Cooperative Sensing using LUT: A powerful method to overcome shadowing problem and maximizing throughput in CRN's

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Abstract : Spectrum scarcity is an major issue in latest wireless technologies used now a days. Literature shows 70% of spectrum is either underutilized or not utilized at all. The main process in determination of spectrum scarcity starts with Spectrum sensing in cognitive radio. Sensing through one Secondary Users (SU) node faces various issues (like hidden node, shadowing problem etc) which occurs due to channel impediments, or obstacles like buildings etc to overcome such problems cooperation based spectrum sensing is brought into existence. Although collaboration between multiple SU's improves the sensing performance, but cooperation between nodes is it an challenging issue. Concept of Look up Table (LUT) is widely as well as efficiently used in this paper to improve the efficiency of the system while doing cooperative sensing. Lookup Table will hold the status of the spectrum which is updated every time by multi node/Cooperative sensing process which makes sensing reliable, fast and robust. In this paper we are introducing an LUT based cooperative sensing method to improve transmission time and hence improve throughput of Cognitive radios system. We have achieved Probability of detection (P_D) significantly improved by 8%, Probability of False alarm(P_{fa}) significantly decreased by 18% and achievable normalized throughput improved by 5% along with significant improvement in end to end delay with respect to traditional sensing method.

***IndexTerms* - Cognitive Radio Cognitive Networks (CRCN), Look up table (LUT), channel assignment, Cooperative sensing, overlay access Spectrum Sensing (SS).**

I. INTRODUCTION

Cognitive radio (CR or SU) being a prototype ensures the efficient utilization of spectrum using spectrum sensing, spectrum sharing and spectrum management effortlessly and accurately between (Primary /Licensed Users) PU & SU [1]. Practically a Secondary User (SU) is unable to perform sensing and transmission operation at same time until unless very Complex and costly MRMF (Multi Radio- Multiple frequency) like hardware is not used simultaneously, which causes major problem of sensing and throughput tradeoff. Periodic sensing is generally used in Cognitive radio system [2]. The basic requirements for efficient spectrum sensing should be reliable, vigorous and fast detection of Primary users signal although if that signal is having low SNR (signal-to-noise ratio). More than two, but not a lots of signal processing techniques are being expended for SS. Most preferred techniques are Energy detection, Cyclostationary detection and matched filter [3]. Single node sensing is not preferred due to shadowing, multipath fading like issue due to obstacles like buildings ,due to which signals received is having uncertainty. To take the edge off these problems, cooperative or multiuser detecting procedures are being utilized [3–7]. Opportunistic spectrum sharing and access were comprehensively discussed in earlier period. In previous decade, Dynamic Spectrum allocation (DSA) technique is coming to picture very widely and Cognitive Radio offers a promising approach to enhance spectrum utilization and is identified as key enabler for DSA networks. Literature shows in few geographical areas most of the time licensed bands (especially TV bands) are either unutilized or underutilized. These frequency bands are called "white space" or "hole" ("*a bandwidth is considered as white space if it is wider than 1 MHz and remains unoccupied for at least 10 minutes"*)[7] and white space occupied by SU should be leaved after the arrival of PU within 2sec as per IEEE 802.22 standard.

In November/2004, we saw the development of the to characterize a the first ecumenical effort to define a novel wireless air interface1 standard predicated on Cognitive Radios (CRs): the IEEE 802.22 Working Group (WG)[1]. The IEEE 802.22 WG is sanctioned with the encroachment of a CR-WRAN (CR-Wireless Regional Area Network) PHY(Physical layer) and MAC(Medium Access Control) layers for use by permit excluded gadgets in the spectrum to facilitate at present dispensed to the Television (TV) band .Because of significant disadvantage of detecting throughput exchange off issue, part of important studies[2] embraced where major issues expressed ideal detecting/throughput exchange off is clarified.

II RELATED WORK

Ying-Chang Liang et al.[2007] explained fundamental tradeoff between sensing capability and achievable throughput of the secondary users[11]. Particularly, they studied energy detection sensing technique for the outline of detecting opening utilizing span to augment the achievable throughput for the optional clients under the imperative that the essential clients are adequately secured.

