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Spectrum Decision in Cognitive Radio

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***Abstract*— Cognitive radio technology is that the outcome of dynamic spectrum access which allows the unlicensed users to occupy the vacant spectrum of licensed users for his or her communication. Spectrum decision is a fundamental requirement in the successful implementation of cognitive radios which enables the unlicensed users to occupy the best channel out of available channel slots. The proposed decision-making scheme is based on the fusion of three key channel parameters i.e. channel idle time, channel occupancy status and channel performance, thereby facilitating the secondary user to occupy the targeted channel without impairing the licensed user's communication while maintaining its own QoS requirements. Decision structural function is used as an evaluation measure to check the robustness of the proposed scheme. We have also evaluated our method using receiver operating characteristic curve which signifies that our proposed method yields promising results.**

Keywords—Cognitive Radio,Wireless Network;Secondary User; Spectrum Sensing;Energy Detection

I. INTRODUCTION

Cognitive radio may be a sort of wireless communication where a transceiver can intelligently detect the channels for communication which are in use and which aren't in use, and enter unused channels while avoiding occupied ones. This optimizes the utilization of obtainable radio-frequency spectra while interference is minimized to other users. this is often a pattern for wireless communication where transmission or reception parameters of network or node are changed for communication avoiding interference with licensed or unlicensed users. In response to the operator's commands, the cognitive engine has to ability to configure radio-system parameters. These parameters consist of protocol, waveform, operating frequency, and networking. This function acts autonomously within the communications environment while information about the environment with the networks it accesses and other cognitive radios (CRs). A CR monitors its own performance continuously in addition to "reading the radio's outputs"; it then uses this information to "determine the RF environment, channel conditions, link performance, etc.", and adjusts the "radio's settings to deliver the specified quality of service subject to an appropriate combination of user requirements, operational limitations, and regulatory constraints" requirements, operational limitations, and regulatory constraints".

II. SPECRTUM DECISION TECHNIQUES

A. First Spectrum decision is a vital mechanism in spectrum management that ensures the efficient operation of both SU and PU networks. The goal is to enable CRU to access to a spectrum band without interfering PU's transmission and maintaining its own QoS.

B. Secondly Spectrum decision refers to a cognitive radio that decides the data rate, determines the transmission mode, and the transmission bandwidth. After, the appropriate spectrum band is selected in accordance with the spectrum characteristics and requirements of the users.

C. Third Spectrum decision framework weighs the spectrum band on three channel parameters, its ideal time, occupancy status and performance and an AND rule is applied to these parameters to give the slot availability.

III. PROPOSED METHODOLOGY

Two types of spectrum decision schemes;

(1) The sensing based spectrum decision scheme.

(2) The probability-based spectrum decision scheme were proposed in.

Each licensed spectrum band is supposed to progress independently with a different channel usage model of PU over time and all channels have the same bandwidth and fading characteristics. Our spectrum decision scheme is based on fusing each separate decision of three key parameters with AND rules, thereby, giving a hybrid spectrum decision scheme. The decision technique developed will first find the channel idle time determined with stochastic analysis, channel occupancy status at that particular time and channel performance based on its capacity. The detailed explanation of our proposed spectrum decision scheme is described in subsequent sections. The template is designed so that the affiliations of the authors are not repeated for multiple authors every time.

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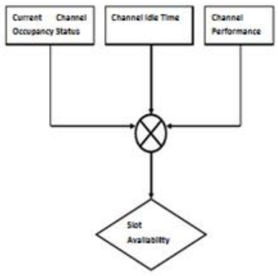

Figure 2. Decision module; giving fusion of three key parameters via AND rule.

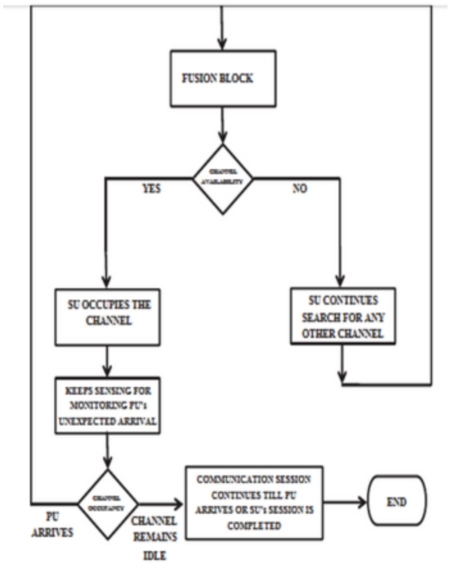

Figure 3. Flow chart of the proposed spectrum decision scheme.

