# Receiver Initiated Dynamic Multiple Common Control Channel Design (RI-DMCCD) Protocol for Cognitive Radio Network

Amran Hossain, Saiful Islam, Sujan Baura, Md.Arifur Rahman Noyon, Sahelee Sultana

**Abstract**— Now-a-days in wireless communication, Cognitive Radio Network (CRN) is hot topics for researchers, in where thinking is updated day by day for the future use. The CRN is a way to improve the spectral efficiency of wireless communication. In CRN secondary users in different channels can access the licensed channels at the absence of primry user and use the available channels for transmitting data to another user. As a result a CRN faces many challenges to successful channel rendezvous amongest the secondary users, maximize throughput and minimize rendezvous delay. A large number of methodologies have been proposed to solve channel rendezvous problem in CRN. But this is not efficient to handle such types of problems. However, in this paper a Receiver Initiative Dynamic Multiple Common Control Channel Design mechanism named as RI-DMCCD have been proposed to handle PUs efficiently and make a channel rendezvous successfully. Furthermore, we have analyzed the proposed mechanism and implemented through simulation and found better performance in terms of different performance metrics.

**Index Terms**— Cognitive Radio Network, Primary User, Rendezvious, Secondary User, Throughput, Wireless Spectrum

## 1 INTRODUCTION

COGNITIVE radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and promptly move into vacant channels while avoiding occupied ones. In Cognitive Radio Networks (CRNs), channel rendezvous scheduling is a crucial task, where the Secondary Users (SUs) operate on available channels which are dynamically changing according to the Primary Users (PUs) activities. The CRN is constructed with licensed users which are known as PUs that use the specific licensed channels and Cognitive users which are known as SUs that try to utilize the channels. The motto of CRN technology is to allow the SUs to access the licensed channels without any harmful interference of the PUs operations [1]. In general, SUs detect the free or idle portions of a channel and access the channel. When the PU appears on the channel that is currently used by SUs, all SUs must defer their transmissions and migrate to other available channels. Channel availability is determined by PU activities, which change dynamically in frequency, space and time; therefore, the set of available channels for each SU might also change dynamically [2]. Thus, at a given time, SUs may operate on different channels independently [3]. The frequency bands that are licensed by the PUs are not completely used or properly utilized i.e. sometimes the licensed bands are free or idle.



This free portion of the spectrum is known as opportunistic spectrum. A CR is a type of radio that is made in such a way that it can automatically sense the channel of its surroundings that these channels are either blocked by the PU or not.The CR can use this opportunistic spectrum without any collision. In CRN, the licensed users are called primary users such as cellular network; TVs, Radio channels, wireless microphones etc and the unlicensed users may be laptop, smart phone, wireless devices, Wi-fi, those are working with the help of opportunistic spectrum of PUs. In Fig. 1[1] is illustrated as simple CRN architecture. At the present time, CRN is a contemporary research area in the field of wireless communication.

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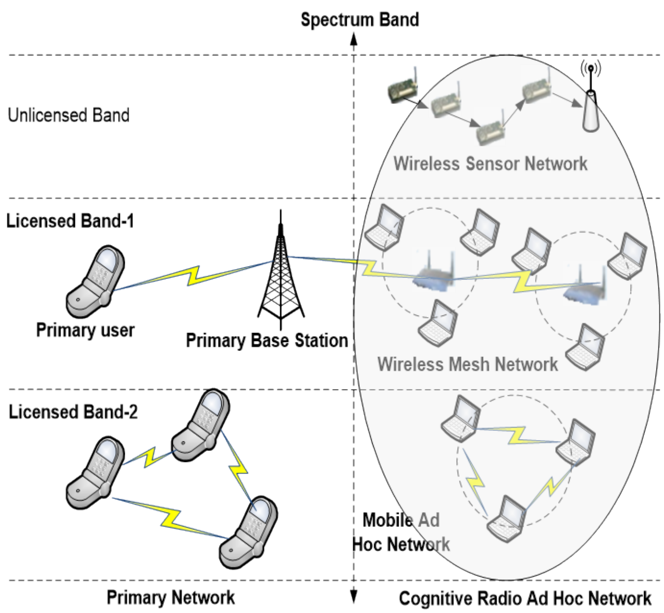


