Efficient Spectrum Sensing and Decision making for Utilizing TV White Spaces

Sri Jagadeesh. R, Meghalatha.CK, Krishna Chaitanya.K, B.Seetha Ramanjaneyulu

Abstract*--Accurate sensing of spectrum is important while utilizing the TV white space frequencies using cognitive radio mechanism. The secondary user needs to know whether the channel is occupied by the primary user or it is vacant. It is also needed to vacate the channel within reasonable time, when the primary user returns back. In this paper, two methods are proposed to aid the process of channel acquisition and handoff of Television white space (TVWS) frequencies, by secondary users. These are based on sensing the spectrum with appropriate intervals and carrying out background sensing of channels. It is found that these methods offer better sensing with low latency and high QoS.

***Keywords*-- TVWS, Spectrum Access, Cognitive Radio, Background Sensing, Channel Allocation**

I. INTRODUCTION

Scarcity of bandwidth is a major hurdle for the deployment of many new wireless implementations. Much of the available bandwidth is already allotted for various services, and hardly anything is left for new services. At this juncture, researchers are trying to solve this problem through several ways. Moving to higher frequencies is one main option, because it gives higher bandwidths. But development of appropriate semiconductor devices is one main challenge here. Distance limitations that the signal can travel at higher frequencies are another hurdle. Another direction of research is to increase the number of bits that can be transmitted for every Hertz of frequency available. Efficient modulation techniques are proposed from time to time, for this purpose. This research is a continuous one and going on.

Making use of some unused slots among allotted frequencies is another direction of this research. That means, among those allotted licensed frequencies, if they are not fully utilized by their licensed users, such frequencies can be offered to the needed users, during the spare time of licensed users. This mechanism is called Dynamic Spectrum Access (DSA) or opportunistic access, because the vacant slots of channels are to be occupied in dynamic manner, by the needed users, whenever the opportunity comes [1]-[3]. Frequencies of terrestrial TV channels are found to be having some free slots in their licensed frequencies, because of their underutilization in some countries or digitization in some other countries. These vacant frequencies are called TV white space (TVWS) frequencies. However, appropriate mechanisms are needed for this dynamic access of channels.

At first the spectrum needs to be sensed, to know whether any vacant channels are available. If vacant channel is available, then the user has to vie for that. There may be other users also who are also vying for this channel. So, a mechanism that resolves this competition needs to be implemented. Often, the case will be of multiple vacant channels and multiple users interested in using them. Also, appropriate pricing or bidding mechanisms have to be implemented for this accessing of channels, because the licensed users may expect revenue when other users want to use their vacant slots. The more important thing is to vacate the occupied channel when the licensed user wants it back to carry out its activities. In this paper, two methods are proposed for efficient sensing of spectrum and using it effectively, by opportunistic users. Section-2 of the paper contains the concepts of cognitive radio and TV white spaces utilization. Section-3 contains the proposed models of accessing free channels. Section-4 contains the results of proposed models. Section-5 concludes the paper.

II. TV WHITE SPACES AND COGNITIVE RADIO

The concept of 'cognitive networks' is a revolutionary concept that proposes to utilize the licensed spectrum of primary users by unlicensed secondary users in such a way that the transmissions of licensed devices are not disturbed or interfered [1]-[5]. It was proposed by Mitola in [2], and research is taking place from the last one decade on various aspects of it like spectrum sensing [6]-[8], sharing [9]-[11], security to licensed users [12], [13], [14] etc, by researchers all around the world. Spectrum leasing was proposed in [15] by Jayaweera and others, in which the primary user (PU) offers some bandwidth or timeslots to the secondary users when the primary user's weak transmissions are relayed by secondary user's powerful transmitter. As the primary user's transmissions get finished fast with the help of secondary use that left over time can be offered to secondary users, without a need of really sensing the spectrum or without the fear of vacating it when the primary user returns back. These types of networks are also called as cooperative cognitive radio networks CCRN. However, it happens only when the primary user needs secondary user's help in relaying its weak signal. Otherwise it is not needed. Using central servers and distributed mechanisms for spectrum leasing are explored in [16] and [17].

It needs to be noted that this scenario is not applicable to be used with TV whitespaces because it is broadcasting type

Revised Manuscript Received on February 11, 2019.

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and the HPTs or LPTs do the job of transmission and relaying and not the individual devices. Also, having time advantage when the primary device is helped by CR device doesn't arise in broadcasting type and hence no scope to allow the saved time slots to secondary devices. Hence, it can be understood that this scenario is more appropriate to be used with non-TV bands.

