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An Efficient Algorithm for Cognitive Radio Network

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Abstract- We consider a cluster-based collaborative spectrum sensing scheme in energy harvesting cognitive wireless communication network, where cognitive nodes (CNs) are clustered based on their received power levels for enhancing sensing performance. A Cognitive Radio network is a set of base stations which make opportunistic unlicensed spectrum access to transmit data to their subscribers. By sensing and adapting to the environment, CR is able to fill in spectrum holes and this maximizing the spectrum utilization. This motivates our objective of maximizing the throughput of a cognitive radio network while maintaining performance of coexistent primary users. In order for the interference level to be minimal the SU must be allocated with an appropriate spectrum band, which causes less interference to the system. Hence both power control and spectrum allocation is necessary for the system to perform better.

Index Terms: cognitive radio,cluster, cognitive nodes, spectrum sensing, MIMO

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I. INTRODUCTION

Cognitive Radio (CR) is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. The two important challenges for cognitive radio system are a) To identify the presence of the primary users over a wide range of spectrum b) To minimize the interference caused by the secondary user. An ideal cognitive system must allow a secondary user in the CR network to transmit simultaneously with the primary user even when the PU transmission is active, as long as the quality of service of the PU transmission is not degraded to an unacceptable level by the interference from the SU.This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior, and network state. The idea of CR was first proposed by Joseph Mitola III and Gerald Q. Maguire. It was thought of as an ideal goal towards which a Software-Defined Radio (SDR) platform should evolve: a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demands. Software Defined Radio (SDR) has now reached the level where each radio can perform beneficial tasks that help the user, help the network, and helps to minimize spectral congestion.The paper focuses on the energy efficient and to implement MIMO in the cognitive environment. To make it more energy efficient the optical sensing time and power allocation need to be designed carefully to reduce the energy consumption. The multiband sensingand spectrum sharingtechniques are used to make the cognitive radio system energy efficient.

A simple example is the adaptive digital European cordless telephone (DECT) wireless phone, which finds and uses a frequency within its allowed plan with the least noise and interference on that channel and time slot. The cognitive radio is able to provide a wide variety of intelligent behavior.

It can monitor the spectrum and choose frequencies that minimize interference to existing communication activity. When doing so, it will follow a set of rules that define what frequencies may be considered, what waveforms may be used, what power levels may be used for transmission, and so forth. It may also be given rules about the access protocols by which spectrum access is negotiated with spectrum license holders, if any, and the etiquettes by which it must check with other users of the spectrum to ensure that no user hidden from the node wishing to transmit is alreadycommunicating. In addition to the spectrum optimization level, the cognitive radio may have the ability to optimize a waveform to one or many criteria. For example, the radio may be able to optimize for data rate, for packet success rate, for service cost, for battery power minimization, or for some mixture of several criteria. The user does not see these levels of sophisticated channel analysis and optimization except as the recipient of excellent service. One of the main goals targeted with cognitive radio is to utilize the existing radio resources in the most efficient way. To ensure the optimum utilization, cognitive radio requires a number of conditions to be satisfied. The primary cognitive radio requirementsare

(a) negligible interference to licensedsystems,
(b) capability to adapt itself to various linkqualities,
(c) ability to sense and measure critical parameters about the environment, channel,etc.
(d) ability to exploit variety of spectralopportunity,
(e) flexible pulse shape andbandwidth,
(f) adjustable data rate, adaptive transmit power, information security, and limitedcost.

The aim of Cognitive Radio is usage of frequency bands that are owned by their licensed users. Therefore, one of the most significant requirements of cognitive radio is that the interference caused by cognitive devices to licensed users remains at a negligible level.One of the main features of the cognitive radio concept is that the targeted frequency spectrum is scanned periodically in order to check its availability for opportunistic usage. According to the results of this spectrum scan, the bands that will be utilized for cognitive communication are determined. Since at different times and locations the available bands can vary, cognitive radio is expected to have a high flexibility in determining the spectrum it occupies. In addition to the spectrum optimization level, the cognitive radio may have the ability to optimize a waveform to one or many criteria. For example, the radio may be able to optimize for data rate, for packet success rate, for service cost, for battery power minimization, or for some mixture of several criteria. The user does not see these levels of sophisticated channel analysis and optimization except as the recipient of excellent service.

The cognitive radio may also exhibit behaviors that are more directly apparent to the user:

(a) awareness of geographiclocation,
(b) awareness of local networks and their availableservices,
(c) awareness of the user and the user’s biometric authentication to validate financial transactions

SYSTEM MODEL

The main challenge to cognitive communication lies in striking a balance between the conflicting goals of minimizing the interference to the primary users and maximizing the performance of the secondary users.