Fig. 1. A CRN architecture

In CRN, SUs are allowed to exploit free of licensed channels without any destructive interference to PUs [4]. In CRN, if two SUs want to interconnect, both should active on at least one common channel. Consequently, both the SUs can determine each other, conversation control message and then complete data communication. Since, SUs operates on dissimilar channels founded on their channel accessibility, so channel rendezvous is the main challenging issue in CRN.

It is observed that most critical part of CRN is to design an efficient MAC protocol considering channel rendezvous problem and protocol overhead. However, in CRN, it is perceived that, there are different protocols exist for channel rendezvous between two SUs. *Firstly*, in Common Control Channel (CCC) approach [5], [6], [7], a dedicated channel is consider as CCC. So CCC may be occupied by PU at any time. Furthermore, probability of collision, decrease the channel rendezvous rate and bottleneck situation may occurred. *Secondly*, in Channel Hopping approach [8], both SUs are used channel hopping sequence as their channel availability and complete communication mutually. For this reason, in this approach increase rendezvous delay and uncertinity of communication may be occurred due to the hop sequences of both SUs does not match although few channels are commaon to all. *Thirdly*, in Effiecient Recovery Control Channel Design approach [9], each SU broadcast a beacon to make pair and happen rendezvous between two SUs and complete data transmission using synchronization technique. However, in this approach, synchronization overhead may increased and it may need a long time that may degrade the communication performance.

As a whole our proposed work makes the following contributions:

1. Design a new MAC protocol to rendezvous between two SUs using even and odd sequence based mechanism considering the all the channels of the list.
2. Synchronization overhead is avoided due to the asynchronous channel rendezvous property of the proposed protocol.
3. Stable and Adaptive solution is provided considering the dynamicity of channel availability with respect PUs occupied channels.
4. Target to maximize throughput, minimizes channel rendezvous time and maximize channel rendezvous rate.

The rest of the paper is structured as follows: in Section 2 the background study and problem statements are presented. Section 3 describes the proposed MAC operation and performance evaluation is illustrated in Section 4 and Section 5 concludes the paper.

## 2 Background Study and Problem Statements

We have studied various existing protocols about cognitive radio network and analyzed their pros and cons. In this section we have categorized a number of MAC protocols those have been proposed for CRNs to solve the channel rendezvous problems as follows: Common Control Channel Approach [5], [6], [7], Channel Hopping Approach [8] and Efficient Control Channel Design Approach [9].

### 2.1 Common Control Channel (CCC) Approach

In the CCC [5], [6], [7] approach, select a dedicated channel as rendezvous channel from channel list, which is used as CCC [5]. Here time is divided into two interval one is as *control/ negotiation interval* and another is *data interval*. During negotiation interval SU complete their negotiation and choose a channel as data communication which is available both of them. After negotiating, SUs complete their data transmission during data interval. Fig. 2 illustrated the operation of a CCC approach. However, in this approach, uses only one channel as CCC, so CCC may be occupied by PU at any time and may increased *channel availability* problem. Furthermore, probability of collision, decrease the channel rendezvous rate and bottleneck situation may occurred in this scenario.

