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Optimized Spectrum sensing Techniques for Enhanced Throughput in Cognitive Radio Network

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ABSTRACT:

Increasing demands on the radio spectrum have driven wireless engineers to rethink approaches by which devices should access this natural, and arguably scarce, resource. Cognitive Radio (CR) has arisen as a new wireless communication paradigm aimed at solving the spectrum underutilization problem. In this thesis, we explore a novel variety of techniques aimed at spectrum sensing which serves as a fundamental mechanism to find unused portions of the electromagnetic spectrum. We present several spectrum sensing methods based on multiple antennas and evaluate their receiving operating characteristics. We study a cyclostationary feature detection technique by means of multiple cyclic frequencies. We make use of a spectrum sensing method called sequential analysis that allows us to significantly decrease the time needed for detecting the presence of a licensed user. We extend this scheme allowing each CR user to perform the sequential analysis algorithm and send their local decision to a fusion centre. This enables for an average faster and more accurate detection. We present an original technique for accounting for spatial and temporal correlation influence in spectrum sensing. This reflects on the impact of the scattering environment on detection methods using multiple antennas. The approach is based on the scattering geometry and resulting correlation properties of the received signal at each CR device. Finally, the problem of spectrum sharing for CR networks is addressed in order to take advantage of the detected unused frequency bands. We proposed a new multiple access scheme based on the Game Theory. We examine the scenario where a random number of CR users (considered as players) compete to access the radio spectrum. We calculate the optimal probability of transmission which maximizes the CR throughput along with the minimum harm caused to the licensed users' performance.

Keywords: Cognitive Radio, Dynamic Spectrum Access, Primary User, Secondary User, Spectrum Sensing, Sequential Probability Ratio Test, Sequential Analysis, Multi antenna Detectors, Game Theory, Nash Equilibrium.

I. INTRODUCTION

Since the evolution of Information and Communication Technology or ICT, its applications have been gaining ground providing users with a wide scope for communication potentiality. To name a few, Voice over Internet Protocol(VoIP), Instant Messaging(IM) or video conferencing instantly connects people from different parts of the world enabling them to communicate with relatively little delay. With such a massive capability, there is a huge demand for radio frequency (RF) spectrum that sources out the bandwidth required for communication. The introductory section covers concepts and theories associated with a wireless communication network. The cognitive radio network defined along with all its components, its function explained, and limitations looked into. Its architecture, functional approaches, varied constraints etc. have also discussed. In addition, different approaches for efficient spectrum sensing and resource utilization discussed. This chapter of the research

intended for exploration and development of enhanced approaches for efficient cognitive radio system discussed.

II. LITERATURE SURVEY

2.1 Background

It is a fact that discussion of literature learning towards a pre-defined set of research objectives, and of strengths and limitations of various technological applications, help in laying out the foundation for innovative research initiatives and future enhancement procedures. This thesis presents the respective literature analysis for cognitive radio spectrum sensing and resource sharing for better efficiency, and this chapter also covers briefly a number of subjective and allied literatures. In this section, we optimize spectrum utilization in cognitive radio and dual threshold power appreciation for efficient spectrum sensing in CRN. In CRN it is intended to optimize the spectrum sensing and develop certain optimal co-ordination among primary user as well as secondary users. The predominant objectives of this chapter are to provide a better understanding of the existing approaches, their strengths and limitations.

2.2 Literature Review

This section discusses some of the predominant researches done to date for cognitive radio spectrum sensing, detection and resource allocation etc. Various techniques proposedso far are also discussed in this section.

2.2.1 Spectrum Sensing for Cognitive Radio

As a secondary user of the spectrum group, Cognitive Radio consumers are permitted to make use of the spectral resources in a situation where they do not obstruct the access of licensed users in the network. A clear objective of Spectrum sensing, is to monitor the spectrum with regard to its availability. This technique holds significance not just before band usage but also during its use. It then decides, from the monitored results, whether the LU signal is present or not.

