DTHD: An Dual Threshold Approach for Spectrum Sensing in Cognitive Radio

Amritpal Singh, Prof. Neetu Gupta

Electronics and Communication Engineering, Global Institute of Management and Emerging Technologies, Amritsar, India

Abstract— Accurate detection of noise is important in cognitive radio. To detect the noise from the radio signals many techniques had been developed till now. This study aims to implement a double thresholding based detection mechanism. The performance of Rayleigh fading distribution, Rician fading distribution, AWGN fading distribution and Weibull fading distribution on radio signals is also examined under this study. The comparison results proves that the proposed technique outperforms the traditional mechanisms and it is also concluded that the Weibull fading distribution is less effective and poses the 0.61 detection probability which is quite lower as compare to detection probability of other fading distributions.

Keywords—*Cognitive Spectrum, Noise, SNR, Detection Probability, Fading Channels.*

I. INTRODUCTION

Cognitive radio is one of the techniques that make the user capable to examine the electromagnetic spectrum to opportunistically transfer in currently present frequency bands. By using the spectrum sensing the evaluation of the frequency bands that can be utilized by unauthorized users can be perform. Over the last decades many spectrum sensing techniques had been developed and it is obtained that energy detection mechanism is widely used due to its various features such as easy to implement [1]. Even though, it is mandatory to have better (SNR) signal to noise ratio in order to implement this technique. To analyze the effect of fading on the signal is quite tedious task therefore various researchers also focused on this concept so that the effect of fading can be reduced or discarded from the signals [2]. The study of this work represents the noise detection probability of Rayleigh, Rician, AWGN and Weibull fading channels through simulation. Fading is a term used mostly in wireless communication systems. It is a fluctuation in received signal's amplitude, phase and angle of arrival because of multipath reflective paths [3]. At the time of propagation; signal can be attenuated over a certain media in wireless communication. The main reason behind fading is multipath propagation or shadowing which affects the wave propagation. Multipath propagation happens when a radio signal transmitted over two or more different paths from the antenna and before its reception on the receiving antenna [4]. There are different fading models which can be used to judge the fading over the channel. Some of them are:

A. RAYLEIGH FADING CHANNEL

This fading channel is referred as statistical model when effect of propagation has happened on a radio signal. In such channel, it has assumed that magnitude of the signal which passed through the transmission media or communication channel may fade. In Rayleigh Distribution, two uncorrelated Gaussian Random variables are defined whose sum have derived the fading in the channel. In other words it can say that this type of fading channel has applied in cases where there is no Line of Sight or LOS between two parties i.e. transmitter and the receiver [5]. Channel adds noise into the signal samples after it suffers from Rayleigh fading. AWGN noise has been added in the signal.

Received signal will be referred as 'y' in the equation such as:

$$Y = hx + n \dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where n in the equation 12 describes the AWGN i.e. Additive White Gaussian Noise with zero mean and unit variance and h refers here Rayleigh fading response with zero mean and unit variance. Transmitted signal is x and it can be acquired by the received signal y using following equalization such as:

$$\hat{y} = \frac{y}{h} = \frac{hx+n}{h} = x + z \quad \dots\dots\dots\dots\dots\dots (2)$$

In the equation (13) estimation of the received signal.

The theoretical for BPSK modulation scheme over Rayleigh fading channel along with AWGN noise can be given as:

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{\frac{E_b}{N_0}}{1+\frac{E_b}{N_0}}}\right) \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (3)$$

B. RICIAN FADING CHANNEL

When there is dominant line of sight i.e. LOS between the transmitter and receiver in such case Rician fading channel has used. The LOS component between the transmitter and receiver is also known as Specular Component and multipath component is known as random or scatter component whose amplitude distribution will have non-zero mean and zero mean respectively [6]. In the below equation 'K' is the Rician factor which defines the ratio between the power of specular component to the power of random component.

$$K = \frac{m}{2\sigma^2} \dots (4)$$

Where 'm' defines the mean $\sigma^2$is the variance. In order to evaluate or simulate the Rician fading channel, Rician factor 'K' needs to be calculated with the mean and sigma. Thus it can be expressed as:

$$m = \sqrt{\frac{k}{k+1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\sigma = \sqrt{\frac{1}{2*(k+1)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The theoretical BER for modulation scheme BPSK over Rician fading channel with AWGN noise can be described as:

$$p_b = \frac{1}{2}\,\text{erfc}\left[\sqrt{\frac{k(E_{b(N_0)})}{(k + E_{b(N_0)})}}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

C. AWGN

Additive White Gaussian Noise is a noise model that is utilized in communication channels in order to define the linear addition of white band or noise and Gaussian filtration to the signal. Nevertheless, the concept of multipath propagation, dispersion non-linearity and scattering does not supported by this channel [7].