Anh Tuan Hoang et al.[2007] mainly focused on adaptive development of spectrum sensing periods so that negative effects to the execution of the Secondary radios system were minimized. They additionally proposed a joint information – transmission/range - detecting booking into a standard queuing model. In view of that, efficient scheduling algorithms which includes channel and queuing states of the Cognitive Radios system to accomplish great QoS were proposed[12].

Developing efficient spectrum-sensing and access mechanisms has been an extremely dynamic research point in the course of recent years [3], [6]–[18]. An extraordinary review of late deals with MAC convention outline and investigation [5]. In [4][6], it was demonstrated that, by improving the detecting time, a significant improvement in throughput can be accomplished for a SU. In [7-8], they extended the outcome in [3] to the multiuser setting, where they configure, examine, and streamline a MAC protocol to accomplish ideal substitution between sensing time and conflict overhead.

Truth be told, in [19], we expected that each SU can at the same time utilize every accessible channel. Consequently, the channel assignment issue and the exploitation of multiuser differences don't exist in this setting. In[7-18], sensing period streamlining and ideal channel sequencing calculations were proposed to proficiently find white spaces and to reduce the investigation delay.

From the studies explained in literature two major problem were found .Many researcher usually work either with single channel sensing to maximize throughput. On the other hand researcher mainly focused on optimizing sensing time to maximize throughput while sensing with single radios problem like hidden node and shadowing problem is very prominent which gives us an idea to use cooperative sensing instead of single node sensing.

Specifically, we consider the situation where each SU can use wrongly at most one accessible channel for correspondence. In an particular situation if SUs are outfitted with only a single radio that utilizes a narrowband radio frequency [5]. Moreover, it is expected that empty spectrum are exceptionally dynamic to such an extent that each SU can detect all channels to find accessible(available) channels and additionally to trade detecting comes about with each other. Under this setting, we are occupied with deciding an arrangement of channels that were designated to each SU ahead of time so that maximum throughput can be obtained. To the best of our insight, this critical issue has not been considered.

The principle commitments of this paper are compressed as takes after. Optimized sensing time is still an unexplored issue and researcher find different ways to optimize this, we proposed a novel method to optimize sensing time to maximize transmission time to improve throughput using LUT concept. In this method we are using cooperative sensing and sensing data is stored in LUT after every time frame so that wideband sensing is not required in every CR Frame cycle specifically at the point when the present channel is detected as occupied. LUT will also help to find vacant channel for spectrum sharing using handoff concept to maximize throughput as Quality of service (QoS) parameter.

Section 1 deals with introduction part followed by extensive literature survey(related work) in part 2. System model is described in section 3. In section 4 validation of system model described in section 2 is obtained using simulation results in CRCN environment carried out in NS2. The paper is concluded followed by future scope in section 5.

At long last, a channel-bouncing based MAC etiquette was proposed in [20-24] for cognitive radio systems to mitigate the congestion/blockage issue in the fixed control channel plan. Spectrum detecting, access, and power control calculations were created, includes QoS insurance for PUs and QoS provisioning for SUs, in [22] and [23]. All these current works, be that as it may, did not consider the situation where Cognitive radios have equipment imperatives, that permit it right to use atleast one available channel. We will research this issue, in this paper.

