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Research paper

Target Channel Selection Algorithm for Cognitive Radio Network

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Abstract

Cognitive radio network has attained more popularity because of giving prominent solution for spectrum inefficiency due to static spectrum allocation. This research proposed target channel selection algorithm which have been employed to improving the throughput and reducing number of handoffs. The proposed target channel selection algorithm is select the channel based on the idle probability and efficiency reward of channel and these are calculated from the surveillance of earlier usage statistics. When the channel selection is based on the above factor, the Secondary User gets chance to utilize the Primary user channel in maximum time to achieve optimal goal. The results show that proposed algorithm-based channel selection shows the better performance than existing algorithms in factors such as throughput, number of handoffs and collision rate.

Keywords: *Channel selection algorithm; Cognitive radio network; Collision avoidance; Common control channel; Spectrum handoff;*

1. Introduction

Spectrum resources are allocated statically for long duration by government or government aided organization like FCC in USA, OfCom in UK, TRAI in India and etc. The licensed user, namely called as Primary User(PU) do not utilize the spectrum resource in efficiently that means massive portion of the allocated spectrum resources are used occasionally. Over the last few years, significant development in wireless technologies like mobile technologies, pattern recognition based medical technologies and etc., force to allocate more spectrum resources for deployment of such new wireless technologies. The success of wireless technologies make particular licensed spectrum resources has saturated and deployment of new wireless technology within naturally limited wireless spectrum resource has incited the spectrum paucity problem. Cognitive radio technology has introduced to overcome spectrum scarcity problem with exploits the underutilized spectrum resources in dynamic manner.

Channel selection algorithm in CRN is responsible to finding an optimal channel with in the available licensed channel and such channel is optimizing the performance of CRN. The objectives of channel selection algorithm in the CRNs are:

- To select the suitable channel for every SU within the list of available channels
- To minimize the number of handoff that is helping to improve the throughput
- To reduce the interference with other SU
- To avoid the interference with PU or giving tolerant interference

In the dynamic environment, many channel selection algorithms have been employed to improve the throughput with selecting the channel based on any one of the factors such as probability of idle time, probability of collision, etc. These factors are calculated with previous activity of PUs and SUs that is Common Control Channel (CCC) is used to monitor the activity and maintain the information about activities. Some of the channel selection algorithms are proposed with common hopping and spit phase approaches. But these approaches are not suitable to the CR networks. Because 1) Tight synchronization needs among all users (PUs & SUs) in common hopping approach to avoid collision but monitoring the PU activities is difficult. 2) Find the perfect duration for control and data phases are sensitive in the split-phase approaches and all the nodes are try to access the control channel at same time and remaining channel are idle. These schemes are unlikely to be used in CR networks. In this research work is providing the following contributions.

- In this research work provide Common Control Channel (CCC) design which is used to share the sensing information and exchange the control message.
- This research work proposed target channel selection algorithm which is work based on idle probability and efficiency reward.
- Finally, evaluate the performance of proposed channel selection algorithm through compare with some common channel selection approaches.

The forthcoming sections are arranged as follows: section 2 and 3 are provides the information about the related work and CCC Design, respectively. The proposed target channel selection algorithm and its working are described in section 4. The performance evaluation with simulation results are presented in section 5 and the research work conclude with section 6.

2. Related works

This section contains the study in the field of cognitive radio network on channel selection algorithm. It consists of some of the existing channel selection algorithms which could provide a more opportunity SU and improve overall spectral utilization of the