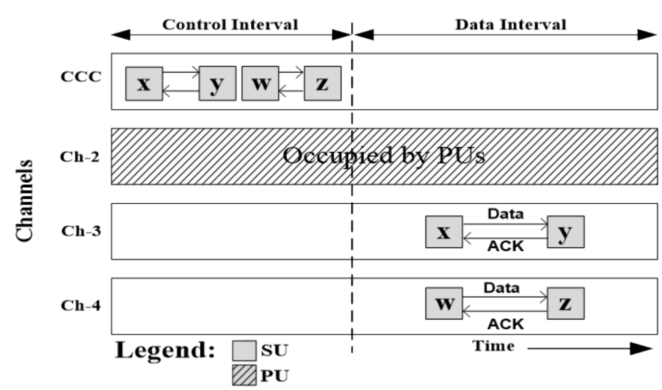


Fig.2. Operation of a CCC Approach

### 2.2 Channel Hopping Approach

In the Channel Hopping Approach [8], SUs generate a channel hopping sequence according to their available channel lists [8]. In this approach, SUs are matched their generated hopping sequence with each other. Whenever, the sequence is matched or common between the sender and receiver, then they goes to that matched or common channel and finally the data transmission is performed. Fig. 3 illustrated the operation of channel hopping approach. However, in this approach, the major problem is, uncertainity of communication may be occurred because the hop sequences of both sender and receiver doesn't match although few channels are common to all. Furthermore, due to the hop sequence problem, rendezvous delay is increased.

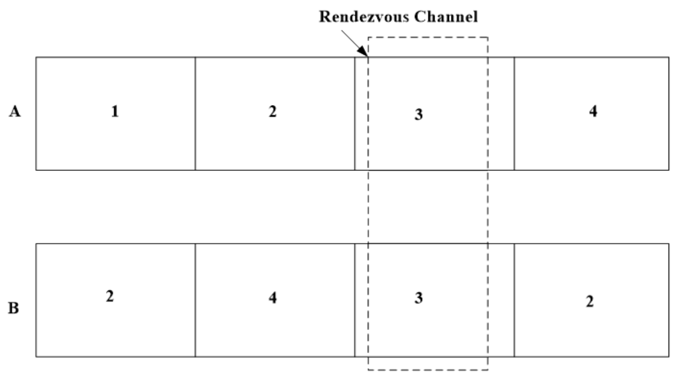


Fig. 3. Operation of Channel Hopping Approach

### 2.3 Efficient Control Channel Design (ECCD) Approach

In the Efficient Control Channel Design (ECCD) Approach [9], a large number of neighboring nodes are the candidates for common control channel (CCC) allocations [9]. In the neighbor discovery process, every SU follows a hopping sequence according to their available channel list to locate any neighbor in their transmission range [1], [2]. When a pair discovers each other with a same hop channel, then they are exchange their beacon message and establish a network link. When all network links are settled amid neighboring nodes, then a network topology is successfully formed. After that, the channel that is common to the largest number of neighboring nodes is selected as control channel list (CCL). Hence, this channel is assumed as rendezvous channel and all SUs are completed their data communication. At any time, this channel is occupied by the PU, and then the channel that is common to the second largest number of neighboring nodes is selected as second CCL and this channel is assumed as rendezvous channel and all SUs are completed their data communication using second CCL and so on.

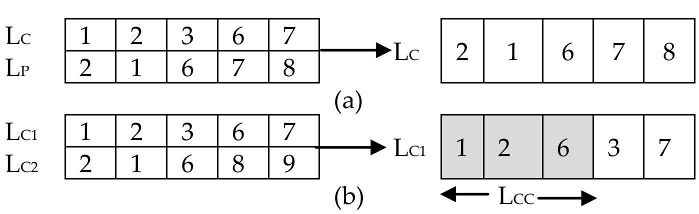


Fig. 4. Operation of effiecient control channel design Approach

In this approach, CCL is updated with two processes, such as (i) CCL is updated with local sensing information, and (ii) CCL is updated with neighbor's information. After updating the CCL all SUs are completed their communication according to previous procedure. However, in this approach synchronization overhead may increased and it may need a long time that may degrade the communication performance.

