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# An Efficient Neighbor Discovery Approach using HTTA Sequence Based Channel Rendezvous in CRN

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**Abstract:- Cognitive Radio Network (CRN) is an intelligent radio that can be programmed and configured dynamically, Cognitive radio (CR) is a new emerging and challenging research area to improve spectral efficiency of wireless communication. A cognitive radio wireless sensor network is one of the postulant areas where cognitive techniques can be used for opportunistic spectrum access. Cognitive radio is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. Now a days ISM (Industrial, Scientific and Medical) band is going to be saturated due to increasing availability of wireless device such as mobile, laptop, notebook, pump top. However, in CRN, improve the channel usability by optimistic spectrum access into licensed bands by the secondary users at the absence of primary user. In CRN, channel rendezvous amongst the secondary users to discover the neighbor is the main challenge. A large number of existing works propose overcome this challenge using pseudo random channel hoping (i.e, switching channel from one to other) sequence. However, we dispute that pseudo random sequence cannot provide proficient channel rendezvous in many scenarios and sometimes even the secondary users do not find out their neighbors. Hence in this paper, we propose a channel hoping method using *Heap Tree Traversing Algorithm* (HTTA) for multi-channel rendezvous amongst the secondary users of CRN. We have analyzed and implemented the proposed mechanism, and found that it provides better results in terms of the number of iteration and success rate for channel rendezvous then the pseudo random approach.**

***Keywords:-*** Cognitive Radio (CR); Primary User (PU); Secondary User (SU); Pseudo Random; Heap Tree.

## I. INTRODUCTION

Now a days wireless communication have changed the traditions and the living style of People, and the demand for wireless communication with high speeds and global connectivity continues to increase. Currently the number of different wireless device rapidly increasing day by day, because of different wireless networks, for example, cellular networks and wireless local area networks, are in place to support mobile services but still new emerging applications require more support to meet communication requirements. The increasing demand for wireless connectivity has shifted the attention and efforts of many researches all over the world towards the opportunistic dynamic spectrum access paradigm. This concept is not new, and was first introduce in 1995. In brief, the idea is that licensed spectrum can be made accessible to secondary user (unlicensed user) when the primary user (licensed user) is absent. Cognitive radio network have emerged in response to the demand of these emerging applications as one form of several new wireless networks [2]. The definition of Cognitive Radio Networks (CRN) is different from the conventional wireless networks [3]. The Cognitive Radio (CR) concept is introduced because of the bandwidth saturation of ISM (Industrial, Scientific and Medical) band [4] for increasing the large number of wireless devices in different networks (i.e., Bluetooth, WLAN (Wireless Local Area Networks), WSM (Wireless Sensor Network), WBAN (Wireless Body Area Network), WMN ( Wireless Mesh Network )). In CR networks they have two types of users ***Primary User*** (PU), who is the owner of licensed band; and ***Secondary User*** (SU), user of ISM band and allowed to use free portions of the licensed spectrum or idle channels without causing any interference to primary user [6].

In CRN, if a pairs of SUs wishes to communicate with each other, they need to rendezvous on the same channel that is available to both of them, and exchange control information, such as request-to-send (RTS) / clear-to-send (CTS) packets of the distributed coordination function (DCF) of IEEE 802.11 [5]. Since the SUs may operate on different channels independently, which arise to the rendezvous problem of CR networks.

