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LITERATURE SURVEY ON SPECTRUM OCCUPANCY MEASUREMENT

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ABSTRACT

The Paper is based on the review of the research work done in the field of the spectrum occupancy. Also, The review of the New technology called cognitive radio is been presented. The research work related to the spectrum occupancy measurement with the use of Cognitive engine. The advantage and limitations are discussed in detail.

Keywords: Spectrum Occupancy, Neural Network, Literature Survey.

I. INTRODUCTION

The Radio Spectrum is fundamentally natural resource and is regulated by government agencies such as federal communications commission (FCC), international telecommunication union (ITU), and telecom regulatory authority of India (TRAI). Due to rapid growth of wireless communication devices and the high data rate applications, lot of demand for additional bandwidth which leads to spectrum scarcity. Also, the recent studies showed poor utilization of allocated bands for different wireless services in terms of different dimensions such as frequency, time and geographical space. Therefore, research into new techniques for efficient spectrum utilization is being aggressively engaged by academia and industry. Cognitive radio (CR) became a promising technology to resolve the spectral scarcity and under-utilization of allocated spectrum. Since, this work presents the design of cognitive engine as an adaptive, intelligent radio and network technology that can detects the available channels automatically in a wireless spectrum and change transmission parameters to improve radio operating behavior. Therefore, before starting with actual research, it has been tried to find relevance of topic and to understand the state of the art of the research contributions of the early researchers. Even their way of thinking and innovations in the particular area are also studied, to understand all these points, the rigorous review of the early literature and the published articles is done. The review is presented in this chapter. It is tried to keep this chapter more informative and the flow is maintained as per the work done by each researchers in sequential manner.

In the initial sections of this chapter, it has been tried to give the insight in basic theory of cognitive radio technology, according to the perspective of the different historical articles. The articles related to spectrum sensing techniques, the measurement campaigns conducted for the spectrum occupancy measurement using traditional antennas are presented in successive sections. The implementation of cognitive engine and throughput parameter measurement related articles are discussed in further sections.

II. LITERATURE SURVEY ON COGNITIVE RADIO TECHNOLOGY

The inefficient spectrum usage facilitates a new communication model to exploit the existing wireless resourcefully [1-4]. These motivated in the field of Cognitive Radio. The main objective of CR is to provide reliable communication along with effective utilization of frequency spectrum. The key issues in CR are awareness, intelligence, learning, adaptivity, reliability and efficiency. This CR technology utilzes all natural resources such as frequency, time and energy proficiently. CR operation can be divided in to three phases: Radio spectrum sensing and analysis, channel state estimation, and radio configuration parameter selection.

2.1 Background of Cognitive Radio

The following steps highlights the growth of the CR from origin to the development till the contemporary time

The Cognitiv Radio(CR) term was first introduced by Joseph Mitola III in his doctoral thesis [5] in 1999.

In 2002, the Defense Advanced Research Projects Agency (DARPA) formed policies based on spectrum management framework to benefit the vacant space of spectrum temporarily and spatially.

The Federal Communications Commission (FCC) has carried out research work with task force to study the spectrum usage for fulfilling the huge demand of spectrum. The underutilization of the spectrum bands is

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confirmed by it and later the FCC issued the Notice for Proposed Rule Making (NPRM) [6]. The main of this work is to use the spectrum efficiently.

The Institute of Electrical and Electronics Enginner (IEEE) designed the 802.22 working group in 2004 which defines the specifications of physical and medium access control layer and wireless regional area network.

IEEE started the Project for upcoming radio spectrum management as 1900 standard task group by the end of 2005. It defines the standard terms and definitions for dynamic spectrum access, interference and concurrence analysis and spectrum management radio systems. In 2006 IEEE organized first conference on cognitive radio CROWNCOM,. The main aim was to collect new ideas related to CR from worldwide researchers. FCC had launched CR technology based unlicensed service project of TV band followed by the conference.