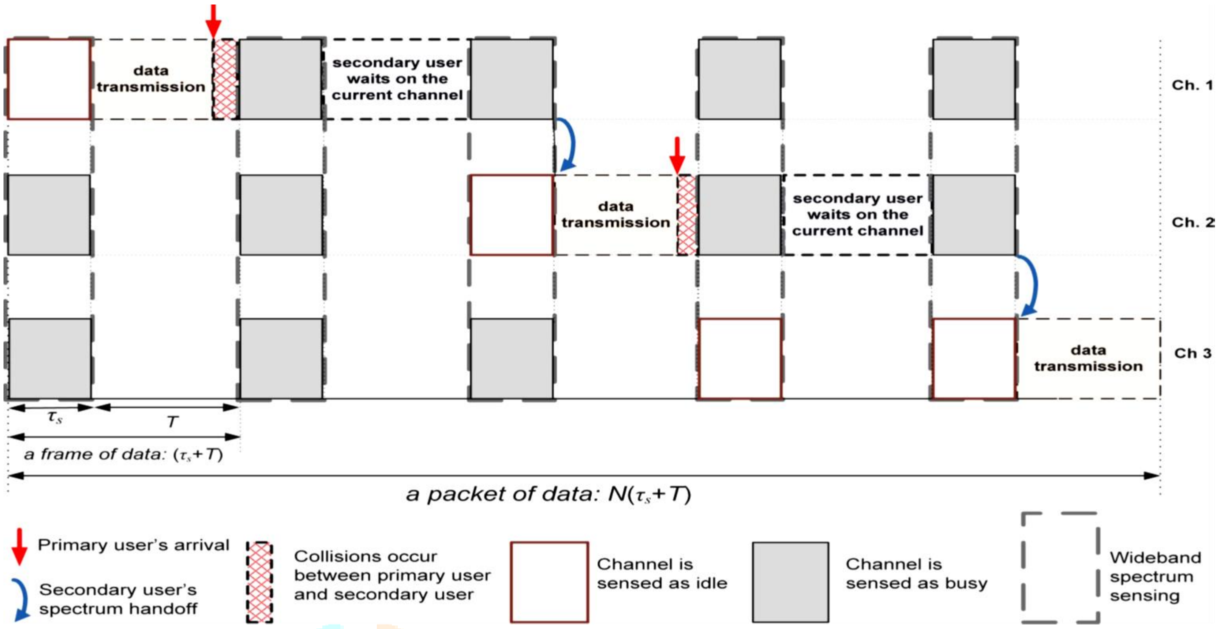

Fig. 1. SU's one-packet transmission including periodic sensing, data transmission, and spectrum handoff [10].

Figure 1. actually shows how single CR uses spectrum and on arrival of PU SU have to vacate the spectrum either it has to wait for same channel or it uses spectrum handoff for data transmission to maintain QoS metrics like throughput while optimizing energy constraints discussed by (Stephen Wang et al.) [10]. In this paper we mainly focuses on developing Cooperative MAC (Co-Mac) using LUT & cooperative sensing technique. In this paper SUs are utilizing the obstruction shirking range sharing methodology.

Specifically, we consider the situation each SU can use fuzzy selection process to occupy at least one accessible channel for transmission. This can be the state of affairs if SUs are outfitted with just a single radio that utilizes a narrowband radio frequency spectrum. Likewise, it is accepted that voids are exceptionally dynamic in nature to such an extent that it is not reasonable for each SU to detect all channels to find accessible channels as well as to trade detecting comes about with each other. Under this setting, we are keen on deciding an arrangement of channels that were apportioned to each SU, channels data will be upgraded and store in LUT well ahead of time before the beginning of next cognitive frame such that sensing time used in next cognitive frame will reduced and due to which improved network throughput can be achieved in a cooperative manner. To the best of our knowledge, this significant problem has not been extensively studied yet. The commitments of this paper can be abridged as takes after.

- A unique sensing technique using cooperative sensing using LUT.
- In this paper authors detail the channel assignment task utilizing LUT for throughput expansion as a whole number improvement issue

III SYSTEM MODEL:

Generally researcher using Energy detection because of simplicity but can be used only for higher signal to Noise raio where as Cyclostationary detection method is used at very low signal to noise ratio. In this paper Hybrid (Energy Detection + Cyclostationary feature detection) using LUT is used in an optimize way so as the spectrum sensing procedure could be done very graet accuracy, robustness and at fast speed too. This method of detecting PU model is worked over NS2 under CRCN environment explained in next section of this paper. The SUs are required to detect and monitor the radio range environment inside their working extent to identify the recurrence groups that are not involved by PUs.

3.1 Cooperative wideband spectrum sensing algorithm Using LUT

Let us consider that RF frequency spectrum is partitioned to "k" independent sub-groups. Obviously a portion of this sub-groups (λ out of k) are empty for specific time in a particular geographic area in the midst of a requirement that $1 \le \lambda \le k$. Henceforth, these empty sub-channels or partially used channels are accessible opportunistically for the purpose of spectrum access. Every CR detects the complete wideband RF spectrum (0, 1, ..., (k−1) sub channels and keep informed the status of all the channels to LUT which is updating with every time frame to maximize the system throughput.

