# Implementation of Channel Hooping Algorithm of Cognitive Radio Networks In Ad Hoc Networks

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***Abstract*- In present days the wireless communications are widely increased, due to this the usage of spectrum is also increased widely. To use spectrum efficiently and effectively we proposed channel hopping algorithm of CR networks and implemented this algorithm in MANETS. In this algorithm we have calculated the expected time taken by the CR user to get the free channel. The delay is reduced when this algorithm is implemented in MANETS compared to CRNs because CRNs are mainly for spectrum sensing but in MANETS, the nodes are self-configured and they can change their location during transmissions. CR users also need to sense the spectrum and vacate the channel upon the detection of the PU's presence to protect PUs from harmful interference. Here we have presented the channel hopping algorithm which enables dynamic access to the spectrum and ensures to vacate the allocated channel if PU returns and move the CR user to some other vacant channel giving priority to PUs. Based on the PU activity on each channel, a ranking table is built to identify the channels which are available.**

***Keywords-Cognitive radio networks, spectrum sensing, ranking table and MANETS***

## I. INTRODUCTION

In present days, the use of wireless communications is highly increased thereby the usage of spectrum is also high. To use the spectrum in efficient way, cognitive radio has become prominent technology, which gives the dynamic access to the spectrum. The main advantage of cognitive radio is to increase the spectrum utilization and increasing the quality of communication.

Cognitive radio networks (CRNs) has been recognized as a promising technology to address the problem of spectrum under-utilization.It does so by detecting the unused portions of the spectrum known as spectrum holes and uses that portion for transmission without causing any interference for the licensed users [1,2]. Inthe context of CRNs, the owner of the licensed channel is known as Primary User (PU) and the other users of thechannel are known as cognitive radio (CR) users or secondary users. Each CR user is equipped with one ormore cognitiveradios, which are capable of opportunistically identifying vacant portions of the spectrum and hopping between them without causing interference to the PUs of the spectrum. Cognitive radio users should vacate the channel whenever the owner of the channel returns i.e.; PU to protect from harmful interferences.To exchange the necessary information, spectrum management and useful data communication, CR users should detect the presence of each other to establish the communication links. Two or more radios of users meet and establish a link on common channel which is known as "Rendezvous" [3]. Some previous work on the topic refers to this process as "neighbor discovery" rather than rendezvous [4]. Rendezvous is a basic and important operation in CRNs. Several CH algorithms have been proposed in the recent literature [5, 6, 7, 8, 9, 10]. These schemes have considered Time to Rendezvous (TTR) w.r.t. number of channels for evaluating the performance. However, these works have one or more of the following limitations: i) robustness to PU activity; ii) allocation of a free channel to CR users in case of PU return iii) not applicable to rendezvous of multiple users.

In this paper, we focus on design of algorithm which deals with the allocation of channel to the primary user whenever it comes to its own channel without making them to wait and also the CR should move to the other free channel. The classical rendezvous results are not appropriate for cognitive radio networks as they are unable to adjust to the dynamic behavior of the primary network and, also unable to avoid interference to the PUs. Earlier discussed solutions assume that after achieving the rendezvous of a node pair over a given channel, they carry out the entire data packet transmission over that channel. There is no method to vacate the band of spectrum if there is an appearance of a PU. In our channel hopping algorithm, the hopping sequence for the CR users is fixed and uses the most recent sensing results by allowing the exchange of data over the channels with the lowest PU activity. Contributions of this work are summarized as follows.i) New algorithm giving immediate priority to PUsover CR users: channel hopping algorithm is proposed to achieve immediate allocation without letting the PU wait to get back its assigned channel from CR user. ii) Move the CR user to some other vacant channel inminimum possible time: a ranking table is built to identify the channels which are available, based on the PU activity on each channel is used where the channels are ordered according to the PU activity. This channel hopping algorithm is implemented in MANETS where the delay is reduced in getting the free channel as compared to cognitive radio networks

The rest of this paper is organized as follows. In Section II we present our proposed method. In Section III, Channel Hopping Algorithm is discussed. Simulation is conducted in Section IV. We conclude our work in section V.