## 3 Proposed RI-DMCCD Protocol Operation

### 3.1 Network Model

In Fig.5 shows that the cognitive radio network model which is consists of primary user (PU) and secondary user (SU). The SUs that are in the same transmission range can communicate with each other using the vacant channel that is not occupied by the PU. *For simplicity*, assume that there are five channels for both sender *S* and receiver *R*. In the sender side, channels (3, 5) are occupied by PU, so sender *S* has available channels {1, 2, 4} on the other hand, in the receiver side, channels (3, 4) are occupied by PU, so channels {1, 2, 5} are available. *Finally*, secondary users both *S* and *R* are communicate with each other using common channel which are in the same transmission range. For better designing of our proposed protocol, we have assumed some assumptions which are as follows: (i) Each SU node is equipped with a single-radio multi-channel transceiver and can act as a sender or a receiver and maintains a common communication characteristic, (ii) Each SU node maintains two sequences one is odd sequence and another is even sequence using the standard channel list of ISM band to make channel rendezvous, which are mentioned *as Dynamic Control Channel List (DCCL),* (iii) A *Beacon Packet* (i.e., Hello Packet) is considered to ensure SU is stayed on the channel and (iv) Each SU node is allowed to utilize free/idle licensed channels without any harmful interference to PU.

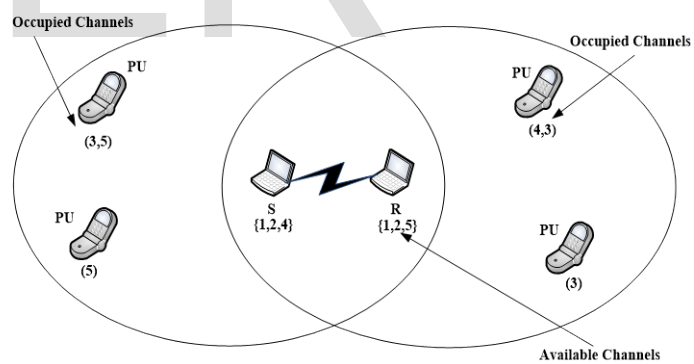


Fig. 5. Simple CRN Model

### 3.2 Protocol Overview

In proposed RI-DMCCD protocol, every SU uses a dynamic mechanism based on the channel conditions it senses to optimize the channel ease of use. In this protocol, a node avoids choosing channels that are occupied by primary users. In this protocol, there are used two sequence such as *one* is odd sequence and *another* is even sequence from the total number of channels which are noted as DCCL. Furthermore, every SU node is completed their communication using the DCCL. Initially, the DCCL list and available channel list (ACL) are made by the every SU. The DCCL list is consists of two sequences such as *Odd-DCCL* list and *Even-DCCL* list where the *Odd-*

*DCCL* list is firstly used for data transmission and the *Even-DCCL* list is used next for data transmission. Since, the proposed protocol is receiver initiated, so the receiver node firstly goes to the first channel of DCCL list, if this channel is available to the available list and sends the beacon to the channel and whenever the sender receives the beacon, it starts to send the data to the receiver without any delay and completed data transmission, otherwise receiver waits during beacon time ($B_T$). After completing data transmission, receiver sends a beacon acknowledgement (BA) to the sender.

Thus, a successful communication is performed between sender and receiver. Now, if the first channel of DCCL list is not available to available list of sender, then it waits also during beacon time ($B_T$). After that, both receiver *R* and sender *S* switches to the next channel of DCCL list. In this case, we ensure the both *R* and *S* must have rendezvoused. In the same way, the receiver *R* sends a beacon to the sender and if this channel is available to sender, then the sender sends data otherwise both *R* and *S* switches to the next channel and so on. Whenever, all channels of *Odd-DCCL* list are occupied by PUs or busy then the DCCL list is updated to make the *Even-DCCL* list. In this case, the data transmission is performed by following the above process.

## 3.3 Protocol Operation

In this section the proposed RI-DMCCD protocol operation is categorized into three phases such as- (i) Initialization phase, (ii) Establish phase, and (iii) Adaptive phase. This all are described in the following sections.