Let M be statistically independent nodes that has been deployed in the collaboration system and the signals received from all the nodes are measurably autonomous, such setting can be explained with the help of hypothesis as :

$$H_0^k : y_n(m) = \ddot{u}_n(m), \quad n = 1,2,3 \ldots . N \tag{1}$$

PU is absent

$$H_1^k : y_n(m) = H_n^k * \mathcal{S}_n(m) + \ddot{u}_n(m), \quad m = 0,1 \ldots \ldots (M-1) \tag{2}$$

PU is present

In which $y_n(m)$, $\ddot{u}_n(m)$, and $\mathcal{S}_n(m)$ can be efficiently described in the matrix form as

$$\begin{aligned} y_n(m) &= [r_n^0, r_n^1, r_n^2, \ldots\ldots\ldots r_n^{(k-1)}] \\ \ddot{u}_n(m) &= [\ddot{u}_n^0, \ddot{u}_n^0, \ddot{u}_n^0, \ldots\ldots\ldots \ddot{u}_n^{(k-1)}] \\ \mathcal{S}_n(m) &= [\mathcal{S}_n^0, \mathcal{S}_n^1, \mathcal{S}_n^2, \ldots\ldots\ldots \mathcal{S}_n^{(k-1)}] \end{aligned} \qquad (3)$$

Where y_n is Primary user received signal, $\ddot{u}_n$ is noise signal detected while sensing and $\mathcal{S}_n$ is Primary User signal for k^{th} sub-channel and N is the total samples taken while detecting spectrum using cooperative sensing.

All these sampled data is stored in LUT and updating after every Cognitive frame so that vacant slots can be checked from LUT for next transmission slot by saving sensing time for consecutive frame.

Let T be the total time taken by the secondary user (Time used for sensing & Successful transmission of one frame) as shown in fig2. Let τ_{Th} be the threshold time for maximum sensing time. Thus if τ is the new sensing time used by SU with the help of LUT such that $\tau \leq \tau_{Th}$.

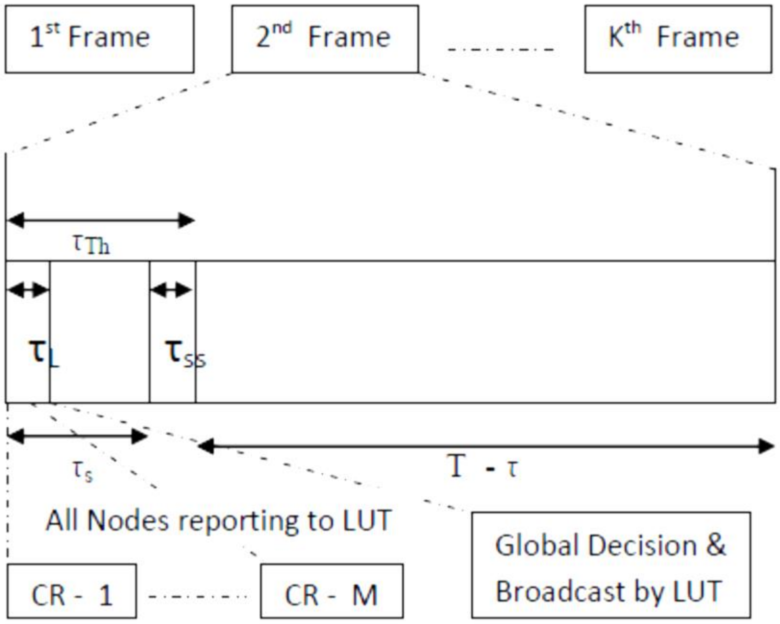

Fig 2: Time frame architecture using LUT

Where τ_L is time utilized for look up table(LUT) refresh & status update for available time slots. Let τ_{ss} be the time saved for sensing with the help of LUT then

$$\tau_{ss} = \tau_{Th} - \tau_s \qquad (4)$$

Now Total time available for the complete frame after saving sensing time is given by Ŧ which is as follow

$$\text{Ŧ} = T - \tau_{ss} \qquad (5)$$

The resultant sensing time will be updated and new time required for sensing in the current frame (after saving extra sensing time due to use of LUT) is given by

$$\tau_s = \tau_{Th} - \tau_{ss} \qquad (6)$$

Hence time available for data transmission in a given frame is now rewritten as $T - \tau_s$.