## II. PROPOSED METHOD

We consider the co-existence of PUs and CR users in the samegeographical area. PUs are licensed to use a fixed spectrum, which can be divided into a set *U*= *{*1, 2. . . *C}* of *C*nonoverlappingorthogonal channels. For simplicity, we assume that all channels have the same capacity. CR users can access licensed bands if they do not interfere with ongoing PU transmissions. To prevent interference to PUs from CR users, CR users should vacate the channel as soon as PU returns on its assigned channel. Therefore a ranking table as in isproposed where channels are ranked on the basis of PU activity detected on each channel. A node performs spectrum sensing periodically after a time out and the period of the sensing cycle is assumed to be equal to the sum of the sensing duration and the time out period. The sensing results are used to build a ranking table of the available channels based on the PU activity detected on each channel. Therefore, channels are ordered based on the PU activity. The channels are ranked from top to bottom. Towards bottom, PU occupied channels are placed whereas towards top free channels are placed. The process of making ranking table is summarized in Fig. 1. In Fig. 1(a), we have shown that periodic sensing capable of sensing spectrum opportunities using either energy detectors, cyclostationary feature extraction, pilot signals, or cooperative sensing is performed to get the information about the vacant channels and occupied channels. Fig. 1(b) shows the ranking table after getting results from periodic sensing. The metric to evaluate the reallocation mechanism i.e. to reallocate a channel to CR user is expected time (Texp) which is definedas the expected time of getting a free channel when a PU returns on its assigned channel. As we have ranked channels in a ranking table, the algorithm proposed here will decide the common hopping sequence for the CR users. We have divided the ranking table into two portions and set a threshold level at channel number C/2. Below it we have assumed that the probability of PUs activity is maximum and above it CR usersactivity is maximum (according to ranking table). The CH sequence that CR users will follow has to take this threshold level into consideration. Then we have set another level at channel number 3C/4 and assumed that the probability of CR users activity above it is maximum and below it is minimum. These two levels and assumptions are the foundation of the channel hopping algorithm. In the next section we will discuss the algorithm.

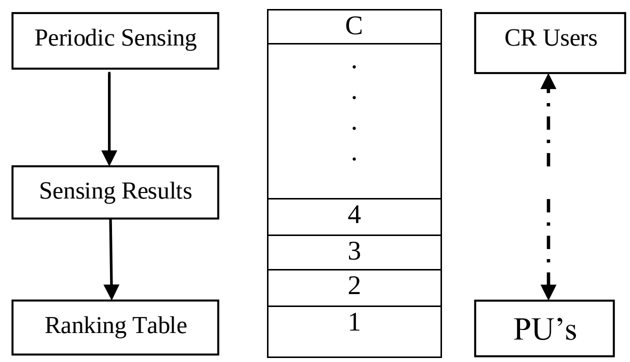
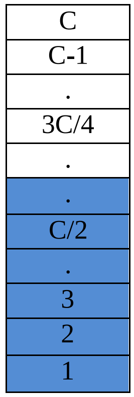


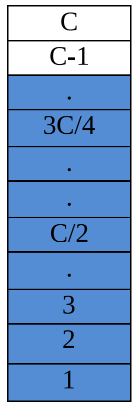

Fig. 1(a) Process of Ranking Table formation (b) Ranking Table

## III. CHANNEL HOPPING ALGORITHM

Channel sequence for the CR users to get a new vacant channelwill use the ranking table. The threshold level i.e. the channel number C/2 is the place where the CR users move eventually and starts hopping till the task of getting a vacant channel is accomplished. The basic idea is whenever a PU returns on its assigned channel, the CR users will move to channel number C/2 and starts hopping one by one upwards and sense whether the channel is occupied or not. If already occupied, they continue hopping till they find a vacant channel uptochannel number 3C/4. If a vacant channel is not found in this portion, they will start hopping downward from channel number C/2 in search of a vacant channel. Let the time taken to sense a channel about its occupancy is $\tau$ units, then to sense $m$ channels the time taken is $m\tau$units. According to how much time it will take by CR users to get a free channel, three cases could be possible. i) *Best case*: There is a probability that the CR users, at first instance finds the channel number C/2, the threshold level channel vacant, then immediately the channel would be assigned to the CR users and time taken is the least possible time, say τ0. ii) *Average case*: There is a probabilitythat the CR users will find a vacant channel in the interval from channel number C/2 to channel number 3C/4, hopping one by one and each hop takes




