alagar Karthick, M. Muhibbullah, Sameh M. Osman, "Integrating Nanomaterial and High-Performance Fuzzy-Based Machine Learning Approach for Green Energy Conversion" Journal of Nanomaterials, ISSN: 1687-4129,Volume 2022,PP:1-11.

[6] Nookala Venu, D. Yuvaraj, J. Barnabas Paul Glady, Omkar Pattnaik, Gurpreet Singh, Mahesh Singh, and Amsalu Gosu Adigo, "Execution of Multitarget Node Selection Scheme for Target Position Alteration Monitoring in MANET", Wireless Communications and Mobile Computing, ISSN:1530- 8669, Volume 2022, PP: 1-9.

[7] Nookala Venu, R.Swathi, Sanjaya Kumar Sarangi, V. Subashini, D. Arulkumar, Shimpy Ralhan, Baru Debtera, "Optimization of Hello Message Broadcasting Prediction Model for Stability Analysis", Wireless Communications and Mobile Computing, ISSN:1530- 8669, Volume 2022, PP: 1-9.

[8] Dr.Nookala Venu, Karthik Kumar Vaigandla, Dr.A.ArunKumar, "Investigations of Internet of Things (IoT): Technologies, Challenges and Applications in healthcare", International Journal of Research (IJR), ISSN: 2236-6124, Volume XI, Issue II, Feb 2022, PP: 143-153

[9] Dr.Nookala Venu, "Analysis of Xtrinsic Sense MEMS Sensors" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), ISSN:2278-8875 Vol 4, Issue:8, August 2015, PP: 7228-7234.

[10] Nookala Venu, Asiya Sulthana, "Local Mesh Patterns for Medical Image Segmentation" Asian Pacific Journal of Health Sciences (APJHS), e-ISSN: 2349-0659 p-ISSN: 2350-0964, Vol. 5, Issue 1, March 2018, PP: 123-127.

[11] Dr Nookala Venu, Mrs Asiya Sulthana "Local Maximum Edge Binary Patterns for Medical Image Segmentation, International Journal of Engineering and Techniques (IJET), ISSN: 2395-1303, Volume 4 Issue 1, Jan- Feb 2018, PP: 504-509.

[12] Karne, RadhaKrishna, and T. K. Sreeja. "ROUTING PROTOCOLS IN VEHICULAR ADHOC NETWORKS (VANETs)." *International Journal of Early Childhood* 14.03: 2022.

[13] Karne, RadhaKrishna, et al. "Optimization of WSN using Honey Bee Algorithm."

[14] RadhaKrishna Karne, Dr TK. "COINV-Chances and Obstacles Interpretation to Carry new approaches in the VANET Communications." *Design Engineering* (2021): 10346-10361.

[15] Karne, RadhaKrishna, et al. "Simulation of ACO for Shortest Path Finding Using NS2." (2021): 12866-12873.

[16] RadhaKrishna Karne, Dr TK. "Review On Vanet Architecture And Applications." *Turkish Journal of Computer and Mathematics Education (TURCOMAT)* 12.4 (2021): 1745-1749.

[17] Karne, Radha Krishna, et al. "GENETIC ALGORITHM FOR WIRELESS SENSOR NETWORKS."