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An Energy Efficient Spectrum Sensing, Access and Handoff Concept using Look Up Table for Cognitive Radios Networks

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Abstract: Continues growth of high data rates specifically broadband network demanded by the subscribers 5G technology act as an driving trend under advanced long term evolution and it requires more spectrum as compared to technologies used now a days. 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. main process in determination of spectrum scarcity starts with Spectrum sensing in cognitive radio. We are using Look up Table (LUT) which hold the status of the current spectrum which is updated after every time slot (sensing and transmission process). Sensing should be reliable, fast and robust. This paper mainly focused on spectrum sensing, access and handoff using LUT based fuzzy selection switch to improve transmission time and avoid traffic congestion hence improve throughput keeping Cognitive radios system more energy efficient. We have achieved Energy consumption vs throughput coefficient significantly improved by 5-8%, Energy consumption vs delay coefficient significantly decreased by 5-15% with respect to existing methods.

Keywords:Cognitive Radio Networks (CRN), Look up table (LUT), channel assignment, Cooperative sensing, Spectrum Handoff, Energy Efficiency, Sensing Transmission tradeoff *Protocols*

1. INTRODUCTION

The Cognitive radio concept was originated by Joseph Mitola while attending a seminar at Royal Institute of Technology situated in Stockholm in 1998 and later published by him in an article [1]. Cognitive radio is a unique technique which is able to encourage efficient improvement of the spectrum deployment between primary and secondary transmission.

As per 2020 futuristic vision Industry faces a big challenge to develop new design so as to meet future extreme capacity and performance demands. To meet such conditions cognitive radios based 5G technology act as an driving trend under advanced long term evolution and it requires more spectrum as compared to technologies used now a days. Some of the CR systems, spectrum administration is facilitated through the action of analysis which is agitated out periodically [1]. In general, the Secondary User is not capable to perform the basic functions of spectrum sensing and utilize the vacant spectrum for transmission at the same time, due to which SUs faces the essential problem of indispensable substitution between best possible sensing and transmission. [1], [2]. As of now researcher did lot of works in this regards, in literature many researcher are keen in optimizing the sensing time so that time available for transmission will be maximizing by maintained the frame length remains same for the secondary users. [1], [2]. However, a lot of the analysis /strategies being implemented for sensing can be acclimated area either individual approach is available[2] or assorted maximum no of channels are sensed and accessed one afterwards another. [2]. As a result, the CR user can either address abstracts or waits after transmission, through the approach sensed earlier.

In wideband CRN spectrum with N number of narrowband channels accessible for sharing, the throughput of the SU can be decidedly added by applying a “spectrum handoff” [3], in which if a Secondary User faces problem due to interference from primary user transmission it will switch to another vacant channel with the help of fuzzy selection based Lookup Table(LUT) concept (LUT Fuzzy selection switch) explained in section 4, Secondary user will start its data transmission on another channel recently sensed through LUT fuzzy switch when secondary user sensed current channel as busy(SU’s must have to leave the spectrum within 2sec as long as PU arrived as per FCC regulation) however this practice is not done excessively as it also consume high energy during spectrum handoff[4] Spectrum Handoff is not preferred where system is battery operated usually in Mobile CR systems (spectrum handoff concept is rarely used [4].

In Cognitive radios networks for accurate sensing Secondary Users (SU’s) will have to coordinate with PU. For more efficient and accurate sensing SU’s should be separated into clustered and each cluster will be having separate LUT for status update of spectrum as shown in figure 1which is explained in detail in system model (section 3) of this research paper and each cluster will share the information with each other so as to optimize sensing time and also helpful in providing energy efficient spectrum handoff to achieve maximum throughput.

2. PROBLEM FORMULATION

The energy consumption problem is becoming more and more severe now a days. The basic reason behind it is explained in following three aspects.

2.1 The very first reason is mobile power, as the devices generally used in cognitive radio networks are mobile devices due to which they have to use battery operated modules while moving from one place to another within the networks. The network will last long if we are able to design system with more energy efficiency so that devices can operate for much longer duration with same energy source(battery) as earlier

2.2 The second major limitation is basically self designed as we have requirement of more and more data to be transmit. The requirement of very high throughput is a very keen area of research for the researcher in past decade. But when we are working on high data rates to improve throughput of the system we require more energy(which is actually limited due to battery operated system).The only way out is to make system more energy efficient beside sending high data during transmission to improve throughput.

2.3 The last but not least problem formulated during this research work is that people are designing eco friendly (green systems). And the energy problem affects our daily life as well as environment also. That is why we have to consider these issues as most urgent to protect our self, our society and planet as a whole.