### 3.3.1 Initialization Phase

In the initialization state, every SU divides the all channels into two sequences *one* is *Odd-DCCL* list and another is *Even-DCCL* list and creates available channel list (ACL). Initially, every SU divides DCCL list into equal time slots during *T* cycle for every channel, and each channel of DCCL list is also divided into two time slots one is Beacon Time (BT) slot another is *Data Transmission (DT)* slots. Firstly, both sender *S* and Receiver *R* tries to communicate with each other by following the *Odd-DCCL* list. In this case, in the starting off each time slot the data communication is performed between sender *S* and receiver *R* during *Data Transmission (DT)* slot by confirming the channel rendezvous with the help of beacon transmission within *Beacon Time (BT)* slot. When there is no common channel of DCCL list between sender *S* and receiver *R* or the beacon reply is not reached to the receiver R, then they have to wait during the BT. After elapsed of BT, then, they switches to the next channel of DCCL. Whenever, the *Odd-DCCL* list is occupied by the PUs, and DCCL is updated with the *Even-DCCL* which is used to perform further data communication.

### 3.3.2 Establish Phase

We have assumed that, there are five channels like {1, 2, 3, 4, 5} and six secondary users where number of three users are receivers (R1, R2 and R3) and number of three users are senders (S1, S2 and, S3) and the ACL of *R1* is {1, 2}, *R2* is {1, 3, 4}, and *R3* is {1, 2, 5}, on the other hand, the ACL of *S1* is {1, 4}, *S2* is {2, 3}, and *S3* is {3, 5}. In this section for understanding the whole protocol operation, we have explained the operation only one receiver *R2* and one sender *S2*. Let receiver *R2 and* sender *S2* wishes to communicate. So firstly, both *R2* and *S2* create an *Odd-DCCL* list that is {1, 3, 5} and an *Even-DCCL* list that is {2, 4}. Afterwards, both of them also create their own ACL list by scanning using their radio.

Let, the ACL list of *R2* is {1, 3, 4} and the ACL list of *S2* is {2, 3}. Here, the transmission is started with the *Odd-DCCL* list and *R2* checks the first channel either busy or free using CCA mechanism. Initially, the receiver *R2* sends a beacon over the first channel {1} of *Odd-DCCL* list to the sender but the channel {1} is not available to the sender, so *S2* does not find the beacon and the *S2* waits during this time slot. Afterward, both *R2* and *S2* switch to the next channel {3} of *Odd-DCCL* list. Now, the *R2* sends beacon over the channel {3}. Since, {3} is common to the both *S2* and *R2* hence the sender gets the beacon from the *R2*. Finally, the *S2* sends data to the *R2*. As a result, the *R2* receives the data from the *S2*. After the completion of data receiving, the *R2* sends a beacon acknowledgement (BA) to the sender. Thus, a successful communication is completed. The main advantage of this protocol is the parallel communication is possible among more than two users which is shown in Fig.6.