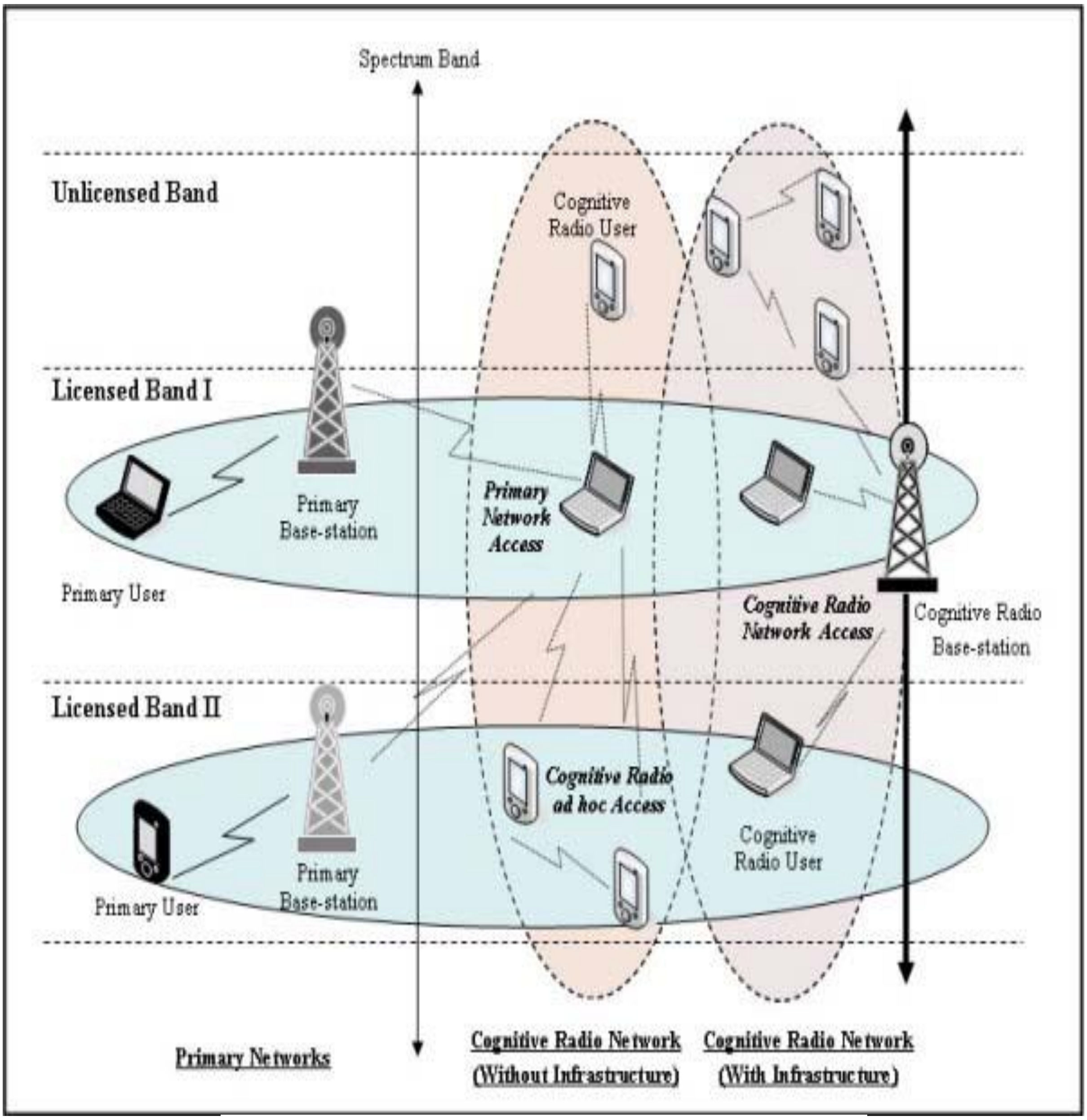

Fig. 1: Cognitive Radio Networks with primary and secondary user

Note that this problem is more challenging issue in CR ad hoc networks [6]. In Fig 2, we show the pairs of SUs a and b, p and q, x and y, opportunistically make channel rendezvous on Ch-2 and Ch-4, where no primary user exist. Note that Ch-1 and Ch-3 is occupied by the primary user, so that SUs do not have any activity on those channel. Currently there are three well known approaches to enable a rendezvous in CR ad hoc networks: 1) Using a ***dedicated common control channel*** approach (CCC), 2) Using a ***channel hopping sequence*** approach, and 3) Using ***message broadcasting*** approach.

Different approaches exist earlier for channel rendezvous between two cognitive user (Secondary User) in CR networks, The *message broadcasting* approach [7] increases message flooding and delay time to discovering its neighbors. The *common control channel* [CCC] approach for channel rendezvous [8] introduce the control channel saturation problem. Finally the *channel hoping using pseudo random sequence* approach [9], if two SUs follow the mutually exclusive sequence to discover each other after lots of iterations or may not succeed. Consider the limitation of above mentioned on different channel rendezvous approach, were motivated to design an efficient channel hoping sequence using ***Heap Tree Traversing Algorithm*** (HTTA) principle for making channel rendezvous between two cognitive user and their neighbor discovery well.

The rest of this paper is organized as follows. The background study and problem statement of existing protocols in section II. Section III present the overview of Heap Tree and Traversing Algorithm and describes the system model and operation of proposed approach. Performance analysis of the proposed method is performed in section IV and finally, section V Summarizes and future task of this paper.

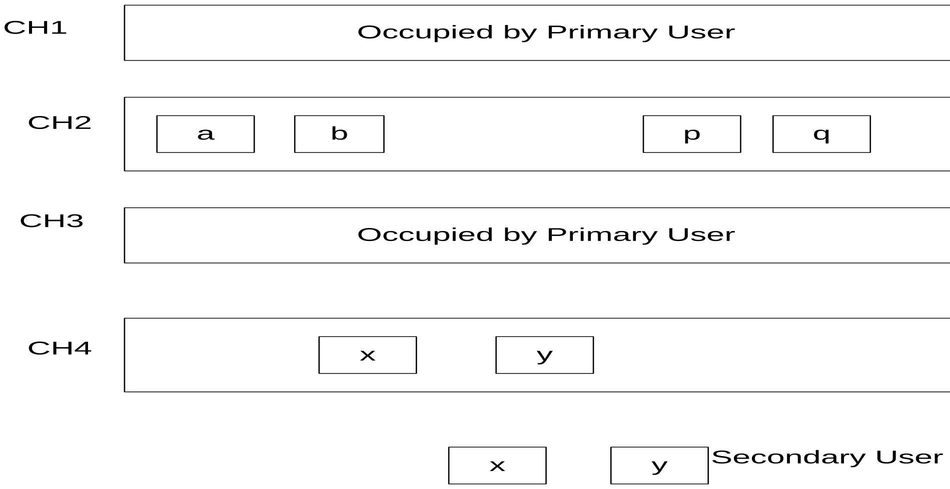


Fig.2: Primary and Secondary user operates on different channel at any given time on CRN