The trade-off between periodic sensing and efficient transmission through spectrum handoff with the help of Look up Table (LUT) concept is an important topic in energy efficiency and throughput enhancement of a cognitive radio system. This paper highlights the energy consumption of primary users (PUs) and a secondary users (SUs) under different scenarios.

3. RELATED WORK

Number of research proposals has been reported in literature for channel assignment in cognitive radios networks.

Yi Shi [2007] stated in his Ph.D report that stressed upon fixed transmission power at each node. He further suggested that for a given channel SU either stops transmission or transmit with full power (say 7max). The basic assumption behind his research helps to simplify the problem of transmission vs interference range set to a deterministic value. His results clearly shows that by adopting this method new energy efficient as well as channel assignment techniques can be developed.

Anh Tuan Hoang et al. [2007] proposed a minimum interaction (PUs Vs SUs) based mixed distributed/centralized control algorithm. They were attempting to expand the scope of cognitive radio system while keeping up the signal to interference plus noise ratios (SINR) into consideration during Pus transmission.[5].

Ying Chang Liang et al. [2008] proposed a mathematical model for the sensing-throughput tradeoff problem by using energy detection as sensing technique. They proved that they were able to achieve one optimal sensing time which provides maximum throughput for SUs. They also use frequency reuse concept to achieve maximum throughput. [6]

Tianming Li et al.[2009] proposed a new power ascendancy game theory based model, in which PUs acts as player in the game. The primary users were acclaimed for shairing their spectrum with SUs during transmission. During a game SUs must ensure the Quality of Service (QoS) for the PUs which actually had licensed spectrum irrespective of successful transmission of SUs conditions.In [7] system achieve unique Nash equilibirium

Anh Tuan Hoang, et al.[2010] communicated that inside the cognitive radio framework, a base station controls and sponsorships a course of action for rural areas. The objective was to enlarge the throughput of the cognitive framework while not affecting the execution of Cognitive radio network was used for uplink as well as downlink transmission. In [8] two-stage blended dispersed/brought together control calculations that require insignificant participation amongst intellectual and essential gadgets. In the principal stage, a conveyed control refreshing procedure was utilized at the subjective and essential hubs to amplify the scope of the intellectual system while continually keeping up the obliged flag to obstruction in addition to commotion proportion of essential transmissions. In the second stage, brought together channel task was done inside the cognitive system to boost its throughput.

Duy Trong Ngo et al. [2011] In this paper OFDM based cognitive radio network was explained they used subcarrier assignment considering power assignment and constraining interference to primary Users using spectrum sharing management A twin disintegration framework was then developed for dual criteria (maximization of throughput as well as maximizing power), During this paper, they suggested that the network collaboration was created potential through the implementation of virtual timers at individual secondary users and thru the exchange of pertinent info over a standard reserved channel[9].

Stephen Wang, et al.[2012] proposed cognitive radios system with one secondary user accessing multiple channels via periodic sensing and spectrum handoff. They proposed a best sensing and channel access technique in such manner that average energy consumption in terms of energy consumption throughout sensing, channel access and transmission was reduced in [10].
They additionally introduced thought of sensing/ transmission exchange and therefore the wait/switch exchange concept.

Sabit Ekin et al.[2012] introduced that the execution of an orthogonal recurrence division multiplexing (OFDM)- based range sharing correspondence framework that accept arbitrary get to and no information concerning the essential client's (PU) channel occupation information. Additionally, no participation, information trade overhead, or subcarrier allotment system between the optional clients (SUs) was accepted. SUs subjectively get to the subcarriers of the main system and keep running into the PUs' subcarriers with an exact shot. to keep up the standard of administration (QoS) request of PUs, the obstruction that SUs causes onto PUs was controlled by changing SUs transmit control underneath a predefined edge, named impedance temperature. [11].

Cagatay Talay [2013] proposed a totally interesting self accommodative directing (SAR) govern for multi-jump intellectual radio adhoc systems. The anticipated steering guideline joined with directing measurements and independent conveyed accommodative transmission fluctuate administration component to create self adaptivity. SAR expects to settle on best courses toward the begin of directing and intends to hold best course by the work of course adjustment and course protection. SAR was contrasted with aforesaid encouraged calculations with point execution varieties serious exploratory assessments were performed inside the ns2 machine. It was demonstrated that the SAR gives higher capacity to the environment than the previously asked calculations and amplifies throughput, limits end-to-end postpone in an exceptionally scope of reasonable circumstances and significantly enhances steering performance[12].