network. Most of the researches carried in the literature offer to estimate the channel handiness and selecting the channel basing only on any one of the PU activity like idle probability, collision probability and etc.
Contention aware channel selection algorithm proposed to select the channel for SUs in CRN based on the probability of collision and lowest contention channel. Most of the time, which channel has lowest contention that channel has low idle probability also. When channel selection algorithm concentrated only on collision avoidance it is increasing number of handoffs. When number of handoffs increased it is automatically affect the throughput because of transaction delay. In common hopping based proactive spectrum handoff framework distributed channel selection algorithm is used to select the channel for handoff. When compared the Common Control Channel (CCC) based rendezvous coordination schemes with common hopping based rendezvous schemes, the later results the lower throughput due to busy of SU hop channel for transmission with PU activity. The proactive single rendezvous spectrum handoff protocol selects channel based on greedy channel selection algorithm by considering the minimum service time and the maximum vacant time. The split phase coordination scheme is used to exchange the control message. In this scheme, reconfiguration is difficult for SUs to exchange control message in new rendezvous channel when previous rendezvous channel is busy with data transaction and increases delay. C-MAC protocol describes the channel selection with multi-stage process such as Incumbent detection, Notification and Detection recovery to improve the throughput. But, this protocol does not differentiate the PU and SU.
However, most of the related works don't consider reducing the number of channel handover problem, but channel handover increases the node energy consumption. Lots of experimental results show that the channel handover cost energy for 110.75% of the energy required for transmission [Kuangyu Chen et al., 2014]. Frequent spectrum handover makes the whole system performance degradation. Therefore, for energy constrained cognitive wireless network, when design the channel allocation algorithm, needs to reduce the handover times as much as possible. Hence, idle probability and efficiency reward based target channel selection algorithm has been proposed in this research.

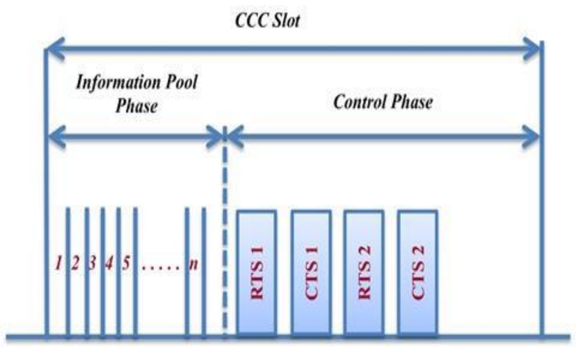

Fig. 1: Common Control Channel Design

3. Common Control Channel Design

The proposed channel selection algorithm operation is based on dedicated CCC which is used to share the sensing information and to exchange the control messages. The unlicensed channel is devoted to CCC and it will not have affected by PU activity. The CCC is fragmented with multiple periodical time slots and each slot is divided into two phases, one is information pool phase and the other is control phase. The information pool phase slot is further divided into n-mini slots and each slot is assigned to one SU for sending its own beacon about sensing information, handoff channel selection and channel switching information.
The SUs exchanges the control message in control phase based on IEEE 802.11 DCF (Distributed Coordination Functions) contention algorithm. To improve the synchronization among control and PU channels, control channel time slots are same length as PU channels time slot. This algorithm is used to avoid collision among SUs control message. CCC design is illustrated in Figure 1.

3.1. Features

The special features of proposed CCC design are listed below. 1) When unlicensed (ISM) band is devoted to CCC, it is always available, and it can be used by any type of wireless user. 2) There is no need to ask permission for use unlicensed band and do not need to pay any fee for license. 3) Sensing results updated in CCC is used to calculate different parameter of the channel for selecting best channel. 4) The details about nodes which are participating in communication is updated in CCC and it is used to avoid hidden terminal problem. 5) To exchange RTS/CTS leads to zero or minimum interference with PU.

4. Target Channel Selection Algorithm

Every SU pair which needs to initiate the transmission or perform spectrum handoff compute and select the best available channel based on the channel selection algorithm. Channel selection plays a crucial task in data transmission in CRN. The essential step in having efficient data transmission is to know how to select the best channel. If SU selects the channel randomly, it degrades the efficiency of the data transmission. When SU randomly selects the channel for transmission, it may be possible that PU transmission is going on and subsequently, the SU transmission causes harmful interference to the PU. Furthermore, transmission over the channel without considering the PU activity may increase the probability of interference with PU. Some required characteristics of the channel selection algorithm are follows

- ✓ Throughput: The channel selection algorithm is increase the probability of message delivery in an available time.
- ✓ Collision avoidance: The channel selection algorithm should ensure the SU does avoid harmful interference to PU.
- ✓ Number of handoff: The channel selection algorithm should select the channel to complete the whole transmission with minimum number of handoffs.