FCC was launched different rules for allowing cognitive radio devices to utilize TV white spaces as secondary users by the end of 2008.

The rules regarding use of white space by secondary users was determined in a Memorandum Opinion and Order by FCC in 2010.

IEEE standard for 802.22 (WRAN) in 2011 and currently focused on the standards for positioning and installation of 802.22 systems.

2.2 Spectrum sensing in cognitive radio

Mansi Subhedar, et.al. has represented a reliable spectrum sensing in cognitive radio system in [7]. Generally, the licensed spectrum is underutilized. The utilization of available spectrum can be increased by adopting a cognitive radio as a hopeful technology. The spectrum sensing identifies the unoccupied spectrum holes which is very challenging to implement. The related issues as well as challenges are represented using comparative study of different methodologies. In this paper, the development of CR network was based on advanced techniques such as distributed spectrum sensing, CR reconfiguration management, interference management, and cooperative communications. The result concluded that the method used for spectrum sensing should be reliable and prompt to realize CR for utilization of scarce spectrum without interfering primary user.

S. Thamizharasan, et.al. introduced a cyclostationary spectrum sensing method for identifying the presence of primary user in spectrum in [8]. It was accomplished by the concept of periodicity in OFDM signals. In the existing method the signals were identified by the periodicity of pilot signals in the OFDM symbols. In proposed method the periodicity concept was obtained by the insertion of guard interval in the OFDM signals for detecting primary user signals. The results of simulation shows the comparison between actual and experimental method in terms of power spectral density.

Energy detection method is another method used to detect presence of primary users. It depended on the knowledge of noise power but affected due to uncertainty in noise. It was overcome by Covariance based detection method, in which correlation between space and time signal was exploited without knowledge of noise and signal power. The covariance difference of signal and noise were used for the detection of licensed users. The performance of covariance based detection method was analyzed under Rayleigh and Rician fading channel of TV bands in terms of probabilities of false alarm and the probability of detection. This was carried by Tanuja Dhope, et.al. in [9]. The performance was also analyzed by using correlation coefficient and smoothing parameters. As per obtained results, Covariance based detector has been performed better than the energy detector with noise uncertainty even under the time-varying fading channels.

The spectrum sensing method based on Euclidean distance was studied by Hector Reyes [10], in which the autocorrelation between samples was used. Universal Software Radio Peripheral (USRP) platform operating with GNU Radio software was used for performing experiment. The false alarm and detection probabilities were observed at different signal to noise ratio through experiment evaluation. The proposed technique performance based on autocorrelation was compared with other spectrum sensing method in terms of noise uncertainty, utilization level and speed of network. The simulations results showed that the proposed Euclidean distance technique was more effective than the autocorrelation and energy detection scheme in terms of probability of detection and false alarm.

Waleed Ejaz, et.al. proposed a reliable spectrum sensing method [11] in which energy and cyclostationary based detection technique were combined on the basis of power and band of interest. The system performance

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was evaluated by comparing the results of matched filter, energy detector, or cyclostationary detector in terms of mean detection time, probability of false alarm and detection.

Mohd. Omar, et.al. proposed the Singular Value Decomposition (SVD) method to detect the presence of the wireless signal based on eigen values [12]. The performance of system was examined by performing simulation using raised cosine, rectangular pulse shape and root raised cosine wireless communication digital signal. They found that the SVD based detection is a more efficient technique used for sensing signal in spectrum. It was performed without knowledge of the transmitted signal properties. The result has shown fewer requirements of execution time and computational complexity as compared with energy detector. Also, it has a better performance in the low signal to noise ratio environment.

Md. Shahnawaz Shaikh, in his paper, studied cognitive radio spectrum sensing techniques in [13]. The radio link present in between transmitter and receiver has multipath propagation of communication signal. But, it varies randomly at the time of transmission and affects on the CR performance. This paper enlightens different spectrum sensing techniques analysis and implementation over AWGN and Rayleigh channels. The performance of different CR spectrum sensing techniques was evaluated through comparative analysis in terms of SNR Vs decision accuracy under varying channel conditions.

