International Journal of Engineering Research and Reviews ISSN 2348-697X (Online)
Vol. 6, Issue 2, pp: (5-14), Month: April - June 2018, Available at: www.researchpublish.com

RELAY BASED COOPERATIVE SPECTRUM SENSING TECHNIQUE USING ENERGY DETECTOR IN COGNITIVE RADIO NETWORK

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Abstract: **The performance of spectrum sensing based on cooperative relaying is investigated. It is found that multiple number of cognitive relay nodes improve spectrum sensing performance. It is shown that the optimal sensing time of CR reduces with the increasing number of relay nodes. Reduction in optimal sensing time results in increase of the optimal throughput of the CR significantly. Impact of SNR on optimal throughput and on sensing time is noticeable. If SNR increases, the normalized optimal throughput increases and optimal sensing time reduces for a fixed number of relay nodes.**

Keywords: **SNR, CR, BER, Spectrum Sensing.**

I. INTRODUCTION

Recently, The cognitive node which are far away from primary user (PU) may not able to detect the PU due to severe fading in channel. To improve efficiency of spectral sensing, we propose a cooperative communication scheme based on cognitive relaying. Cognitive relay node sense the activity of primary user and forward received data to the cognitive radio (CR) which is far away from primary user. In this condition the probability of detection increases, which in turn reduces the bit error rate. Using number of relay nodes reduce the sensing time and increases the sensing time and increases the throughput of the system. Cognitive radio, has been proposed as a means to improve the utilization of wireless spectrum using spectrum sensing. It is a technology upon which the entire operation of cognitive radio resets it enables unlicensed users (also referred to as secondary users or cognitive users) to communicate with each other over licensed bands by detecting spectrum holes. Cognitive radio is a promising technology for future wireless networks. In order to reduce the interference to primary system, CR users have to detect the spectrum with low overhead and reliably in sensing slots, which has to occupy part of the available resources. Here, we propose a spectrum sensing solution that is based on cooperative technique to detect and collect available channels in information to enhance the performance of spectrum sensing .The exponential growth wireless services increases the demand for spectrum band which is limited. On the other hand, recent survey by Federal Communications Commission (FCC) revealed that 70% of the licensed spectrum (primary user band) in US is not utilized. This contradictory situation can be solved by the reuse of licensed band when the primary user (PU) is temporarily inactive. CR is smart and agile technology in this context. Spectrum sensing is an essential component of CR. In spectrum sensing, CR keeps detecting the vacant primary spectrums to use it and meet the growing demandIn order to ascertain the presence of a PU, CR users carry out the detection cycle periodically. Every detection cycle is a combination of sensing time and data transmitting time. To reduce the interference to the PU, it is better to increase thesensing time which in turn reduces the data transmitting time. If we increase the data transmission times to improve the throughput of the secondary network, the sensing time decreases. If the sensing time decreases, it’s hard to guarantee on interference free communication. Thus the tradeoff between the sensing time and the throughput of the secondary network becomes a point of interest.In this paper, we have investigated the performance of spectrum sensing for a CR node which is far from PU.

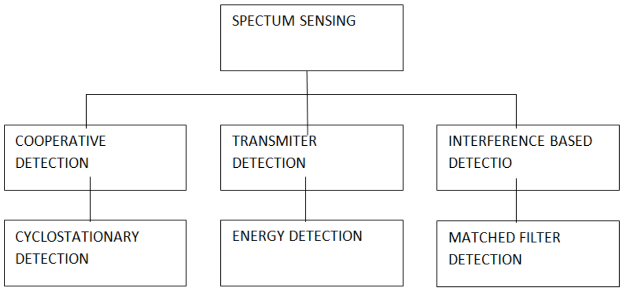

Fig 1: Types of spectrum sensing

The CR node which is far away from PU may not perform spectrum sensing with great efficiency due to severe fading in channel and may create interference to PU. In this condition, to improve the spectrum sensing efficiency, we propose a cooperative network based on relay nodes. The performance has been investigated in terms of BER, throughput, optimal throughput and optimal sensing time