The proposed target channel selection algorithm starts with channel information update step which is used to collect the information regards PU channel. Based on this information, efficiency reward and idle probability of the channel has been calculated and using these values in target channel selection algorithm.

4.1. Channel Information Update

The mini-slots in CCC are used to update the sensing information of the channels. The general information about the channel such as idle slots, transmission power, bandwidth of the channel, power specified noise on the channel and probability of channel access are updated. Also, the information about every successful transmission such as data packet size, distance between sender and receiver and the transmission duration on the channel without collision are included. This information is used to find the idle probability and efficiency reward of the channel.

4.2. Finding Efficiency Reward

Number of available channels N

Let $\left\{C_1, C_2, \ldots\ldots, C_N\right\}$ to denote a channel set

Number of available secondary users' m

Let $\{s_1, s_2, \ldots.., s_m\}$ to denotes a secondary user set

The mean vector of the reward of channel *i is*

$$\mu_i = (\mu_i^1, \mu_i^2, \ldots.., \mu_i^n) \text{ where } (1 \le i \le N)$$

Probability of selecting channel *i* is

$$\omega_i = (\omega_i^1, \omega_i^2, \ldots.., \omega_i^n)$$

n denotes number of times the channel *i* is selected for transmission

Total efficiency reward of the channel *i* is

$$R^i(\mu_i) = \mu_i^1\omega_i^1 + \mu_i^2\omega_i^2 + \ldots.. + \mu_i^n\omega_i^n$$

$$R^i(\mu_i) = \sum_{j=1}^{n} \mu_i^j \omega_i^j$$

Find maximum reward channel in the FCL is

$$R(\mu_{mx}) = \underset{1 \le i \le n}{\arg\max} \sum_{j=1}^{n} \mu_i^j \omega_i^j$$

4.3. Finding Idle Probability

If each of primary channels only have two states: busy or idle and it is modelled as the first-order two-state Markov process illustrated in Fig. 2.

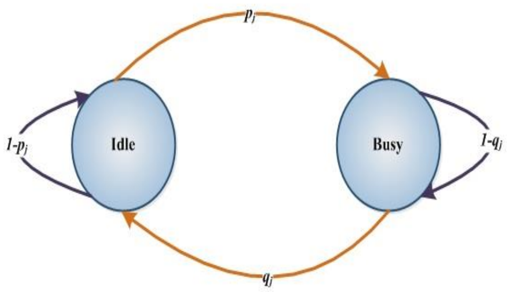

Fig. 2: Markov Chain Two State Model

According to the first order two state Markov process, the probability that channel is in busy state is follow,

$$p_j^{busy} = \frac{p_j}{p_j + q_j}$$

p_j is the time to change the idle state to busy state

Idle probability of the channel *j* in the slot *t* is

$$q_j^{idle} = (1 - p_j^{busy})$$

Probability of the channel *j* in the next *k* slot is

$$q_j^{idle}(k) = (1 - p_j^{busy})^k$$

The expectation of the length of the slots where channel *j* is successfully idle is as follows

$$E_j(k) = \sum_k k(1 - p_j^{busy})^k$$

Find the maximum idle probability channel for complete transmission is

$$c^* = \underset{1 \le j \le N}{\arg\max} \sum_k k(1 - p_j^{busy})^k$$

Transmission capacity of the channel is

$$TC_i = R^i(\mu_i).W_i.E_i(k)$$

Where W_i - Bandwidth of the channel

4.4. Channel Selection

The purpose of this developed target channel selection algorithm is to improve the throughput and to reduce the collision rate of the CRN with developed CCC based spectrum handoff scheme. This algorithm is considered the idle probability and efficiency reward of the channel to select the best channel to initiate or continue the transmission. When choosing the high idle probability channel, it gives more opportunity to access the channel for own data transmission. Number of handoffs is reduced with using the more opportunity channel for data transmission. When the number of handoffs is reduced, energy consumption also reduced. The target channel selection algorithm is shown in Fig. 3.

