

# Mitigating Control Channel Saturation Problem in Cognitive Radio Network

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## Abstract

Cognitive radio is opportunistic spectrum access network which means it allows the unlicensed users to use the licensed spectrum opportunistically. However spectrum resources optimization relies on information exchange between unlicensed or secondary users. Normally, it assumes that all necessary information can be exchanged via a reliable channel and this introduces the usage of common control channel (CCC). However, it also brings some challenging such as, availability and reliability of CCC, control packets overhead, control channel saturation problem etc. In this paper, we try to compensate the control channel saturation problem by using channel clustering mechanism. First, we cluster the available channels of the network and, second, secondary users select a proper cluster. The operations of the clusters are independent and users can perform control and data communication simultaneously on different independent cluster. It can significantly reduce the rate of control packets collision and it mitigates control channel saturation problem. And we also discuss about assigning efficient control and data period to guarantee the fairness among users.

## I. INTRODUCTION

Cognitive radio technology enables a new way to compensate the spectrum shortage problem of wireless environment. It allows the secondary user to utilize the free or idle portions of licensed spectrums while ensuring low interference to the primary users or spectrum owners. Generally, the necessary information is embedded in control packets and these are exchanged via a channel with assumption that this channel is available for every user in the network. It is called common control channel and all the users use it for control packet exchanging. Therefore, the control channel is congested and the chance of control packet collision is higher when the number of users in the network is significantly high. This is called control channel saturation problem [1] and it may cause single point failure of the entire network.

### A. Problem Statement

Most of the proposed MAC protocols for cognitive radio assume the existence of a common control channel (CCC) on the licensed or unlicensed bands and it is available for every secondary user of the entire network. All control information will be exchanged among users via that dedicated CCC and data communication will take place on other channels [1][2]. Fig (1) shows the basic operation of a network with a common control channel.

Whenever a user has data to send and wants to initiate communication with any other user, it goes to control channel first and negotiates with intended receiver by exchanging necessary control information. After negotiation has been done successfully on control channel, data communication can be accomplished in other data channels [3]. However, the control channel can be saturated and increase the rate of control

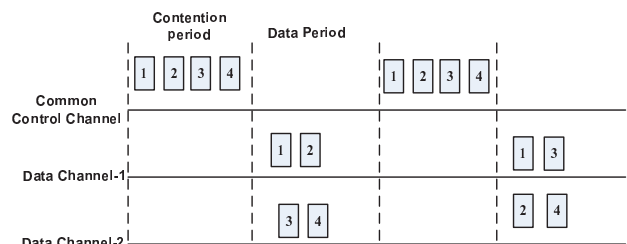


Fig. 1. Basic operation of a network with a common control channel.

packet collision when the number of users in the network is significantly high. The main idea of this works is making the network less dense. First, we cluster the channels and none of these is overlapping which means no channel is common in more than one cluster. Second, the secondary users are deployed into different clusters and every user has to operate only on their own cluster. Therefore, the network becomes logically sparse although it is physically dense since secondary users operate on their own different clusters independently.

### B. Related Works

Recently, frequency hopping approach gets much attention to compensate the problems of CCC. The main purpose of using frequency hopping is to eliminate the need of common control channel. However, it needs tight synchronization among users and to overcome this problem, independent frequency hopping approaches have been proposed in [4] and [5]. In [4], the authors proposed sequence-based rendezvous mechanism which is the use of frequency hopping spread spectrum technique. In their proposal, non-orthogonal sequence is used to maximize the probability of rendezvous of two radios on a

channel. In [5], independent pseudo-random hopping sequence is assigned for each user to relieve strict synchronization between SUs. When a node has data to send, first, it will search the intended receiver by hopping one channel after another while following its own sequence until it meets the receiver on a channel. After rendezvous on a channel, sender and receiver will negotiate to generate common hopping sequence. Data communication will be done between these two nodes by following the common hopping sequence. However, in both proposal[4] and [5], whenever a node has to initiate communication with other nodes, it has to find the intended receiver and it needs significant amount of time which is known as time to rendezvous (TTC). The probability of rendezvous might be very low or TTC might be long as the number of available channels of network is height. It is also possible that two nodes might not converge on a channel if the pre-determined TTC is short or insufficient.