D. WEIBULL FADING CHANNEL

The Weibull fading channel is most suitable for modeling the multipath signal fading effects. It is a version of Rayleigh distribution. If X and Y are zero mean Gaussian variables then the envelope of $R = (X^2 + Y^2)$ is Rayleigh distribution and if the envelope is defined as $R = (X^2 + Y^2)^{\frac{1}{k}}$ then it is known as Weibull fading distribution. And it is evaluated as [9]:

$$f(r) = \frac{kr^{k-1}}{2\sigma^2} e^{-\frac{r^k}{2\sigma^2}} \ldots\ldots (12)$$

II. PROBLEM FORMULATION

A "Cognitive Radio" senses the spectral environment over a wide range of frequency bands and exploits the temporally unoccupied bands for opportunistic wireless transmissions. Since a cognitive radio operates as a secondary user which does not have primary rights to any pre assigned frequency bands, it is necessary for it to dynamically detect the presence of primary users. Spectrum sensing is the basic and essential mechanisms of Cognitive Radio (CR) to find the unused spectrum. Spectrum sensing (spectrum detection technique)is the main task in cognitive cycle and the main challenge to the CRs. Energy detection (also denoted as non coherent detection), is the signal detection mechanism using an energy detector (also known as radiometer) to specify the presence or absence of signal in the band. Various techniques have been developed traditionally to detect the energy in the cognitive radio but are not able to perform efficiently because the techniques faces the variations in the value of the detected value of the energy. Other backlog was that none of filtration was performed over the signals in order o remove the noise from the signals. The traditional method is based on the single threshold value which is again a lacking point. Hence there is a need to develop such a technique which can overcome the problems of the existing techniques.

III. PROPOSED WORK

After having a review to the previous work it is detected that the problem of variations in the value of the energy, single threshold value and existence of noise in the signals were faced. Hence in order to solve these issues the proposed work aims to implement the double threshold value in order to overcome the issues of the single threshold value, and also analysis of the network over different fading channels. The methodology of the proposed work is as below:

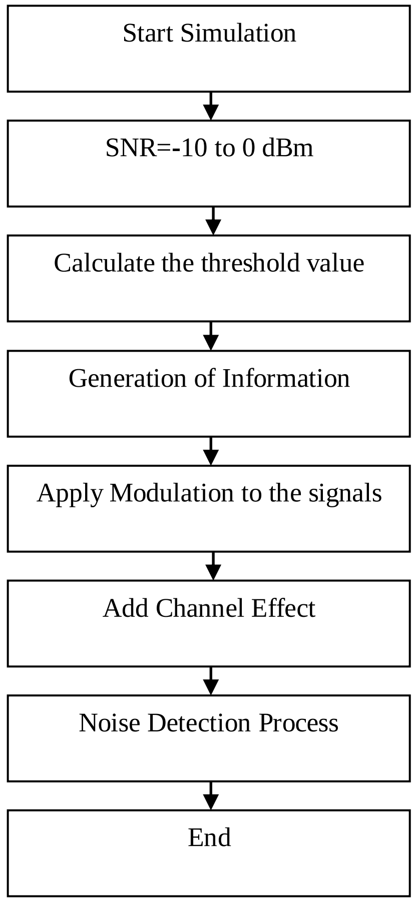

Fig.1 Block Diagram of Proposed work

IV. RESULTS

This study has been conducted in order to remove the noise from signal in cognitive spectrum. The effective of various fading channels on carrier signal has been analyzed by considering the value of SNR to -10 that is static in each and every case. This section renders the simulation results of proposed work that are obtained using MATLAB. The objective of the proposed work is to apply matched filters to remove noise from carrier signal and to enhance the value of SNR.