Energy Consumption for sensing of available spectrum

$$E_s = P_s * \tau_s \qquad (7)$$

Energy utilized for data transmission in a particular frame of CR –user.

$$E_t = P_t*(T - \tau_s) \qquad (8)$$

Total energy consumed during one frame of data transmission is equal to the sum of energy used while sensing and energy consumed while transmission.

Therefore

$$E_{Total} = E_s + E_t \qquad (9)$$

If in a extreme case sensing energy is maximum utilized to its threshold value then the saved (extra) energy required for sensing in that case will be equal to $'E_s$ such that

$$'E_s = P_s * \tau_{ss} \qquad (10)$$

In this case total energy required for one frame of sensing & transmission is

$$E_{Total} = E_s + E_t + 'E_{ss} \qquad (11)$$

Sensing energy+ Transmission energy + Saved energy

From equation 10 & 11 it is conclude that using LUT not only optimal sensing will takes place but also we can increase the residual energy (energy saved by using less time using LUT for sensing) for next frames. Introducing this thresholding parameter for sensing time, we can utilize more time for transmission which results in improved throughput.

LUT is to maintain the state and information about the channel availability for other SU which are working in cooperative manner and to make the process of sensing fast reliable and robust.

Let the following matrix define LUT functioning which maintain the state and information about the channel and it works on fuzzy selection which is as given below:

LUT[i][j]

Where i=0,1,2…..n (channel information)

& j =0,1,2(States of channel via fuzzy selection)

If

State	Status
j=0	Partially Available
j=1	Unavailable
j=2	unused

then

LUT[channel index][state index] : [i][j].

In fig 2 sensing is done with the help of LUT. For one complete transmission of packet of data SU perform wideband sensing during sensing time slot to acquire accessibility of vacant slots within the spectrum over all the available channels where as in our method this process is done with the help of M different node(SU's) and the information collected by all the nodes are stored in LUT for global decision and broadcasting of data for next upcoming Frame/slot(Sensing +transmission). Let the average SNR received from PU;s on every channel is γ which is almost similar for every available channel during one successful packet transmission. The detection probability (P_d) as well as probability of False alarm (P_{fa}) are given by

$$P_d = \mathbb{Q}\left(\frac{1}{\sqrt{2\gamma+1}}\left(\mathbb{Q}^{-1}(\mathcal{P}_{fa}) - \sqrt{\tau_s f_s \gamma}\right)\right) \qquad (12)$$

$$P_{fa} = \mathbb{Q}\left(\sqrt{2\gamma+1}\left(\mathbb{Q}^{-1}(\mathcal{P}_d) + \sqrt{\tau_s f_s \gamma}\right)\right) \qquad (13)$$

Where $\mathbb{Q}(x)$ is Gaussian probability appendage function with $\mathbb{Q}^{-1}(.)$. f_s is sampling frequency in Hz and $\mathcal{P}_d$ *and* $\mathcal{P}_{fa}$ are the values of target probability of detection and target probability of false alarm respectively, and these are assumed to be same for every channel available within the spectrum. We all known that for a fixed estimation of examining recurrence(Sampling frequency), there must be a min value of sensing time to facilitate the condition of target probability of detection and target probability of false alarm satisfied. And this minimum value is denoted by

$$\tau_s(min) = \frac{1}{\gamma^2 f_s}\left(\mathbb{Q}^{-1}(\mathcal{P}_{fa}) - \mathbb{Q}^{-1}(\mathcal{P}_d)\sqrt{2\gamma+1}\right)^2 \qquad (14)$$

When sensing is done with the help of energy detection method, energy consumption while sensing is calculated by the time utilized in sensing time (τ_s). Therefore minimizing $\tau_s$will help in providing maximum time for transmission and improves throughput of the system.

IV SIMULATION RESULTS:

Keeping in mind the end goal to delineate the execution of helpful wideband spectrum detection in light of Hybrid (Energy Detection + Cyclostationary feature detection) sensing, input signal is considered under AWGN, shadowing, multi path fading and Rayleigh fading channel. Simulation has done in NS2 and CRCN environment. The signal specification and simulation parameters are given in Table 1.