## II. CHANNEL CLUSTERING

We assume that there are  $n$  number of orthogonal channels  $N = \{1, 2, \dots, n\}$  and all users are within the transmission range of each other. Every secondary user has equipped with a single transceiver and can switch across channel with minimum delay. First, user  $i$  selects some available channel and create a channel list  $CH_i = \{1, 2, \dots, k\}$  and  $CH_i \subseteq N$ .  $CH_i$  becomes the list of channel belong to cluster  $i$ . Then, user  $i$  broadcasts  $CH_i$  on every channel by switching one channel after another. User  $j$  also create a channel list  $CH_j \subseteq N$  and if the channel  $x$  is selected by both user, user  $j$  will received  $CH_i$  on channel  $x$ . If user  $j$  is willing to join the cluster  $i$ , it modifies its channel list with  $CH_j = CH_i$  and it becomes the member of cluster  $i$ . Otherwise it creates its new channel list  $CH_j = CH_{new}$  and  $CH_{new} \cap CH_i = \phi$ . Every user in the network can simply join a cluster or it can create its own cluster by choosing the independent channel list as mention before.

However,  $CH_{num}$  is the total number of channels for each cluster and it should be defined,  $CH_{num} \leq \lfloor \frac{|N|}{n} \rfloor$ , where  $n$  is the number of clusters. To guarantee that none of available channels is overlapping, it should be satisfied:  $CH_i \cap CH_j \cap \dots \cap CH_n = \phi$  and  $CH_i \cup CH_j \cup \dots \cup CH_n \leq N$ .

### A. Inner-Cluster Operation

In this section, we present the detailed operation of a cluster. We pre-defined the time into equal super frame structures and each frame is divided into two intervals: broadcast period, contention period and data period as shown in Fig(3)a. In broadcast period, the first time slot is assigned cluster head and it is used to transmit a broadcast packet for every user in the cluster. The rest are assigned for the new users and the users who are going to leave this cluster.

Super Frame Structure	Member list	Common Hopping Sequence
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Fig. 2. The broadcast packet format

