Dual Channel Sensing Method Using Opportunistic Spectrum Access for CRN

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ABSTRACT

Background: Spectrum detection and its proficient use are the fundamental interesting issues in Cognitive radio (CR) systems. The issue elevates if the system has various Secondary Users (SUs) in it. Spectrum acquiring or accessing plays a vital role in a multichannel cognitive radio environment. Objective: To invalidate the current issue of Spectrum identification, a modern method of spectrum detection namely Channel Acquiring and Detecting Protocol (CADP), for CRNs has been presented taking into account the assignment issues of channel, where each SUs are able to sense two channels at once, in an organized way among the less used channels. Other Assignment technique called Markov Chain based Greedy Assignment Scheme (MCGAS), has been framed for identifying the best optimal channel for accessing. The algorithms for CADP and MCBGAS are described. Results: CADP has been compared with (MCBGAS), with a specific end goal to build the throughput of the SUs. For comparing the results of CADP and MCBGAS, NS2 simulator has been used for calculating throughput and packet delivery ratio. Conclusion: By simulation, we concluded that our proposed CADP performs faster than MCBGAS in assigning as well as accessing the channels in an opportunistic way.

KEYWORDS: Cognitive radio networks, Spectrum detection, Primary Users, Secondary Users, Channel Acquiring and Detecting Protocol, Markov Chain based Greedy Assignment Scheme

INTRODUCTION

All around the world there is a huge interest in Reconfigurable Radio networks, due to the fast developing interest in the wireless networks. As on date, number of users of mobile phones is reaching nearly 4 billion and it will be crossing 7 trillion by 2017 as suggested by Wireless World Research Forum.[1] To meet these desires with the restricted radio spectrum, more adaptable approaches to share radio networks and frequencies amongst numerous networks are required, which can be answered by ‘Cognitive radio’.

Cognitive Radio networks (CRN) is a Reconfigurable Radio networks, where the nodes in the networks adjusts itself to a powerfully changing environment with the point of enhancing the utilization of spectrum. Reframing the definition, [2] “Cognitive Radio (CR) - is a radio with acquirement capabilities, which means, radio which is ready to acquire learning of its working environment and change its operational specifications appropriately”. Cognitive radio methodology has a lot of advantages regarding the efficient usage of spectrum, since the availability of spectrum is important and rare these days. So there is an awesome enthusiasm for researchers regarding Cognitive Radio from Europe and around the world. [1] One contextual analysis on cognitive radio is in the utilization of purported ‘White Spaces’ in the UHF band and the other one identifies with the advancement of Radio Environment Maps techniques in which the decision making has taken the advantage of Cognitive radio technology.

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Elaborate discussion about CRN has been given in [3], where the network uses wireless devices as well as spectrum assets in an opportunistically. Such method of usage can be called as – Opportunistic Spectrum access. In CRN, the Secondary Users (SUs) utilizes the unused spectrum of Primary Users (PUs) without any hindrance. Identifying the unused spectrum is quite complex, where the Cognitive Users (CUs or SUs) periodically has to sense for the free slots [3]. If a spectrum hole (or White Space) is identified CUs can utilize the slot else have to wait till it gets one. There may be situation where there are more than SUs can try to sense the channel at a time in a given Multichannel CRN.

Fig.1 shows a cognitive radio network with 5 SUs and a PU, trying to access 6 channel slot. SUs are not permitted to access the channel if it is already possessed by a PU [4]. In such case, synchronization among the SUs are need to detect the unused spectrum, which is a demanding issue. Moreover, from Fig.1, out of 6 channels, SU can access channel 1 and 2, whereas PU will be accessing its own spectrum at channel 3.

Literature Review:

Various investigations have been performed to proficiently distinguishing opportunistic spectrum access as well as dynamically in CRNs for a single SU. [5] – [15]. Authors in [5], designed a testbed for Opportunistic spectrum access in a real – time scenario. This testbed analyze, implement and evaluate the empty slot of channels using the Cloud computing. At the point when several SUs are considered in a CRN, both access conflict among contending SUs and its performance while executing are not yet examined.

In [6] discussion, about the problems of channel sensing at the MAC layer that can be resolved by sensing-period adaptation technique. It also discusses how to reduce the delay for identifying a new empty channel. Author in [7] address a scheme which estimates the idle channel probability based on the statistical data and traffic prediction techniques.