WU Jing et al.[2014] proposed the power and range designation in multi-bounce CRN with direct topology. The general objective was to limit blackout likelihood and advance range utility, including all out reward and decency, while meeting the cutoff points of aggregate transmit power and impedance edge to essential client at the same time. The issue was fathomed with curved enhancement and counterfeit artificial bee colony (ABC) calculation jointly[13].

Xiukui Li[2015] proposed "gathering" idea. Actuated intellectual radio(CR) hubs frame numerous "gatherings" as per a few criteria. Each gathering comprises of a head hub, some passage hubs and customary hubs. Amid detecting stage, hubs sense channels and arrange the channel and vacancy task; in this way, amid information transmitting stage, every hub could speak with its diverse neighbor hubs in appointed channels amid given schedule openings. Henceforth, hubs could be associated together to shape a system without basic channels and the system network was improved[14].

4. SYSTEM MODEL

In this paper 10 SU's are considered which are equipped with only single CR each for simplicity and cost effectiveness. The CR system operates in 512–698MHz frequency range, or UHF channels 21–51, excluding channel 37. Based on channel availability, a secondary device dynamically chooses two 6-MHz & 10-MHz UHF channel for its operation. Data collected from each SU are stored in LUT which keeps on updating after every frame.
The SU on UHF band are TV broadcasting services and wireless microphones. The secondary CR systems must meet a set of performance parameters to protect incumbents according to regulatory requirements. It must be able to detect the presence of an incumbent signal stronger than the Incumbent Detection Threshold (IDT) within the Channel Detection Time (CDT) with a success probability greater than or equal to the Probability of Detection (PD), and with probability of false alarm lower than or equal to the maximum Probability of False Alarm (PFA).

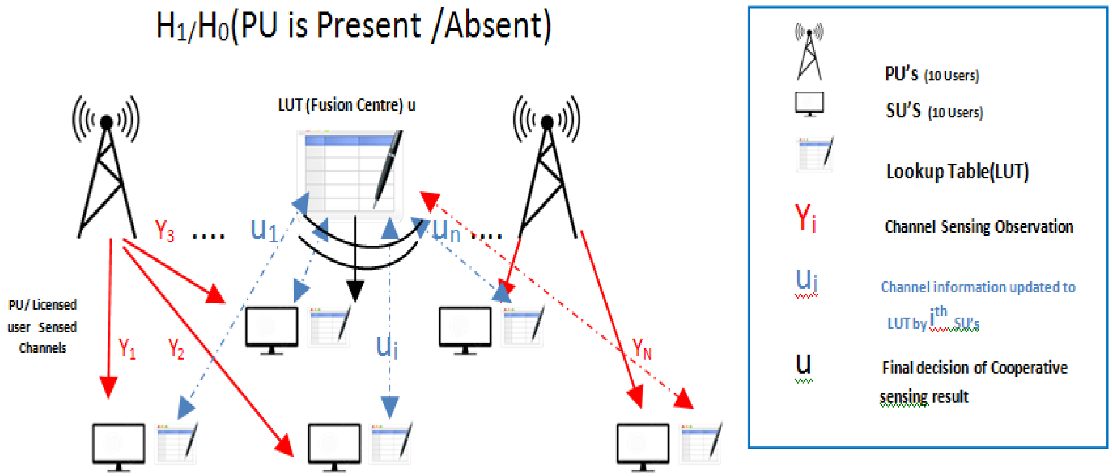


Fig1 : Proposed System Model of Cooperative sensing using LUT

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 $1 \leq \lambda \leq k$. 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 :

PU is absent

$$H_0^k : y_n(m) = ü_n(m), \quad n = 1,2,3 \ldots .N \qquad (1)$$

PU is present

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

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

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

Where y_n is Primary user received signal, $ü_n$ 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 $\tau \leq \tau_{Th}$.