(a)

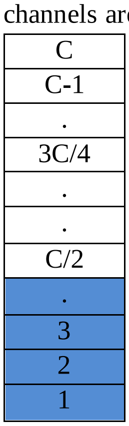



(b)

time τ units, then after hopping on *m* channels, CR users finds a vacant channel after *mτ*units of time. iii) *worst case*: There is a probability that the CR users will not find any vacant channel in the interval from channel number C/2 to 3C/4, then the CR users will have to hop one by one downwards

from channel number C/2 and if itfinds any vacant channel, then it will take it. After the next sensing interval, it will have to vacate the channel and again search for a vacant channel in the interval from C/2 to 3C/4 because there is always a higher probability that a PU request for its channel in that interval. We are assuming that CR users will find a vacant channel in the interval from channel number C/2 to 3C/4. The process is summarized in Fig. 2

The channel hopping algorithm is formally described in Fig. 2(b) where Cis the no. of channels, τ is the time to sense a channel and Texpis the expected time to get a vacant channel. In the Channel hopping Algorithm, failure i.e. CR users will not find any free channel occurs only when channels are occupied by PUs and it is obviously the case because PUs should always be on priority over CR users. Therefore we can again characterize the behavior of the CH algorithm based on PU activity for three cases.




*A. Low primary user traffic load*

As in the first step of the CH algorithm, a ranking table based on the PU activity is formed. It indicates the PU traffic and the amount of occupied channels out of total C channels by PUs. Based on the ranking table, if the number of occupied channels is less than 50%, i.e. the channels starting from channel number C/2 are all free, and then it will be considered as a low PU traffic load and is also the best case.

In this case, the CR users hopping in search for a vacant channel, immediately, without any delay would be assigned channel number C/2 and the time taken would be negligible, say τ0. An e.g. is shown in Fig. 3(a) wherein let CR users were initially using channel number C-1 and suddenly PU returns on this channel, then CR users will eventually move to channel number C/2 vacating the channel for PU. In Fig. 3(a, b and c), channels occupied by PUs are shown shaded.

Fig. 3 (a)Low PU traffic load (b) Medium PU traffic load (c) High PU traffic load

*B. Medium primary user traffic load*

If the number of PU occupied channels is more than 50% (C/2) but below 75% (3C/4), then it would be considered as a case of medium traffic load, where in CR users hopping in search of vacant channels would come to location C/2 first and then start hopping upwards one by one. Time taken to hop on one channel is taken as *τ* unit. After hc[illegible] on m channe[illegible] finds a vacant channel, it would r[illegible]o that vacan[illegible]el after Texp (expected time) units of time. An e.g. is shown in Fig. 3(b) where the dotted line indicates the hopping and as in previous example if initially CR users were on channel C-1 and if PU returns, it would start hopping from channel number C/2 upwards and move to a vacant channel.