In [8], a cognitive network with hardware constraints are elaborated for efficient spectrum sensing and access. The work also formulates a stopping issue which is the optimal solution for the spectrum sensing for SUs. Authors of [9], introduced a new optimization technique which is based on cross layer in order to make the SUs that are in far distance to participate in communication in a recursive fashion.

In a single SU scenario, channel sensing techniques are studied. Proposal of MAC protocols which work freely with any central coordinator in an opportunistic manner by using partially observable Markov decision process framework,[10] whereas in [11], the author, uses a multi arm restless bandit process by designing a sensing technique to achieve high throughput. Studies about the structure, optimality and evaluation of a myopic sensing scheme are also done.

SUs are organized in a systematic way to access the channel are studied. In all studies, SUs have to sense the unused channel after a prescribed waiting time but empty channels may be available and unnoticed by SUs. A cross layered spectrum access and dynamic routing technique has been introduced by [12] while considering joint routing, transmit power control, etc.

In paper [13], developed a scheduling scheme based on spectrum that calculates the number of packets to be transmitted for a SU by using a common scheduler thereby achieving higher throughput. A queuing analytic framework has been developed for the measuring the QoS at the data link layer in [14] for an infrastructure based CRN. Activities of PUs, bursty traffic pattern, buffer size are the parameters considered for the queuing model.

For our work, a framework based CRN has been considered [15] where there are numerous SUs able to detect two channels each, specifically in the form of Best1 and Best2 channel, at once to exploit the void channels. Amid this, SUs are regulated in a manner that it can use the Best2 channel, just if the Best1 channel is
"occupied" [15]. In particular, a neat framework is required for channel acquiring and detection protocol (CADP) and detecting of Best2 channel, to access the spectrum opportunistically. The general form of spectrum sensing is the Myopic Spectrum sensing (also called as Blind Spectrum sensing) which states that whenever PUs arrive to the respective spectrum, then the SU has to vacate the corresponding channel.

The workflow of the paper is given as follows: (1) Channel Acquiring and Detecting protocol has been proposed, where each SU can sense dual channel in parallel at a time. (2) Markov Channel Greedy Assignment has been proposed based on the Blind Sensing policy.

The organization of the paper is as follows: Section 2 describes the problem definition and implementation model of the proposed work. The performance comparison of CADP and MCBGAS has been elaborated in detail in Section 4. Lastly, the proposed work is concluded in Section 5, which is followed by References.

**Implementation Model:**

For our work, following considerations are assumed. A centralized channel called Base Station (BS) has been used that helps during the transfer of data among the SUs in a collaborative or cooperative manner. Also it simplifies the process of identifying the empty slots[16]. The main advantage of such BS is reducing the complexity of SUs and easy to manage them. Since SU's are scattered in a random manner, possibility of receiving signals from other BS are increased. To avoid such interference, techniques mentioned in [17] will be better option.

In proposed model, a BS is located in the center of the CRN where there are ‘Y’ -> number of SUs are available within its range. For BS to cover all the SUs in its range, it has to analyze the distance between them by applying heuristic random network coding or clique positioning, etc [18] SUs and BS Also there ‘X’ -> non-interfered licensed channels, which can be using unused channels opportunistically whenever the PUs are away. In Fig.2, there are 4 SUs and single PU is considered for our work. All the devices uses a common control channel (CCC) based on ISM frequency band, for sharing their information among themselves [16].

SUs can utilize a single channel due to the device constraints, but they are allowed to sense more than a single channel at a time slot. BS process all the demands on a round robin fashion to each SUs in a given time slot. If any non interfering channel available, corresponding SU will be serviced. If the SUs demand outreaches the ‘X’ non interfering channels, BS will either refuse further demands of the SUs or line them for the next empty slot. Therefore, the number of SUs is not exceeding the number of non interfering channels, in short, Y ≤ X, has been considered [15].