2.2.2 Local Spectrum Sensing and Scheduling

The purpose of spectrum sensing is to choose one of two assumptions, paralleling the deficiency and existence of the certified user gesture. Various detection methods comprising coordinated filter detection, power detection, characteristic detection, wavelet based recognition, and covariance-based detection have been proposed for confined range sensing on a particular Cognitive Radio customer to recognize the licensed consumer indication inside a confident spectrum band. The best technique for recognition of an identified indicator under additive white Gaussian noise (AWGN) is the coordinated filter uncovering that makes the most of the conventional SNR. It can be applied when pilots of licensed users are made identifiable to Cognitive Radio consumers. Power detection is the simplest spectrum sensing technique, which makes a decisionon the existence or nonexistence of the primary user presence on the basis of energy of theexperimental indicator. It does not necessitate any prior information of the licensed user signal but is susceptible to the uncertainty of noise power. Feature recognition is performed by examining the cyclical autocorrelation features of the conventional indicator. It is capable of differentiating the licensed user indicator from the intervention and noise, and of even working in extremely small signal-to- noise ratio regions. A wavelet-based approach has been developed to classify and place the spectrum break through examining the indiscretion of possible power spectral density (PSD) by wavelet transform. It can be used for wide-band spectrum sensing to approximate the amount of sub-bands and the consequent incidence borders. A licensed user signal received at the SU may be dispersive in nature, uses multiple receiver antennas or oversampled. Covariance-based detection utilizes this correlated property of a LU signal to differentiate it from white noise. It has been implied in many written work that the certified user signal is present or not within the whole sensing block.

2.2.3 Cooperative Spectrum Sensing and Reporting

Spectrum sensing to facilitate Cognitive Radio emergence and improve spectrum deployment is complex. Confined spectrum sensing technique does not 31 always assure an acceptable presentation due to noise improbability as well as channel fading. For example, a CRN user may be unable to sense the signal from a licensed transmitter shadowed by a large construction and it might cause interference to the licensed users. Introducing spatial diversity will bring down the possibility of detection error when several users work together in spectrum sensing. The essential detection instant on some individual Cognitive Radio user might also reduce. In mutual spectrum sensing, Cognitive Radio users initially present confined spectrum sensing, individually. Subsequently every user informs either a binary assessment or sensing data to a connected node. At last, the connecting nodes create an assessment on the existence or nonexistence of the licensed user gesture based on its conventional information. An uncomplicated form of cooperative spectrum sensing is to broadcast and join the samples received by every Cognitive Radio users in the local spectrum sensing stage.

2.2.4 Spectrum Utilization for Cognitive Radio

Once the nonexistence of a primary user signal, through spectrum sensing, has been established in a given spectrum band, Cognitive Radio users are permitted to activate in theband as extended as they adjust transmission parameters to keep away from objectionable intervention with licensed users while ensuring proper signal reception . The performance of the CR users and the interference with the licensed users need to be well balanced in spectrum utilization.

2.2.4.1 Spectrum Shaping

Orthogonal Frequency-Division Multiplexing (OFDM) is an impressive broadcast technique for Cognitive Radio [88] as it allows turning off tones to openly avoid licensed users as well as supports adaptation to radio environment and obtainable resources. Momentarily, with Orthogonal Frequency-Division Multiple Access (OFDMA) like the several access method, Cognitive Radio users can employ non-adjacent sub-bands through dynamic spectrum aggregation to maintain elevated data range . Accessible spectrum estimation methods have been classified into timedomain as well as incidence field approaches. It is inherent that an elevated cosine window can be applied to the time domain pulse to hold down OOB radiation. However system throughput is decreased in the windowing technique as extension of symbol duration is required to check Inter- Symbol Interference (ISI). An additional time-domain technique at the expense of throughput decrease is adaptive symbol transition which puts in extensions between orthogonal frequency-division multiplexing symbols . In the frequency domain, an effortless tone-nulling method disables orthogonal frequency-division multiplexing subcarriers at the edges of the used frequency band with the most important effect on the OOB discharge in bands right next to each other. Furthermore, active intervention termination has been described in through connecting withdrawing tones adaptively on the edges. It facilitates deeper spectrum indentation although the computation is concentrated on the transmitter. Likewise, subcarrier weighting , multiple-choice series , as well as preferred mapping are specified to contain OOB emission on the basis of transmitted data. In multi-user scenarios, it is not advisable to apply the above-discussed methods where user dependence will be initiated. Lately, spectral precoding was proposed in which have exhibited proficiency in decreasing OOB production. The precoding matrix has been created from precisely considered source sets to provide time stability of neighboring orthogonal frequency-division multiplexing spectrum nulls at notched frequencies . Meanwhile, the coding block is required to be relatively long, so it is difficult to apply these pre-coders to users utilizing only a few subcarriers within the available frequency band.