Table 1: Specifications for simulation.

Parameters	**Value**
Wait probability of SU	0.1 - 1.0
Bandwidth	6/10 Mhz
Modulation	OFDM
P_d	0.9
P_f	0.1
Frame length	T= 0.1-2 sec
Sensing Power	110mW
Transmission power	410mW

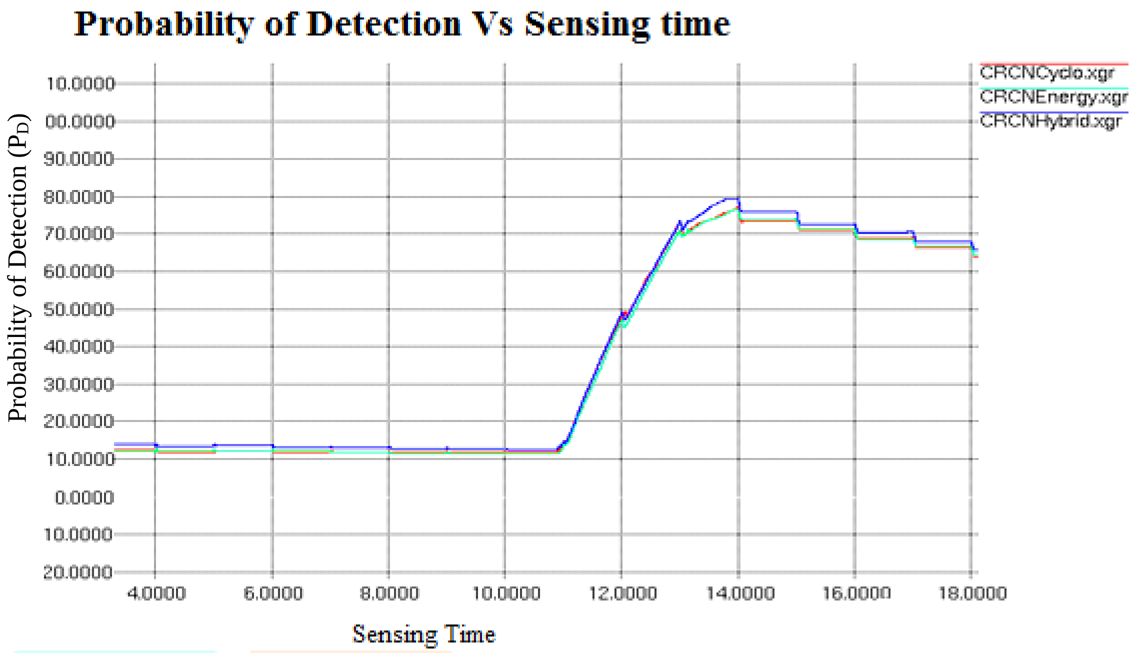

Fig 3. P_d vs sensing time

P_D probability of detection vs Sensing Time(τ_s) is drawn in fig 3. Given results clearly depict that at $\tau_s = 13sec$ probability of detection P_D by hybrid sensing method using LUT has significant improvement of 8% with respect to ordinary Energy detection and cyclostationary method.