1.1 Motivation:

In an earlier paper [7], a joint spatial-temporal sensing was proposed. In the proposed scheme, a secondary node performs spatial sensing to determine its mid when the primary transmitter is on and uses localization information obtained in the process of spatial sensing to improve the performance of temporal sensing, which estimates the on/off state of the primary transmitter. As the use of wireless devices and applications continues to grow, the demand for spectrum resources keeps increasing. In the current spectrum regulatory framework, spectrum of frequency is allocated to licensed users over a geographic areaHence we highlight the major contributions of our paper. We introduce cooperative spectrum sensing based on multiple relay nodes with direct link between PU and CR.We have investigated the BER of a CR in the proposed model with respect to a number of relay nodes and cooperative diversity techniques. We have investigated the optimal throughput of the CR which is far from PU and senses the spectrum with the assistance of a number of relay nodes.Impact of number of co-operating relay nodes on optimal sensing time is estimated.The rest of the paper is organized as follows. In the system model is introduced. In the analytical expression for BER is discussed. False alarm probability, detection probability and throughput are discussed in the simulation results and discussions arepresented.

1.2 Objectives:

The cognitive node which are far away from primary user (PU) may not able to detect the PU due to severe fading in channel. To improve efficiency of spectral sensing, we propose a cooperative communication scheme based on cognitive relaying cognitive relay node sense the activity of primary user and forward received data to the cognitive radio (CR) which is far away from primary user. In this condition the probability of detection increases, which in turn reduces the bit error rate (BER).employment of a number of relay nodes reduce the sensing time and increases the sensing time and increases the throughput of the system The performance of spectrum sensing based on cooperative relaying as investigated. It is found that multiple number of cognitive relay nodes improve spectrum sensing performance. It is shown that the optimal sensing time of CR reduces with the number of relay nodes.Reduction in optimal sensing time result in increase of the optimal throughput of the CR significantly. Impact of norm optimal throughput and sensing time is noticeable. If SNR increases, the normalized optimal sensing time reduces for fixed number of relay nodes. The above study is useful in designing relay based CR network.

II. LITERATURE REVIEW

A cooperative communication scheme is described which is based on cognitive relaying for the cognitive radio network where the destination cognitive relay node is at far distance from the primary user. The beat error ratio cognitive relay is determined with respect to the number of relay nodes. The optimal throughput is also estimated for this scheme. [1]

Analysis of multiple CR during the channel sensing is studied here. The Energy Detection is used for spectrum sensing. At the last a comparison between a selected relay based on maximum value SNR and SNR of others relays in multi-channel is done in this paper and the performance of all relays and selected relay based on SNR is evaluated. [2]

The performance analysis of relay based cognitive radio networks is presented. A detect-amplify and- forward relaying strategy for cooperative spectrum sensing over non-identical Nakagami-m fading channels are discussed. An advanced statistical approach is introduced to derive new exact closed-form expressions for average false alarm probability and average detection probability. [3]

A relay-based cooperative spectrum sensing framework is proposed to reduce interference to primary user and improved channel capacity with an acceptable detection probability in cognitive radio networks. The proposed framework integrates spectrum sensing into signal transmission by assigning different signal types to primary user and cognitive users. [4]

The detection model is presented with multiple secondary users to perform cooperative spectrum sensing. The influence of some parameters is considered to make the overhead more efficient, and analyzed that the relay amplification gain can efficiently alleviate the performance loss caused by report channel fading. Moreover, verification of the existence of the optimal number of cooperative users, and its effect on the influences of the amplification gain and reporting error probability on the optimal number of users is done. [5]

The cyclostationarity based cooperative spectrum sensing is presented to detect the idle bands and then located the secondary users into these bands. The processing complexity is reduced using a relay for transmission and spectrum sensing. As such, an optimum relay is selected to perform both cooperative communication and cyclostationarity based spectrum sensing. [6]

The power and time of total relay processing is saved and a higher bandwidth efficiency in relay usage is achieved using a simple multi-relay switching scheme and energy detection is employed for the detection of a spectrum hole. A relay is used only if the strength of faded signal-to-noise ratio for its reporting channel to the cognitive destination is larger than a preset threshold. Otherwise, another switched-to relay is considered and tested for its usage. The probabilities of false alarm and correct detection are derived. [7]

The different spectrum sensing techniques are discussed to detect the presence of the Primary User. The techniques covered are fuzzy logic cooperative spectrum sensing, asynchronous cooperative spectrum sensing, cooperative spectrum sensing based on network coding, cooperative spectrum sensing with relay diversity, and distributed cooperative spectrum sensing based network coding.[8]

