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Deep View Point Methods of Channel Allocation in Cognitive Radio Networks

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Abstract:

The Cognitive Radio (CR) is an emerging technology in wireless communication system which offers a keen solution to the firm scarcity of spectrum utilization in Cognitive Radio Networks (CRNs). The primary goal of CR is to improve the Secondary Users (SUs) spectrum utilization when Primary Users (PUs) temporarily become idle. The existing static allocation such as spectrum and channel allocation leads to spectrum scarcity. The existing CR Medium Access Control (CR-MAC) protocols have issues like delay, packet collisions, and Quality of Service (QoS) during channel selection randomly. In this paper, we can propose to design CR-MAC protocol based on channel quality and to achieve context awareness and intelligence for adaptive channel selection. The utility function of Channel Quality Indicator (CQI) is adopted with each channel in CRN to determine the channel quality. The best quality of channel is favored the Common Control Channel (CCC) and dynamically changed in each round. Omni-directional TDMA based Slotted Cognitive Function (SCF) is used to maintain the transmission control. The data transmission is managed by using directional antenna based Distributed Co-ordination Function (DCF). The priorities are assigned based on the channel weights respectively. The higher weighted channels are assigned to higher priority. The proposed hybrid MAC based channel quality protocol has minimized congestion and delay using NS-2 simulation.

Keywords— **CQI, CCC, SCF, DCF, CRN**

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I. INTRODUCTION

IN wireless communication system CRN is a new architecture that focuses on an improvement of existing spectrum utilization and a limited natural resource [1]. In wireless communication system, the existing static spectrum allocation leads to spectrum scarcity. The static spectrum allocation technology should not effectively utilize according to time, space and geographical location [2]. The CRN consists of wireless users, random access capability and cognitive radio functionality. According to cognitive radio intelligence, limited spectrum availability and the unused wireless spectrum band, the CRN uses these factors to build a strategy to permit its secondary users (SUs) to share and access licensed wireless spectrum band with its primary users (PUs) without any intervention with these users and without any poverty in their QoS [1]. Generally, the idle or free licensed channels are detected by SUs and then it can access the available channels [2].

During the communication, the licensed channels are occupied by PUs and then all SUs in the CRN defer transmission, and migrate to other available channels. The functionality of PUs should be determine the available channels in the network which changes dynamically in frequency, space and time respect to the existing channels. In such dynamic situation, exchanging the control messages between SUs becomes one of the essential issues of MAC protocol for CRN [3]. Based on the radio nodes that embraces the aptitude to make logical verdict for fluctuating the parameters of transmission, physical layer and those of MAC layer allowing for the deviations in the atmosphere, the capability of cognitive function, CRNs have been strongly recommended [4], [5].

The licensed spectrum should be accessed by SU through the methods such as overlay, underlay or interweave its signal with the present signal [5]. The main objective of the CRs is to reach the best existing spectrum the intelligent cognitive functionality and the aptitude of reconfigurable, the problem of the multichannel hidden, sensing error, selection of CCC, delay of sensing the channel, the primary users of interference and the problem of network coordination might cause the MAC protocol to grieve from grave performance degradation [6]. The CR-MAC protocol design could have two methods are standardization efforts leading to the formulation of the IEEE 802.22 working group and application/scenario specific protocols. The earlier methodology is especially targeted on infrastructure-based networks, in which a centralized organizer or base station manages the spectrum allocation and sharing among the CR users. The CR users, however, could participate within the spectrum sensing function and afford channel information to the central controller. The standardization efforts cause uniformity in design and policy, thereby permitting multiple independent CR operators to coexist. On the other hand, application or states of affairs specific protocols are optimized for a particular type of atmosphere, or user specified application goal [7].

Recently, the wireless communication systems seek the better reliability and best QoS levels. Mostly in real time application, dissimilar users are probable to tolerate dissimilar levels of delay for each service, rendering necessary to take into account the impact of QoS constraint in wireless system's analysis. An adequate metric that investigates the statistical QoS guarantees under time-varying channel conditions is the effective capacity metric [8]. In CRN, the architecture of the spectrum sharing mechanism offers the spectrum sharing service between Primary Networks (PNs) and Secondary Networks (SNs). In underlay approach, the higher priority is assigned to PUs. In CRN, the major role of dynamic spectrum sharing is to allow both PNs and SNs to communicate synchronously on the equal frequency with suitable interference control to possess PNs. In specific, it is naturally essential that a certain interference temperature limit due to SUs' transmissions must be maintained at each primary receiver. Therefore, power allocation for SUs should carefully be performed to meet stringent interference requirements in this spectrum-sharing model [9].

The SUs should cooperate with all nodes to perform spectrum sensing, cooperative spectrum sensing problems has recently expanded much importance due to its ability fading and interference [10].