A. *Spectrum Decision Framework*

In the proposed framework, three channel parameters, channel idle time, channel performance and channel occupancy status have been incorporated and an AND rule has been applied to these parameters to give the slot availability. This decision module is shown in Fig. 2. If the slot has been identified as available, then the SU will occupy the channel and start its communication. Simultaneously, SU will keep sensing the channel and if PU arrives, then SU will vacate the channel and the process of decision framework will restart for that particular SU. The complete algorithm is shown via flow chart in Fig. 3. The CRN is assumed to operate in five licensed spectrum bands, the carrier frequency of these bands ranges between 1 MHz to 5 MHz. The Poisson distribution is used to model the PU activities, i.e., its arrival and departure, and the secondary connections.

PU's activity is shown in Fig. 4 Three parameters

Arrival and departure times are probabilistically calculated via Poisson distribution given as follows;

$$f(k;\lambda) = P(T=k) = \frac{\lambda^k e^{-\lambda}}{k!}, \qquad (1)$$

where T is a discrete random variable and k =0, 1, 2, 3, ..., n. Let the channel idle time be represented by τ which is a vector representing idle time for all the channels. Let the channel number be represented as i, where i =1, 2, 3, ..., n. Here, we define a selection map ξ, which is assigned a value '1' for those channels whose idle time is greater than the experimentally set threshold γ.

Mathematically, we define it as follows:

$$\xi(i) = \begin{cases} 1; & \tau(i) > \gamma \\ 0; & otherwise \end{cases} \qquad (2)$$

Channel performance is monitored based on respective channel capacity and traffic analysis. Let the channel capacity be represented by κ given in Eq. 3 where H denotes a Rayleigh channel gain which is a complex Gaussian random variable and δ denotes signal-to-noise ratio. Here, we define a selection map ζ, which is assigned a value '1' for those channels whose performance is greater than the experimentally set threshold.

Mathematically, we define it as follows:

$$\kappa = log_2\left(1 + \delta\left|\mathbf{H}\right|^2\right) \qquad (3)$$

$$\zeta(i) = \begin{cases} 1; & \kappa(i) > \epsilon \\ 0; & otherwise \end{cases} \qquad (4)$$

The targeted channels are continuously sensed to get channel occupancy status. SU is continuously sensing the slot(s) and estimating the power spectral density (PSD) using the period gram for any particular signal y[k] carrying energy transmitted by PU(s) as follows;

$$P_K(e^{j\omega}) = \frac{1}{K}\left|\sum_{k=0}^{K-1} y[k]e^{-jk\omega}\right|^2 \qquad (5)$$

$$P_K(e^{j\omega}) = \frac{1}{K}\sum_{k=0}^{K-1} y[k]e^{-jk\omega}\sum_{s=0}^{K-1} y[s]e^{js\omega}, \qquad (6)$$

where the power is found to be less than an experimentally set threshold, the SU considers it vacant. Let ρ denotes the channel occupancy status, which is assigned a value '1' for vacant channels and '0' for the occupied ones. The above three results are fused using AND rule to decide for spectrum to be occupied by SU of a CRN.

Mathematical model of the proposed technique is given as under;

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$$(\xi_i \otimes \zeta_i \otimes \rho_i)(t) \xrightarrow{x} x((\xi_i \otimes \zeta_i \otimes \rho_i)(t)) \Rightarrow c_i(t), \quad (7)$$

where ξ, ζ and ρ denote the channel idle time, channel performance and channel occupancy status respectively. Similarly, ci(t) denotes the selected channel for SU to occupy, based on AND rule of the three parameters mentioned above. Therefore, the rule that connects ci(t) with the parameters (ξi, ζi, ρi) is given by the decision making algorithms. Let x represents the rule known as spectrum decision rule. This rule allows SU to decide to occupy a specific spectrum hole which has been declared the best available channel by our decision module.