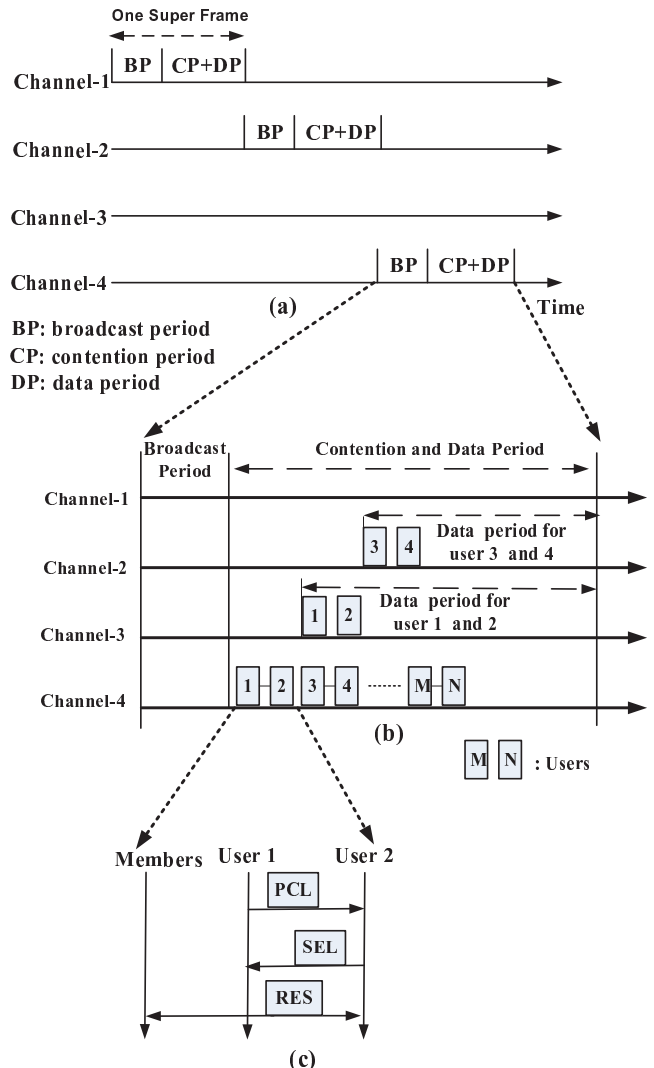


Fig. 3. The operation within a cluster

Cluster head creates a common hopping sequence based on its channel list  $CH$ . It will be broadcasted at the first time slot of broadcast period on very channel by following the sequence. The broadcast packet format is presented in Fig(2) and it contains the information about super frame structure, members of the cluster and common hopping sequence. All members of the cluster follow the hopping sequence for receiving broadcast packets and channel negotiation for data communication.

The contention and data period are used for channel negotiation and data communication. In order to use the channel efficiently, the contention period and data period are not fixed although the super frame is. When the contention period starts, users in the cluster attempt to negotiate with intended receivers if they have data to send. The operation is based on the classical CSMA mechanism. First, every member of the cluster  $i$  generates its own preferable channel list  $PCL$   $CH_i$ . If a user has data to send, it will send a control packet which includes a  $PCL$  to the intended receiver, user  $j$ . Receiver chooses a channel,  $y \in PCL$  and sends back to sender with  $SEL$ . All other users can know that channel  $y$  is selected by users  $i$

and  $j$  for data communication since they all are within the transmission range of each other and this selected channel will be deleted from their PCL. These both users,  $i$  and  $j$ , will migrate to selected channel, channel  $y$  as soon as they finished channel negotiation in order to use the channel efficiently. Therefore, the data period for those users is longer than the others. Nevertheless data communication should not exceed super frame in order to follow the common hopping sequence. Fig (3) shows as an example of channel negotiation and data communication.

In Fig(3), members of a cluster are performing contention on channel -1. At the beginning of the contention period, the channel negotiation has been done successful between user-1 and user-2. Therefore, both users migrate to selected channel, channel-2, for their data communication and the remaining users continue the contention. User-2 and user-4 also move to their selected channel, channel-4, as soon as they finished channel negotiation and so do the other users.

### B. Leaving and joining clusters

Users need to migrate to other clusters for the following purpose:

#### 1. Balancing the members of clusters.

If a cluster has many members, the contention period might not efficient for all members. It can also increase the rate of control packet collision and lead back to control channel saturation problem again.

#### 2. Need to communicate with other cluster.

A member of a cluster may need to communicate with a member of others cluster.

When user has to leave the cluster, the leaving information of a user will be broadcasted on next broadcast period. Therefore, the cluster head and other members get the information and the user id will be deleted from the member list. As soon as the information has been broadcasted, user leaves the cluster and joins another. After leaving the cluster, user sense the channels of other cluster and choose one available channel to wait broadcast packet. The operations of the clusters are exactly the same as presented in section-(A) and new user will definitely receive the broadcast packet within a time interval  $T_r$  which can be estimated as:

$$T_r \leq \sum_{i=1}^k (S_i + \alpha) \quad (1)$$

Where,  $k$  is the total number of available channels of a cluster  $S_i$  represents total amount of time for staying in  $i$ th channel which is actually equal to one super frame and  $\alpha$  stands for channel switching time. After getting a broadcast packet from cluster head, the new user can join the cluster and become the member.

### C. Coexistences with Primary Users

The main purpose of following the common hopping sequence is to avoid PUs' transmission. In our proposal, this will

be the responsibility of cluster head because it has authority to modify the common hopping sequence. At the end of every super frame, the cluster head performs channel sensing. It sense all licensed channel and if it can sense primary users' signal on any channel  $z$  which includes in hopping sequence,  $z \in CH_i$ , the sequence will be modified. Only free channels will include in hopping sequence and it will be broadcasted at the beginning of the next super frame. If it does not sense any primary user activity, the cluster head will broadcast old sequence without modification. Choosing cluster head and selecting secondary cluster head in case of cluster head failure, we refer to [6].