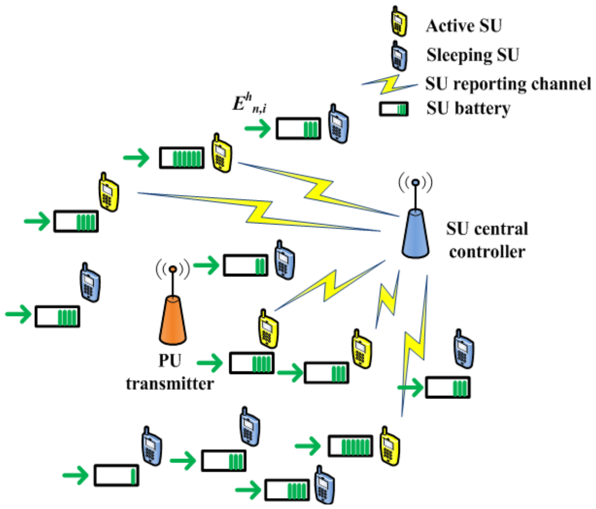

Fig.1: Energy harvesting CR system with spectrum sensing

The energy arrival process at the nth SU is assumed to be a sequence of independent and identically distributed random variables corresponding to time slot with mean value. Each SU is assumed to have a battery with and infinite capacity spectrum sensing and each SU uses energy detection a time slot of duration consist of sensing time t, sub-slots of time r for the secondary users to report their sensing decisions to a central controller in a framework, and the time for secondary user’s transmissions. As depicted in fig 1, in any time slot, only some of the SUs, according to the sensing policy, perform sensing while other SUs remain idle to save energy or due to an energy-shortage.

Rayleigh fading is a statisticalmodel for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modelled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes

Lagrangedual decomposition algorithms have the following properties:

- They are typically simple and efficient. For example, sub gradient algorithms involve two Steps at each iteration: first, each of the sub-problems is solved using a combinatorial algorithm; second, simple additive updates are made to the Lagrange multipliers.
- They have well-understood formal properties, in particular through connections to linear programming (LP) relaxations.
- In cases where the underlying LP relaxation is tight, they produce an exact solution to theoriginal decoding problem, with a certificate of optimality.

In cases where the underlying LP is not tight, heuristic methods can be used to derive a good solution; alternatively, constraints can be added incrementally until the relaxation is tight, at which point an exact solution is recovered.

Dual decomposition, where two or more combinatorial algorithms are used, is a special case of Lagrangian relaxation (LR). It will be useful to also consider LR methods that make use of a single combinatorial algorithm, together with a set of linear constraints that are again incorporated using Lagrange multipliers. The use of a single combinatorial algorithm is qualitatively different from dual decomposition approaches, although the techniques are very closely related.

This mapping is often defined as

Y^{*}= argmaxh(y)

Where Y is a finite set of possible structures for the input x , and h : Y _R is a function that assigns a score h(y) to each y in Y.

For our detector the error probabilities are given by

P_{HI}= Prob(T(Y_A) >$\lambda_{A,}$ T(Y_P) <λ_P| Primary is "ON")

P_{MO}= 1 - Prob(T(Y_A) >λ_A, T(Y_P) <λP| Primary is "OFF")

If the primary is "ON", harmful interference occurs only if the anchor is seen but not the primary. With relatively small multipath and a high shadowing correlation between the anchor and primary bands, this probability will be very small. Similarly, we manage to find an opportunity if we see the anchor and find the primary band empty. Under the model in Sec. III, we have

P_{HI}(λA, λP, ρ)=Prob(T(Y_A) >$\lambda_{A,}$ T(Y_P) <λ_P| Primary is "ON")

And

P_{MO}(λ_A, λ_P , ρ)

=1 - Prob(T(Y_A) >λ_A, T(Y_P) <λP| Primary is "OFF")

Where,

$P_{MD}(\gamma,\lambda)=1-P_D(\gamma,\lambda)$

For any two achievable points ($P^1_{HI,}$ P^1_{MO})and ($P^2_{HI,}$ P^2_{MO}) we can achieve all points on the line (ɵ P^1_{HI} + (1-ɵ) P^2_{HI}, ɵ P^1_{MO}, ɵ P^1_{MO} + (1- ɵ) P^2_{MO})