Moreover, x(ξi, ζi, ρi) indicates a decision making outcome, which leads to the decided channel ci(t) for communication by SU. The possible outcome of the decision block will be either to occupy a particular channel whose channel idle time, channel performance and channel occupancy status are found greater than the set respective

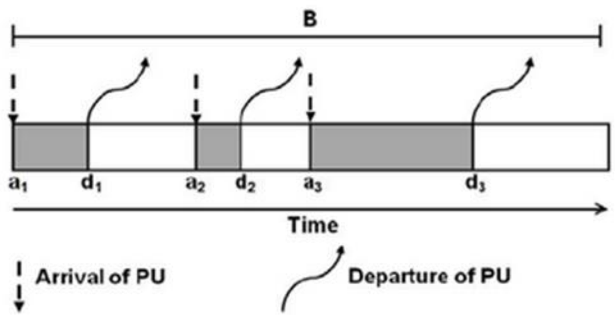


Figure 4. PU's activity in a particular spectrum band B showing vacant(white space) and occupied (grey) spaces. Arrival and departure times of the PU are represented as a_i and d_i respectively. Channel idle time is found using $a_i - d_{i-1}$

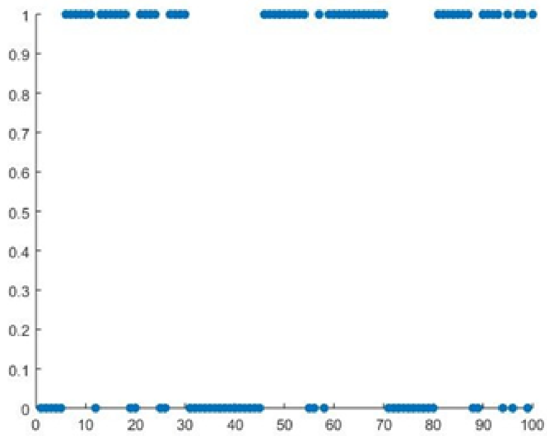
threshold. If the PU has arrived unexpectedly in this particular channel, when our decision scheme has declared the channel vacant, the SU will vacate the channel and decision module will restart its functionality.

IV SIMULATION

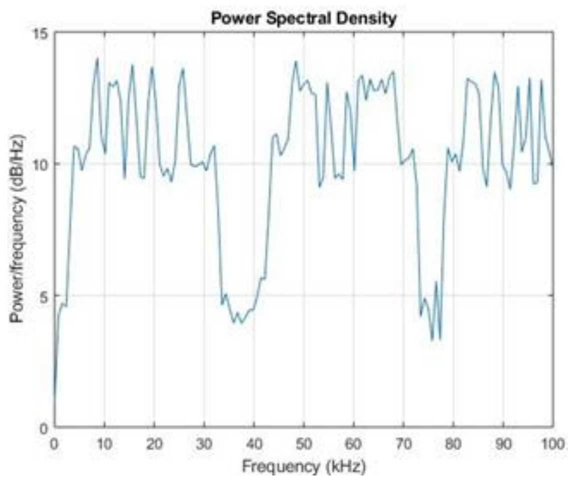
At present, modeling and simulation is the only paradigm which allows the simulation of complex behavior in the environments cognitive radio networks. In our project, we simulated the cognitive radio network spectrum using MATLAB. The code for simulation of Cognitive Radio is given in appendix.

- For our simulation, we have considered a total bandwidth of 100 kHz.
- Frequency difference between consecutive user slots is 1 kHz.
- Total number of slots taken is 100.
- 70% of total slots are registered for primary users and remaining 30% are unregistered.
- Registered slots are [6, 30], [46, 70] and [81,100].
- For every experiment, numbers of active primary users are randomly selected within a range of 50 {+/-} 10.
- Number of slots required for secondary users in each experiment are taken from a set S : {40,45,50,55,60,65,70,75}.
- Secondary users are allocated, at first in the unreserved slots followed by empty reserved slots.
- Efficiency for this simulation is calculated by:
- Efficiency = (Number of allocated secondary users)/(Total secondary USERS)*(100).
- This experiment is repeated 10 times to obtain secondary user slot allocation efficiency.