The study of the performance of network coding in presence of opportunistic relay selection is presented. The relay selection schemes should be aware of and account for, the network coding operation in case of its presence. The efficiency of the algorithm and the method of relay selection are given. Based on system level simulation results, it is demonstrated that such an awareness provides considerable capacity gains as compared to its traditional opportunistic counterparts, in addition to increased fairness among the encoded sources.[9]

The issue of spectrum sensing in a distributed CR network is discussed here, and proposed a novel relay based cooperative spectrum sensing method, which makes one secondary user with higher signal-to-noise ratio spend part of its sensing time acting as the relay node. Different from conventional relay based methods, this method does not require idle SUs, and thereby is able to work well even when all SUs in the network sense and access the licensed spectrum band simultaneously. Moreover, via maximizing the agility of the entire CR network, its relay policy is optimized. [10]

The issue of cooperative spectrum sensing in cognitive radio network with path loss effects is discussed. Cooperative relays are introduced between primary user and cognitive center. The deteriorating effect of path loss is evaluated by measuring the detection performance of energy detector employed in cognitive radio network. Both single relay and multiple relays regimes are employed. [11]

The three-node cognitive radio system to do the optimization of spectrum sensing is explained here. The cognitive relay nodes forward the received signal after doing the sensing. In this condition, system’s total bit error ratio decreases while the detect probability increases. With the cooperation of cognitive relay nodes, the optimal sensing time reduces. [12]

Detection performance of an energy detector used for cooperative spectrum sensing in a cognitive radio network is investigated over channels with both multipath fading and shadowing. The analysis focuses on two fusion strategies: data fusion and decision fusion. Under data fusion, upper bounds for average detection probabilities are derived for four scenarios as single cognitive relay, multiple cognitive relays, multiple cognitive relays with direct link, multi-hop cognitive relays. [13]

The performance of cooperative spectrum sensing is limited by the probability of reporting errors. An efficient quasi-orthogonal structure space-time code with a high diversity gain and coding gain was applied to reduce the transmission error rate. Moreover, a relay diversity based on cooperative spectrum sensing was proposed to increase the diversity of detection when some secondary user channels were in heavy shadowing. Simulation results show that the proposed algorithms further improve the cooperative spectrum sensing performance in the Rayleigh fading channel. [14]

In order to improve the detection performance of cognitive radio networks, the system model is improved based on a multiple-user cooperative spectrum sensing scheme with the best relay in this paper. A cooperative detection border is proposed that whether relay users are needed for cognitive user. Therefore, selecting the best relay is operated according to the quality of channel, and a theoretical analysis is introduced for detection performance of the scheme over Nakagami fading channel. The results show that detection time is reduced substantially and agility gain is also increased greatly. [15]

A selective-relay based cooperative spectrum sensing scheme is proposed, which is able to control and reduce the interference from cognitive reporting users to primary user without the dedicated channel. The receiver operating characteristics of the traditional cooperative sensing scheme and the proposed scheme by jointly considering the signal detection and reporting phases is explained. It is proven that, given a target detection probability, a unique optimal signal detection overhead exists to minimize an asymptotic overall false alarm probability in high SNR regions. The dedicated channel resources can be saved without sacrificing ROC performance. An overall false alarm probability can be minimized. [16]

A scenario in which a secondary transmitter can communicate with a secondary receiver via a direct communication link or a relay channel, depending on the state of a primary transmitter is considered. A cooperative communications strategy that exploits the presence of spectrum holes both in time and in space by combining cooperative relaying with joint spatial-temporal spectrum sensing is presented. The numerical results show that the proposed scheme significantly reduces the average symbol error probability compared to schemes based on pure temporal or spatial sensing. [17]

The cooperative spectrum sensing problem for a cognitive radio mesh network is considered. Based on multiple relay model, two cooperative spectrum sensing strategies called amplify-and-relay and detect-and relay, are presented and also derived the closed-form expressions of false alarm and detection probabilities. The detection performance improved as the number of relays increases. [18]

A decode-and-forward transmission strategy is developed which exploits the presence of spectrum holes both in time and in space. A strategy based on pure temporal sensing alone uses the direct link when the primary transmitter is off, whereas a scheme based on spatial sensing alone uses the relay channel. The numerical results show that the proposed scheme, employing joint spatial temporal sensing, significantly reduces the average symbol error probability compared to schemes based on pure temporal or pure spatial sensing. [19]