Joining these two points by randomization according to 0 ≤ ɵ ≤ 1. The performance of multiband energy detection for the single anchor case can be characterized by the set of all achievable error probability pairs. Let R_{MB}(ρ) denote this region for a given frequency correlation coefficient ρ. Formally, we can define this region as

R_{MB}(ρ) = Convexhull {(P_{HI}(λ_A, λ_P , ρ); P_{MO}(λ_A, λ_P , ρ) : 0 ≤ λ_A,λ_P ≥ ∞ }

II. SENSING TECHNIQUES IN COGNITIVE RADIO

Waveform Based Sensing

Known patterns are usually utilized in wireless systems to assist synchronization or for other purposes. Such patterns include preambles, midambles, regularly transmitted pilot patterns, spreading sequences, etc. In the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself. This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing. The performance of sensing algorithm increases as the length of the known signal pattern increases.

As one of the methods for analyzing the Wireless Local Area Network (WLAN) channel usage characteristics, packet preambles of IEEE 802.11b signals are exploited. Measurement results presented in Waveform-based sensing requires short measurements time, however, it is susceptible to synchronization errors.

Let us assume that received signal has the following simple form:

$$y(n) = s(n) + w(n),$$

Wheres$(n)$is the signal to be detected, $w(n)$ is the Additive White Gaussian Noise (AWGN) sample, and n is the sample index. Note that $s(n)$ = 0 when there is no transmission by primary user. The waveform-based sensing metric can be obtained as,

$$M = Re\sum_{n=1}^{N} y(n)s*(n),$$

where N is the length of known pattern . In the absence of primary user, the metric value becomes

$$M = Re\sum_{n=1}^{N} y(n)s*(n),$$

=Similarly, in the presence of a primary user's signal, the sensing metric becomes

$$M = \sum_{n=1}^{N} |s(n)|^2 + Re\left[\sum_{n=1}^{N} w(n)s*(n)\right].$$

The decision on the presence of a primary user signal can be made by comparing the decision metric M against a fixed thresholdλ_w. This is equivalent to distinguishing between the following two hypotheses:

$$H_0: y(n) = w(n),$$
$$H_1 1: y(n) = s(n) + w(n).$$

The performance of the detection algorithm can be summarized with two probabilities: probability of detection $P_D$and probability of false alarmP_F. $P_D$is the detecting a signal on the considered frequency when it truly is present, thus large detection probability is desired. It can be formulated as

$$P_D = P_r\,(M > \lambda_w | H_1),$$

Whereλ_w is the threshold value.$P_F$is the probability that the test incorrectly decides that the considered frequency is occupied when it actually is not, and it can be written as

$$P_D = P_r(M > \lambda_w | H_0).$$

The decision threshold $\lambda_w$can be selected for finding an optimum balance between $P_D$andP_F. However, this requires the knowledge of noise and detected signal powers. The noise power can be estimated, but the signal power is difficult to estimate as it changes depending on ongoing transmission characteristics and the distance between the cognitive radio and primary user. In practice, the threshold is chosen to obtain a certain false alarm rate. Hence, the knowledge of noise variance is enough for selection of a threshold.

Cyclostationarity-Based Sensing

Cyclostationarity feature detection is a method for detecting primary user transmission by exploiting the cyclostationarity features of the received signals. Cyclostationarity features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation. Instead of Power Spectral Density (PSD), cyclic correlation function is used for detecting signals present in a given spectrum. The cyclostationarity-based detection algorithms can differentiate noise from primary users' signals.

This is a result of the fact that noise is Wide-sense stationary Wide-Sense Stationary with no correlation while modulated signals are cyclostationarity with spectral correlation due to the redundancy of signal periodicities.The CSD function outputs peak values when the cyclic frequency is equal to the fundamental frequencies of transmitted signal x (n).

Energy Detector-Based Sensing

Energy detector-based approaches, also known as radiometry or period gram, are the most common ways of spectrum sensing because of their low computational and implementation complexities. Moreover, they are more generic as receivers do not need any knowledge on the primary users' signals. The signal is detected by comparing the output of energy detector with a threshold which depends on the noise floor. Some of the challenges with energy detector-based sensing include selection of the challenges with a threshold for detecting primary user, inability to differentiate interference from primary users and noise, and poor performance under low Signal-to-Noise-Ratio (SNR) values. Moreover, the energy detector does not work efficiently for detecting spread spectrum signals.

