A Two Channel Sensing Method in Cognitive Radio Networks Using Opportunistic Spectrum Access

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Abstract: Spectrum sensing and its efficient utilization are the main intriguing problems in Cognitive radio (CR) networks. The problem heightens if the network has multiple secondary users (SUs) in it. To nullify the existing issue of spectrum sensing, a new spectrum sensing and access protocol called Channel sensing and Access Protocol (CSAP), for CRNs has been introduced based on the channel assignment problem where the SUs can sense two channels at a time, by coordinating the access among the unused channels. The protocol has been further broadened using Markov chain based greedy method (MCGA), in order to increase the throughput of the secondary users. Simulation results are given for both the methods, by using NS2, which shows the proposed mechanism of CSAP utilizes the spectrum to the maximum and MCGA increases the throughput.

Key words: Cognitive radio networks · Spectrum sensing · Markov Chain greedy · Secondary users · Channel sensing

INTRODUCTION

Cognitive Radio network, is a rising new technology, which has evolved from the current wireless networks. Basically Cognitive network [1] is defined as – a network that has cognitive operations that can perceive the network condition, plan to decide, follow up on specific conditions, realize form the results and observe the end to end goal. However this definition is an incomplete one, further the same can be rewritten as “Cognitive network [2] is said to be a network of connection that is enhanced by a knowledge plane that extends across layers horizontally and through innovations vertically”. The Cognitive radio network is a complex heterogeneous wireless system that incorporates consistent flow and discrete occasions. And Cognitive radio network purposefully works in Layer 1 and Layer 2 of OSI model [1]

Cognitive radio networks (CRN) are explained in detail [3] which says, it is the network which utilizes both the wireless station and radio spectrum resources in an opportunistic manner depending on the resources that is available. Cognitive radio (CR) is the fundamental technology to utilize the unused spectrums available. It has been identified as the important fifth generation wireless networks. In CRN networks, two users are available. One is the primary user (PU) and other is the secondary user (SU). The SUs occupies the unlicensed spectrum without disturbing PUs, a licensed spectrum user. To identify the available spectrum either the PU informs about the spectrum usage to SU or the cognitive user (CU)(otherwise called as SU) by itself has to discover the free spectrum spaces by means of direct sensing of licensed bands [3]. All the SUs can communicate among themselves in an adhoc fashion. In addition to this, designing a network for such users is very difficult in the wireless networks.

In CRN, spectrum sensing is a process of sampling PUs’ signal and making a decision on the PU activities over the spectrum band. If the outcome of the spectrum sensing shows the absence of PUs, the spectrum band is to be considered as available for SUs; otherwise SUs have to refresh themselves from transmitting on the spectrum band. When there are multiple SUs in a multichannel CRN,
two or more SUs may simultaneously choose to sense the same channel and then decide to utilize this spectrum opportunity if the channel is detected to be available. Interference among SUs may happen, if there is no coordination among them and when they transmit over the same detected spectrum opportunities at the same time, which leads to SUs’ unsuccessful transmissions and wasting those spectrum opportunities. Thus, effective ways of discovering the spectrum opportunities and coordinated access among competing SUs to these spectrum opportunities are the most challenging issues in CRNs [1].

In this paper, we consider an infrastructure based CRN where there are multiple SUs capable of sensing two allocated channels, namely the 1st-choice channel and the 2nd-choice channel, at a time to increase the chance of finding empty channels. During this, the participating SUs are coordinated to efficiently sense and access the channels because a SU may sense and access a 2nd-choice channel only if the 1st-choice channel is “busy”. Specifically, the channel sensing and access protocol (CSAP) and the assignment of 2nd-choice channels should be well designed not only to avoid any interference but also efficiently identify and utilize spectrum opportunities.

A number of research reviews have been performed in identifying the spectrum opportunities and dynamic spectrum access in CRNs [2, 15], in three forms. First form is, accessing of a channel by a single SU whereas the second form is accessing of multiple channels by a single SU and finally third form is accessing multiple channels by Multiple SUs. In the first form, the issues of sequential spectrum sensing by a single SU, particularly focusing on the optimal spectrum sensing order, have been studied to minimize the delay in finding an available channel [2, 4] or maximize the discovery of spectrum opportunities [2, 5]. The above work considers only the case with one SU. When multiple SUs are considered in the network, both access collision among the SUs and overall system performances are not investigated. For the second form, the optimal channel sensing and access policies were investigated in [7-10] for a single SU to select multiple channels. For the third form, the spectrum sensing and access strategies of multiple SUs are performed, either in a distributed or centralized manner [11-16].

Implementation Model: For our work, we consider an infrastructure based architecture which is preferred by industry [18, 19] and has the advantage of reducing the complexity of SUs and ease of management [21]. The primary network consists of ‘M’ non-overlapping licensed channels while the CRN can only opportunistically utilize the channels whenever they are unused by PUs. There are ‘N’ SUs located in the coverage area of the Base Station (BS). A dedicated common control channel (CCC) [11, 15] is assumed for exchanging the control messages between BS and SUs while data packets of SUs can only be transmitted on unused channels licensed to the primary network. Due to the hardware constraints, each SU can only sense and access one channel at a time [11, 15], but can sequentially perform two channel sensing in a single time slot [2-6].