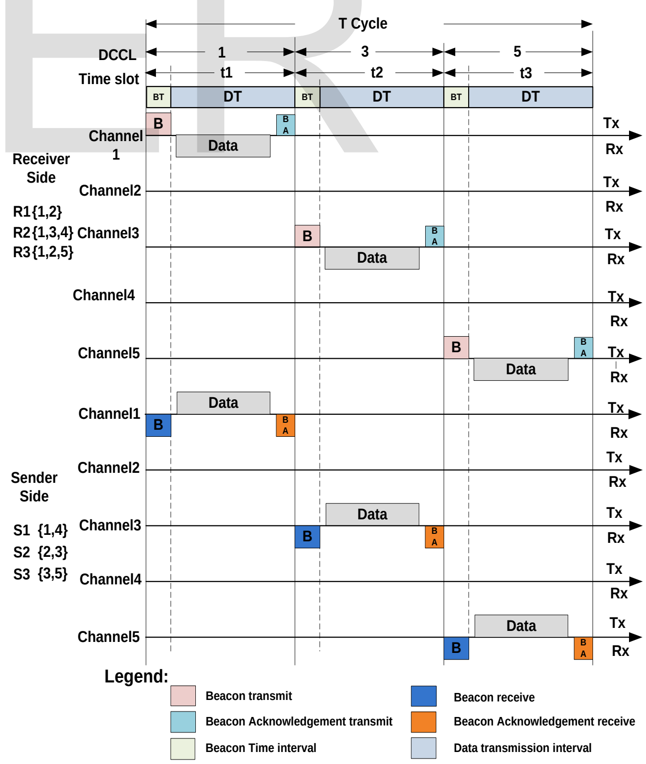


Fig. 6. RI-DMCCD protocols operation in establish phase

### 3.3.3 Adaptive Phase

In adaptive phase operation is illustrated in Fig. 7. Here, we have assumed that after sometimes or next cycle, when ACL list of *R2* and S2 is updated with few additional channels due to non-occupation of PU and also updated with fewer channels

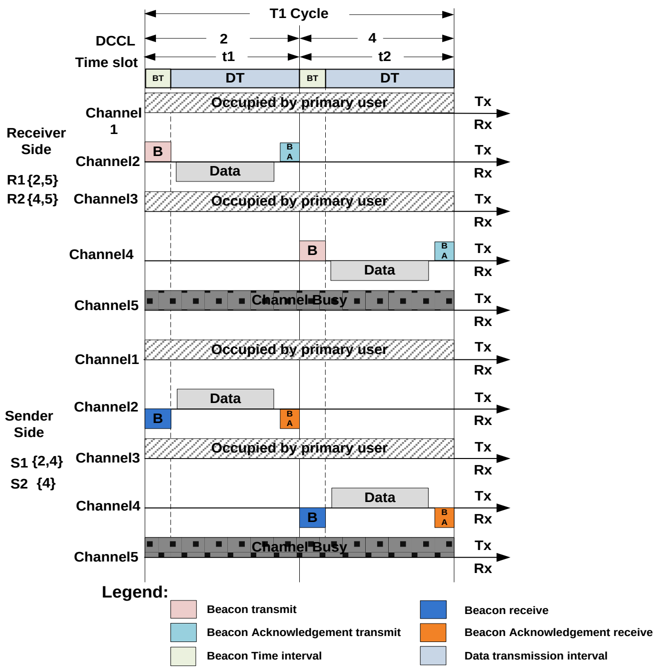


Fig.7. RI-DMCCD protocols operation in adaptive phase.

due to channel occupation of primary users. On the other hand ACL list of *R2* and *S2* is updated due to channel busy. Suppose all channels of *Odd-DCCL* list have been occupied by the PUs. In this situation, the ACL list of *R2* is {4, 5} and the ACL list of *S2* is {4}. In this scenario, the DCCL list is updated with Even-DCCL, that is {2, 4}. Now, the *R2* sends beacon over the first channel {2} of Even-DCCL list to the sender but the channel {2} is not available to the sender, so *S2* does not find the beacon and the *S2* waits during this time slot. Afterward, both *R2* and *S2* switch to the next channel {4} of *Even-DCCL* list. Now, the *R2* sends beacon over the channel {4}. Since, {4} is common to the both *S2* and *R2* hence the sender gets the beacon from the *R2*; hence the data communication is performed over the channel {4}. In this way, the data communication is continuing between *R* and *S* until all the channels of *Even-DCCL* list are occupied by the PUs. Whenever, all the channels of DCCL list are blocked by the PUs, then the DCCL list is updated into {1, 3, 5} this is called Odd-DCCL list and so on.

## 4 Performance Evaluation

We have established the performance evaluation of proposed RI-DMCCD MAC protocol and compare the result with that of a CCC approach and ECCD MAC protocols. We have used our own simulation model developed in C++ environment and we have implemented proposed RI-DMCCD MAC, CCC approach and ECCD MAC protocols and compare the results with among them. For simplicity, in simulation, 10 channels are used for modelling licensed channels for PUs and randomly some of the channels made free/unlicensed and set available to the SUs. Maximum 40 nodes are deployed in 250 x 250 m² area to make variation in number of PU and SU. 20 nodes are chosen randomly as the sources and the other 20 nodes as destinations. The transmission range of each node is set to 250*m*. Each data packet is considered to cost 1 Joule for single transmission, which is used to calculate energy consumption of each node. In case of data packet transmission failure, 1 Unit (i.e., Second) is assumed, which is used to calculate delay of each node. In simulation, for evaluation the performance of proposed RI-DMCCD MAC, ECCD-MAC and CCC MAC, we have considered five performance metrics such as- *Rendezvous performance, Rendezvous Delay, Packet Transmission Success Rate*, and *throughput performance*.