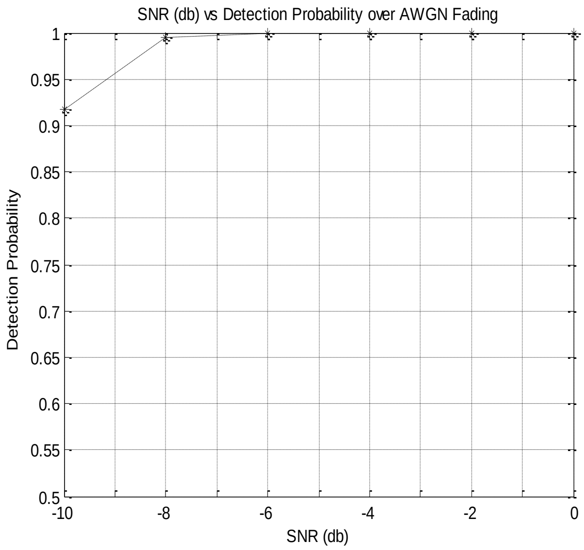

Fig.2 SNR and Detection Probability of AWGN fading

The graph 2 shows the relationship among SNR and detection probability of AWGN fading channel. Detection probability is a term that is used to evaluate the probability time taken by the filter to detect the noisy content from the signals. Higher detection probability results to higher value of signal to noise ratio.

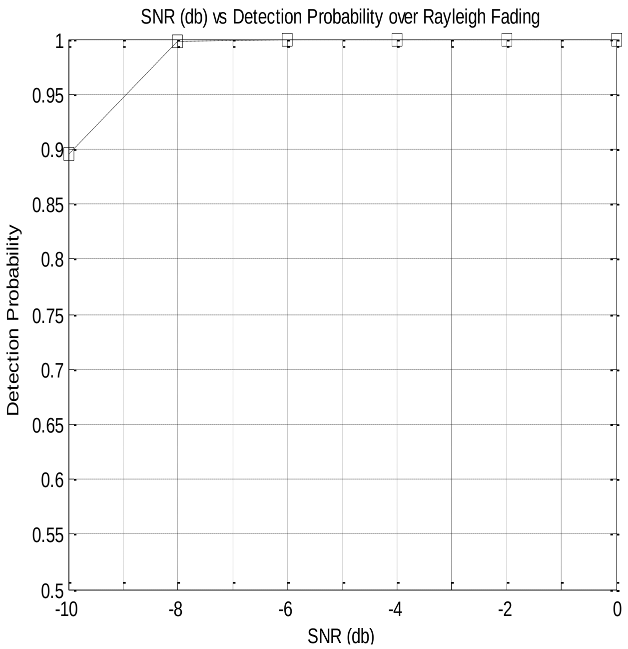

Fig.3 SNR and Detection Probability of Rayleigh fading

The figure 3 represents a graph which shows the SNR vs detection probability over Rayleigh fading channel. The x axis in the graph depicts the values corresponding to SNR which lies between -10 to 0 and axis y shows the values of detection probability that ranges from 0.5 to 1. The initial value of detection probability is 0.9 and SNR is -10.

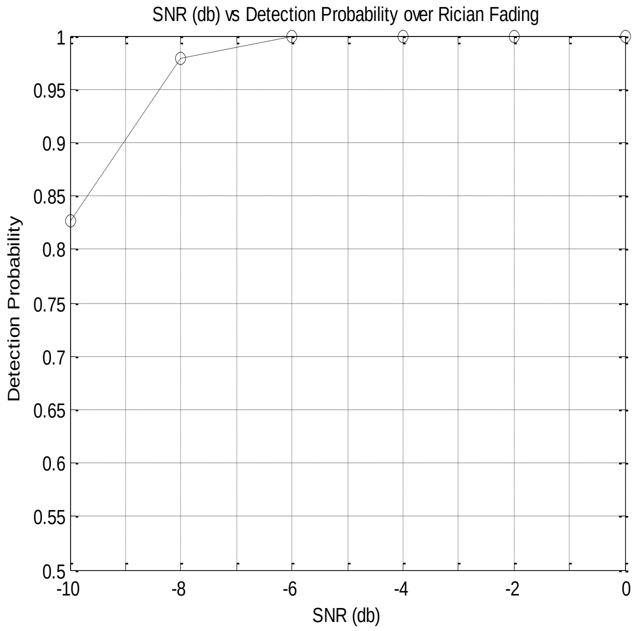

Fig.4 SNR and Detection Probability of AWGN fading

Similarly figure 4 illustrates the SNR and detection probability in case of AWGN fading channel. The initial value of detection probability is evaluated to be 0.83 and the value of SNR is measured to -10.