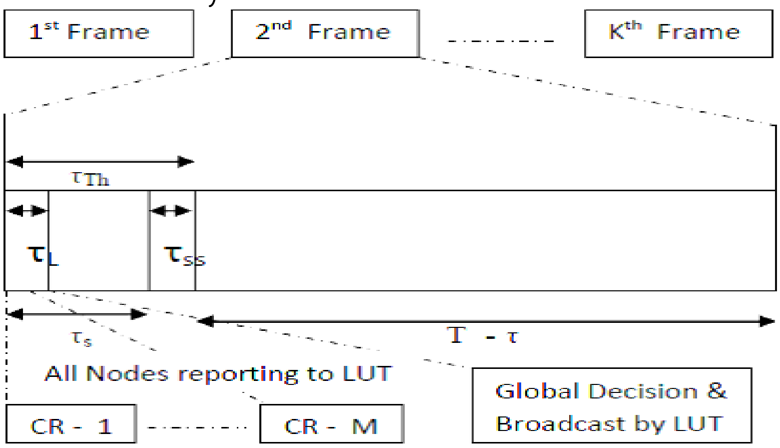


Fig 2: Time frame architecture using LUT

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

$$Ŧ = T - \tau_{ss} \qquad (5)$$

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 $\acute{E}_s$ such that

$$\acute{E}_s = P_s * \tau_{ss} \qquad (10)$$

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

$$E_{Total} = E_s + E_t + \acute{E}_{ss} \qquad (11)$$

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

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

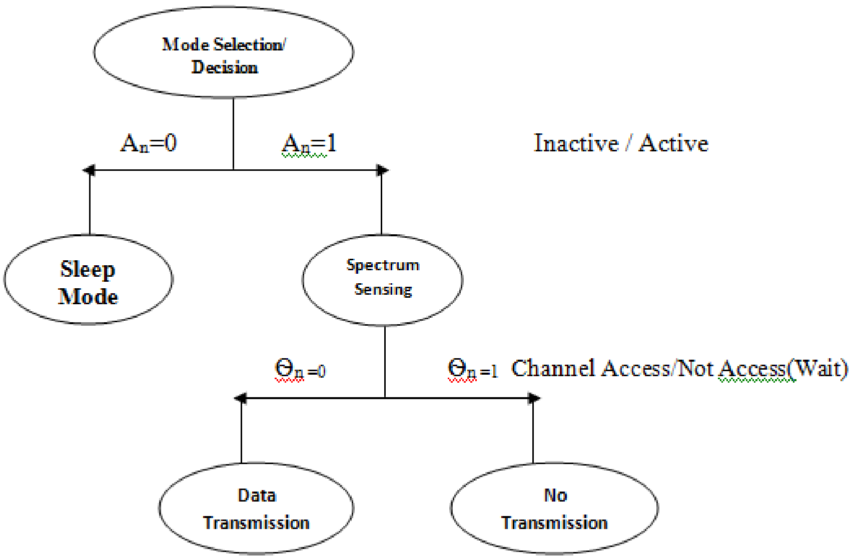
$$P_{fa} = \mathbb{Q}\left(\sqrt{2\gamma+1}\left(\mathbb{Q}^{-1}(\mathcal{P}_d) + \sqrt{\tau_s f_s \gamma}\right)\right) \quad (13)$$

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

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

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 τ_s will help in providing maximum time for transmission and improves throughput of the system.

4.1 Channel Selection Algorithm:



Energy Consumption

During Sensing Total Energy consumed $= P_s\tau_s$.

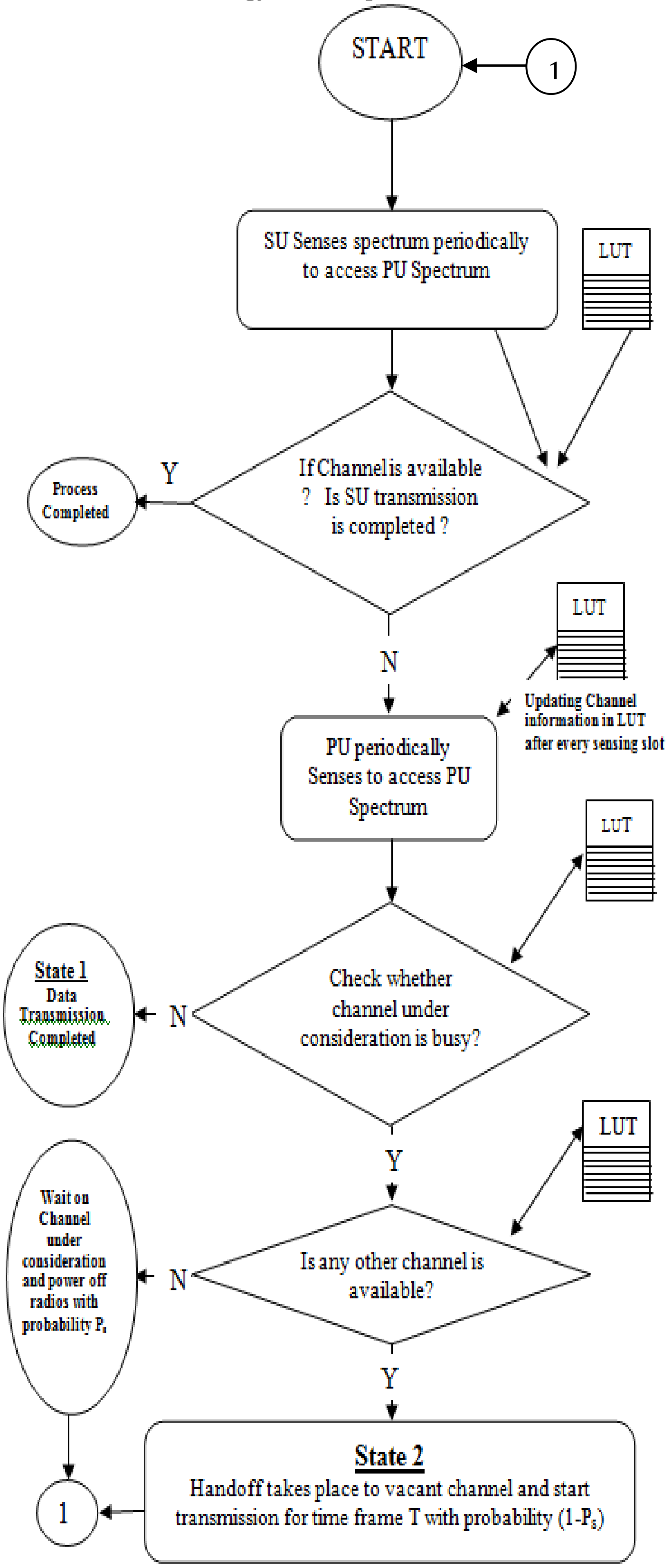
During Data transmission Total Energy consumed =
$P_s\tau_s + P_T(T- P_s\tau)$
Sensing + Transmission