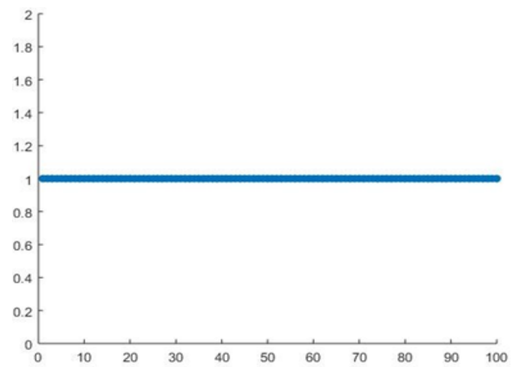
B. Simulation Graphs



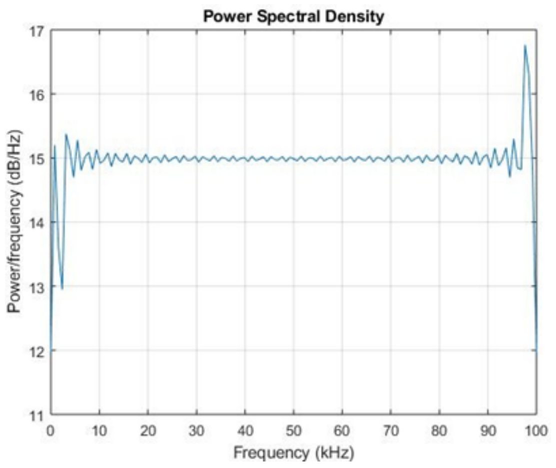
ALLOCATED SLOTS



UNALLOCATED SLOTS



ALLOCATED SLOTS



UNALLOCATED SLOTS

V. FUTURE SCOPE

• In future research the work will extended for the band of multiple frequencies, and to design the primary premises in such a way that the primary user should be able to allot the frequency on the demand of secondary user in that multiple frequency band. The primary user should also have to manage the secondary users request along with the time duration and cost for that allotted time interval.

• Also in future CR user can utilize the single frequency bandwidth to design in such a way that, the frequency is shared with multiple networks where there will be multiple users. Not only with single frequency but also with multiple frequencies to be shared share with multiple networks.

• Based on the previous sections, which briefly surveyed the CR area, some conclusions will be drawn about the future research directions that must be pursued in order to turn CR into a mature area.

• Seamless spectrum handovers are a major requirement in CR scenarios, as any lack of QOS assurance for secondary users is undesirable, especially for some classes of data traffic (e.g. multimedia streams and real time traffic). Spectrum handovers also affect link state parameters and therefore, can be wrongly perceived as network instability.

• Proactive spectrum selection and interference avoidance intelligent decision mechanisms are expected for taking optimized spectrum access and sharing decisions. The main goals are delivering the maximum performance to secondary users and avoiding harmful interference to primary systems, which are expected to be unaware of the dynamic spectrum access according to the orthodox vision of the CR paradigm.

• Interdependency between the propagation characteristics of radio signals and the frequency band in usage: Interdependency between the propagation characteristics of radio signals and the frequency band in usage should also be investigated in terms of applicability to CR scenarios i.e. avoidance of spectrum outages, tuning of the area of coverage.

• Energy efficiency: In CR scenarios spectrum sensing is one of the main sources of energy and time consumption, but also one of its key components. The lower the number of channels that have scanned, the lower the power that is consumed and the time that is spent. Prototyping is the other approach but usually requires more resources that are not always available. Hence the existence of alternative solution is highly desirable.

• Cost reduction: due to unavailability of spectrum the auction cost increases. By the implementation of CR the data transmission on the existing spectrum will be at high speed. So neither cost rate nor inflation will be increased. Eventually call rate and data rates will be lowered.

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CONCLUSION

This project gives some idea regarding cognitive radio technology, its diverse classifications and spectrum decision. Spectrum is a very valuable resource in wireless communication systems and it has been a major research topic from last several decades. Cognitive radio is a promising technology which enables spectrum sensing for opportunistic spectrum usage by providing a means for the use of white spaces.

Considering the challenges raised by cognitive radios, the use of spectrum sensing method appears as a crucial need to achieve satisfactory results in terms of efficient use of the available spectrum and limited interference with the licensed primary users. The work of this project contributes towards simulation of Cognitive Radio, Spectrum Sensing and Spectrum Allocation. All the work in this project are based on MATLAB.

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