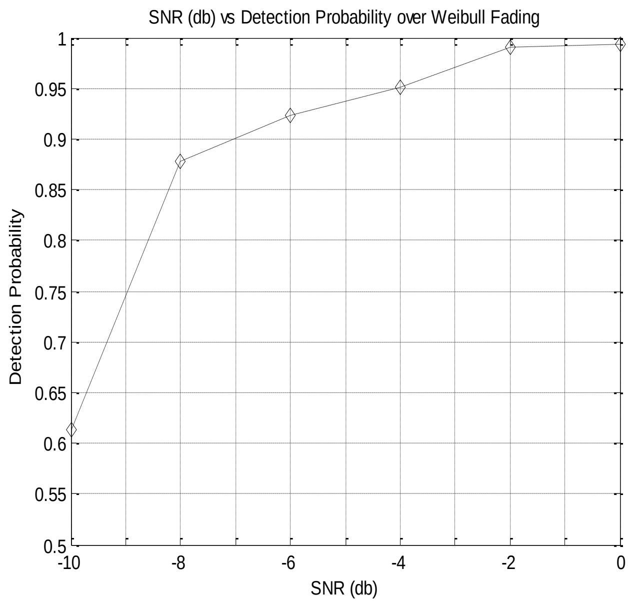

Fig.5 SNR and Detection Probability of Weibull fading

Figure 5 depicts the value of detection probability and SNR for Weibull fading channel. The graph shows that the detection probability of Weibull fading channel is 0.6 and SNR is -10. The detection probability of Weibull fading channel is quite lower as compare to other fading techniques.

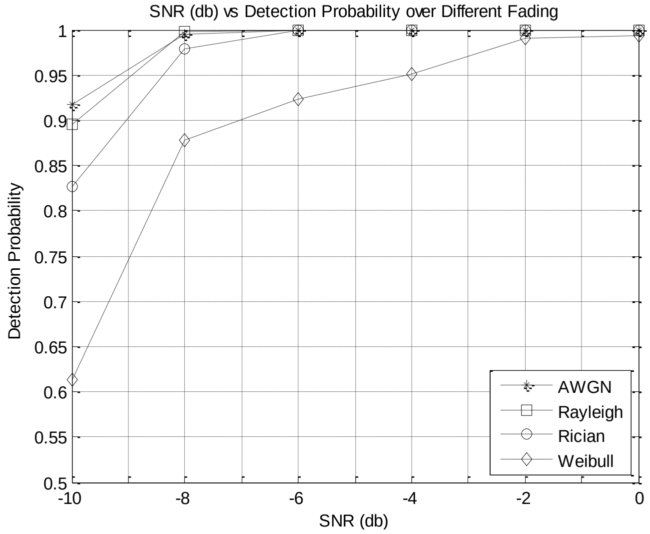

Fig.6 SNR and Detection Probability of Different Fading

The figure 6 shows the graph that drew a contrast between detection probabilities of various fading channels. The comparison is done between AWGN, Rayleigh, Rician and Weibull Fading channels. The contrast shows that the detection probability of Weibull fading channel is lower as compare to others and the detection probability of Rayleigh fading channel is higher as compare to the other fading channels. Hence it can be concluded that the Rayleigh fading channel is more efficient fading channel to detect the noisy content from the signals whereas the Weibull is less efficient as it fails to detect the more noisy content from the carrier signals.

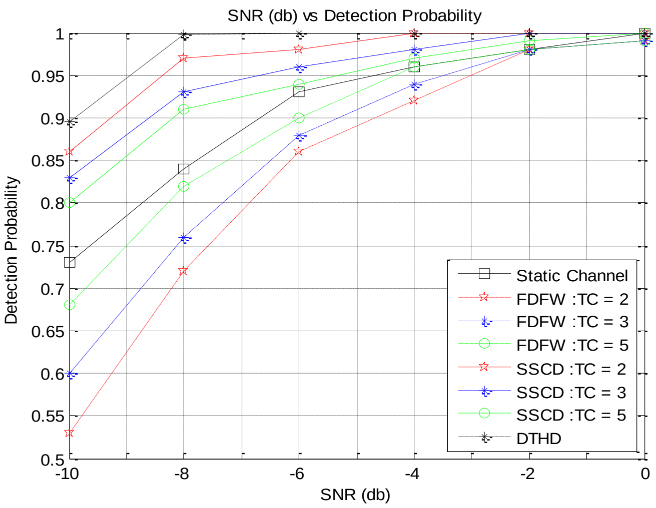

Fig.7 Comparison of traditional works.