2.2.4.2 Resource Allocation

Cognitive Radio users regulate their transmission parameters by resource allocation to achieve distinct management necessities and understand effectual interference monitoring. Due to the subsistence of certified users as well as potential common interference among two different classes of users, the task of resource allocation for opportunistic spectrum consumption in CRNs is not equivalent to thatof current wireless networks. Usually, a Cognitive Radio user is able to broadcast for an extended time as the interference to the licensed user is under a predefined threshold. The most common controls to protect LUs peak and average interference power.

III. EXISTING SYSTEM

3.1 Introduction

Optimal resource provisioning and efficient resource utilization are the predominant factors that ensure optimal quality of service in Cognitive Radio network (CRN). Taking into consideration the requirement of an efficient technique for optimal resource or spectrum utilization, this chapter discusses a group formation paradigm of cells in CRNs. The predominant contribution in this thesis and this particular section of the manuscript is improved capability for cell information regarding a large number of licensed users so thatthey can provide maximum information to their following secondary or unlicensed users across network. Thus, the discussion of the proposed cell grouping approach to share respective information to the licensed users is presented in the following sections.

3.2 Inter Network Cell Information Sharing:

A Significant Catalyst for Optimal Spectrum Utilization in CRNs A cognitive radio is an intelligent radio that can be programmed and configured dynamically. Here the radio detects the channel by itself and accordingly changes its parameters. Parameters like routing; frequency, etc. are adjusted by the cognitive radio according to the requirement. Cognitive radios continuously controls its own activity and determine the radio frequency environment, channel conditions, link performance, etc. andadjusts the settings to deliver the required quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints. It is able to perceive the external environment and uses artificial intelligence technology to learnfrom environment. It also makes its internal state adapt to the statistical changes of receivedwireless signal by changing Some operating parameters so as to realize high reliable communication at any time and in any place and the effective use of spectrum resources. ACognitive Radio incorporates multiple sources of information, determines its current operating settings, and collaborates with other cognitive radios in a wireless network. The promise of cognitive radios is improved use of spectrum resources, reduced engineering andplanning time, and adaptation to current operating conditions.

3.2.1 Characteristics of cognitive radio networks

• Determine their own environment and react

• Provide robust services

A communication network is stated to be an interconnection of different users whereit exchanges its allied information with each other by means of certain transmitters and receivers. When the information is needed to be transmitted automatically then cognitive radio network is employed. The transmitters in the cognitive networks are signaled in sucha way that they can automatically detect the available channels and pass signals through them [149]. In such functional scenarios, sufficient spectrum availability or channel availability can be of great significance. This is a fact that the spectrum or the channel in communication network are confined or limited and so they are needed to be shared efficiently among the participating users across the network to facilitate optimal resource provisioning and QoS. To define key elements of a cognitive radio network,

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users having its own spectrumauthority or that possess channels of their own are named Licensed Users.On the contrary, those users who do not own channel of their own and require the spectrum owned by the licensed users are stated to be Unlicensed Users. Unlike the conventional approachesthat reveal the content of information circulated in the network, the proposed system emphasizes on transferring and gathering information across the network. In the proposed research model, the cells undergo a game called groups formation where they Yes No Assigned To PU Channel and Resource reassignment Initiate communication using primary user Resource and Channel pre-allocation Busy Free Channel State Assign left resources to secondary users Secondary users wait until communication is done Communication switch from one group to another in search of available channels and intend to utilize optimal channel or spectrum resource while ensuring minimal interferences which are the two fundamental requirements of a cognitive radio network.In the proposed research model, a channel has been defined as a logical connectivity existing in between a transmitter and receiver node or user which conveys information from one or multiple transmitters to one or multiple receivers [150]. In this thesis work, a CRN has been considered with two predominant types of users called LU and Unlicensed Users in the individual cell in the communication network. Since the LUs are already registered with channels, they can perform signal transmission or receiving at any time using their preallocated resource or channels.