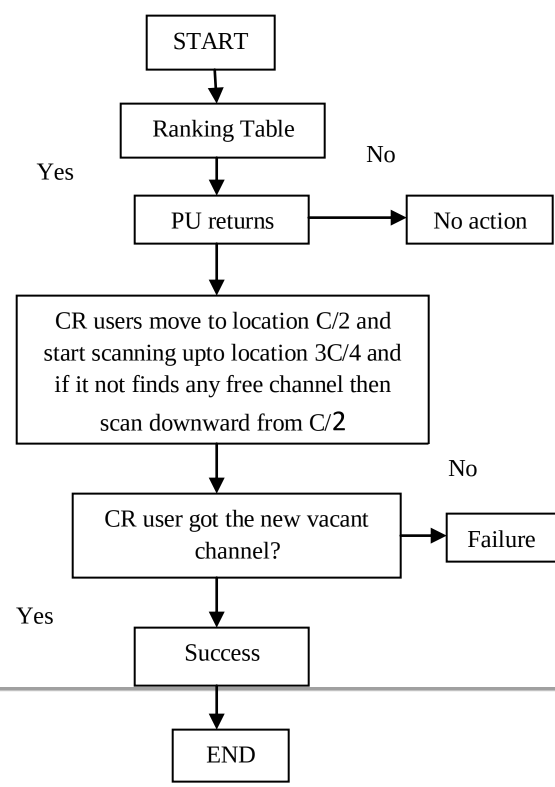


Fig. 2 Channel hopping algorithm

*C.High primary user traffic load*

If all the channels from channel number C/2 to 3C/4 in the ranking table are occupied by PUs, then there is obviously a very high PU traffic on the network. In this case, when CR users end up hopping upto channel number 3C/4(finds no vacant channel), then the CR users will start hopping downwards from channel number C/2 as there is a probability that some channels got vacant due to communication completion between PUs. While hopping downwardsif CR users finds a vacant channel, it would take it and in case if there is not any vacant channel, then CR users will have to stop hopping and this is a case of failure. While if CR users finds a vacant channel, and they occupies it. In the next cycle the CR users here will again start hopping from channel number C/2 to 3C/4 in search of a vacant channel because below C/2, probability of PUs return is very high. Fig. 3(c) shows the case when PU traffic is very high.

*D.Mobile ad hoc network*

A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers (and associated hosts) connected by wireless links - the union of which form a random topology. The routers are free to move randomly and organize themselves at random; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural or human- induced disasters, military conflicts, emergency medical situations etc

*MANET Connectivity Analysis*

In our considered MANET, a node *m* can communicate directly with other node say node *n*, only if the distance between the nodes *m* and *n* is less than the radio range of node *m*. if the distance between them is more than the radio range then they can communicate using intermediate nodes. A MANET is said to be connected only if the nodes in the network communicate with each other either directly or indirectly.

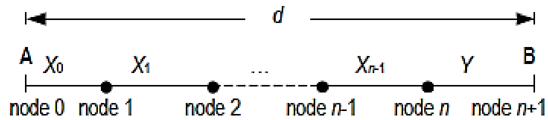



Fig.4One-dimensional MANET model.

We begin by defining node 0 to be node A, node 1 to be the node closest to the right side of node 0, node 2 to be the node closest to the right side of node 1, and so on (see Fig. 1). Let $Xi$be the random variable of the distance between node $i$ and node $i$+1, $i$=0,1,2,…,$n$–1, and $Y$ be the random variable of the distance between node $n$ and node B. Similar to the technique used in nodes A and B are connected only if $Xi \leq 1$, $i$=0,1,2,…,$n$–1 and $Y \leq 1$. Define $qn(k)$ to be the probability density function of $Xi$, $i$=0,1,2,…,$n$–1, that is, the distance between nodes $i$ and $i$+1 is $k$. A distance $k$ is formed between neighboring nodes $i$ and $i$+1 if node $i$ is placed at a particular location, say, $z$ away from mnode A, and all other nodes are placed outside the segment between $z$ and $z+k$. Due to the uniform placement of all intermediate nodes, ignoring the border effect, we get

$$q_n(k) = n\left(\frac{1}{d}\right)\left(1-\frac{k}{d}\right)^{n-1}, \quad 0 \leq k \leq d. \qquad (1)$$

IV. SIMULATION RESULTS

MATLAB is used to analyze the performance of our channel hopping algorithm, focusing in particular the expected time taken to get a free channel by CR users on return of PU on its assigned channel giving immediate priority to PUs over CR users. We assumed that in ranking table, the channels above channel number 3C/4 are reserved for rendezvous for CR users, although rendezvous between CR users is not an issue of this work. The number of available channels C is set in the beginning and does not change during the simulation time. The traffic for both the PU and CR user can be obtained after having the ranking table formed after a sensing cycle. The channels in the ranking table are placed according to sensing results and the amount of time of being occupied. The channels which are occupied for most of the time are placed at the bottom and we will consider the probability of channels of being occupied in simulation. As we have already described there might be three possible cases depending on the PU traffic load, here we have assumed the time taken to get a vacant channel in case of low PU traffic load is negligible, say $\tau 0$. Similarly, the time taken to get a free channel can be obtained by considering the probability that a free channel is available or not. As stated for medium PU traffic load, there is a probability that CR users hopping in search of a vacant channel immediately gets a channel above channel number C/2 or a channel just below channel number 3C/4. So, the time taken for getting a free channel depends on number of hops