## II. BACKGROUND STUDY OF PROBLEM STATEMENT AND MOTIVITION

Many works to solve the rendezvous problem and we describe these existing solution into three major groups, based on their operation. A**.** *Message Broadcasting* Procedure [7], B**.** *Common Control Channel* (CCC) Mechanism [8], C**.** *Channel Hopping* using Pseudo Random Sequence [9].

### *A. Message Broadcasting Procedure*

Message broadcasting procedure, to find neighbors in CR networks a secondary user broadcast a control message to its neighbors and every nodes those get that message repeatedly broadcast the same information over multiple channels [7]. As a result

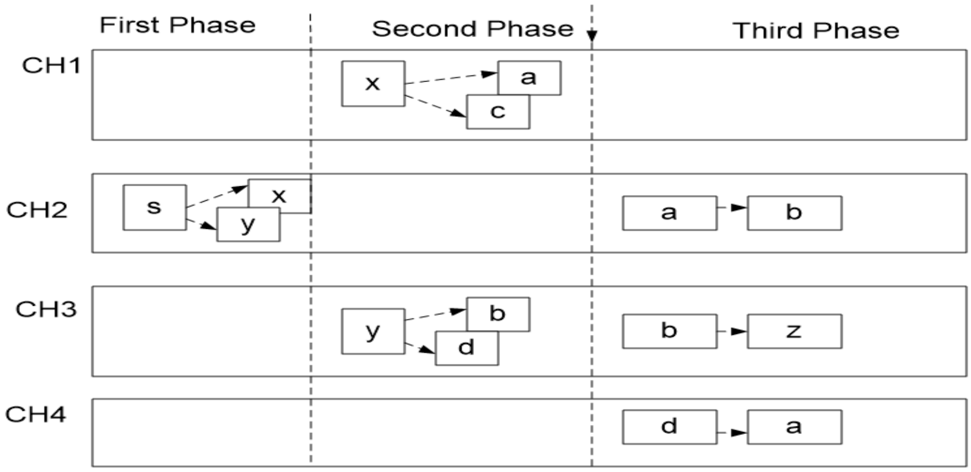


Fig. 3: Procedure of message broadcasting

All the secondary nodes in the CR networks received this control message and make a rendezvous with initial node. As shown in Figure 3, in first phase node s (initial) broadcast control message to its neighbors x and y in channel-2, in second phase node x and y repeatedly broadcast the same message a, c and b, d in channel-1 and 3, finally in phase 3, destination node d rendezvous the initial node s in channel-4. However, frequently channel switching, message broadcasting increases message flooding and incurs large delay in discovering its neighbors.

### *B. Common Control Channel (CCC) Approach*

In CCC approach, one of the available channel is assigned as the CCC or rendezvous channel [5], [7]. All the necessary control information is exchanged among the cognitive users via the CCC. In this approach, time is divided into two intervals – control interval or negotiation and data interval. When a node (SU) wants to initiate communication, it first switch to the rendezvous channel (CCC) during the control interval, and attempts to negotiate with intended receiver. After negotiating on the CCC, data communication can be performed during the data interval via available channels known as data channels. In Fig. 4, show the operation of CRN using CCC; here, channel 1 is occupied by primary user, and channel 2 is assigned as CCC, and the rest are dedicated for data communications.