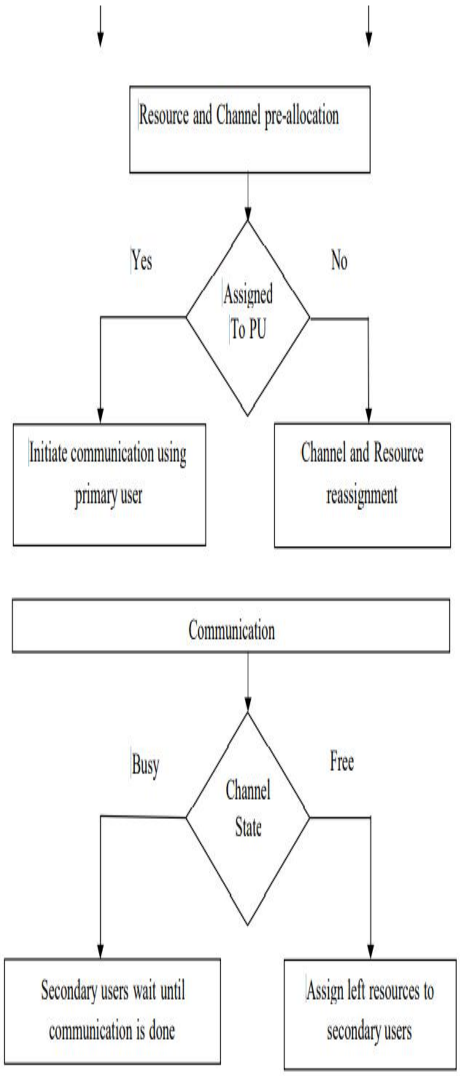

Figure 3.1 Channel allocation scheme for group formation strategies

This is not the case for unlicensed users, who use the same channels which are already assigned to the LUs. The ability of UUs to use resource is restricted and they are required to wait till the LUs are done with their transmission. It means that the unlicensed users can utilize spectrum or resources only when the spectrum is idle andis not being used by any licensed users. Each cell in the network is responsible for a certain number of UUs. The cells are the media which tell the UUs about the status of the channels belongingto the LUs. For

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the proper use of the channels by the UUs during the absence of the LUs,the cells should keep an account of the status of almost all the LUs so that it can provide better service to its UUs. But each cell has knowledge of only limited number of LUs.

The predominant objective of the presented research work and this thesis phase is to optimize the cells' knowledge regarding a large number of LUs so that they can provide maximum information to their following UUs and thus enable the network for efficient resource or channel utilization. Thus, the proposed algorithm as shown in above figure 3.1 plays a major role, where each and every cell shares the information of each other's LUs byentering into different groups. It, thus, allows the cells to form different groups and obtain a decision making capacity.

IV. PROPOSED SYSTEM

4.1 Introduction

In this research phase, energy detection approach has been employed for the use of cooperative analysis of spectrum; then the secondary user passes on sensing results to fusioncenter by two methods which are discussed as follows:

4.1.1 Data fusion

All cognitive individuals enhance the signal received by the primary users and those signals are then passed on to fusion center. In this approach the secondary users do not require complex detection processes; hence the bandwidth of reporting channel and that ofthe sensing channel should be nearly the same. In the developed model, the fusion methods of maximal ratio combining (MRC) and square law combining (SLC) have been employed to the fusion center. The information of the channel state ranges from primary tosecondary user and its passing on to fusion center is required in MRC technique. On the other hand, in SLC the information of the channel state is required and is passed by secondary user to fusion center considering fixed amplification at every secondary user. Incase, different amplification factor is considered, information of the channel state through primary to secondary users and then from secondary to the fusion center is required. Therefore, in this thesis a framework has been developed that comprises multiple users in cooperative spectrum analysis through data fusion. The developed energy detector determines the energy used for a signal to reach the receiver from the transmitter. There are two types of energy detectors: analog energy detector and digital energy detector. The former consists of a pre-filter, squarer, and an integrator. The pre-filter reducesthe noise and the integrator gives the measure of the energysignal uses to reach the receiver from the transmitter. 56 Squarer Denoising Prefilter Integrator

4.1.2 Decision Fusion

The individual secondary user or the unlicensed user settles on a decision on the PU's action and individual decisions are accounted to a combination focus on a reporting channel.The capacity of complex sign handling is required at every SUs. The combination guideline at the combination focus can be OR, AND, or Majority principle, which can be summed up as the "k-out of-n rule". Two principle assumptions are made: There is no error in reporting channel The SNR insights of the primary signs are known at SU. Detection

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performance has been researched by considering reporting errors with OR combination managed under Rayleigh fading channels. In the proposed model, it has been assumed that energy detection can be implemented at every SU. Energy detector comprises a finite time integrator and a squaring law device. Outputof the integrator at any instant is input energy to squaring device over the time interval 'T'. Noise pre-filter limits noise bandwidth and input noise going to the squaring device has the spectral densityas flat and band-limited.