![Proposed Network Diagram](image)

**Fig. 2:** Proposed Network Diagram No of SUs are 4 with a PU. All the SUs are coordinated by the BS.

In case of Channel Model, Markov chain model is used for modeling each channel. [9],since it supports the transition probabilities between the different states, i.e ON and OFF state of radios. If s_i is the state of the channel i at particular time slot t, then the transition probability matrix of the two state Markov chain, is given by eqn (1)

$$
\begin{align*}
\Pr. \text{ of } (s_i(t+1) | s_i(t)) &= \begin{pmatrix} 1 - \lambda_i & \lambda_i \\ \mu_i & 1 - \mu_i \end{pmatrix}
\end{align*}
$$

\(\lambda_i\rightarrow\) represents the transition probability from ON to OFF state and \(\mu_i\rightarrow\) represents the transition probability from OFF to ON state.
To minimize the wastage of time, BS has the rights to assign channels to SUs in prior so that conflicts among SUs will be eliminated. Again, each SU will be assigned with two channels in a priority fashion for detecting the empty slots sequentially[15]. Though in a Multi CR network, a node can be allowed to sense through multiple channels, detecting via two channels are preferable for our work due to the following advantages: (a) multiple channel sensing or detection may reduce the time for transmission. (b) Highest preferable empty slots can be detected easily, rather than the least preferable channels which can be utilized by other SU nodes. The throughput achieved among the single channel sensing and the dual channel sensing is given in Fig.3, which clearly says, that dual channel sensing is far better than single channel sensing.

![Figure 3: Throughput analysis between Single and Dual Channel Sensing](image)

We all aware that time duration are total time taken for detecting a channel as well of data transmission. Whenever an empty slot is being detected by SU nodes, any activity of PU is checked and if none is found each SU can sense/detect the empty slot through its dual channel. Each time slot length can be denoted as $\Delta t$, and spectrum detection time as $\psi_s$. The total transmission duration of a Best “n” channel at a time slot t can be denoted in eqn (2)

$$\psi_{ts} = \Delta t_s - n * \psi_s$$

where $n = 1, 2$.

**Methodology:**

**CADP – Channel acquiring and Detecting Protocol:**

Channel sensing for a channel is done similar to the existing method “sense before transmit” [12] means all SUs will be detecting for an empty channel when there is no PU activity, in a dual manner. To avoid the conflict among the conflicts among the SUs, a Conflict Number (CN) will be allocated by BS [15]. Also, consider a Contender Channel List (CCL) for the Best1 and Best2 Channels are represented in a given time ‘t’ is:

$$CCL (t) = (B_{t1}, B_{t2}) \quad B_{t1} \ and \ B_{t2} \rightarrow \ Best1, \ Best2\ channels$$

The steps involved in the CADP are explained in the following flowchart Fig.4.
Algorithm for CADP:

Step 1: BS delegates each SU with an Available Channels (AC) in a time slot $\Delta t$.
Step 2: CN will be sent along with the CCL to form AC for a given timeslot. i.e

$$AC(t) = (B_{t1}, B_{t2}, CN_t)$$  (4)

Step 3: At $t+1$, any SU will try to detect empty slot through AC.
Step 4: If SU found the Best1 channel is available for access, then the transmission of data will be done through Best1.
Else SU will try to use the Best2 channel without any conflicts among its peers by using the CN.
Step 5: If no conflict, then SU uses the entire time slot through its Best2 channel.
Else SU has to wait for the next free slot.

Implementation Steps:

The implementation model of the proposed work involves the following steps:
A. Network creation for a CR environment
B. Implementation and Throughput calculation of CADP
C. Implementation and Throughput calculation of MCBGAS
D. Performance analysis of CADP and MCBGAS

Network Creation for a CR environment:

For the proposed work, a centralized node simulation area is created. The data transmission between nodes is performed via BS. In our work, BS will be servicing 42 nodes where a collection of 6 nodes form a sub network. Out of 42 nodes, minimal no. of nodes are considered as PUs and others as SUs which can be viewed in Fig.5
Implementation and Throughput calculation of CADP:

The basic method of sensing a channel “Sense - before - transmit” [SBT] is considered [19] for our work but in a dual fashion. In addition a Conflict Number (CN) has been included to avoid the contentions among the SUs. If the Best1 and Best2 channels are available, then it can be used by other SUs too. To achieve a good throughput, it’s always recommended to assign the ‘least used channel of PU’, to the Best1, whereas others can be assigned for Best2. Each SU node passes all the details to the BS in order to support the opportunistic spectrum access (Fig.6) All the communication among the nodes and BS, will be performed in a “Request – Response” form (Fig. 7)