### 4.1 Rendezvous Performance

Fig. 8 shows the comparison of Rendezvous success rate among the CCC MAC, ECCD MAC and RI-DMCCD MAC approaches. The X-axis of the graph shows that the number of PU with occupied channels and the Y-axis shows the Rendezvous success rate in percentage. In fig. 8 it is seen that, when there is one PU at channel 4, the rendezvous rate of CCC, ECCD and RI-DMCCD protocols are 25%, 25% and 70% respectively. On the otherhand when there is three PU occupied the channels 2, 4, 6 then , the rendezvous rate of CCC, ECCD and RI-DMCCD protocols are 25%, 25% and 60% respectively. So it can be concluded that our proposed RI-DMCCD percentage of rendezvous success rate is higher than the CCC and ECCD approchaes.



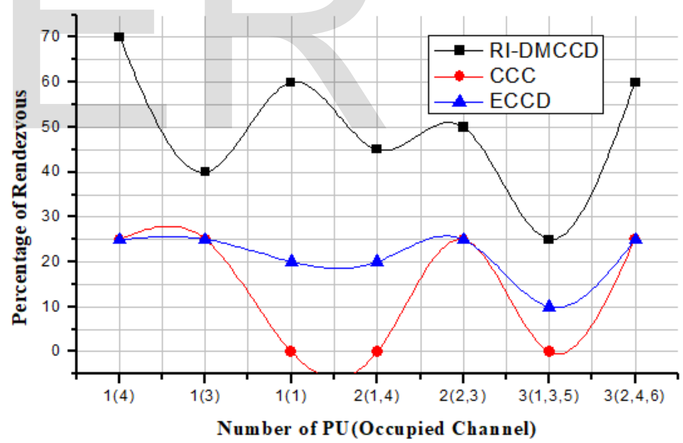


Fig. 8. Percentage of rendezvous rate among the RI-DMCCD, CCC and ECCD

### 4.2 Rendezvous Delay Rate

Fig.9 demonstrates the comparison of rendezvous delay rate among the CCC, ECCD and RI-DMCCD approaches. In Fig. 9 it is seen that, when there is one PU at channel 3, the rendezvous delay rate of CCC, ECCD and RI-DMCCD are 18, 15 and 12 respectively. In Fig. 9, if channels are occupied by PU is increased it is see that rendezvous delay rate is lower than the other protocols. So it is concluded that the rendezvous delay rate of proposed RI-DMCCD is lower than other protocols.

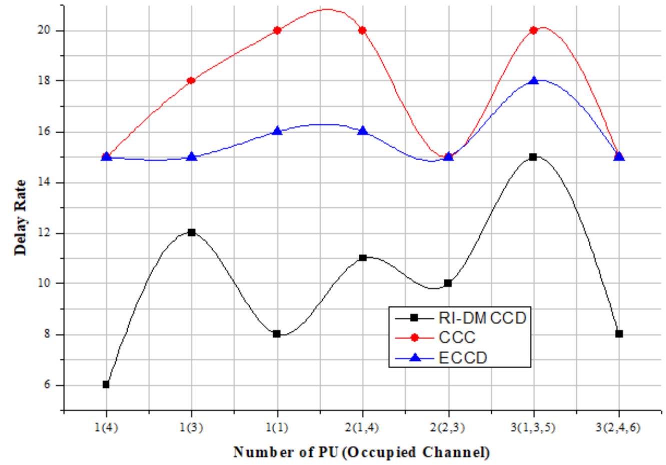


Fig. 9. Rendezvous delay rate among the RI-DMCCD, CCC and ECCD

### 4.3 Transmission Success Rate

Fig.10 shows the evaluation of transmission rate among the CCC, ECCD and RI-DMCCD approaches. In Fig. 10, it is seen that, when there is a PU at channel 3, then the transmission rate of CCC, ECCD and RI-DMCCD are 20%, 20% and 35% respectively. On the otherhand if channels are occupied by PU is increased, then comparatively transmission success rate of RI-DMCCD is higher than other protocols, which is shown in Fig.10. Finally, it can be concluded that transmission success rate of RI-DMCCD is highest than the other two approaches.