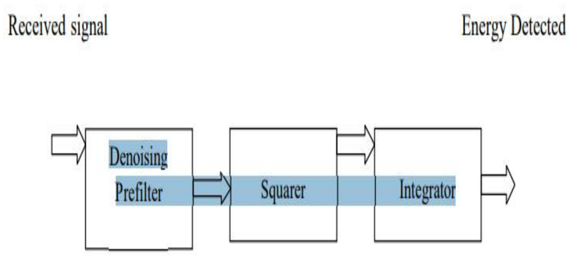

Figure 4.1 Analog Energy Detection Techniques

An analog energy detector contains a de-noising filter, squarer and integrator. A digital energy detector has the same components as the analog one except for the additional analog to digital converter. Figure 4.1 shows the architecture of Analog detector and Figure 4.2 digital energy detector.

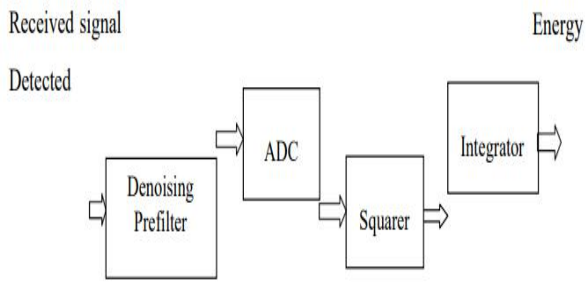

Figure 4.2 Digital energy detection techniques

Energy detection method is one of the sub-optimal signal detecting procedures whichhas been massively utilized as a part of radio interchanges. The recognition strategy can be performed in time domain and in frequency domain. Figure 4.1 demonstrates the energy detection process with the theories they take after

$H0$ = [m] = W[m];

Absence of signal Eq. (4.1) $H1$: [m] = X[m] + W[m] ;

Presence of signal Eq. (4.2) Here, m= 1, 2, ... , M;

where M is the window under surveillance. Here, X[m]represents sample of target signal which has definite power $'u'$ and W[m] is a sample noisethat is considered to be additive white Gaussian noise (AWGN) which has 0 mean and changes same to signal power. Hypothesis ‘H0’ shows nonappearance of the primary user and the frequency band of interest only has noise whereas ‘H1’ denotes existence of primary user. Thus, for both state hypotheses numbers of significant cases could be there. Some of them are as follows: 4.1.2.1 $H1$ would be $TRUE$ in case of existence of primary user i.e.($H1/H$

1) is considered as possibility of detection. 4.1.2.2 $H0$ would be $TRUE$ in case of existence of primary user i.e.($H0/H1$) is considered as possibility of mis-detection.

4.1.2.3 $H1$ would be $TRUE$ in case of existence of primary user i.e.($H1/H0$) is considered as possibility of false alarm.