The white noise can be modeled as a zero-mean Gaussian random variable with variance. For a simplified analysis, let us model the signal term as a zero-mean Gaussian variable as well. Because of these assumptions, the decision metric M follows chi-square distribution with 2N degrees freedom and hence, it can be modeled as,

$$M = \begin{cases} \frac{\sigma_w^2}{2}\chi_{2N}^2 & \mathcal{H}_0, \\ \frac{\sigma_w^2+\sigma_s^2}{2}\chi_{2N}^2 & \mathcal{H}_1. \end{cases}$$

$$P_F = 1 - \Gamma\left(L_f L_t, \frac{\lambda_E}{\sigma_w^2}\right),$$

$$P_D = 1 - \Gamma\left(L_f L_t, \frac{\lambda_E}{\sigma_w^2 + \sigma_s^2}\right),$$

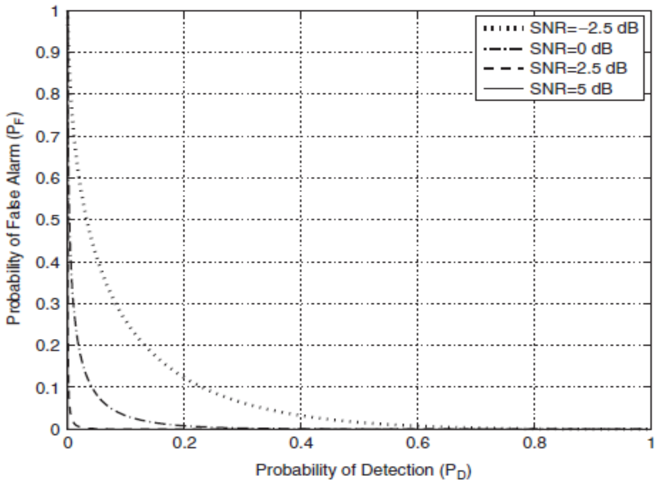

Fig.2 : ROC curves for energy detector based spectrum under different SNR values**.**

III. SIMULATION RESULTS AND OUTPUT

The above theoretical analysis is verified and shown through numerical simulations in this section. The capacity of cognitive radio network is analyzed and discussed below with simulation results.The simulation result as shown in Fig.2: shows the capacity of a single cognitive radio network.

The result shows that the capacity increases with increase in the signal to noise ratio (SNR).

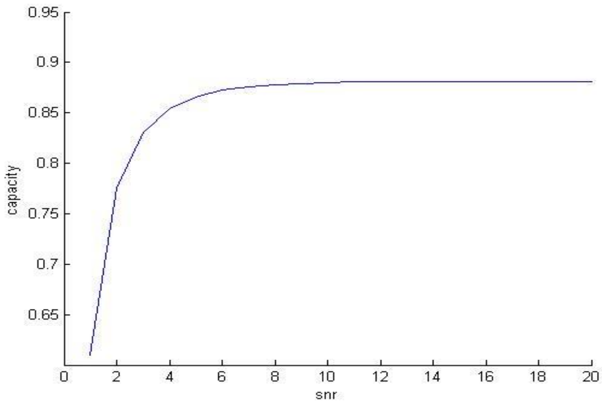

Fig.3: Capacity of a single cognitive radio

According to fig 2, for any given *n*, there exists one optimal set that maximizes the achievablethroughput of EH-CWCN under collision constraint and energy constraint. Fig. 2 illustrates the achievable throughput as a function of *n*. It can be shown that there exists an *n*such that the maximum achievable throughput canbe acquired. As the *n* decreases, the local detection thresholddecreases to satisfy the target detection probability, which causes the increasing of the probability at the same time. When the *n* continues to increase, more CNs participates in collaborative sensing and less time can be allocated to transmit data under the collision constraint.

The probability dominates the achievable throughput when *n* is very small, and while the transmission duration dominating the achievable throughput when *n* is very large. When a licensed (Primary) user is detected the Cognitive Radio (CR) vacates the channel. This property of cognitive radio is described as the spectrum mobility and also called handoff. This is the process that allows the Cognitive Radio user to change its operating frequency. Cognitive Radio networks try to use the spectrum dynamically to operate in the best available frequency band and maintain the transparent communication. Spectrum sensing is an important and a sensitive job out of these four functions in Cognitive Radio since interfering with other users is illegal.

The multiband sensing and capacity improvement in cognitive radio networks were constructed and its various performances were evaluated. The simulation results of sensing and improvement in efficiency were obtained using MATLAB simulator. Analysis of spectrum sensing scheme has been increased by increasing the number of spectrum opportunities.