S. Hongjian et.al. in [14], discussed about the different wideband spectrum sensing algorithm with many challenging issues. Special attention was paid on sub-Nyquiest technique which consist of compressive sensing and multichannel sub-Nyquist sampling techniques.

A wideband spectrum sensing acquire directly the wideband signal using a standard ADC and then use digital signal processing techniques to detect spectral opportunities. Quan. et.al. [15] proposed a multi-band joint detection algorithm to recognize the primary signal among multiple frequency band signal. In this technique, first sampling of wideband signal was done using ADC then these series sample data were converted to parallel data using serial to parallel circuit. The Fast Fourier Transform was applied to represent signal in frequency domain in terms of narrowband spectrum. The hypothesis testing was used to determine the presence of primary users in spectrum. It has been prove that the implementation algorithm has better performance than the single band sensing.

Another solution would be the filter bank algorithm for detection of wideband signal was suggested by Farhang-Boroujeny in [16]. Where, different central frequency filters were used for estimation of baseband signals. So, in the process first the wideband signal was down converted to baseband and then passes through low pass filter. This algorithm has been found better solution to dynamic nature of wideband spectrum sensing. But, require more number of RF components for implementation due to parallel structure.

Tian and Giannakis in [17] proposed a wavelet-based spectrum sensing algorithm in which wideband spectrum power spectral density (PSD) was represented in terms of train of frequency sub bands. Each band has a smooth PSD, but discontinuities and irregularities were found at the border of sub bands. So, wavelet transform has been found better technique to overcome above problems at the time of wideband PSD based spectrum sensing.

2.3 Spectrum sensing using Machine Learning Techniques

The availability of channel in spectrum is determined by using spectrum sensing in cognitive radio, but it takes more time for sensing. It can be reduced by using predictive method for detection of spectrum holes. So, neural network was used as powerful tool for the spectrum prediction by Vamasi Tumuluru et.al. [19]. The multilayer perceptron model (MLP) was used to predict unoccupied channels of spectrum with backpropagation algorithm for training the network. MLP predictor performance has been evaluated using matlab simulation and found improved performance of cognitive radio using sensing prediction method with saving maximum amount of sensing energy.

A combined property of energy detection and cyclostationary feature detection based spectrum sensing using neural network was introduced by Yu Tang et.al. in [20]. These methods were selected for feature extraction due to simplicity, low computational complexity and ensure higher performance in detecting signals of low signal to noise ratio. Artificial neural network was used for training the network to detect primary users' existence in spectrum. The results shown better accuracy of prediction and enhanced the performance stability in least computational complexity.

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A low computational cost algorithm was developed for spectral vacancies by A. Canavitsa et.al. in [21]. The objective was to decide primer user occupancy based on fixed size of past observation window and occupation of window by secondary users was in least disturbance to the primary user transmission. A real data was used from the measurement campaign conducted on a voice radio communication systems operating in the 450-470MHz band. The performance shown the superiority and robustness of the method with low probabilities of error and the channel status was totally depends on the size of prediction window.

Jide Popoola et.al. in [22] presented automatic modulation classifier method for detection of primary users in licensed bands of spectrum. The objective was to sense digitally modulated primary radio signals in spectrum. It was achieved by modulation classifier design using neural network. The four feature keys were extracted to distinguish between different types of modulation as input to network. A total 2500 data with four feature set inputs and five target outputs were used for training neural network. The analysis was done on matlab environment using ANN tool in which 50% data was used for training, 25% data for validation and 25% data for testing the network. The developed model was performed better at low signal to noise ratio with fast detection rate in the range of 5.1ms.