Fig 3: Opportunistic Sensing and Access model with Mode selection model with energy consumption details.

Step 1: Initially SU's have enough energy for sensing and transmission otherwise SU's will remains in Sleep mode (A_n=0)
Step 2: If SU's have sufficient energy (A_n=1), SU's is trying to sense spectrum during sensing
Step 3: If SU's found that no channel is available for transmission or PU's utilizing all the available channels (Θ_n =1) SU has to wait on current channel and stop transmission Energy consumed during this interval = $P_s\tau_s$
Step 4: If the current channel is available (Θ_n =0) during sensing, SU will access that channel and start transmission under such condition
total energy consumption = $P_s\tau_s + P_T(T- P_s\,\tau)$.

During sensing SU's collect all the information regarding channel status and store the available information into LUT and keep on updating LUT after every time frame. A fuzzy selection switch is attached to LUT which clearly check and instruct SU's to perform data transmission, wait or spectrum handoff for a particular channel found through spectrum sensing. But this will be done for one complete frame having during of T(Time between two consecutive sensing slots) as shown in Fig 4.

4.2 Flow Chart of Energy Consumption Model



Energy Consumption details of proposed method

Energy consumed due to Sensing only = $P_s * \tau_s$

When vacant channel is available, Total energy consumption= $P_s\tau_s + P_T(T - P_s\, \tau)$.

Next time slot starts

Process repeat itself Energy consumption = $P_s\tau_s + P_T(T - P_s\, \tau)$.
Sensing + Transmission.

If vacant channel is not available (Information collected from Sensing & LUT)

During Wait period

Energy consumption= $P_s\tau_s$

&

During Handoff

Total energy consumed =
Sensing + Transmission (As handoff energy is almost negligible)

Fig4: Proposed Method for Energy Efficient channel sensing, access & Spectrum Hand off using LUT to achieve QoS

Assume that time delay during spectrum handoff is so small such that it can be neglected. During sensing and LUT updated information about the channel availability it has been observed that there is not even a single channel available for transmission.
We assumed that the energy consumption for transmission is also negligible ($P_s\tau_s$ + 0) when there is no availability of vacant channel.