In [18], a sensing scheme named RECOG that is suitable to satisfy the QoS of VoIP which is a combination of multiple procedures is proposed. While the secondary device is engaged in transmitting the VoIP traffic of secondary device, it has to sense the spectrum periodically to find out whether the primary user is back. To do so it has to suspend its transmission for about 100 milliseconds and then resume its VoIP transmission. As 100 milliseconds is a large break for VoIP traffic, it causes jitter. To address this problem, they have divided this into multiple slots, and based on the sensing information in each such sub-slot, a conclusion is made about the presence of primary user.

This was done by implementing threshold values for each slot and a statistical phenomenon to know the primary user's presence. To address the problem of graceful handoff, progressive scanning for available channels is done in the background which finalizes 3 channels, of which one will be used when handoff is needed. Another component of it called QoS manager deals with reducing the buffering at Access Point (AP), when AP is involved in sensing. This helps to avoid overflow and retransmissions. But, RECOG doesn't take advantage of the geo-specific database and depends heavily on its own sensing, which is time–consuming and energy–consuming. It also doesn't exploit cooperative spectrum sensing.

Another later work of sequential sensing [19] deals the problem as finite horizon optimal stopping problem. In general, it is a type of multi armed bandit (MAB) problem, where the channel is like arm and CR tries to identify the arm that gives best reward. In each play, it senses, probes and transmits to arrive at the best possible channel. If repository is there, this work can be reduced. In the proposed work, it is aimed to introduce efficient methods for spectrum accessing and channel allocation, to make fast switchover of channels by secondary users when the primary users of the channels return back to use their licensed channels.

III. PROPOSED METHODS AND SCENARIO CONSIDERED

The conventional method of channel sensing is that the frequency being used is scanned periodically say, for every 10 thousand milliseconds to check whether its primary user has returned. Then it continues to use the same frequency if the primary user has not returned or and allocates a new frequency to the SU if it is not vacant. To allocate this new channel, it needs to carry out the sensing of spectrum for the remaining channels that can be used. In this work, two methods are proposed. Performance of these methods is compared with the conventional system.

Proposed methods are implemented using GNU radio. Three models are developed for this purpose. The following main blocks are used: Random uniform source, Frequency xlating FIR Filter, Add, Fading Model, Constellation Receiver, Error Rate, Threshold, Python Module, Power Squelch, QT GUI Frequency Sink, QT GUI Label. In this paper the proposed model has 5 different PUs as shown in Figure-1 which are differentiated from allotted frequencies (range of 400 to 500 MHz) and one secondary user (SU). Each primary user (PU) device consists of a 'Random Uniform Source' block which generates a sequence of random number based on specified sequence. This generated signal is modulated by 'Constellation Modulator' block and transmitted through 'Frequency xlating FIR Filter'. Here 'Frequency xlating FIR Filter' works as narrow band frequency selector in the given bandwidth. Like this all 5 PUs and single SU transmits signals which are mixed up. The SU transmitting frequency allocation is varied based on Models. In receiving part 'Frequency xlating FIR Filter' selects the specified narrow band frequency. The 'Power squelch' threshold value informs the presence of a user.

In the first model, the transceiver transmits the SU data for some duration says, ten thousand milliseconds, after which it stops for a brief period, for about 100 milliseconds by breaking the SU transmissions. During these 100 milliseconds, it checks the channel to find out whether its primary user has returned over. If the primary user returns, then the transceiver takes another 100 milliseconds and checks whether the next channel frequency is vacant. If the scanned channel is free then that frequency is allocated and the device resumes its operation. If that scanned channel is not free then it jumps to next frequency and scans that frequency to know whether it is vacant. This process of jumping to next channel and scanning continues until it gets the vacant channel. This is the usual procedure followed in cognitive radio system. A model with this procedure is developed at first, and is used as reference for the later two methods that are proposed and implemented in this work.

In the second model, background channel sensing is used for exclusive scanning of all the channels that are possible to be available Background channel sensing is carried out periodically for 100 milliseconds for most recent occupancy information of channel by PU's. It corresponds to the first method proposed in this work.

A background channel scanner is introduced for this purpose. Advantage of this method is that, continuous scanning of PUs is done without halting the SU operation. Backup channel scanner inspects all the other frequencies except the one chosen by SU. Here also, the SU transceiver operates for ten thousand milliseconds continuously. After that, the SU transmission is interrupted for 100 milliseconds, during which that channel which is in use by SU till that time, is scanned. If PU has returned, that will be known during this time. If PU returns, then that channel has to be vacated by secondary user. At this instant, it need not scan other channels, as is done in the previous method. Instead, it can select one of those channels that are found to be vacant during the background scanning process. Advantage here is the time saved in scanning for the channel.