Liang Yin et.al in [23] was performed the experiment to predict the spectrum behavior learning using neural network. The multilayer perceptron (MLP) based neural network model was developed to satisfy the objective of handover channel list in advance to secondary users by forecasting the status of channel about busy or idle. The training data was collected from measurement campaign conducted in South Chaina for entire week over the frequency range 20MHz to 3GHz. The performance was assessed by comparing measured value to predicted values for different days, services and frequencies in terms of Root Mean Square Error.

Nida Baldo et.al. in [24] was devised a controller based on neural network for dynamic channel selection in Cognitive Radio application. It was based on multilayer perceptron neural network. The wireless network challenges related to cognitive control was discussed and given better solution about dynamic selection of channels.

The spiking neural network is the third generation of neural network and has a better performance of cognitive tasks in pattern recognition. It has powerful computation capability than other networks with cost of low learning efficiency. A new algorithm based on synaptic efficiency adjustment method was proposed to improve learning efficiency by keeping high computational capability. The training time was reduced only selecting target spike time in algorithm. The voltage difference between the output neuron potential and threshold firing was applied to different synapses. The learning property of algorithm was investigated for single and multiple spikes input neurons. As per result obtained from simulation, the learning performance of given network algorithm is better than existing other methods with achieving higher efficiency in the training of spiking neural network. This was invented by Xiurui Xie in [25]

Radial Basis Function (RBF) neural network was method was used by Shibing Zhang et.al. in spectrum prediction [26]. Cognitive radio node detect complete spectrum every time at the time of sensing, consumes time and also network resources. This issue can be solved by detecting spectrum holes using historic information from licenced users. The RBF neural network width and hidden nodes number can be selected by newly developed algorithm. The channel occupancy simulation was done using Gold sequence and M sequence. The comparison of predicted data and measured data shows that RBF can find the spectrum occupancy state very accurately with least resource consumption.

The evaluation performance of Radial Basis Function neural network and Multilayer Perceptron was studied to estimate of TV idle channel by Ojenge Winston et.al. in [27]. The performance was evaluated by varying the number of layers, number of neurons, activation function, learning rates for MLP and spread of RBF, maximum number of neurons in layer. Both the network MLP and RBF is implemented using Matlab. Mean Square Error (MSE) values is used for performance evaluation. MLP has low MSE than RBF models and strongly depends on time slots, day of week , and watched TV channels in household. Also it further indicated that the MLP architecture performance was better in terms of faster training for given data.

Cognitive core is a one of important component in cognitive engine. It consists of knowledge base, learner and optimizer. Artificial intelligence technique may be used for implementation of above component. Here Xu Dong et.al. in [28] was used neural network for implementation as a learner in cognitive engine. Multilayer

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Perceptron with supervised learning technique was used for implementation of model. The experiment was performed on the Wimax platform. The data obtained from Wimax were used for training neural network. The performance of system was evaluated by the comparison in terms of bit error rate of actual and predicted values by MLP neural network. It was found that the prediction performance improved by selection of more training data, increase of modulation level with tradeoff between iteration time and complexity.

Nadine Abbas et.al. in [29] proposed a novel Artificial Intelligence and machine learning techniques for cognitive radio network. The literature review was organized on different AI techniques such as Support Vector Machine, Neural Network, Genetic Algorithm, Fuzzy Logic, Baysian, Markov model, Reinforcement Learning, Entropy, Multi Agent system, Game Theory and Artificial Bee Colony Algorithm. The challenges, strength, limitations and of different technique was summarized for cognitive radio applications.

2.4 Literature Related to Spectrum occupancy measurement campaign

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III. LITERATURE RELATED TO SPECTRUM OCCUPANCY MEASUREMENT CAMPAIGN

Numerous spectrum occupancy measurements were conducted by academia, group of researchers, and Industry in several parts of world to recognize spectrum utilization of particular wireless technologies. First spectrum occupancy measurements campaign was conducted in USA by National Telecommunication and Information and Administration (NTIA) in 1998 [30]. This results in very large difference due geographic differences. from the results, Coastal cities had greater spectrum utilization than Midwest cities.