Throughput:

To support all the nodes, BS sometimes uses the past history of the particular node which is shown in Fig.8. To analyze the past history of a node, data prediction method as mentioned in [20] can be used for the proposed scenario. The throughput for CADP can be calculated by using following function, by considering the channel capacity as ‘C’ has been shown in Fig.9. Redefining eqn (2) for a channel ‘n’ in eqn (5)

\[
\eta_n = \begin{cases} 
\frac{(\Delta t_s - \Delta t_x) \times C}{\Delta t_x} & \text{if PU activity is NIL and Best1 Channel} \\
\frac{(\Delta t_s - 2\Delta t_x)}{\Delta t_x} \times C & \text{if PU activity is NIL and Best2 Channel} \\
0 & \text{Others}
\end{cases}
\]
Fig. 8: BS analyze the history of a particular SU which was informed by another SU

Fig. 9: Throughput measurement of CADP

Implementation and Throughput calculation of MCBGAS:

Generally, in Greedy approach, which works in stages where in each stage a feasible solution is identified by considering all the constraints and parameters [21]. One best optimal solution will be preferred among all feasible solutions. For this purpose, we use a vector which stores all the history of channels.

In our work, this Greedy approach has been used for SUs, especially for Best2 channels. Also, we present Markov chain model which helps to determine proper values for SUs by utilizing Greedy approach, for assigning the channels[15], [22]. Hence we name this strategy as “Markov Chain Based Greedy Assignment Scheme” (MCBGAS).

Algorithm for MCBGAS:

*Step 1*: Initialize probability vector, vector and channel assignment matrix to zero.
*Step 2*: Apply Markov Chain model for current and previous states of the channels. Update the vector.
*Step 3*: Arrange all the channels in a descending order.
   //Assign Best1 Channels
*Step 4*: Arrange all SUs based on their availability. Assign Best1 channels to highest neighboring SUs. Remaining SUs will go for the Best2 channels
//Assign Best2 channels

Step 5: If the no. of available channels is greater than SUs, then preferred SUs are elected in reverse order and are assigned with the available channels. Similarly remaining SUs also get the perfect Best2 channels for data transmission.

Throughput: Throughput can be calculated by using $\eta_{\text{max}}$, which is maximum no. of chances to decide a proper Best2 channel. $P_c$ is probability vector for Best2 channel and $P_e$ is conditional probability for the channel with a capacity of ‘C’. By redefining eqn (2) which can be found in the Fig.10

$$\eta_{\text{max}} = \sum \prod (1 - P_{i_2}) P_{i_2} \frac{\Delta t}{\Delta t_i} C \quad \text{if PU activity is NIL and Best2 Channel}$$

![Fig. 10: Throughput analysis of MCBGAS](image)

RESULTS AND DISCUSSION

Performance analysis of CADP and MCBGAS:

By evaluating the performance of CADP and MCBGAS are done for throughput and packet delivery ratio. Throughput by definition says that number of packet reached destination successfully within the stimulated time whereas packet delivery ratio is defined as the number of packets reached destination successfully to the number of packets generated by source which can be seen in Fig.11 and Fig.12

![Fig. 11: PDR comparison for CADP & MCBGAS](image)  
![Fig. 12: Throughput comparison for CADP & MCBGAS](image)

Conclusion And Future Enhancement:

We proposed a unique spectrum detecting technique for the SUs which can sense dual channels in a given timeslot where they are coordinated by a BS to avoid conflicts and to ensure opportunistic access among them. Markov Chain Based Greedy Assignment Scheme an extended version of blind spectrum sensing is also discussed and compared with the CADP. The performances of CADP and MCBGAS in terms of throughput and
packet delivery ratio are simulated using NS2. Performance of CADP is much faster than MCBGAS since the appendix of the additional field along with the available channels(AC), whereas in MCBGAS states of all the channels whichever participating should be known. Also by using the past history of nodes in CADP, time for analyzing is much reduced.

Extension of the proposed work may be multiple channels sensing in complex scenarios. Since a malicious SU may act as the attacker to capture the sensed channel, security mechanisms like identity based schemes inbuilt on a BS can be used to provide authentication for SUs [23]

REFERENCES