The study of the sensing performance of a cognitive user by allowing another cognitive user to act as its relay is presented. The scaling factors of the unconstrained scheme is varied, and the formulas of detection and false alarm probability for cooperative scheme based on cooperative relay are developed. Attention is paid on studying how to find a proper relay for cognitive user so that the detection capability of cognitive user can be improved. Results are well interpreted and supported by exhausted numerical computations. [20]

A cooperative spectrum sensing technique is exploited for applications in a relay based cognitive radio network. Relays are assigned in cognitive radio networks to transmit the primary user’s signal to a cognitive coordinator. This research is focused on the detection of primary user in single or multiple cognitive relay scenarios. An upper bound is also given for detection probability. Our analysis is validated by numerical and simulation results. [21]

The outage probability of a wireless amplify-and-forward cooperative two relay network which consists of a source, a destination and two network clusters is investigated. Each cluster is defined by a number of cognitive nodes and a primary node. The cognitive nodes relay the source information by employing opportunistic spectrum access using either repetition-based or best relay selection relaying protocol. Closed-form expressions of outage probability are obtained for non-identical independent Rayleigh fading channels. Selection cooperation exhibits lower outage probability than that of the repetition-based relaying protocol. An improvement of the performance can be provided . [22]

III. PROPOSED SYSTEM

Fig. shows the system model for the cooperative communication. In cooperative spectrum sensing, the relay stations are introduced in the CR network. In this model CR1, CR2, CRm are within effective transmission radius of primary transmitter (PTX). Hence, the detection probabilities of CR1, CR2.crm will be high. But is beyond . Hence, it is hard for to take decision about the presence or absence of PU. To improve the performance of spectrum sensing of , we consider that CR1, CR2, CRm sense the activity of the PU individually and send their received data to .

The effective transmission radius of each CR is rc. CR1, CR2. CRm and are within each other's communication area. In our model, PTX is the source node; CR1, CR2... CRm are the relay nodes and they work on time division duplex mode; CRd is the destination node. The time frame of each relay CR is divided into two slots. In the first time slot, each relay CR received the signal of PU. In the second time slot, the relay CRs amplify the received signals and send the amplified signals to the destination CR. Signal from relays and signal of direct link is combined by maximal ratio combining

A. Cooperative Scheme:

We consider a relay-based spectrum sensing. A number of cognitive relays are added in the cognitive radio network, as shown in fig. As the primary user starts using the band, cognitive radios receive the signal of the primary user. Therefore in the first phase, all cognitive relays listen to the primary user signal. Instead of making individual hard decision about the presence of the primary user, relay-based cognitive radios simply amplify and retransmit the noisy version of the received signals to the cognitive coordinator in the second phase

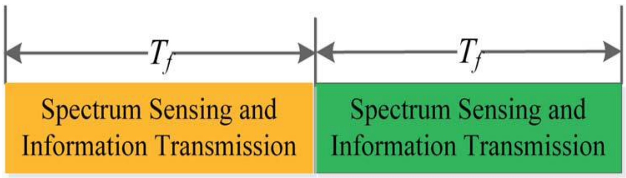

Fig 2: The frame structure of proposed spectrum sensing Framework

In our proposed framework, all time slots can be used to transmit different user signals; in comparison, only half of the time slots can be used by the distributed spectrum sensing framework. However, considering the fact that the energy of noise increases with the increase in time slots, we cannot double the channel capacity. To compare the improvement of channel capacity, we depict the channel capacity obtained using these two frameworks in illustrates that the channel capacity gain of our proposed method increases with the increase of P2/σ2 w, and that, at P2/σ2 w = 15 dB, a capacity gain of about 1.6 times can be obtained.

IV. CONVENTIONAL ENERGY DETECTOR

The energy detector (ED) has been widely used for detecting unknown deterministic signals in many applications. It is known as a suboptimal detector, which can be applied to detect unknown signals as it does not require a priori knowledge on the transmitted waveform. Usually, a non fading additive white Gaussian noise (AWGN) channel is assumed when studying the performance of energy detection. Energy detector measures energy of primary signal band and compares with a properly set threshold. It requires longer sensing time to achieve desired level of performance. It has low computational complexity which makes it an attractive candidate for cognitive radio.