Marc McHenry et.al. was conducted spectrum occupancy measurement campaign under initiation of NSF [31]. The aim of this measurement was to identify underutilized spectrum in the dense urban environment of Chicago. It was conducted for two days in Chicago, which was found 17.4% occupancy.

The New Zealand campaign in [32] was arranged to study the unoccupied spectrum availability in the form of frequency, time, and space for future secondary use. The measurement was performed at indoor and outdoor locations over 12-week period during weekdays in the morning, and afternoons in 806 MHz to 2.7 GHz frequency band in Auckland, New Zealand. The spectrum was divided into nineteen frequency sub bands as per bandwidth of the signal and wireless service. The campaign consists of dipole antenna (806~1000MHz), discone antenna (1000~2750MHz) and Rohde & Schwarz ESVN40 Test Receiver components for measurement system. As per spectrum occupancy measurement analysis; the spectrum utilization was more at outdoor location (about 6.21%) than indoor location (about 5.72%).

An indoor and outdoor location measurement campaign was conducted at Aachen, Germany by Matthias Wellens et.al. over the frequency range 20-6000 MHz in [33]. The measurement set up consists of Agilent E4440A spectrum analyzer and wide band antenna includes a large discone antenna of type AOR DA-5000 (20 - 1520 MHz), a smaller discone antenna AOR DA-5000JA (1.5-3GHz) and random antenna Antennentechnik Bad Blankenburg AG KS 1-10 (3-6GHz). The occupancy status was decided by selecting the decision threshold as 3 dB above the measured noise floor throughout the investigated band. The result shows higher occupancy in outdoor scenario compared to indoor scenario due to less ambient noise. The Amplitude Probability Distribution was used to determine the secondary use potential candidate.

In the measurement campaign at Singapore [34], the measurement has been taken on the roof top of the Institute for Infocomm Research building at outdoor location for 24 hours over twelve weekday period. The campaign was conducted for the evaluation of various services spectrum utilization, and identification of the bands free for transmission of secondary signal in future use. The occupancy was detected with the help of decision threshold. The measured value above the threshold shows occupied spectrum. The total average occupancy in Singapore was found only 4.54%. Also it has been observed that broadcasting bands, and GSM 900 bands have found higher occupancy. Aeronautical radio navigation, radiolocation, primary radar, and secondary radar have found very low utilization, and therefore, these are suitable for secondary usage.

The spectrum measurement in urban environment at urban location was performed by Radio Communications of the Catalonia Technical University group in Barcelona [35]. It was conducted for two days in 75 MHz - 3 GHz frequency range. The results obtained from campaign reveals the spectrum occupancy was 22.72% for 75 MHz to 3 GHz frequency range. Also it has been observed that the uplink frequency of cellular GSM 900 have less occupancy than downlink frequency because of continuous transmission of signal continuously. The TV bands are more popular. UMTS uplink had found very low utilization about 2.86%, and these bands can be useful for future CRNs. The result showed that 1-3 GHz band be a potential candidate for the CR in future.

A measurement campaign for wideband spectrum access was conducted by Miguel López-Benítez et.al in [36] over 75MHz-7.075GHz frequency range for 24 hours. The main objective of this campaign was to study impact of different locations on spectrum utilization in perspective of cognitive user. The wide band measurement set-up consists of Single Pole Double Throw switch for antenna selection, filters to avoid overloading, and attenuate unwanted signals, a low noise preamplifier for enhancing the sensitivity of system. The result showed the occupancy level mainly dependes on the location at which campain was carried out.