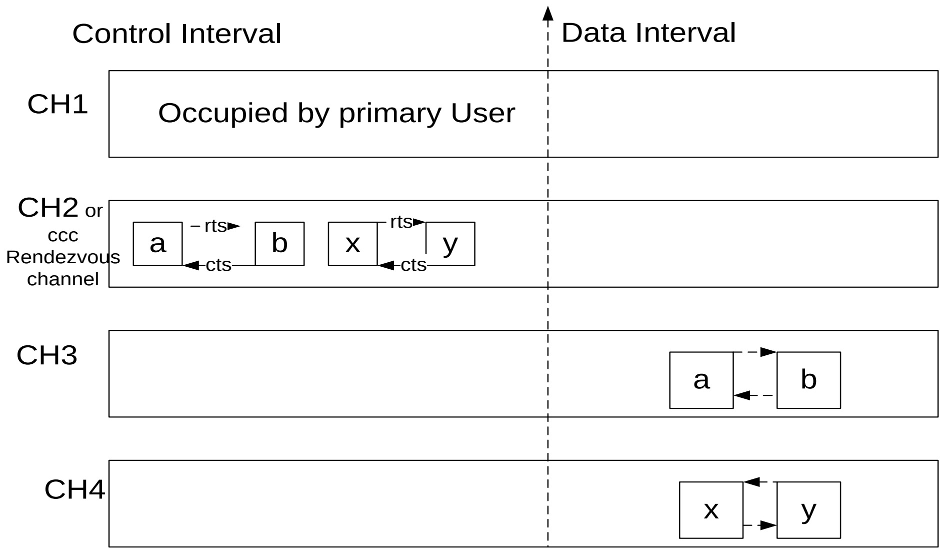


Fig. 4: The basic procedure of channel rendezvous and negotiation for data communication using common control channel (CCC).

Obviously CCC mechanism is simple and efficient of CRN, yet it has some drawbacks, lack of CCC availability this is the main drawback of using CCC approach. When a PU appears on a CCC, then all Sus must break their transmissions and vacate the channel immediately. Another is control channel saturation problem, when the number of user in the network is increase, and all user use only one channel for negotiation then obviously decrease the overall throughput of the network.

*C. Channel Hoping using Pseudo Random Sequence*

The third famous approach to simplify the rendezvous problem in CR networks by using sequenced-based protocols men's *channel hoping using pseudo random sequence* [9]. In channel hoping approach [9], every SUs generates a pseudo random sequence. When an SU (sender) wants to initiate communication with its neighbor (receiver), its switches from one channel to another, by following a predefined hoping sequence, until it finds its neighbor. When both sender and receiver meet on a common channel, they need to exchange necessary control information to complete rendezvous.

| No. of Ite.→ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SU↓ | Channel ID | | | | | | | | | | | |
| x | 1 | 3 | 5 | 7\| | 1 | 3 | 5 | 7\| | 1 | 3↓ | 5 | 7\| |
| y | 3 | 5 | 7\| | 3 | 5 | 7\| | 3 | 5 | 7\| | 3↑ | 5 | 7 |

Fig. 5: A basic operation of channel hoping approach using pseudo random sequence

As shown in Figure 5, SU x have four available channels namely, 1, 3, 5, and 7; and channel 3, 5 and 7 are available to y, possible pseudo random sequence of x and y is 1-3-5-7 and 3-5-7 with a cycle length of 4 and 3. Although x and y have three common channels (3, 5, 7), there have needed minimum ten iterations for rendezvous on channel 3. A large number of iterations are required for channel rendezvous, if we use pseudo random channel hopping sequence. If sender and receiver follow the mutually exclusive pseudo random sequence, a lots of iterations are required, neighbor discovery of Sus or may not be succeed.

Consider the limitations of different channel rendezvous approach mentioned above, in this paper we have proposed a channel hoping sequence based on Heap *Tree Traversing Algorithm* (HTTA). The proposed method makes a pattern which can form the sequence having a length of (3n) where n is the number of available channels. Though appropriate simulations and implementations of proposed mechanism, we have found the better solution and less number of iterations for Sus channel rendezvous.

## III. DISCRIVE THE SYSTEM MODEL AND (HTTA) BASED CHANNEL HOPING AND RENDEZVOUS

*A. What is Heap Tree?*

A binary heap is a complete binary tree which satisfies the heap ordering property. The ordering can be one of two types:

- **Max-Heap**: A max heap is a complete binary tree in which the value in each internal node is greater than or equal to the values in the children of that node. Example: Suppose we want to build a Max-Heap tree from the following list of the number: 3, 2, 5, 4, 7, 8

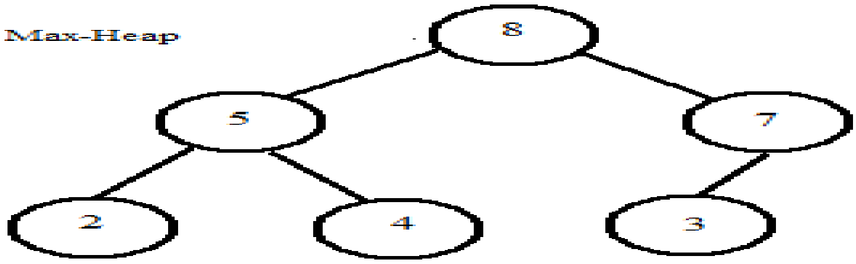

Fig. 6: Max-heap for following list of number

- **Min- Heap**: A min heap is a complete binary tree in which the value in each internal node is less than or equal to the values in the children of that node.

Construct a Min-Heap Tree for Example.