Depending on the probability of channels of being occupied after a sensing cycle, we can calculate the expected time to find a vacant channel for the three cases described above by using the formula in (6.1). We have formulated the expected time to get a free channel in (6.1), taking in evidence the probability of each channel about its occupancy. Here we have taken the probability of success (getting a free channel) as *p* and probability of not getting a free channel as *q*. If channel number C/2 is free, then the expected time taken is $p(C/2)\tau$ where $p(C/2)$ is the probability that channel number C/2 is free and $\tau$ is the time taken to hop on one channel. Similarly, if channel number C/2 is not free, then it will hop one by one in search of a vacant channel and search till channel number 3C/4.

We can have expected time taken ($T_{exp.}$) to get a free or vacant channel by using (2). Moreover, for simplicity it is assumed that in case a CR user doesn't find a vacant channel, the CR user packet is dropped instead of being retransmitted i.e. the failure. It is assumed that collisions between CR user packets are ignored because the main aim of this paper is to show how efficiently CR users can detect the spectrum holes towards the PU activity. It is to be noted that our algorithm makes provision for CR users to move to some other vacant channel to make room for PUs as opposed to other schemes where the main concern is rendezvous. Sequence based rendezvous is proposed but no provision is there for PU return. These schemes have calculated the expected time to rendezvous (TTR) w.r.t number of channels as a measure of performance evaluation. Whereas, we are focusing in particular the expected time taken by CR users to get a free channel w.r.t number of hops making any rendezvous scheme robust to PU activity.

$$Expected\ Time = p\left(\frac{C}{2}\right).\tau + q\left(\frac{C}{2}\right).p\left(\frac{C}{2}+1\right).2\tau + q\left(\frac{C}{2}+\right.$$

$$1.pC2+2.3\tau ...+q3C4-1.p3C4.C4.\tau+q3C4.pC2-1.C4+1.\tau..$$

$$...+q(2).p(1).\frac{3C}{4}.\tau \qquad (2)$$

The significant parameters taken in the simulations are as follows: the duration of one hop $\tau$ = 1 unit, Number of channels C, expected time taken to get a free channel $T_{exp.}$ We can show the behavior of the channel hopping algorithm by taking an example. In the example to be followed, we have taken the total number of channels, *C* as 28 and we have assigned probability to each channel based on how much time it has been occupied

Let, for illustration, we have taken the values of probability of channels from bottom to top as follows:

(0.98, 0.97, 0.96, 0.94, 0.92, 0.90, 0.89, 0.86, 0.84, 0.83, 0.82,0.78, 0.72, 0.71, 0.70, 0.69, 0.67, 0.62, 0.60, 0.51, 0.49, 0.45, 0.42, 0.40, 0.37, 0.35, 0.20, 0.18)

The relationship between expected time to get a free channel and number of hops to geta free channel for the example we have taken is shown in Fig.5.As we have earlier defined, when PU traffic is low, the time taken to get a free channel is negligible as shown in Fig. (5) because the CR users doesn't need to hop in search of a vacant channel and as number of hops increases, the expected time to get a free channel increases. For the example that we have taken, the relationship between expected time and number of hops shows that the expected time is maximum when CR users doesn't find any vacant channel (hopping on all channels up to channel number 3C/4) and is calculated to be 97.88 units and the minimum expected time to get a free channel is 1.42 units. It is to be noted that we have calculated expected time to get a free channel for CR users i.e. the relocation time of CR users to some other vacant channel as opposed to time to rendezvous (TTR)in other schemes. There could be three possible cases as defined earlier i.e. best case when traffic is below 50%, average case when traffic is upto 75% and worst case when traffic is more than 75%. For the example we have taken, Fig. (6) shows the expected time to get a free channel for the three PU traffic load conditions.