The figure 7 shows the comparison of various traditional techniques used for spread spectrum with respect to their detection probability and SNR. The comparison is done between static channel, FDFW with various values of TC, SSCD and DTHD (Double Threshold based Detection) which is the proposed mechanism. And it is observed that DTHD has the highest detection probability i.e. 0.9 and SNR whereas FDFW (FD with Fixed Window) with TC=2 has lowest detection probability i.e. 0.53 and SNR.

V. CONCLUSION

It is concluded that the focus of this study is to remove the noise from cognitive spectrum in order to enhance the sensitivity of the spectrum. The various concepts such as radio communication, cognitive spectrum, noise and different fading channels are described in this study. The spectrum can lose its sensitivity due to the noise in the signals. It was reviewed that lot research work had been conducted that implements various fading channels to detect the noise from the signals. Hence this study implements a novice mechanism of double thresholding in order to analyze the impact of various fading channels. The various fading channels such as Rayleigh, Rician, AWGN and Weibull are analyzed under this study. After deriving the results it is concluded that the Weibull fading channel is less effective as compare to other techniques to detect the noise from the signal as it poses the lowest value of detection probability. After performing a comparison among proposed and traditional work it is obtained that the proposed work outnumbered the traditional techniques. In this work the detection probability is evaluated on the basis of double threshold value this can be evaluated automatically by applying artificial intelligent mechanisms in future.

VI. REFERENCES

[1]. Jamal Elhachmi, “Spectrum Allocation in Cognitive Radio Networks Using Genetic Algorithm", International Journal of Science and Research (IJSR), vol. 5, no. 5, pp. 74-85, 2016.

[2]. B. Hou, "Cognitive Radio Spectrum Allocation Strategy Based on Improved Genetic Algorithm", Communications and Network, vol. 05, no. 03, pp. 22-26, 2013.

[3]. Mansi Subhedar “spectrum sensing techniques in cognitive radio networks: a survey”, International Journal of Next Generation Networks, Vol.3, No.2,Pp 37-51,June 2011

[4]. Tevfik Yucek, “A Survey of Spectrum Sensing Algorithm for Cognitive Radio Application”, IEEE Communication Surveys And Tutorials, Volume: 11 Issue: 1, Pp 116-130, March 2009

[5]. Yonghong Zeng, “Spectrum Sensing Algorithm for Cognitive Radio Based on Statistical Covariance”, IEEE Transactions On Vehicular Technology, Vol. 58, No. 4, Pp 1-12, May 2009

[6]. Yonghong Zeng, “Eigen value based Spectrum Sensing Algorithm for Cognitive Radio”, IEEE Transaction of communication, Vol 57, No. 6, Pp 1-12, June 2009

[7]. Lu Yang, “Opportunistic User Scheduling In Mimo Cognitive Radio Networks” IEEE, Pp 7303-7307, 2004

[8]. Nicos c. Segias, “On the cascade weibull fading channel”, ELSEVIER, Vol 344(1), Pp 1-11, 2007

[9]. Fabio beloni, “Fading Models”, Pp 1-4, 2004

[10]. Suzan Bayhan, “Scheduling in Centralized Cognitive Radio Networks for Energy Efficiency”, IEEE, Vol:62 , Issue: 2,Pp 582-595, 2012

[11]. Vamsi Krishna Tumuluru, “ A Novel Spectrum Scheduling Scheme for Multi-channel Cognitive Radio Network and Performance Analysis “IEEE ,Pp 1-9