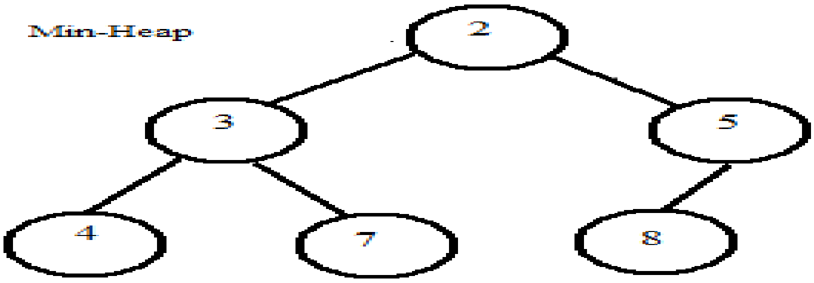

Fig. 7 max-heap for following list of number

In a heap tree the highest or lowest priority element is always stored at the root, hence the name "heap". A heap is not a sorted structure and can be regarded as partially ordered.

*B. How Binary Tree Traversing?*

There are three standard ways of traversing a binary tree, this three algorithms called Pre-order, In-order and Post-order, are as follows:

➢ *Pre-order:*
- Process the root R
- Travers the left sub tree of R
- Travers the right sub tree of R

Pre-order traversal sequence for (Fig.6) is: 8-5-2-4-7-3 and for (Fig.7) is: 2-3-4-7-5-8

➢ *In-order:*
- Travers the left sub tree of R
- Process the root R
- Travers the right sub tree of R

In-order traversal sequence for (Fig.6) is: 2-5-4-8-3-7 and for (Fig.7) is: 4-3-7-2-8-5

➢ *Post-order:*
- Travers the left sub tree of R
- Travers the right sub tree of R
- Process the root R

Post-order traversal sequence for (Fig.6) is: 2-4-5-3-7-8 and for (Fig.7) is: 4-7-3-8-5-2

*C. Proposed Channel Hoping Sequence using HTTA*

In this paper, we assume the node of the heap tree as the available channels to the Sus of CR networks. It means that the number of nodes is equal to the number of available channel, denoted by n. Furthermore, the smaller numbered of channel is considered to be the smallest node and larger number of channel is considered to be the highest node, and so on. Therefore, the traversing sequence that we get using HTTA will actually provide a channel hoping sequence for the SUs.

➢ *Condition for Generating a Sequence:*
- At first construct a Heap Tree (Max or Min) by use the available channels of Sus.
- Secondly travers the Tree sequentially in Pre-order, In-order and Post-order.
- Each Traversing sequence is must be equal to the number of available channels.
- And finally all traversing sequence add and store the sequentially (pre – In – Post) order, this sequence is equal to the 3n.

Length of the hoping sequence is depends on the number of available channels, let us n=3, the HTTA hoping sequence will form a cycle having a length of nine (i.e., 3n). Based on the example of Fig.6 number of available channel (node) is 6 (3, 2, 5, 4, 7 and 8) then HTTA provides the channel hopping sequence (pre order – in order – post order) as 8-5-2-4-7-3-2-5-4-8-3-7-2-4-5-3-7-8 having a cycle length of eighteen.

Show the relation table between the number of available channels and length of cycle of HTTA sequence.

| Available channel (n) | Length of Cycle (3n) |
|---|---|
| 2 | (3*2) = 6 |
| 3 | (3*3) = 9 |
| 4 | (3*4) = 12 |
| 5 | (3*5) = 15 |

Table 1: Length of cycle of HTTA sequence with respect to the number of available channels

*D. Comparative Analysis between HTTA based Sequence and Pseudo Random Sequence.*

➢ *Pseudo Random Sequence:*

Suppose a secondary user (sender) S has four available channels (1, 3, 5 and 7) and receiver R has three available channels (3, 5 and 7). So, channel 3, 5 and 7 is common between S and R. If S and R maintain the pseudo random sequence of Fig. 8, rendezvous between S and R on Ch-5 in eleventh iterations.

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 1 | 3 | 5 | 7 | 1 | 3 | 5 | 7 | 1 | 3 | 5 | 7 |
| R | 3 | 5 | 7 | 3 | 5 | 7 | 3 | 5 | 7 | 3 | 5 | 7 |

Fig. 8: Pseudo random hoping sequence for S and R, rendezvous on channel (Ch-3) in eleventh iteration

➢ *Proposed HTTA Sequence:*

Let us consider the similar scenario as described in section D-1 generate the proposed HTTA sequence as in Fig. 9 and 9-1. The sender S has four available channels (1, 3, 5 and 7) and the HTTA sequence for Min-Heap is 1-3-7-5-7-3-1-5-7-3-5-1 (for Max-Heap sequence is: 7-5-1-3-1-5-7-3-1-5-3-7) with a cycle length of twelve. In contrast, R has three channels (3, 5 and 7) with a HTTA sequence for Min-Heap is: 3-5-7-5-3-7-5-7-3 (for Max-Heap sequence is: 7-3-5-3-7-5-3-5-7) having a cycle length of nine. We see, the Fig. 9 and 9-1 for use HTTA based method, channel rendezvous between S and R occurs in third and first iterations.