Fig. 3 shows a simplified block diagram of an energy detector which consists of essentially four blocks namely band-pass filter (BPF), squaring device, integrating device and threshold device. For input signal x(t) , BPF will select the center frequency and the bandwidth of interest. BPF is followed by a squaring device which measures the received energy. Integrating device determine the observation interval and the last device receive the output of integrator which serves as decision statistic and is compared with a threshold value to decide whether signal is present or not.

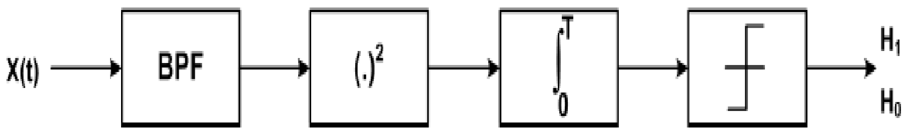

Figure 3: Block diagram of an energy detector

V. SYSTEM IMPLEMENTATION

Fig. 1 shows the system model for the cooperative communication. In cooperative spectrum sensing, the relay stations are introduced in the CR network. In this model, CR1, CR2..CRM are within effective transmission radius (rp) of primary transmitter (PTX). Hence, the detection probabilities of CR1, CR2..CRM will be high. But CRd is beyond rp.

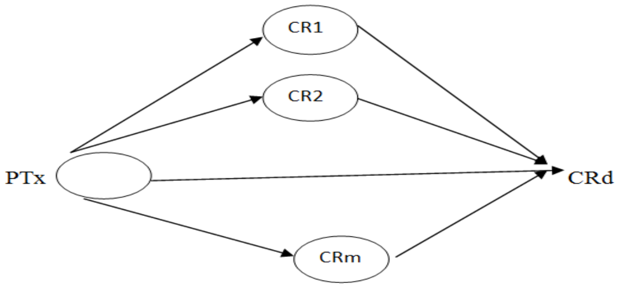

Fig 4: System Model

Hence, it is hard for CRd to take decision about the presence or absence of PU. To improve the performance of spectrum sensing of CRd, we consider that CR1, CR2..CRM sense the activity of the PU individually and send their received data to CRd. The effective transmission radius of each CR is rc. CR1, CR2..CRM and CRd are within each other's communication area. In our model, PTX is the source node; CR1, CR2... CRM are the relay nodes and they work on time division duplex mode; CRd is the destination node. The time frame of each relay CR is divided into two slots. In the first time slot, each relay CR received the signal of PU. In the second time slot, the relay CRs amplify the received signals and send the amplified signals to the destination CR.

The destination CR uses energy detector to make a decision about the presence or absence of the PU by comparing the combined received signal with a predefined threshold (□). Let x(n) be the transmitted signal from the PU at time slot 1, the received signal at j-th relay CR is given by

(yprj(n)= P hprj x(n)) wprj(n)

wherej=1,2,..M, P1 is the transmitted power of the PU, hprjis the channel coefficient between the PU and the j-th CR and wprjis AWGN noise. At time slot 2, the relay CRs amplify and forward the received signals. The received signal at the destination node from j-th relay is given by

yrjd n = a j Yprjhrjd+ wrjd(n)

wherej=1,2,…M , hrjdis the channel coefficient between the j-th relay CR and the destination CR,