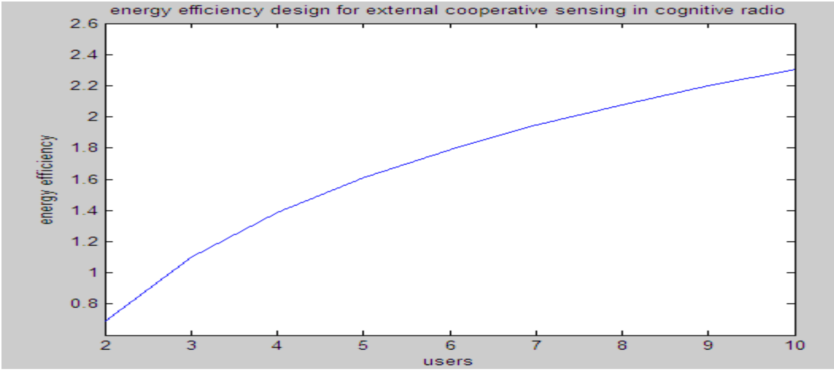

Fig.4: Capacity of cluster radio

The simulation for energy efficient and capacity improvement were evaluated. Multiband sensing is a technique where, multiple bands are sensed in parallel to reduce the sensing delay. Any primary user or primary network can send the information to multiple users. Only the licensed user can use the multiband sensing. Multiband sensing leverages multipath fading and shadowing to reduce the impact of the shadowing uncertainty on the non-interference guarantee given to the primary users.

Spectrum allocation and licensing leads are the important parameters to the systematic underutilization of the spectrum. In most locations and at most times, most bands are effectively unused. The consensus is that the underlying cause is a lack of flexibility in the current regulatory model. There are two important dimensions of flexibility. Flexibility of use refers to the ability of spectrum licensees to choose their application, modulation, and coding strategies freely without needing detailed regulatory approval.

This allows a license to react to consumer demand and take advantage of new technologies. The second dimension is flexibility of spectrum access allowing systems to get access to additional spectrum as needed without having to go through the government regulators. The key consideration is to avoid causing harmful interference to other users. The idea is to shift the objective of peaceful coexistence from being considered purely at the "regulatory layer" to something that is addressed at runtime by wireless systems themselves.

IV. PEAK DETECTION ALGORITHM

Peak detection algorithm will be added additionally with advanced MMSE (Minimum Mean Square Error) equalizer. It will identify the high priority channels quickly; by this the processing tie will be less in receiver side. The peak must have higher intensity than its neighbors, the peak must be above a chosen threshold, and the peak must have an associated signal to noise ratio (SNR) higher than a set threshold. The main advantage of peak detection algorithm is that it takes into account all the users rather than the evaluation of an average spectrum that could hide independent features. In addition the spectra maintain their original shape obviating the need for a shifting or alignment process.

V. OUTPUTS OF MIMO

THROUGHPUT Vs USERS

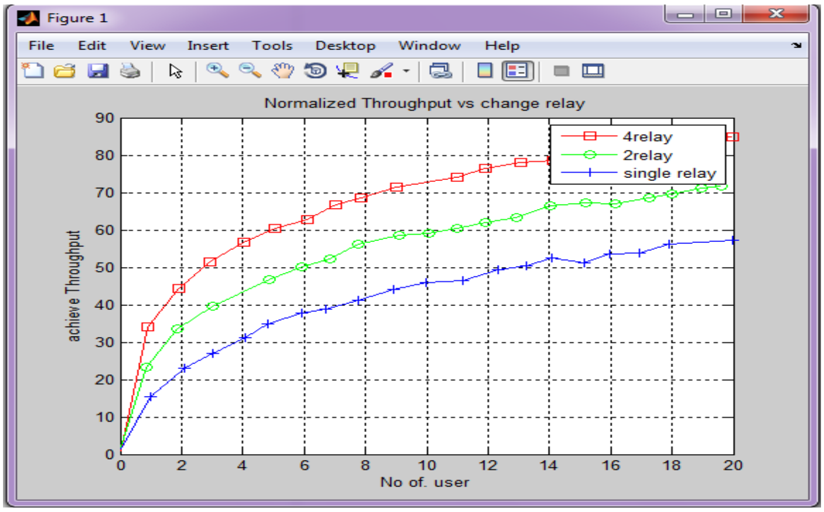

Fig. 5 Throughput Vs Users

The above graph illustrates the changes between the throughput and the number of users. For a single relay throughput is achieved as 60 because in single relay due to some loss of bits the throughput will reach up to 60 and for 2 relays throughput is achieved as 70. Therefore in 4 relay the throughput is increased to the maximum of 90 and the spectral efficiency is increased.