### D. Discussion

The main purpose of this job is mitigating the control channel saturation problem. Therefore, assigning the contention period is critical. If the contention period is not long enough for every member, it can also degrade the overall performance of network. To estimate the necessary contention period, we ran Matlab based simulation. We defined the control packets size as 160 bits which is the same as the size of RTS/CTS in 802.11 and run simulation with two different transmission rates, 10 Mbps and 5 Mbps. It is also assumed that the collision occurs whenever more than two members of cluster choose the same back off time and transmit control packets simultaneously. Whenever collision occurs, SUs negotiate again. Fig.4 shows the simulation result which described number of SUs and necessary time for at least once successful control packet exchanged within one contention period. For example, there are twenty users in the cluster and the transmission rate is assigned 5 Mbps. It will guarantee that every user can exchange control packets successful at least once within a contention period which is approximately  $11e-5$  seconds. Therefore, the contention period should be dynamically defined according to the number of members in the cluster in order to guarantee the fairness among users.

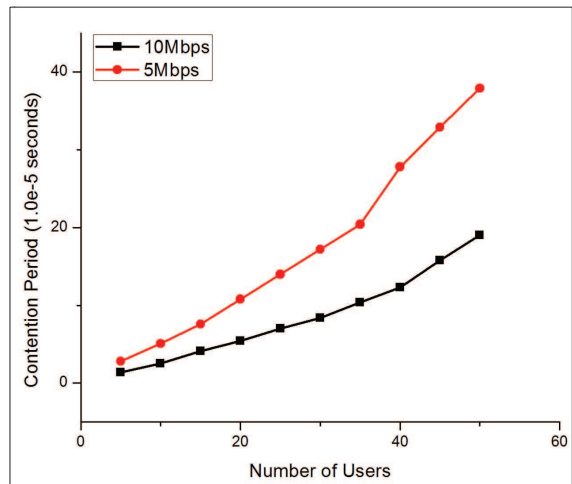


Fig. 4. Total number of users and necessary time for contention

### III. CONCLUSION

In this paper, we present channel clustering mechanism to mitigate the control channel saturation problem. The main purpose of the mechanism is making the network less dense and it can significantly reduce control channel saturation problem. Moreover, it also reduces the complexity of the network and helps to manage the network easily. We also described that suitable contention and data period according to the total number of members in the cluster to guarantee the fairness among users.

### IV. ACKNOWLEDGEMENTS

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### REFERENCES

- [1] T. V. Krishna and A. Das, "A survey on MAC protocols in OSA networks," *Computer Networks*, vol. 53, no. 9, pp. 1377–1394, June 2009.
- [2] J. Jia, Q. Zhang, and X. Shen, "HC-MAC: a hardware constrained cognitive MAC for efficient spectrum management," *IEEE Journal on Selected Areas in Communications* 26 (1) (2008), pp. 106–117.
- [3] J. So and N. H. Vaidya, "Multi-channel MAC for ad hoc networks: handling multi-channel hidden terminals using a single transceiver." Proceedings of the 5th ACM international symposium on Mobile ad hoc networking and computing (MOBIHOC), May 2004.
- [4] L. DaSilva and I. Guerreiro, "Sequence-based rendezvous for dynamic spectrum access." IEEE DySpan, 2008, pp. 1–7.
- [5] C. Cormio and K. R. Chowdhury, "Common control channel design for cognitive radio wireless ad hoc networks using adaptive frequency hopping," *Ad Hoc Network* doi:10.1016/j.adhoc.2009.10.004, 2009.
- [6] T. Chen, H. Zhang, G. M. Maggio, and I. Chlamtac, "CogMesh: A cluster-based cognitive radio network." IEEE DySpan, April 2007, pp. 168–178.