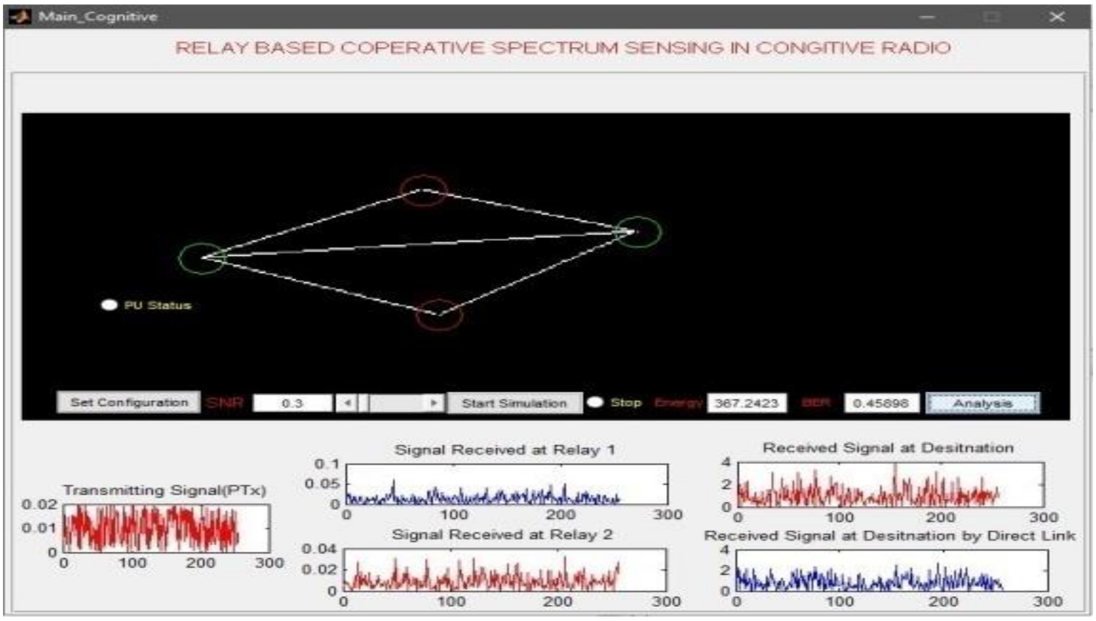

Fig 5: System model

In recent years, the fractional Fourier transform (FrFT), also known as the chirp z-transform, has been introduced to wireless communications, as an extension of the Fourier Transform. Chirp signals form the orthogonal basis for this transform, and they exhibit very good energy concentration in the FrFT domain. Chirp signals can therefore be filtered out easily in the FrFT domain. Owing to these very good energy concentration properties, chirp signals have started being used in several applications, from underwater acoustic communications

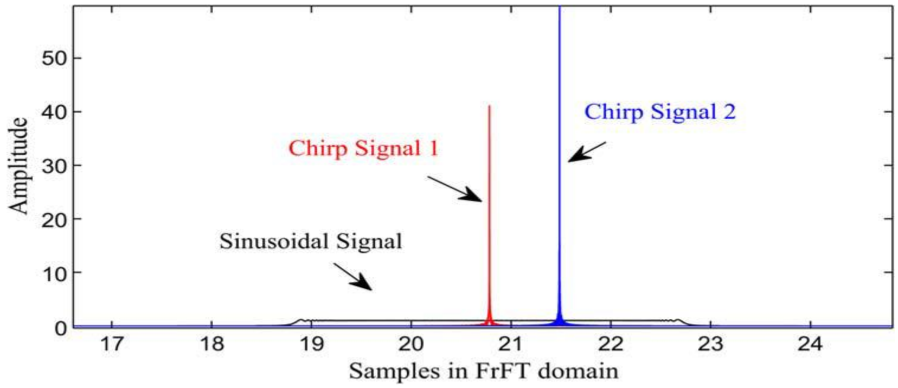

Fig 6: Chirp signal and sinusoidal signal in FrFT domain.

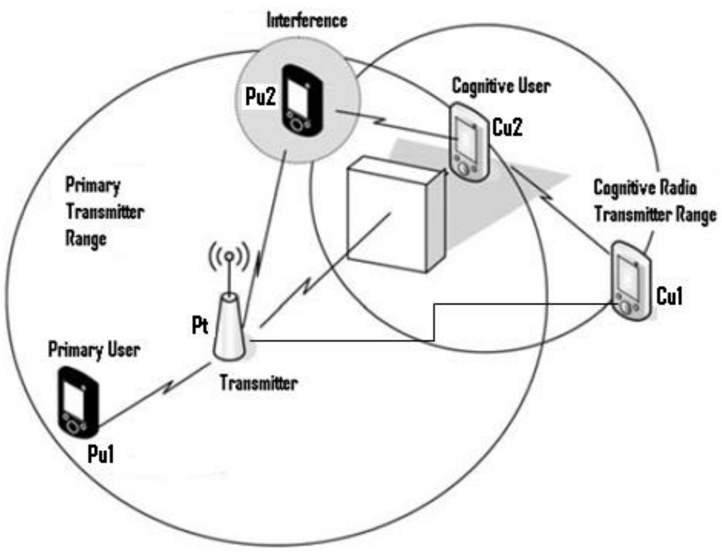

Figure 7: Cooperative Spectrum Sensing for two CR users

All users in the cognitive radio network are equipped with a single antenna.