In the developed channel selection algorithm, first the channel information is updated by the SUs through the CCC pool phase. Based on the updated information the idle probability of the channel in the next slot is calculated. In the next step, the idle probability ($q_j^{idle}(k)$) of the all channel for next *k* slot is derived. In this *k* is denoted the number of slots required to complete transmission by SU. The expectation length of the idle slots ($E_j(k)$) are calculated with cumulative result of the idle probability of the channel. In the next step, the transmission efficiency reward of all the channels is calculated with consideration of mean vector of transmission efficiency reward for all the successful transmission on the channel (μ_i^j) and the probability of the selecting channel (ω_i^j) is calculated based the reward of selecting channel in next slot.

Step 1: Update the channel information

Step 2: Find the idle probability of the channel for next k slots ($q_j^{idle}(k)$)

Step 3: Compute the Expectation of the length of the slots where the channel is successfully idle ($E_j(k)$)

Step 4: Calculate the efficiency reward of the channel ($R^i(\mu_i)$)

Step 5: Sorting the channel based on the idle probability length of the channel

Step 6: Find the lower median value of the sort order and consider the channels which have more idle probability than median value

Step 7: Evaluate the expected transmission capacity of the channel (TC_i)

Step 8: Selecting the channel which has the maximum expected transmission capacity

$$c^* = \arg\max_{1 \le i \le N}(TC_i)$$

Step 9: Remove the channel from the FCL

Fig. 3: Target Channel Selection Algorithm

Sorting all the channels based idle probability of next k slots. In this sorting order, find the maximum idle probability channel and also the minimum one. In the next step, the lower median value of the sorting order is estimated when FCL has more than two available channels. When found, the lower median value of the sorting order, it's easy to separate best case and worst-case channels based on the idle probability. In this step it removes the worst-case channel for calculating expected transmission capacity. Because the channels which have lower idle probability and maximum efficiency reward is reduced by the excellence of channel selection. In the next step, expected transmission capacity of the channel for next k slots is computed with idle probability of the channel, efficiency reward of the channel and then bandwidth of the channel. In the next step, the best available channel (c^*) is selected which has the maximum expected transmission capacity.

5. Performance Evaluation

In this section, performance of target channel selection algorithm is investigated and compared with existing channel selection algorithm. This simulation shows the performance of target channel selection algorithm within simultaneous change in SUs count and traffic load of PU and SU varying in time to time. SUs are randomly deployed within a square area of 500x500m^2. Simulation runs for 300 seconds. The other parameters used to obtain results are listed in table 1.

Table 1: Simulation Parameters

SU Packet Size	2000bits
PU Packet Size	20000bits
Number of Sus	10-50
Number of Channels	10-40
Quiet Period	15µs
Timeslot	2ms
Licenced channel data rate	1Mbps

5.1. Collision Rate

Fig. 4., shows that the number of collisions among SUs under different number of SUs. The greedy channel selection algorithm selects the channel based on the minimum service time. In the single rendezvous scheme, collisions are avoided between the SUs with minimum rendezvous delay. But, SU control packets are affected by collision in multiple rendezvous scheme. The collision rate of the SUs is investigated for different channel selection algorithm.

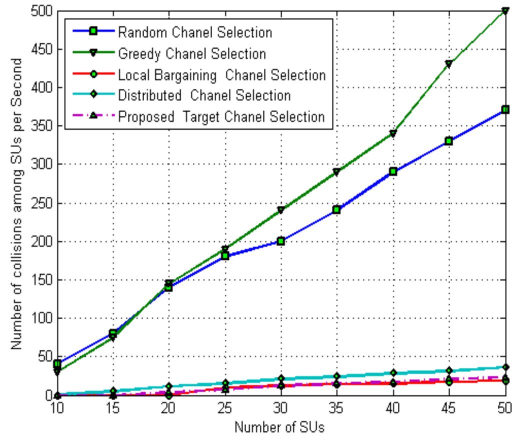

Fig. 4: Collision Rate

The local bargaining algorithm performs the best among all other algorithm. Because, local group is avoiding the collision among the SUs successfully. With this local group SU selects the channel and informs about the channel selection to the group neighbours with four-way handshake method. The primary goal of the local bargaining algorithm is to reduce the collision among SUs.