Different building blocks required for the simulation are built in GNU radio companion as described below.

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Multiple PUs and their Transmitters: In this Multiple PUs, every PU has its own Frequency (i.e. 410 MHz, 430 MHz, 440 MHz, 470 MHz and 500 MHz) and various 'Random Uniform source' parameters. These are as described in Figure-1.

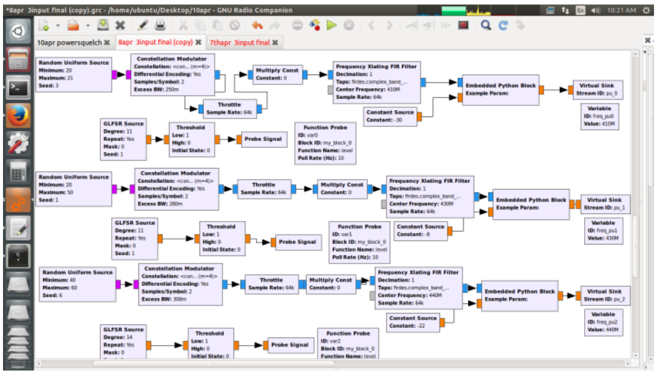

Figure-1. Multiple PUs flow graph

SU Transmitter: The SU transmitter also is similar to PUs but the center frequency of 'Frequency Xlating FIR Filter' alters based on the availability of vacant channel. This logic is developed in Python Module. Flow graph of PU transmitter is shown in Figure-2

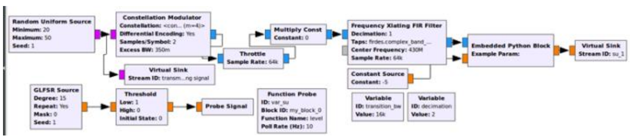

Figure-2. SU transmitter Flow graph

Receiver and Scanner: SU Receiver is meant for receiving the signals sent by SU Transmitter. It is used for bit error rate (BER) calculations. In addition to this, a receiver is assumed with PU transmitter unit itself. Most of the times the combined unit is referred to as 'transceiver'. Purpose of this receiver is to perform the channel scanning, to inspect the state of PU. The transmitted SU signal is displayed in 'QT GUI Frequency Sink'. Receiver's flow graph is shown in Figure-3.

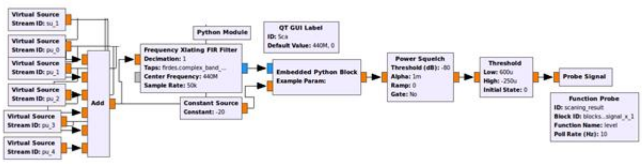

Figure-3. Receiver and Scanner flow graph

In the next method, in addition to background scanning, channel swapping is employed. The purpose of channel swapping is to temporarily allocate a vacant channel to SU, to shift it to another channel, and do the sensing process on that channel, which the SU was using till that point of time. By combining this swapping with background scanning, it need not interrupt SU for that 100 milliseconds scanning that is required to know whether the primary user of the channel in use has returned. Here a temporary frequency is allocated in that 100 milliseconds gap instead of interrupting the SU transmission.

IV. SIMULATION RESULTS

The system for simulation is considered with five primary users and one secondary user. Figure-4 shows all loaded Pus' signals with different colours.

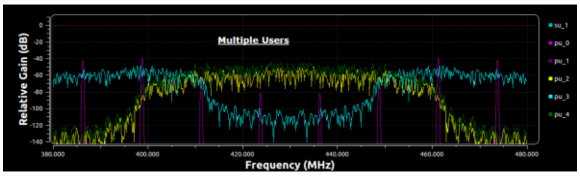

Figure-4. Multiple PU's representation

Spectrum occupancy of SU for its typical operation is shown figure-5. The various parameters in it are, Variable_timer that shows System time in seconds, Variable_MulConst which is a Multiplying Constant value for switching control, Threshold_receiver thyat represents the occurrence of PU and the Secondary_user_freq_tx_0 that is the allotted frequency to SU.