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 1 | 3 | 7 | 5 | 7 | 3 | 1 | 5 | 7 | 3 | 5 | 1 |
| R | 3 | 5 | 7 | 5 | 3 | 7 | 5 | 7 | 3 | 3 | 5 | 7 |

Fig. 9: Rendezvous on Ch-7 in third iteration of Proposed HTTA based sequence (for Min-Heap).

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 7 | 5 | 1 | 3 | 1 | 5 | 7 | 3 | 1 | 5 | 3 | 7 |
| R | 7 | 3 | 5 | 3 | 7 | 5 | 3 | 5 | 7 | 7 | 3 | 5 |

Fig. 9-1 Rendezvous on Ch-7 in first iteration of proposed HTTA based sequence method (for Max-Heap).

*E. Adjust The Sequence of Channel By Shifting.*

We observed that the proposed HTTA based channel rendezvous scheme might not provide channel rendezvous in few random cases shown in Fig. 11 and 11-1. The two SU S and R have four available channels 1, 3, 2, 5 and 3, 4, 6, 7. So, Ch-3 is common between S and R. Although S and R maintain the HTTA based sequence (show in Fig.11 and 11-1), but after twelve iterations, no possibility of channel rendezvous between S and R occurs.

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 1 | 3 | 5 | 2 | 5 | 3 | 1 | 2 | 5 | 3 | 2 | 1 |
| R | 3 | 4 | 7 | 6 | 7 | 4 | 3 | 6 | 7 | 4 | 6 | 3 |

Fig. 11: Channel rendezvous does not occur on Ch-3 even after twelve iterations for HTTA based channel sequence (for Min-Heap)

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 5 | 3 | 1 | 2 | 1 | 3 | 5 | 2 | 1 | 3 | 2 | 5 |
| R | 7 | 6 | 3 | 4 | 3 | 6 | 7 | 4 | 3 | 6 | 4 | 7 |

Fig. 11-1 Channel rendezvous does not occur on Ch-3 even after twelve iterations for HTTA based channel sequence (for Max-Heap)

In such scenario, the secondary user S and R will never make channel rendezvous. However, to solve the problem, we have added an adaptive module. called *Channel Sequence Shifting*. In the adaptive module, if any SU is not able to make channel rendezvous for several iterations, it would guess that the generated HTTA based sequence is not allowing it to make channel rendezvous with other SU. Therefore, considering the original HTTA based sequence as an origin, it will make a 1-bit *right-shift* or *left-shift* in its channel sequence [1]. However, even after 1-bit *right-shift*, if channel rendezvous does not occur, then the node will make 1-bit *left-shift* in its channel sequence or Vic versa from the origin. As shown in Fig. 12 and 12-1, 1-bit *right-shift* and *left-shift* in the given scenario (of Fig. 11 and 11-1) and channel rendezvous occurs due to *Adjust the Sequence of channel By Shifting*.

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 1 | 3 | 5 | 2 | 5 | 3 | 1 | 2 | 5 | 3 | 2 | 1 |
| R | 3 | 3 | 4 | 7 | 6 | 7 | 4 | 3 | 6 | 7 | 4 | 6 |

Fig. 12: Channel sequence shifting (*right-shift*) by R, where channel rendezvous on channel (Ch-3) on second iteration

| SU | Number of Iteration | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| S | 5 | 3 | 1 | 2 | 1 | 3 | 5 | 2 | 1 | 3 | 2 | 5 |
| R | 6 | 3 | 4 | 3 | 6 | 7 | 4 | 3 | 6 | 4 | 7 | 7 |

Fig.12-1 Channel sequence shifting (*left-shift*) by R, where channel rendezvous on channel (Ch-3) on second iteration.

## IV. PERFORMANCE EVALUATION

We have analyzed the performance of the proposed HTTA based channel hoping sequence, where the results are evaluated and compared with the existing pseudo random channel hoping sequence approach. Analysis were done in C/C++ compiler (codeblocks-10.05) in a PC having Windows 8.1 64-bit OS, Intel© Pentium© CPU B950 @ 2.10GHz Processor, and 2 GB RAM.

Table 2 explain the results of the number of iterations required for channel rendezvous using pseudo random and proposed HTTA based sequence. In this case, we have considered tow seconder user S (Sender) and R (Receiver). The sender is considered to have different number of available channels: two (Ch-1 and Ch-3), three (Ch-2, Ch-3 and Ch-5), four (Ch-1, Ch-3, Ch-4 and Ch-6), five (Ch-1, Ch-3, Ch-2, Ch-5 and Ch-7) and so on. Hear, the available channels assumed for experimental purpose. At the same case receiver side is considered to have different number of channels: two (Ch-3 and Ch-8), three (Ch-3, Ch-8 and Ch-9), four (Ch-3, Ch-9, Ch-10 and Ch-11) and five (Ch-3, Ch-8, Ch-10, Ch-11 and Ch-12). Hear, at least one common channel is considered between sender and receiver for making a successful channel rendezvous.