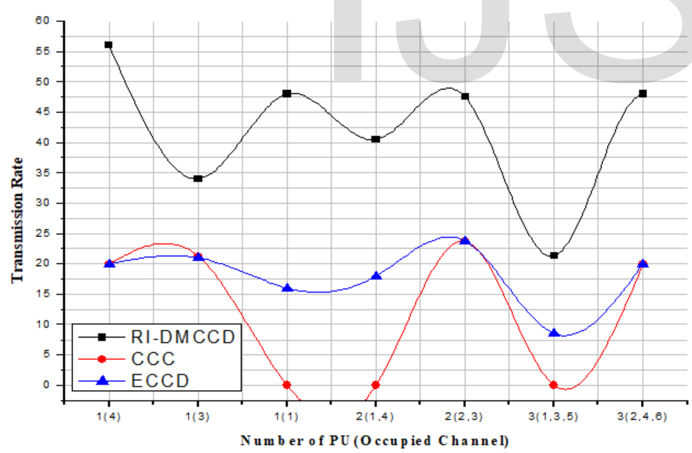


Fig. 10. Percentage of transmission success rate among the RI-DMCCD, CCC and ECCD

### 4.4 Throughput Performance

Fig.11 is illustrated the performance of throughput among the CCC, ECCD and RI-DMCCD approaches. In Fig. 11, it is seen that when the traffic is increased then average throughput is increased in RI-DMCCD protocol and other two protocols throughput is decresed comparatively with proposed protocol due to parallel transmission between SUs. So it is concluded that, aggregated throughput of RI-DMCCD MAC protocol is always higher than the CCC and ECCD MACother protocols due to the multi channel parallel transmission.

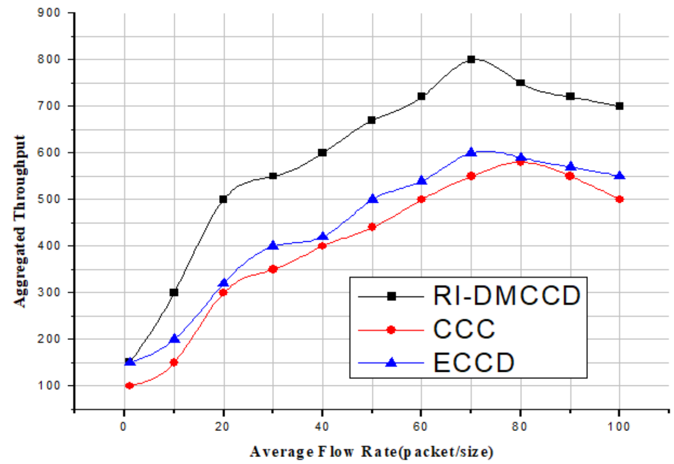


Fig. 11. Throughput among the RI-DMCCD, CCC and ECCD

## 5 Conclusion

In this paper we have proposed a new MAC protocol for the cognitive radio ad hoc network to make successful rendezvous between two SUs. Under this protocol, all nodes are maintained an odd and an even DCCL list for rendezvous and data transmission. Using these DCCL list, many pair of nodes can communicate simultaneously that degrades the probability of rendezvous delay and maximize throughput. In this protocol, there is no need to synchronization among the nodes that increases the performance of this protocol. Furthermore, if any channel is occupied by the PU, the transmission is to be continued using another channel of the DCCL list. Finally, the proposed MAC protocol is better than other mentioned protocols in terms of different performance metrics.

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