V. RESULT

5.1 ROC Curve for Energy Detector

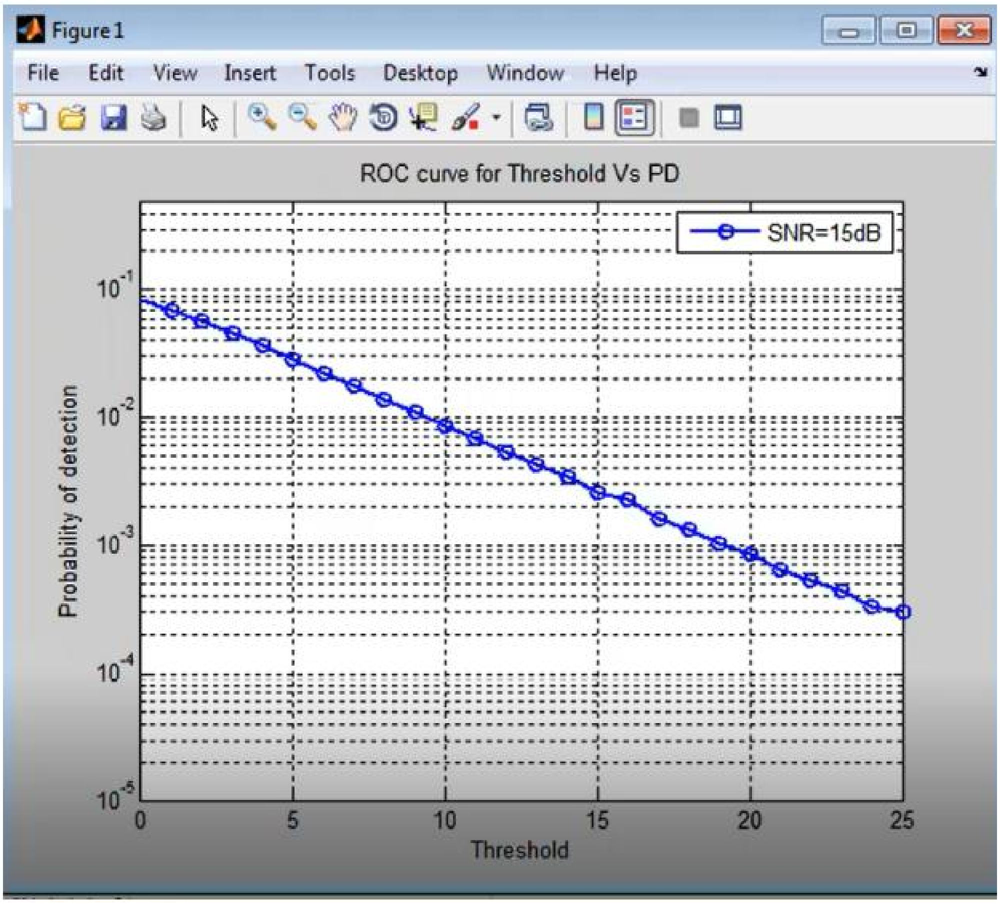

Fig.5.1 ROC Curve for Energy Detector

With reference to methodology in this paper, in initial part of algorithm ED method is used to sense the signal. Here received signal is compared with test statistics and threshold Vs Pd graph is plotted, If received noise signal at SU >Threshold then PU is considered to be alive and If received noise signal at SU < Threshold then, spectrum is available for SU's communication, which ultimately improves throughput of SUs. In Figure 2 Average detection probability is compared with threshold. Result explains that Pd and T are having inverse relation.