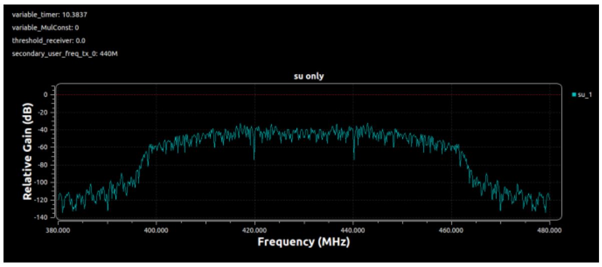

Figure-5. SU occupancy in the spectrum

In this 'Secondary_user_freq_tx_0' signal frequency can take any values of 410MHz, 440 MHz and 500 MHz based upon the timer value and the PU occupancy.

The first method is implemented with backup channel sensing, the spectrum occupancy of which is shown in Figure-6. Here 'v_scaningFrequencies_time' variable represents the scanning frequencies by Backup channel scanner (other than the allotted frequency to SU at that time) and transmission Time in seconds. Based on the timer value the receiver frequency is allotted according to the availability of vacant channel frequency.

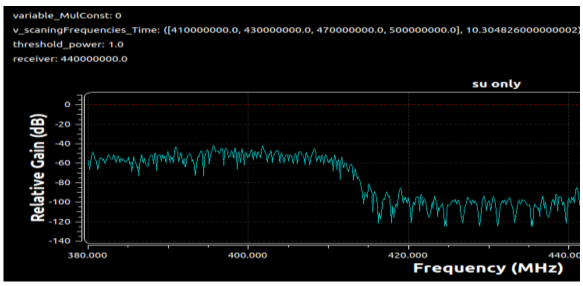

Figure-6. Simulation results for backup scanning method

In this case, if the scanned PU frequency is not vacant, then the transceiver takes information of vacant PU channel details from Backup channel scanner, so that no need of another 100 milliseconds for scanning.

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In the next method, where swapping is proposed, ‘v_scaningFrequencies_time’ is a variable which represents the scanning frequencies by Backup channel scanner (other than the one allotted to SU) and transmission Time is seconds, ‘threshold power’ value specifying the condition of occurrence of PU and ‘receiver’ variable showing the transmission frequency. In this model PU1 is prioritized among multiple PU frequencies, because it is the one that is found to be least used, and recently used. Due to this, there is less probability for its immediate return of primary user, and hence that frequency can be selected.

Performance Analysis of proposed methods with conventional method:

Performance of proposed methods is compared with that of the conventional method, in terms of channel allocation delays. In the conventional method, search for new channel starts after it is found that PU has returned. So the SU needs to carry out spectrum sensing at that point of time. It may take 100 to 500 milliseconds, to get the vacant channel. In the case of methods with background sensing, even though additional hardware is required for adding new backup channel scanner, it takes a fixed time of 100 Millisecond only for new frequency allocation to SU transmission. It is because of the reason that as the available vacant channel details are found during background sensing process, it needs a fixed 100 mSecs only, that is spent on scanning whether the PU of the frequency that is in use by SU at present, has returned. In the second method, where channel swapping is proposed, this 100 mSecs delay also will not be there, because during the scanning time of its presently occupied channel, the SU is shifted to another channel temporarily to continue with its ongoing transmissions, without interruption. This comparison is depicted in Figure-7 which shows Model-3, that corresponds to second method offers minimum delay of channel allocation.

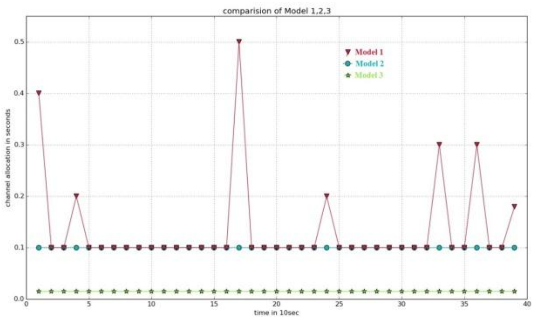

Figure-7 Channel Allocation Delay of Proposed methods

V. CONCLUSION

Two channel allocation methods of cognitive radios that are based on background sensing are proposed in this work. Channel allocation delays of the proposed methods are compared with that of conventional method. It is found that the first method of background channel sensing offers a fixed delay of about 100 mSec when compared to 100-500 mSec of the conventional method. With the second method that proposes to implement channel swapping, it is further reduced, to almost zero delay. The work carried out here is for a primary user scenario with the availability of some vacant channels all the times. However, if it includes multiple SUs requesting for the channels, then PU channels may not be available to all the SUs all the times. In such cases, we can expect to observe an increase in these delay values, instead of the fixed 100 mSec and zero values that are observed in the present work.

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