4.2.1 Assumptions/ Preliminaries

Let

$X_i = 0$; Status of i^th channel as idle

$X_i = 1$; Status of i^th channel as busy

&

$\hat{X}_i = 0$; Status that i^th channel sensed as idle

$\hat{X}_i = 1$; Status that i^th channel sensed as busy

$\mathcal{P}_d$ & $\mathcal{P}_{fa}$ are probability of Detection and Probability of False Alarm respectively both are function of τ_s.
Mathematically

$$\mathcal{P}_d = \mathcal{P}(\hat{X}_i = 1 | X_i = 1)$$

Channel sensed as busy| Channel is actually busy

$$\mathcal{P}_{fa} = \mathcal{P}(\hat{X}_i = 1 | X_i = 0)$$

Channel sensed as busy| Channel is actually vacant
Let ρ be probability of channel sensed as busy. There exist four cases ($\mathcal{P}_{c_1}, \mathcal{P}_{c_2}, \mathcal{P}_{c_3}$ & $\mathcal{P}_{c_4}$) .As $\mathcal{P}_d$ & $\mathcal{P}_{fa}$ are function of τ_s therefore $\mathcal{P}_{c_1}, \mathcal{P}_{c_2}, \mathcal{P}_{c_3}$ & $\mathcal{P}_{c_4}$ are also functions of τ_s.[10-15].

Case 1: Probability of i^th channel that it is correctly sensed as idle.

$$\mathcal{P}_{c_1} = \mathcal{P}(\hat{X}_i = 0 | X_i = 0)\,\mathcal{P}(X_i = 0) = (1 - \mathcal{P}_{fa})(1 - \rho)$$

Case 2: Probability of i^th channel that it is wrongly sensed as idle.

$$\mathcal{P}_{c_2} = \mathcal{P}(\hat{X}_i = 0 | X_i = 1)\,\mathcal{P}(X_i = 1) = (1 - \mathcal{P}_d)(\rho)$$

Case 3: Probability of i^th channel that it is truly sensed as busy.

$$\mathcal{P}_{c_3} = \mathcal{P}(\hat{X}_i = 1 | X_i = 1)\,\mathcal{P}(X_i = 1) = (\mathcal{P}_d)(\rho)$$

Case4: Probability of i^th channel that it is falsely sensed as busy.

$$\mathcal{P}_{c_4} = \mathcal{P}(\hat{X}_i = 1 | X_i = 0)\,\mathcal{P}(X_i = 0) = (\mathcal{P}_{fa})(1 - \rho)$$

4.2.2 Parameters used during simulation

Let $\mathcal{J}(\tau_s, \mathcal{P}_s)$

Total average energy consumption required during one complete transmission of packet.

$$\mathcal{P}_d(\tau_s) \geq \mathcal{P}_{d_t}$$

Probability of detection should always be greater than or equal to target Probability of detection ($\mathcal{P}_{d_t} = 0.9$).

$$\mathcal{P}_{fa}(\tau_s) \leq \mathcal{P}_{fa_t}$$

Probability of false alarm should always be less than or equal to target Probability of false alarm($\mathcal{P}_{fa_t} = 0.1$).

$$\mathcal{R}(\tau_s, \mathcal{P}_s) \geq \mathrm{R}$$

Average Throughput should always be greater than or equal to throughput threshold value.

$$Đ(\tau_s, \mathcal{P}_s) \leq Đ$$

Average delay should always be less than or equal to threshold delay value.

4.2.2.1Mathematical expression for $\mathcal{J}(\tau_s, \mathcal{P}_s)$:

For simplicity let us assume SU transmission time of one packet of duration Ś is

$$T_r = \frac{Ś}{P_t}$$

where P_t probability of data transmission
The average time required can be determined as

$$\mathrm{N}(\tau_s, \mathcal{P}_s) = \frac{Ś}{P_t T_r}$$

If the current channel while sensing found as idle (**State 1** in fig. 4), the probability ($p(\tau_s)$) is given by

$$p(\tau_s) = \mathcal{P}_{c_1} + \mathcal{P}_{c_2} = (1 - \rho)(1 - \mathcal{P}_{fa}) + \rho(1 - \mathcal{P}_d).$$

Similarly the probability of remaining (M-1) channels if found busy (denoted by $P(\tau_s)$) will be given as

$$P(\tau_s) = (\mathcal{P}_{c_3} + \mathcal{P}_{c_4})^{M-1} = (\mathcal{P}_d\rho + \mathcal{P}_{fa}(1 - \rho))^{M-1}$$

There exists one more condition that when the current channel is busy and there will be atleast one channel is sensed as vacant. Under such circumstances SU has option to switch (Handoff) to vacant channel for the completion of data transmission with the transmission probability of (1- P_s) .This is the clear case of state 2 as shown in fig.4 with probability of P

$$\mathrm{P}(\tau_s, \mathcal{P}_s) = (1 - p(\tau_s))(1 - P(\tau_s))(1 - P_s)$$

Therefore total probability (P_t) that SU will successfully transmit data is given by

$$P_t(\tau_s, \mathcal{P}_s) = p(\tau_s) + \mathrm{P}(\tau_s, \mathcal{P}_s) = p(\tau_s) + (1 - p(\tau_s))(1 - P(\tau_s))(1 - P_s)$$

Therefore total energy cost during sensing, channel assignment and channel handoff (switching) will be given as

$$Ʉ(\tau_s, Ƥ_s) = N\,(\tau_s)\,E_s + N\,P_t(\tau_s, Ƥ_s)\;J_{sw} + Ś\,E_t$$

Where N is total time slots used for transmission of data, E_s energy used during sensing, J_{sw} is energy consumed during one time channel switching, E_t is energy consumption during data transmission. As we already considered that spectrum handoff will take negligible amount of energy therefore total energy remains same even if the case of channel handoff takes place.