In each time slot, the BS will collect all SUs requests and perform admission control. If the number of SUs’ requests exceeds the number of licensed channels, only ‘M’ SUs among all the requests will be accepted while other requests will be rejected or queued until the next time slot. Hence, we assume that the number of channels is not less than the number of SUs, i.e., \( N = M \), throughout this paper.

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The following steps are implemented for our work, which given as below:

- Sensing more channels will significantly diminish the effective SU transmission time.
- If the channel with the highest availability is preferably sensed, the remaining channels may have a lower probability of being available and the further improvement may be less significant.

The following steps are implemented for our work, which given as below:

- CR Network creation
- Channel Sensing and Access Protocol (CSAP) implementation and its Performance Analysis
- Markov Chain based Greedy Method (MCGA) implementation and its Performance analysis
- Comparison of CSAP and MCGA

CR Network Creation: An infrastructure based simulation environment of Cognitive radio network with more number of nodes are created. The control packets and messages will be sent among the source destination in the network, shown in Fig. 1. A Centralized Base Station named as Service provider, has been providing service for a network of 42 nodes. All these 42 nodes are
In time slot $t$, the BS preassigns each SU $i$ an access list including the candidate channels in a priority order and a Contention Slot (CMN) $C(i)$, denoted by

$$AL_i(t) = (C_1, C_2, C_3).$$

In time slot $t + 1$, SU $i$ may sequentially sense the candidate channels in the access list $AL_i(t)$. If SU senses the 1st-choice channel as unused, it will transmit over this channel immediately. Else, it continues to sense the 2nd-choice channel, then it contends to access the free channel based on the CMN (Fig 2). If it wins the contention, it will transmit data packets during the remainder of the time slot. Otherwise it waits until the beginning of the next time slot.

The performance evaluation of CSAP is provided in the form of a graph. The throughput and the packet delivery ratio are considered as the parameters, in our work. Fig 3 and Fig 4 are given below. The no. of packets reaching the destination has been increasing, once the timeslot increases.

The packet delivery ratio graph shows the no. of packets sent at a particular time, from the source towards the destination [17].

**Markov Chain based Greedy Method (MCGA) Implementation and its Performance Analysis:** The purpose of going for a specific methodology, is to minimize the delay in finding an available best channel, among all the free slots. The proposed Algorithm MCGA, involves the following steps. Fig. 5. The assumption is the network follows Markov chain model, for its working.

**Step 1:** Assign all free 1st choice channels to Sus.

**Step 2:** Arrange all the SUs based on the probability of accessing the 2nd choice channel.

**Step 3:** The condition for $N = M$ has to be checked.

**Step 4:** The 2nd best choice channel will be assigned to a SU, satisfying the Step 3.
Fig. 2: SU 36 moves out of its own network and a sense the network through its 2nd choice channel.

Fig. 3: Throughput of the Channel and Access Protocol.

Fig. 4: Packet Delivery Ratio of the Channel and Access Protocol.
Step 5: Once the best available 2nd choice channel, achieved, communicate with the BS.

The performance evaluation of MCGA, i.e dual channel sensing, is provided in the form of xgraph. The throughput and the packet delivery ratio are considered as the parameters, in our work. Fig 6 and Fig 7 is given below. The no. of packets reaching the destination has been more increasing, once the timeslot increases, by using dual channel accessing mechanism.

The packet delivery ratio graph shows the no. of packets sent at a particular time, from the source towards the destination [17] by using dual channel accessing mechanism (MCGA).

Performance Evaluation: Parameters like packet delivery ratio, speed, number of nodes available in the network, delay, etc are considered as the QoS factors in evaluating the system performance.

The following figures described the performance comparison of Channel Sensing and Access Protocol with MCGA using measured parameters (Throughput, packet delivery ratio, end to end delay) and outputs are shown using graphs. Fig.7 shows the delay comparison after using CSAP in a single channel and MCGA in a dual channel.

Fig. 8 shows the PDR of using CSAP in a single channel and MCGA in a dual channel.
Fig. 6: Packet Delivery Ratio measurement after applying MCGA scheme

Fig. 7: Delay comparison of CSAP Vs MCGA

Fig. 8: PDR comparison of CSAP Vs MCGA
The packet loss has been reduced much better in dual channel accessing mechanism than the single Channel sensing and access protocol. Fig.9. shows the difference between them.

CONCLUSION

Discussion about the proposed spectrum sensing and access protocol in CRNs are done, in which the SUs are allowed to access two channels in a single time slot, in a coordinated manner of spectrum opportunities. The work has been extended further by using Markov chain based greedy channel assignment scheme (MCGA). By using NS2, the simulation results demonstrated that significant performance can be achieved better than the present approaches. Further enhancement can be done on accessing the channel using multiple ways and uses a nil Bayesian work of channel states.

REFERENCES