Measurement of spectrum utilization by Vaclav Vantela et.al in [37] carried out in three locations in Europe during years of 2008 and 2009 respectively over 400MHz to 3GHz radio spectrum. The measured method was based on the energy detection principle. Here major wireless communication systems behavior and utilization performance within different regions and environments were studied. It has been observed that the overall utilizations in the band 400MHz to 3GHz at different location was 6.5%, 10.7%, 7.7% respectively. Measurement in the ISM band offers significant frequency reuse and opportunities.

Meftah Mehadwi et.al performed a measurement at university of Hull-UK[38]. The measurement campaign used for Bilog Antenna CBL6143 with frequency range of 30 to 3000MHz, applies the signal received to Spectrum Analyzer Agilent 4407B. The data was processed by using computational package MATLAB. From the results GSM1800 and GSM900 bands have larger occupancy because of broadcasting downlink. Where Aeronautical radio navigation, Fixed satellites, WBA and ISM have low utilization. Generally the frequency above 1GHz was relatively underutilized.

A wideband spectrum occupancy measurement campaign was conducted by K Qaraqe et.al at Qatar in indoor and outdoor environment [40]. It was conducted over frequency range from 700MHz to 3000MHz. the objective was to study indoor and outdoor environments spectrum utilization concurrently for three consecutive days. The set up consist of a Rhode and Schwarz FSH6 portable Spectrum Analyzer connected to a laptop through USB optical cable. The energy detection principle was used to determine utilized or idle band with the knowledge of threshold level, where it was selected above 3dB level of noise floor measured without antenna. It was obvious from the measurement result that spectrum occupancy highly depends on the location. So it was recommended to consider location information for efficient spectrum utilization method.

The effect of frequency, direction of antenna, resolution bandwidth and selection of period of measurement on measurement campaign was studied by M. Mehdawi[41]. The aim was to select accurate and suitable parameters for measurement set up. The experiment set up was included four different antennas (Yagi, Discone, Bilog, DTA218) and spectrum analyzer. The Yagi and Bilog antenna have a directional radiation pattern while Discone and DTA218 with omnidirectional radiation pattern. The optimal antenna was selected by comparing the relative field performance in whole TV band. As per results, the directional antennas have higher reception of signals than omnidirectional antennas with greater duty cycle of spectrum occupancy for Biog antenna. At the same time omnidirectional and wideband made attractive Discone and DTA218 for radio measurement applications. The influence of frequency dimension was also evaluated by proper selection of frequency range and resolution bandwidth. The selection of narrow resolution bandwidth has increased the resolving ability of system. Also, the optimum duration was decided by a priori knowledge about the radio system behavior.

S Barnes et.al conducted a measurement campaign to resolve the deficiency of knowledge about occupancy of spectrum in South Africa [42]. This was conducted at GSM 900MHz and GSM 1800MHz band UHF. UHF band has found 20% occupancy but GSM 900MHz band occupancy has 92%, GSM 1800MHz of 40%. Results obtained from experiment, cellular band has high occupancy.

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The frame work for measurement was suggested by K Patil et.al [43] for conducting spectrum measurement of occupancy campaign in India over the frequency range from 700-2700MHz to identify less occupancy licensed band.

TV band spectrum occupancy was studied using theoretical duty cycle model and validated. The different methods and the effect of various parameters at the time of evaluation of spectrum occupancy in concern with CR are discussed in [44]. The results obtained from the measurement campaigns conducted in [45] show the current spectrum regulation inefficiency. The worldwide measurement campaigns overview in the concern with CR is described in [43]. A generic spectrum surveying framework has introduced standardization and automation to spectrum surveying [45].