• The antenna at any user can be utilized for both, transmission and reception.

• There is independent, additive complex white Gaussian noise with zero mean and double sided power spectral density (No) at each receiver.

• All wireless channels are independent from each other in space.

VI. RESULTS AND FUTURE DISCUSSION

1. Results:

In this section we provide extensive simulation results to investigate the performance of spectrum sensing with energy detection method in the proposed scenario. The performance is investigated with different cooperative diversity technique, at different SNR, and for multiple number of relay CRs. In our case-study the primary user is using QPSK modulation to transmit its data with 6 MHz bandwidth. The sampling frequency and the value of bandwidth is considered as same for simplicity. The frame time is 100ms and target detection probability is 0.9. We choose P(H0) = 0.8 and P(H1) = 0.2 for simulation purpose.

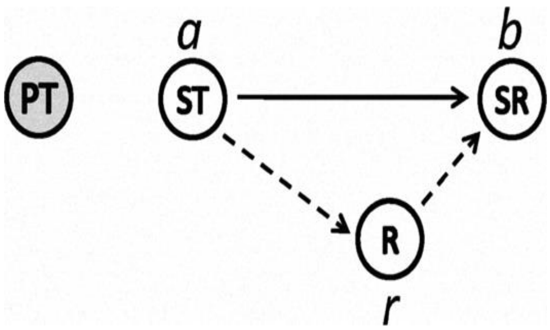

Fig 8: Cooperative communication

We proposed a cooperative communication protocol with regenerative relays for opportunistic spectrum access in cognitive radio networks. Our protocol combines joint spatialtemporal spectrum sensing and relaying to increase the transmission capacity of cognitive radio networks

The simulation was carried out using Matlab software Version 7.9.0.529 (R2009b) 32-bit (win32) running on Microsoft windows xP Professional Version 2010 Service Pack3. The receiver operating characteristics (ROC) analysis was used for the signal detection theory to study the performance of the energy detector. ROC has been widely used in the signal detection theory due to the fact that it is an ideal technique to quantify the tradeoff between the probability of detection and the probability of false alarm.