The greedy channel selection algorithm is worst among all other multiple rendezvous. Because the predetermined channel is same for all the SUs which needs to start or continue the transmission in particular time slot. The random channel selection algorithm selects the channel without considering the history or factors. When the SU selects the channel randomly that is already busy in SU transmission, collision occurs. Collision rate of the proposed algorithm is nearly equal to the local bargaining algorithm. The proposed channel selection algorithm is reducing the collision with perfect control message exchange.

5.2. Handoff Delay

The fig. 5., shows the average spectrum handoff delay within different number of SUs. The spectrum handoff delay in random channel selection algorithm is zero. In the random channel selection algorithm, SUs does not consider the channel observation history for channel selection and it does not exchange any control message between SUs to avoid collision.

But, the local bargaining algorithm selects the channel by forming local groups and exchanges the channel selection to all the neighbours with four-way handshake method (request, acknowledgement, action, acknowledgement) for each handoff. In the proposed target channel selection algorithm, channel selection and control message exchange are completed within the mini slot. When the number of SUs is increased, spectrum handoff delay is increased slightly in the proposed channel selection algorithm.

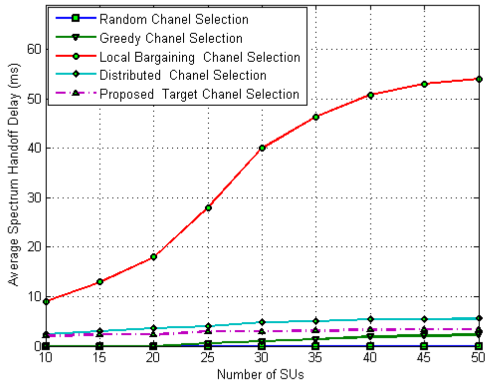

Fig. 5: Average Handoff Delay

5.3. Throughput

The throughput of the SU for multiple rendezvous scheme is shown in fig. 6. The proposed target channel selection algorithm performs best among all the other algorithms. When selected, the channel based on the maximum idle probability and maximum transmission efficiency gives more opportunity to the SUs to access the channel without handoff.

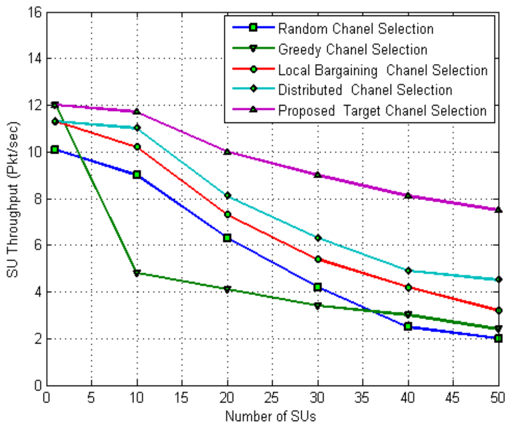

Fig. 6: Throughput Comparisons

When considering single SU pair in the network, greedy and proposed channel selection algorithms achieve best throughput. At the same time increasing the number of SUs, the greedy channel selection algorithm affected by collision, performs a low throughput. The local bargaining algorithm which has lowest collision rate is affected by handoff delay. The handoff delay performs a significant role in throughput.

6. Conclusion

The target channel selection algorithm is developed to select the channel based on the idle probability of the channel and transmission efficiency of the channel which is calculated from transmission history of the channel. The channel selection algorithm targets to reduce the number of handoffs. The maximum transmission opportunity and maximum transmission capacity reduces the number of handoffs and minimizing the average service time. The performance of the CCC is based target channel selection algorithm evaluated. When extend this research towards handoff process, then find that target channel selection algorithm reduces the number of handoff to complete the SU transmission considerably.

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