BER Vs SNR

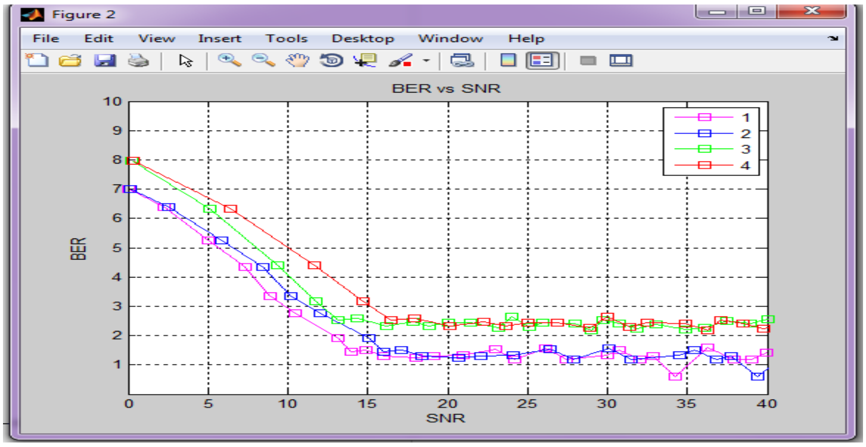

Fig.6 BER Vs SNR

The above graph illustrates about the error occurred in the data achieved in the throughput. The 4 relay is occurred upto 3 and the other relays are upto 1. Since the throughput is 40 times increased but the error occurred in that signal will only at a single point. So that the throughput is increased with the less loss of data's.

SENSING TIME Vs USER

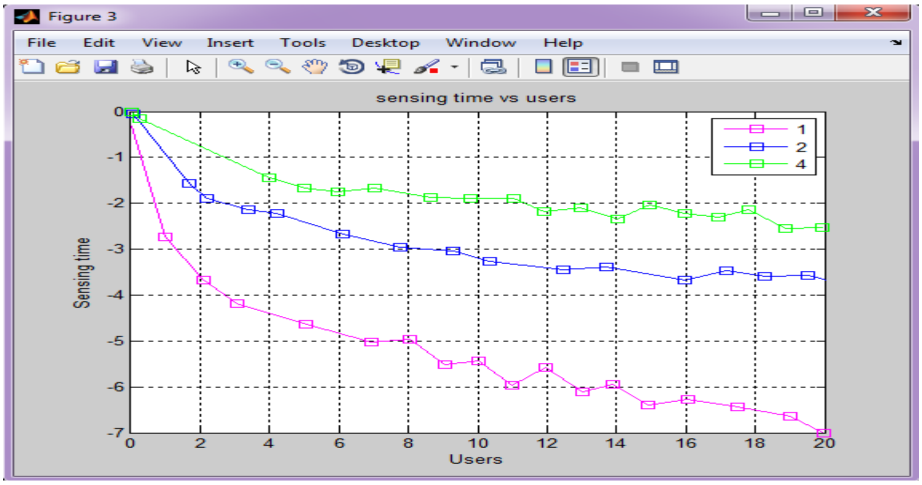

Fig. 7 Sensing Time Vs Users

The above graph shows the changes between Sensing time and users. The sensing time is nothing but the signal detection of the users. In the single relay the sensing time is reduced upto -3, but in the 4 relay the sensing time is almost reduced to -7. So we can conclude that the sensing time is reduced for the more number of users in the 4 relay (channel).

VI. CONCLUSION

The multiband sensing, spectrum sharing and hybrid spectrum access strategy technique are proposed for cognitive radio network. In the proposed techniques the number of spectrum opportunities discovered is more with less overhead there by increasing the throughput. Various performance analysis namely throughput and capacity have been analyzed. The number of spectrum opportunities discovered is less in the existing techniques which leads to reduction in the throughput. Thus multiband sensing, spectrum sharing and hybrid spectrum access strategy provides a better performance which has a greater throughput and greater capacity.The cluster based sensing, spectrum sharing, and hybrid spectrum access strategy techniques are proposed for cognitive radio networks. In the proposed techniques the number of spectrum opportunities discovered is more with less overhead thereby increasing the throughput. The number of spectrum opportunities discovered is less in the existing techniques which leads to reduction in the throughput. In addition to the implementation of MIMO the throughput is increased over 90mbps and the BER have been reduced for the signals.

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