In Table 2 maximum 60 are shown for pseudo random sequence though in some cases, channel rendezvous does not occur within that limit and the results beyond that are bounded within 60 iterations. However, proposed HTTA based sequence makes successful channel rendezvous within less number of iterations.

### *A. Comparison The Number of Iterations*

The final result are shown in Table 2, where show the number of required iterations to makes a successful channel rendezvous for both pseudo random sequence and proposed HTTA based sequence. The numerical result of number of iterations can be plotted as Fig. 13, where the HTTA based sequence always gives better result than pseudo random sequence. However, pseudo random sequence scheme on average performs well when the number of channels for receiver is 4, some cases pseudo random sequence create an infinite loop where don't occurred rendezvous. Only one case both method gives the same result.

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| Number of Channels for Sender | Number of Available Channels for Receiver | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | | 3 | | 4 | | 5 | |
| | Pseudo Random Sequence | Proposed HTTA Sequence | Pseudo Random Sequence | Proposed HTTA Sequence | Pseudo Random Sequence | Proposed HTTA Sequence | Pseudo Random Sequence | Proposed HTTA Sequence |
| 2 | 60 | 8 | 4 | 5 | 60 | 8 | 6 | 9 |
| 3 | 5 | 4 | 60 | 11 | 5 | 7 | 11 | 16 |
| 4 | 60 | 6 | 10 | 10 | 60 | 14 | 6 | 17 |
| 5 | 7 | 7 | 7 | 15 | 17 | 7 | 60 | 17 |

Table 2: Comparison between Pseudo Random Sequence and HTTA based Sequence channel rendezvous

*B. Presents the Numerical Analysis*

Show the result of numerical analysis (in Fig. 13) by a chart to illustrate and comparison of number of iterations required for channel rendezvous with respect to Table 2.

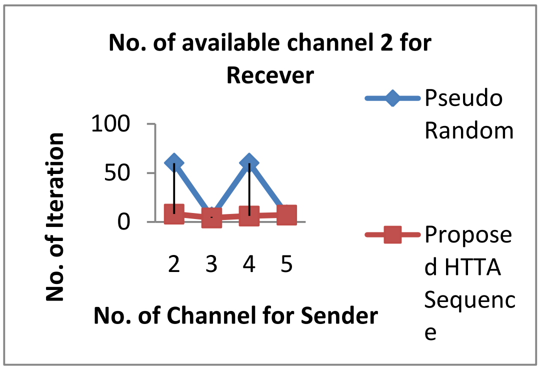


Fig. 13(a) Comparison of the number of iterations required for channel rendezvous, when available channels for receiver is 2.

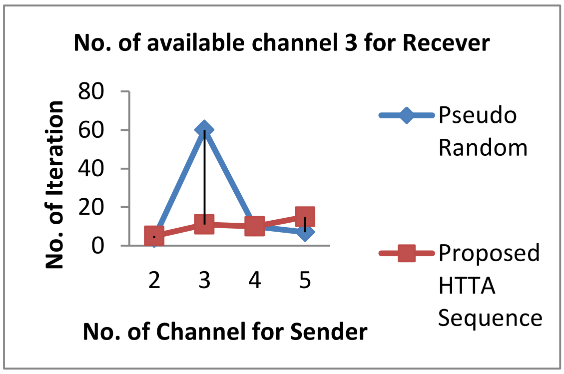


Fig. 13(b) Comparison of the number of iterations required for channel rendezvous, when available channels for receiver is 3.

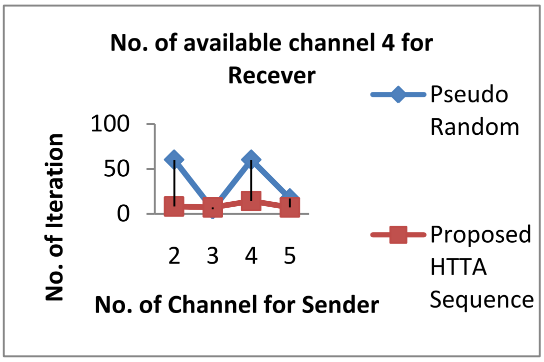


Fig. 13© Comparison of the number of iterations required for channel rendezvous, when available channels for receiver is 4.

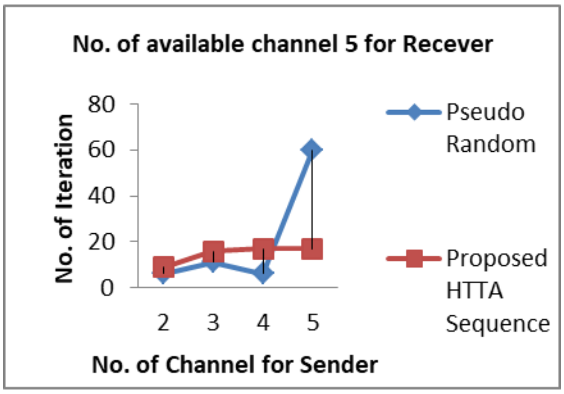


Fig. 13(d) Comparison of the number of iterations required for channel rendezvous, when available channels for receiver is 5.