4.3 Throughput Coefficient:

Let μ is throughput coefficient which is directly proportional to throughput of the system and inversely proportional to the average throughput of the system, $\mu \in [0,1]$
Mathematically

$$\mu = \frac{R}{R_0}$$

where R_0 (Average throughput of SU) $= (1-\rho)C_0$
ρ = probability of channel being busy
and

$$C_0 = \log_2(1+SNR)$$

SNR= signal to noise ratio at the receiver terminal of SU

4.4 Delay Coefficient:

Let λ is the delay coefficient, It is the ratio of system delay (Đ) to that of packet duration of data to be transmit (Ś) , $\lambda \in [0,1]$
Mathematically

$$\lambda = \frac{Đ}{Ś}$$

4.5 Other Parameters used in simulations are as follows:

Table 1: Specifications for simulation

Parameters	Value
Wait probability of SU	0.1 - 1.0
Bandwidth	6/10 Mhz
Modulation	OFDM
P_{dt}	0.9
P_fa	0.1
Frame length	T= [0.1-2] sec
Sensing Power	110mW
Transmission power	410mW
J_{sw}	1-100mJ
PU- SNR	10
ρ (probability of channel being busy)	.35

5. SIMULATION RESULTS:

To validate above algorithm and flow chart we have performed simulation in NS2 and CRCN environment. The parameters taken during this simulation is explained in Table 1.
We are take various parameters under consideration like :

- SU wait probability P_s.
- Whether using LUT [Proposed Work] or Without LUT[d].
- Useful Bandwidth 6GHz/10GHz.
- Total Frame Duration [0.1-2sec]

Different cases arrived for simplicity we fixed three parameter and by varying one parameter say P_s at a time to check the energy efficiency w.r.t throughput coefficient and delay coefficient

For analyzing results we firstly take system is having total frame duration T=100ms(.1sec) Useful TV band =6GHz(1 TV Band) and system with LUT and by varying P_s =[0.1-1]

Table2 Comparison of Energy consumption vs Throughput Coeff. of proposed technique with [10](without LUT)

Sr. No	P_s=0.0		P_s=.5		P_s=1.0	
	Base Paper[d]	Proposed	Base Paper[d]	Proposed	Base Paper[d]	Proposed
1	590mJ	555mJ	522mJ	515mJ	422mJ	415mJ

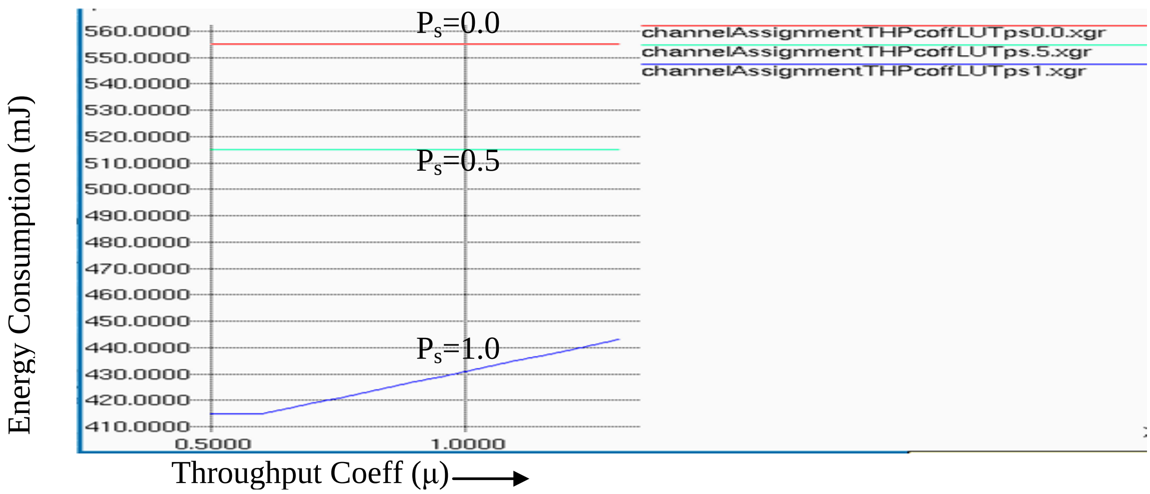


Fig.5 : Energy Consumption vs Throughput coefficient (μ) for different values of PU's wait probability(Proposed method)