IV. ADVANTAGES AND LIMITATIONS

The motto of spectrum occupancy analysis is to determine the percentage of spectrum utilization by primary users, so that the secondary users can avail the available spectrum. Spectrum sensing is a first step of cognitive engine. It assists in the detection of spectrum holes by offering high spectrum resolution. Now the spectrum sensing problem has gained new aspects with cognitive radio and opportunistic spectrum access concepts. It is one of the most challenging issue in CR systems. Challenges associated with spectrum sensing methods were reviewed using different methods such as energy detection, cyclostationary detection, matched filter detection, covariance based detection, Euclidean based and singular value decomposition method. The implementation of spectrum sensing scheme in terms of the challenge and issues were discussed in detail using comparative study of different methodologies [7-13]. All above methods were implemented for narrowband spectrum sensing. The next work was carried out by further researchers to find spectrum holes in wideband spectrum. They examined various wideband spectrum sensing algorithms such as sub Nyquist technique, multi-band joint detection and wavelet based algorithm [14-17]. However, this approach was often slow and consumes more energy for sensing of whole spectrum.

In CR systems, the main requirement of spectrum sensing is the ability of rapid and accurate detection of the presence of primary user with minimum energy consumption. It can be achieved by using predictive methods for discovering spectrum holes in the spectrum. Using the reliable predictive scheme the unlicensed users will sense only those channels which are predicted to be not busy. By achieving low error probability in predicting the free channels, the spectrum utilization can also be improved. Therefore a spectrum predictor was designed using neural network model based on multilayer perceptron and radial basis function, which does not require a prior knowledge of the traffic characteristics of the licensed user systems [18-29].

The number of measurement campaigns was conducted by group of research, academia and Industry in different parts of the world to know the spectrum occupancy by primary user [30-45]. The study of unoccupied spectrum availability in the form of frequency, time and space was arranged for future secondary use purpose. The measurements were carried out for one day to twelve week period during weekdays and weekend over 300MHz to 3GHz frequency band at indoor and outdoor locations. A measurement campaign was conducted with the help of Dipole antenna, Discone antenna or Bilog antenna with spectrum analyzer. The collected data is processed by Matlab computational package. As per analysis done by number of researchers, the spectrum occupancy varies from 15% to 60% depending on geographical location and time. The maximum numbers of bands were underutilized and it can be helpful for allowing secondary users to utilize the unused spectrum of licensed and unlicensed primary users without interference on temporary basis. The different antennas used for measurement of spectrum have limitation of large size and in some applications measurement was performed by rotating antenna manually.

Cognitive Radio was implemented on reconfigurable hardware like ASIC and FPGA based platform. FPGA provides a better solution of flexibility in implementation than ASIC. Also, the disadvantages of narrowband coverage and inflexibility of traditional hardware device was overcome by implementation of CR on Universal Software Radio Platform (USRP). The USRP was programmed through a GNU radio and in MATLAB environment. The functions of CR such as spectrum sensing, spectrum access and spectrum handover to secondary user were accessed using designed platform. The result shows that the CR platform was highly reliable with well working of communication in the optimal channel with deficiencies in the delay of spectrum sensing and switching [38-44]. The considerable balance between cost, power, flexibility and size of system

implementation was ensured by credit card sized single board computer using Raspbery Pi platform jointly with signal processing and communication system simulink toolbox [37].

In CR, the secondary user performance increases by increasing the sensing time but at the same time decreases throughput of secondary users which directly affected on quality of service. The throughput of secondary user can be maximized by formulating optimization of spectrum sensing time based on prior knowledge of the available primary users presence and absence probabilities [40-45]

After this rigorous literature survey, it reveals that CR is the promising and challenging field in doing the research and still there is a vast scope for new researchers. And the thrust area of the research is, use of CR technology to access the underutilized spectrum in wireless environment dynamically. Therefore it is important to design an intelligent cognitive engine based on Artificial Neural Network (ANN) that the device should be simple in implementation with compact in size, low cost, minimum consumption of energy and time for sensing and having maximum throughput.

V. CONCLUSION

The paper presents the previous work done in the field of the Spectrum occupancy measurement is elloraboted in detail. The paper presents the research work on the Cognitive radio engine and cognitive radio will help to work to the experimentation of the current work.

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