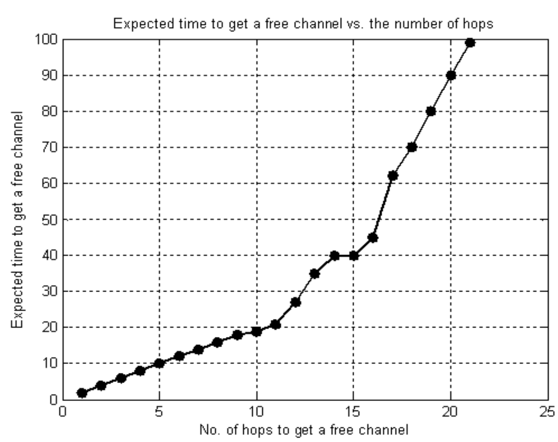



Fig.5 Expected time to get a free channel vs. the number of hops

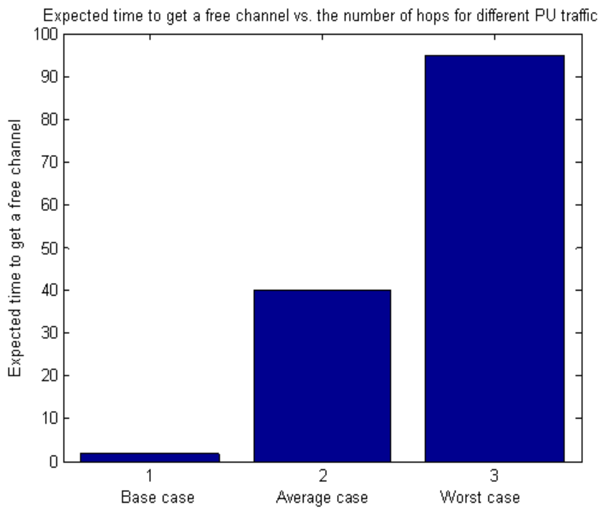



Fig. 6. Expected time to get a free channel vs. the number of hops fordifferent PU traffic

For the formation of MANET we have taken the parameters as: number of nodes as 100, environment size as 100 and transmission range as 15meters.After forming the MANET network, we implemented the channel hopping algorithm in that using the same parameters defined earlier, which reduces the delay in getting the free channel as compared to CRN which is shown in Fig. 7

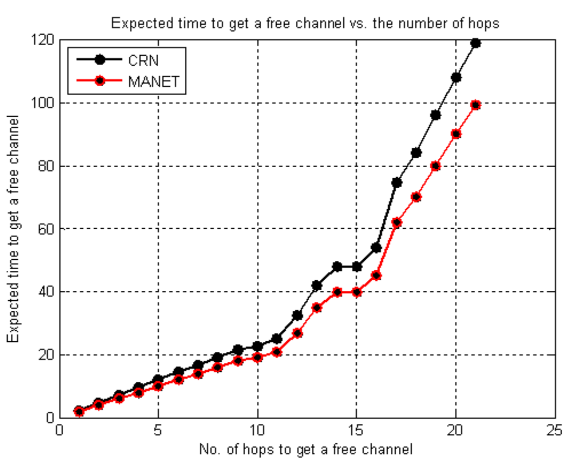



Fig.7Comparison of CRN and MANET Network

## V. CONCLUSION

In this paper, we proposed a channel hopping algorithm for CR users, whenever the PUs returns to its assigned channel then CR users should give the priority to PUs and the CR user should move to the other free channel in a least possible time. Using this algorithm, first we calculated the expected time to get the free channel in cognitive radio networks and then implemented the same algorithm in MANETS where the delay in getting the free channel is reduced as compared to CRNs because MANETS are infrastructure less networks.

Future study can be carried on including a provision for rendezvous of CR users as well which simultaneously can provide flexibility to PUs.

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