*C. Comparison of success Rate*

To compare the performance of *Pseudo Random Sequence* and Proposed *HTTA based Sequence*, maximum 60 iterations are assumed to have a success rate of 0% and 0 iteration equals to a success rate of 100%. As shown in Fig. 14, Proposed *HTTA* based approach given higher success rate than that of *Pseudo Random Sequence* based approach.

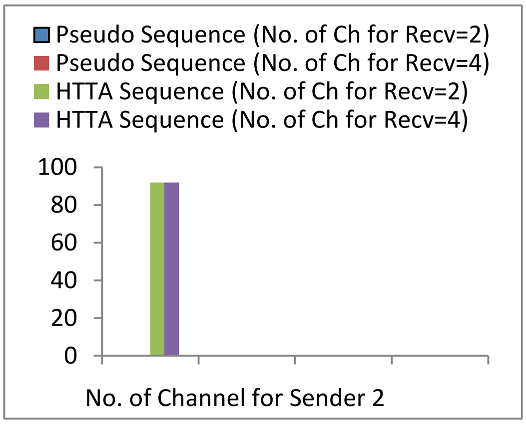


Fig. 14(a) Comparison of success rates of channel rendezvous for available channels of sender is (2) and receiver is (2 and 4)

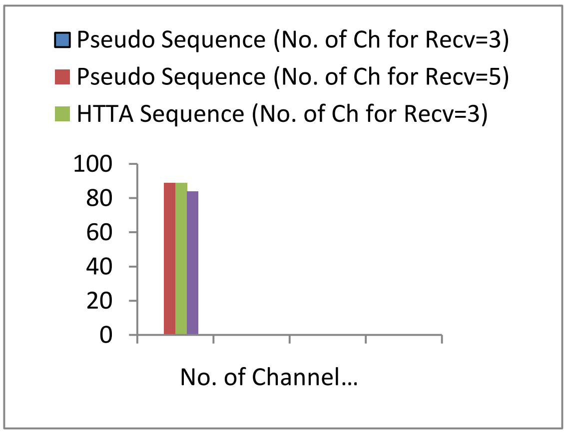


Fig. 14(b) Comparison of success rates of channel rendezvous for available channels of sender is (4) and receiver is (2 and 4).

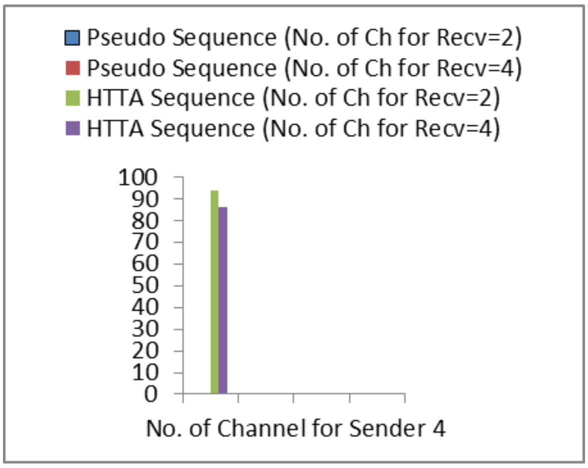


Fig. 14(c) Comparison of success rates of channel rendezvous for available channels of sender is (3) and receiver is (3 and 5)

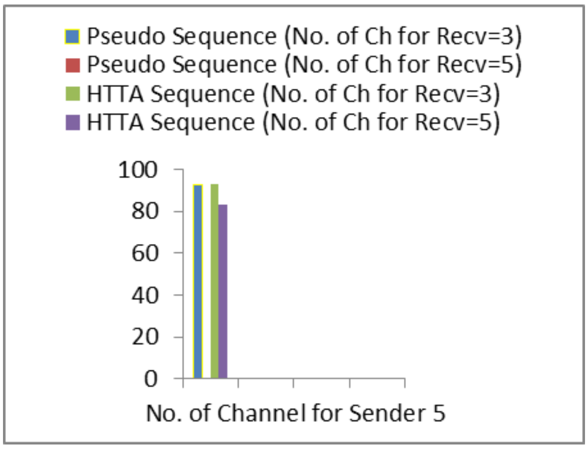


Fig. 14(d) Comparison of success rates of channel rendezvous for available channels of sender is (5) and receiver is (3 and 5).

## V. SUMMARIZES AND FUTURE TASK

We have proposed a channel rendezvous mechanism for secondary user's neighbor discovery in CR Networks. The proposed approach that uses *Heap Tree Traversing Algorithm (HTTA)* mechanism to drive the channel hoping sequence for the SUs. It provides less number of iterations for channel rendezvous with a better success rate than that of existing pseudo random based approach. In future, we developed the proposed approach toward a complete medium access solution for Cognitive Radio Network.

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