[12]. Rahul Urgaonkar ,"Opportunistic Scheduling with Reliability Guarantees in Cognitive Radio Networks, IEEE, Pp 1-9, 2008
[13]. Danijela ýabriü , "A Cognitive Radio Approach for Usage of Virtual Unlicensed Spectrum", Mobile Wireless Communications, Pp. 1-4, June 2005
[14]. Partha Pratim Bhattacharya, "Smart Radio Spectrum Management for Cognitive Radio" International Journal of Distributed and Parallel Systems (IJDPS) Vol.2, No.4, Pp 12-24, July 2011
[15]. Matthew Sherman , "IEEE Standards Supporting Cognitive Radio and Networks, Dynamic Spectrum Access, and Coexistence" IEEE , Vol. 46, No. 7, pp 72-79, July 2008
[16]. V. Mehar Swarup, "A Comparative Study of Scheduling Schemes for Cognitive Radio Networks: A Quality of Service Perspective "IEEE, January 2013.
[17]. Li Zhang et al, "Opportunistic Spectrum Scheduling for Mobile Cognitive Radio Networks in White Space", Wireless Communications and Networking Conference (WCNC), 2011 IEEE, March 2011
[18]. Xing Liu, "Energy-Efficient Sensor Scheduling Algorithm in Cognitive Radio Networks Employing Heterogeneous Sensors" Volume:64 , Issue: 3,Pp 1243 – 1249, 2013
[19]. Sener Dikmese, "Spectrum sensing and resource allocation for multicarrier cognitive radio systems under interference and power constraints", EURASIP Journal on Advances in Signal Processing, December 2014
[20]. Anita Garhwal, "A survey on dynamic spectrum access techniques for cognitive radio" International Journal of Next-Generation Networks (IJNGN) Vol.3, No.4, pp 15-32, 2011
[21]. Simon Haykin , "Cognitive Radio: Brain-Empowered Wireless Communications", IEEE journal on selected areas in communications, VOL. 23, NO. 2, Pp 201-220, 2005
[22]. Yuan Yuan , "Allocating Dynamic Time-Spectrum Blocks for Cognitive Radio Networks", Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing, Pp. 130-139, September 2007
[23]. Tevfik Y ¨ucek , "A Survey of Spectrum Sensing Algorithms for Cognitive Radio Applications" IEEE communications surveys & tutorials, VOL. 11, NO. 1, pp 16-30, 2009
[24]. Loukas Lazos, "Spectrum Opportunity-Based Control Channel Assignment in Cognitive Radio Networks", Sensor, Mesh and Ad Hoc Communications and Networks, 2009. SECON '09. 6th Annual IEEE Communications Society Conference on, June 2009
[25]. Jalaj Bhandari , "User Scheduling in Cognitive Radio Networks" Journal of Computations & Modelling, vol.3, no.3,Pp 177-193, 2013
[26]. Mansi Thoppian , "AC-Layer Scheduling in Cognitive Radio based Multi-Hop Wireless Networks" IEEE, Pp 191-202, 2006
[27]. Rolla Hassan, "Priority-Based Scheduling for Cognitive Radio Systems" IPCSIT vol. 37 ,Pp 145-150, 2012
[28]. Ian F. Akyildiz, "NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey", Computer Networks, vol. 50, no. 13, pp. 2127-2159, 2006.
[29]. Joseph Mitola, "Cognitive Radio Flexible Mobile Multimedia Communication", Springer Mobile Networks and Applications, Volume 6, Issue 5, pp 435–441, September 2001.
[30]. A. Ghasemi, "Spectrum sensing in cognitive radio networks: requirements, challenges and design trade-offs", IEEE Communications Magazine, vol. 46, no. 4, pp. 32-39, 2008.
[31]. B. Lo, "Cooperative spectrum sensing in cognitive radio networks: A survey", Physical Communication, vol. 4, no. 1, pp. 40-62, 2011.
[32]. Didem Goz¨ upek, "Throughput and Delay Optimal Scheduling in Cognitive Radio Networks under Interference Temperature Constraints", Journal of Communications and Networks, VOL. 11, NO. 2, Pp 147-155, 2009
[33]. Ayubi Preet, "Review paper on Cognitive Radio Networking and Communications" ,International Journal of Computer Science and Information Technologies, Vol. 5, No. 4 , Pp. 5508-5511, 2014
[34]. Ying-Chang Liang, "Sensing-Throughput Tradeoff for Cognitive Radio Networks" IEEE transactions on wireless communications, VOL. 7, NO. 4, pp 1337-1336, 2008
[35]. Anindita Saha , "Dynamic Spectrum Allocation in Cognitive Radio Using Particle Swarm Optimization ", International Journal of Emerging Technology and Advanced Engineering, Volume 4, Issue 4, Pp. 54-60, 2014
[36]. Hongjuan Li, "Utility-Based Cooperative Spectrum Sensing Scheduling in Cognitive Radio Networks "IEEE, Pp. 165-169, 2013.