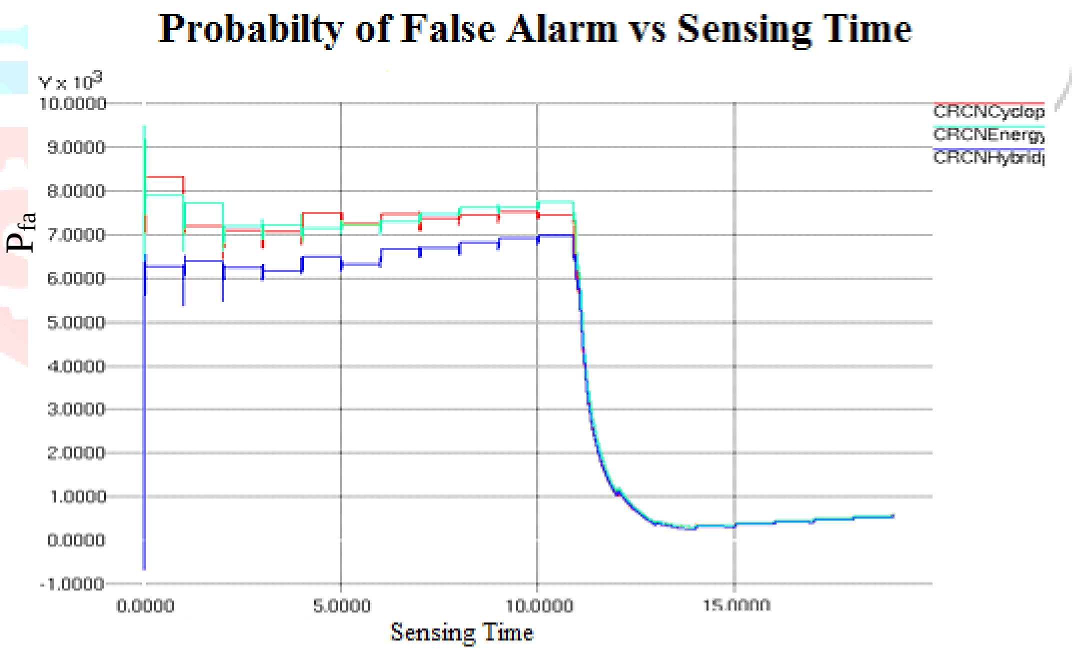

Fig 4. P_{fa} vs sensing time

P_{fa} probability of false alarm vs Sensing Time(τ_s) is drawn in fig 4. Given results clearly depict that at $\tau_s = 1msec$ probability of detection P_{fa} using hybrid sensing method using LUT has significant decreased by 18% with respect to ordinary Energy detection and cyclostationary method.

For rapid response of our method we also calculated end to end delay which clearly shows significant improvement in speed of detector using cooperative sensing using hybrid method with LUT as global decision and broadcast method as depicted in fig 5.

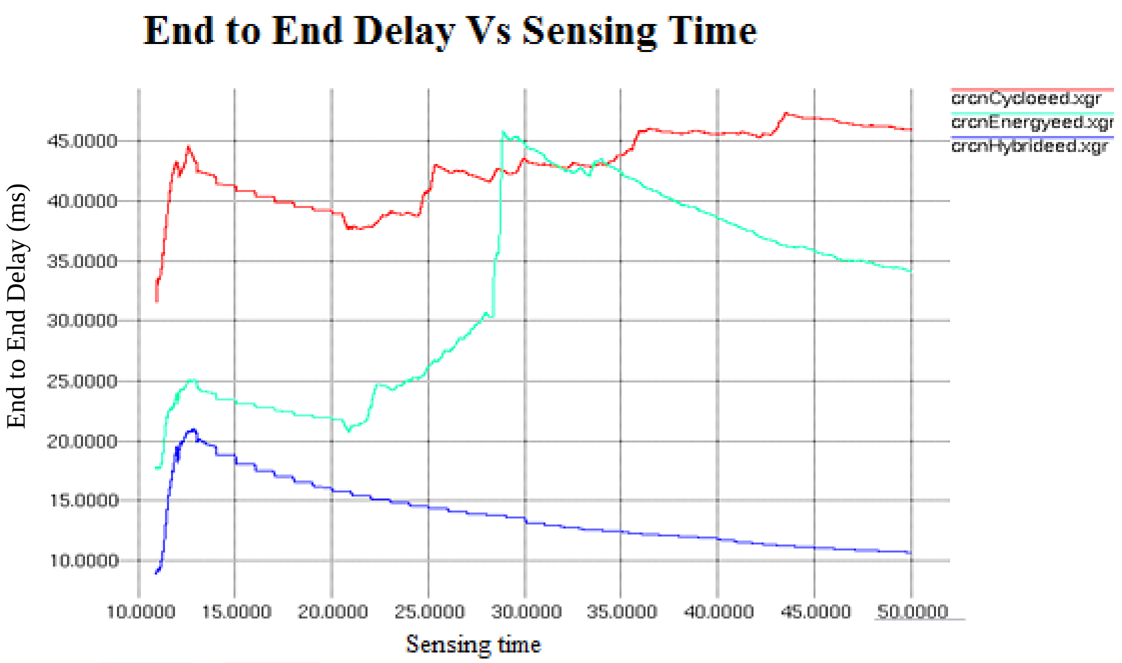

Fig5. End to end delay vs sensing time

Next results shows the effect of LUT on normalized throughput of the system and how LUT helps in optimizing sensing time with the help of NS2 simulator as shown in fig 6..