5.2 Throughput variations with the sensing time

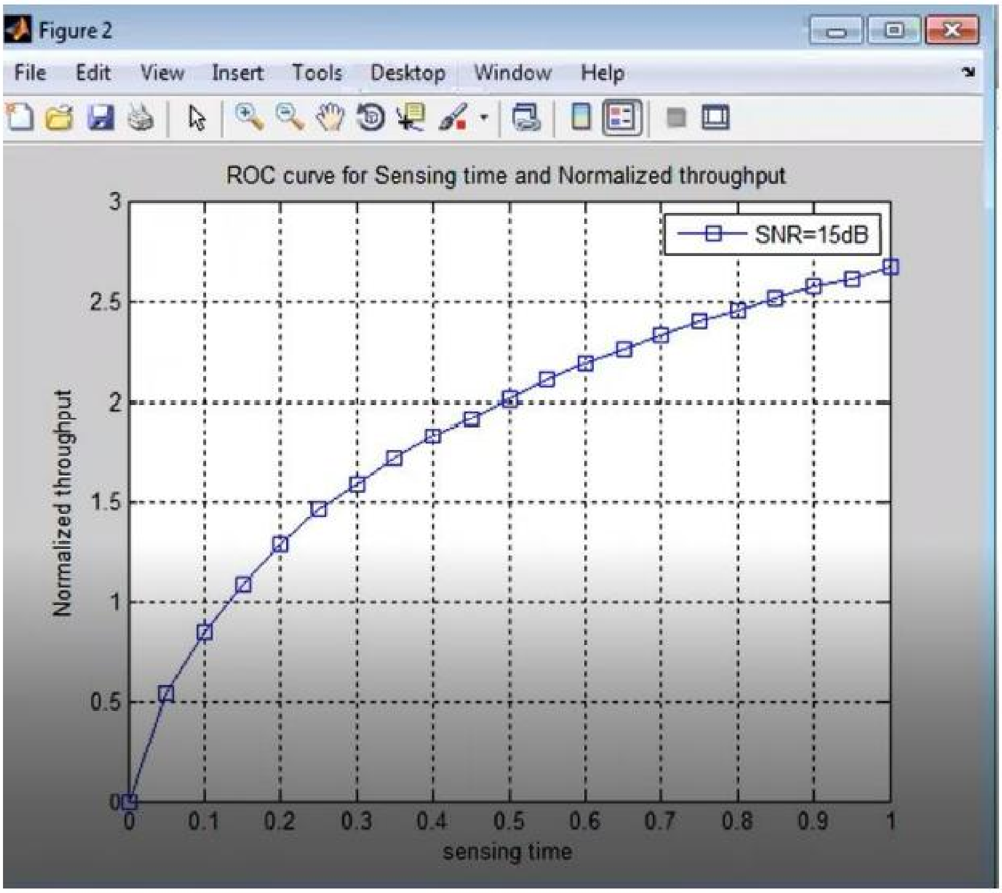

Fig.5.2 Throughput variations with the sensing time

In these phase , the sensing time is calculated to optimize throughput. With increasing value of sensing time,the throughput also increased. This shows the robustness of algorithm.

5.3 Throughput variations with the Number of Sus

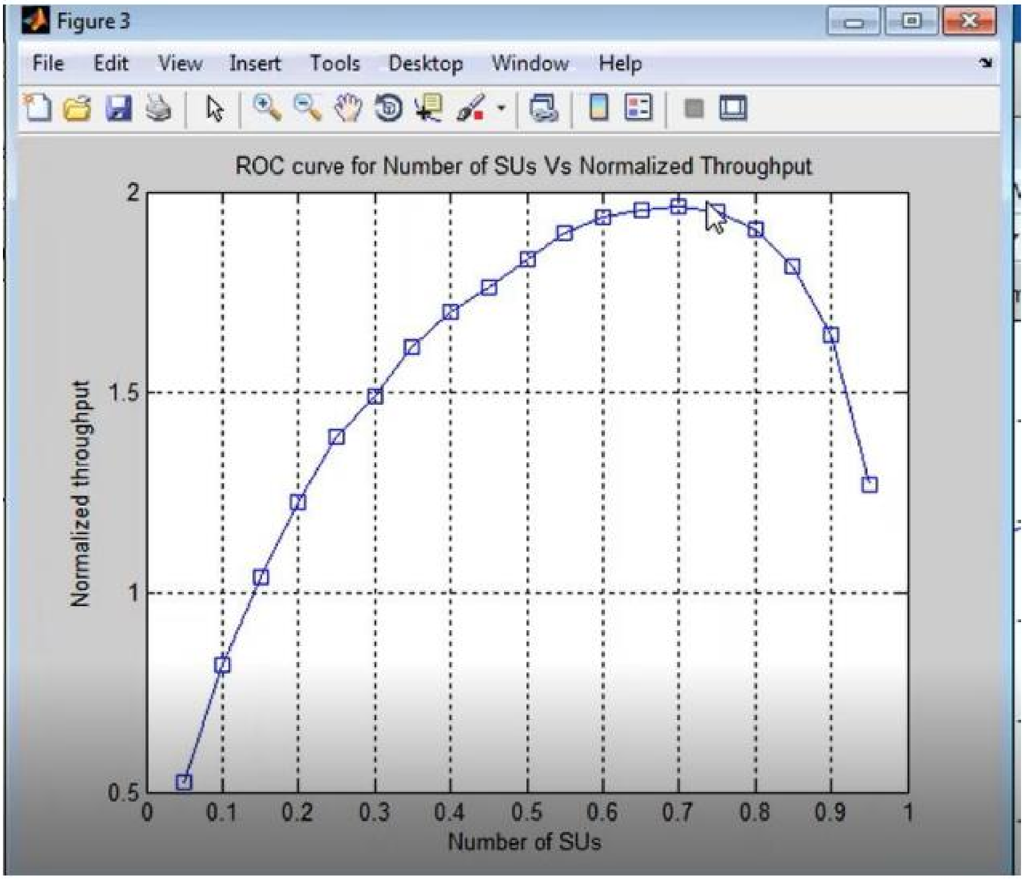

Fig.5.3 Throughput variations with the Number of Sus

In this phase of optimization, optimum number of SUs involved in sensing is estimated to optimize throughput. With increased number of su's throughput also increased.

VI. CONCLUSION

We proposed this method and algorithm to optimize the " throughput" , in cooperative spectrum sensing Maximum throughput of SU's can be achieved by two step optimization algorithm.Determination of optimal sensing time that maximizes total average throughput of secondary Users(SU's) and optimal number of SUs that maximizes the total throughput.We jointly optimize the sensing time and number of SUs for each channels.Simulation results shows that with increasing number of SUs and sensing time, the throughput also increases.

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