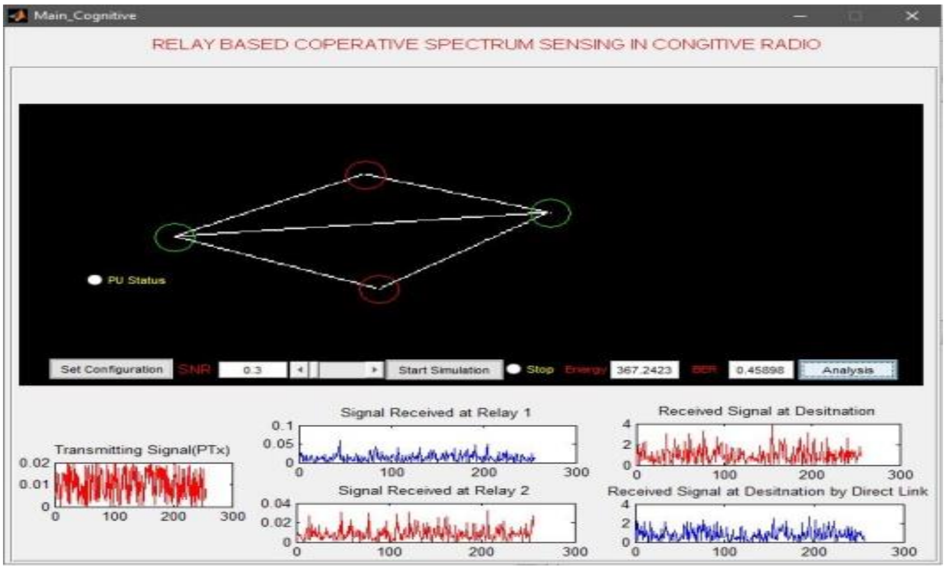

Fig 9: co-operative communication

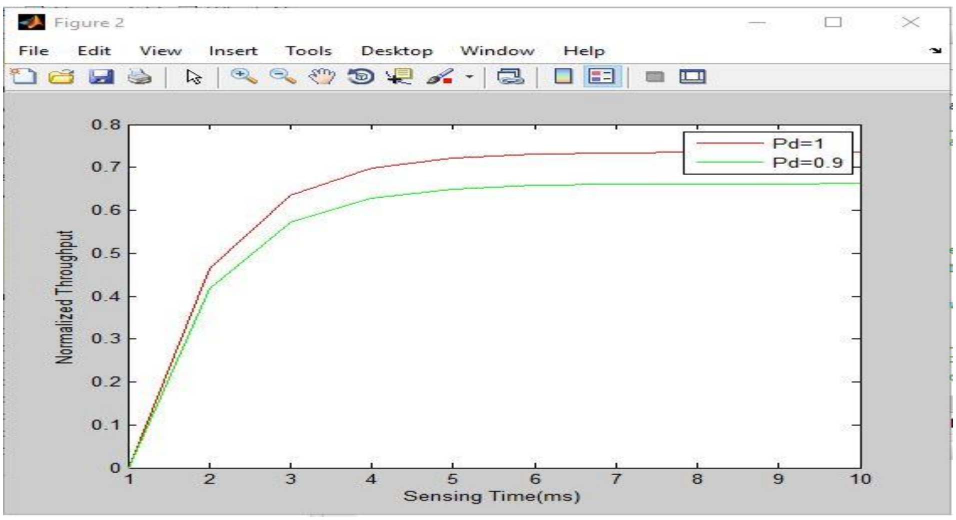

Fig 10: graph of normalized throughput verses sensing time

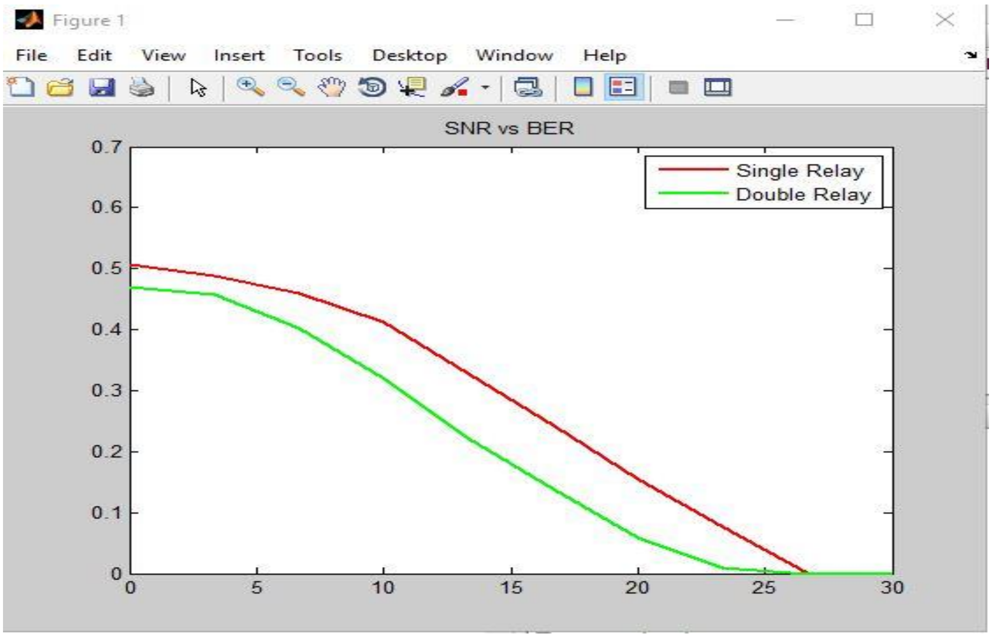

Fig 11: graph of SNR verses BER

VII. CONCLUSION

In this paper, the performance of spectrum sensing based on cooperative relaying is investigated. It is found that multiple number of cognitive relay nodes improve spectrumsensing performance. It is shown that the optimal sensing time of CR reduces with the increasing number of relay nodes. Reduction in optimal sensing time results in increase of the optimal throughput of the CR significantly. Impact of SNR on optimal throughput and on sensing time is noticeable. If SNR increases, the normalized optimal throughput increases and optimal sensing time reduces for a fixed number of relay nodes. The above study is useful in designing relay based CR network.

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