Table 2 and fig. 5 Clearly shows significant improvement in Energy Consumption w.r.t throughput coeff. Under single TV Band with Bandwidth (BW) taken as 6 MHz. The Energy Consumption w.r.t delay coeff. is also calculated using same parameters and for validating the proposed technique output results are again compared with base paper[10].

Next Table 3 shown comparison between Energy Consumption w.r.t delay coeff.

Table3 Comparison of Energy consumption Vs Delay coeff. of proposed technique with [10](without LUT)

Sr. No	P_s=0.0		P_s=.5		P_s=1.0	
	Base Paper[d]	**Proposed**	**Base Paper[d]**	**Proposed**	**Base Paper[d]**	**Proposed**
1	590mJ	570mJ	522mJ	518mJ	422mJ	358mJ

Table 3 and fig. 6 Clearly shows significant improvement in Energy Consumption w.r.t delay coeff. Under single TV Band with Bandwidth (BW) taken as 6 MHz. The Energy Consumption w.r.t delay coeff. are calculated using above mentioned parameters and for validating the proposed technique output results are again compared with base paper[10].

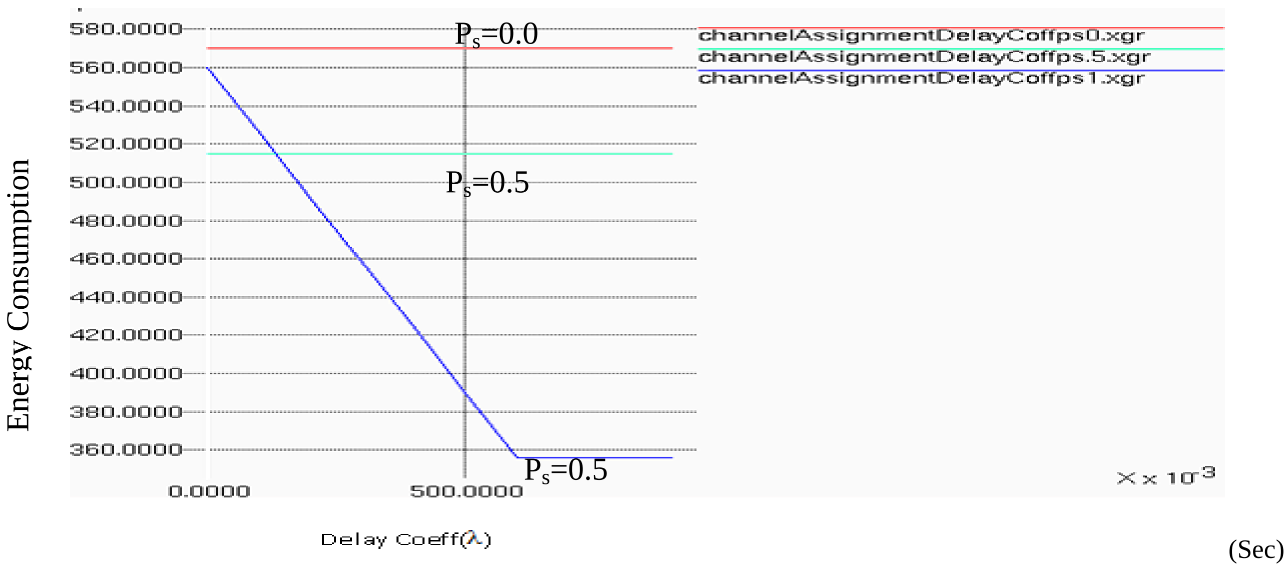


Fig.6. Energy consumption vs Delay coefficient (λ) for different values of PU's wait probability(Proposed method)

6. CONCLUSION

In this paper, we have proposed a noval technique which is basically dependent upon LUT based fuzzy switch to select channel sensing , access and handoff if necessary to improve energy consumption w.r.t throughput coeff as well as delay coeff.

The results clearly depict that we have achieved Energy consumption vs throughput coefficient significantly improved by 5-8%depending upon different values of SUs wait time (P_s), as well as Energy consumption vs delay coefficient significantly decreased by 5-15% with respect to existing methods.

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