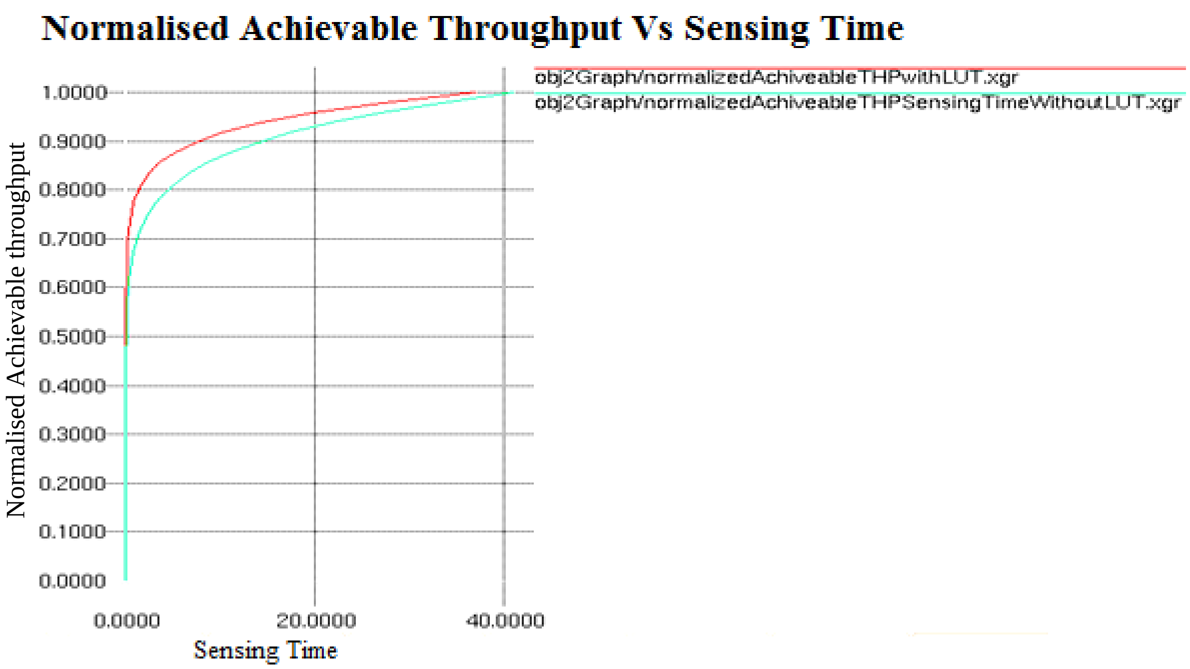

Fig 6. Normalized achievable throughput Vs sensing time

Fig 6 clearly prove the effect of Lookup Table in Normalized achievable Throughput as after sensing time $\tau_s = 10sec$ achievable throughput using LUT in cooperative sensing was improved by 5% which is highly significant where spectrum is not allocated for achieving throughput of a system.

V CONCLUSION & FUTURE SCOPE

In this paper, we have proposed Cooperative Sensing using LUT method to get better detection of the spectrum sensing. It has been observed from the result section that the proposed method explained in this paper detect the wideband spectrum more efficiently than traditional detection methods used earlier by different researchers.

Results clearly depicts that probability of detection (P_D) using hybrid sensing method using LUT has significant improvement of 8%, Probability of false alarm (P_{fa}) has significant decreased by 18% and normalized achievable throughput improved by 5% alongwith significantly improved end to end delay with respect to ordinary Energy detection and cyclostationary method. This paper mainly focused on sensing speed accuracy and robustness and serves as a stride towards blueprint and examination of joint spectrum sensing schemes. Results point to noteworthy performance of our system, encourage upgrades might be accomplished through joint effort of various nodes in various molds along these lines spurring further research here. Execution examination of range detecting in this situation is the subject of our ebb and flow inquire about.

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