A. *Problem Identification*

In [11] multi-constraint QoS aware MAC protocol (MQ-MAC) for a cluster based cognitive radio sensor network has developed. The data channel and a backup channel are allocated to SUs through the respective cluster head (CH) by using dynamic channel priorities in MQ-MAC protocol. The CHs used to forming the channels into optimal and moderate channels and allocate them among the number of nodes affording to their traffic priorities. Then the channels states are characterized as good or bad channel. The CH and its members are used CCC for channel state, is static which leads to congestion. In [12] a dynamic resource allocation and priority based scheduling for heterogeneous services in CRN has been developed. The Secondary Base Station is the most responsible for resource allocation for SU. The SUs in SNs are classified into four categorized

1. SU with Minimum-Rate Guarantee (MRG)
2. SU with Minimum Delay Guarantee (MDG)
3. SU with Minimum-Rate and Delay Guarantee (MRDG)
4. SU with Best Effort Service (BES)

For every incoming packet streams, the packets priority is calculated on the service type and queuing delay. The objective function of channel quality indicator is estimated for every stream by multiplying the priority with channel gain. Then the streams are stored in the descending order of theses objective values, and then allocated to the respective category of SU.

As an extension to this work, we propose to design a channel quality based hybrid MAC protocol CRNs. The rest of this paper organized as follows, in section II we discussed about the related work, in section III Channel quality based hybrid MAC protocol is introduced, in section IV Dynamic CCC approach is introduced, and in section V simulation results are discussed.

II. RELATED WORK

They investigated the joint optimal sensing and distributed Medium Access Control protocol design problem for CRN.

They investigated the designing problem of cooperative optimal sensing and MAC protocol for CRN. Then, they formulated throughput maximization algorithm to maximize the total throughput of the secondary network to achieve significant performance gains of the optimal sensing and protocol configuration [9].

They proposed TDMA based energy efficient cognitive radio multichannel MAC protocol called ECR-MAC for wireless Ad Hoc networks [13]. They developed a multi-constrained QoS aware MAC protocol, MQ-MAC, for a cluster based CRSN. In MQ-MAC, and prioritized with respect to the urgency of their generated data packets [11].

They proposed MAC protocol with the collision-free access to the current data channels and further they presented the provision of reservation of free channels by secondaries for extended periods to increase utilization without affecting dangerous interference to primaries [14]. They proposed a parallel sensing scheme with sequential channel selection order as part of MAC protocol and they evaluated the energy efficiency and throughput of the system [15]. They proposed a lowest ID clustering algorithm and generic algorithm for fairness improvement [16].

They presented an Antenna selection (AS) scheme; in particular, they presented a joint transmit and receive multiple AS method for underlay CR environment, consequently maintaining the multiplexing benefit of Multiple Input Multiple Output (MIMO) systems[17]. They proposed a cooperative and a non-cooperative multichannel (MC)-MAC protocol and the fair multichannel (FMC)-MAC protocol for cognitive radio ad hoc network (CRAHN). Furthermore a mathematical model by Markov chain is constructed for FMC-MAC and the performance measures are derived [18].

III. Channel Quality Based Hybrid MAC Protocol for Cognitive Radio Network

B. Overview

In this paper, we propose to design a channel quality based MAC (CQHMAC) protocol for CRNs. Channel Quality Indicator (CQI) used to find every channel quality in the presented networks [19]. The best quality of channel is preferred as the CCC and dynamically changed in all round. The control of the transmission controlled by omni-directional TDMA based Slotted Cognitive Function (SCF) and the data transmission is controlled by directional antenna based Distributed Co-ordination Function (DCF) [20]. Different weighted values with the channels are assigned to the SUs based on their category [12]. The highest weighted channels are allotted to SU with higher priority.

C. Channel Quality Indicator

The CQI is utility functions which determine the channel quality that depends on the position of the CR itself and on the spatial circulation of neighboring CRs, sources of interference, and noise ratio during the measurements. The CQI is adapted with each sub channels in the network. The functionality of CQI of any sub channels are defined using signal-to-interference-plus-noise ratio (SINR) detected by the SU-BS during channel allocation and accessing.

The CQI is calculated as

$$CQI = \log_2(1+SINR) \quad (1)$$

The SINR is calculated as

$$SINR = \frac{\rho_{signal}}{\rho_{i+\sigma}} \quad (2)$$

Where ρsignal is an incoming signal power, ρi is the power of the interference and σ is the noise respectively.

If ρi = 0, then the SINR is reduced to Signal-to-Noise Ratio (SNR).

IV. Dynamic Common Control Channel Selection

We considered G be the cognitive radio, during the communication the CQI is used to measure channel quality and channel allocation to SU. The CQI can depend on G location and the spatial distribution of neighboring Gs and noise at the time of the measurements.

CCC is intended as the token ring network to guarantee a fair and contention free medium access for all ring-participating Gs. Token ring protocol guarantees maximum latency for the network through a token holding time (Tho) parameter.

Tho denotes to the maximum period that each ring contributing node is permissible to transmit before passing the token. Considering N ring contributing nodes which are accessing the medium, the network layer can upper bounded by the maximum token rotation time (Tro). Considering N ring participating nodes which is accessing the medium, the network layer is upper bounded by the maximum token rotation time (Tro)

$$T_{ro} = NT_{ho} \tag{3}$$

Note: N is announced within the tokens

Thus, the measurement of CQI for one channel can be performed in bounded time, as it is guaranteed that a given Gj can attends every ring-participating neighbor within one Tro period.

In addition, for multiple available channels, the time required by G to scan a set Q of spectrum opportunities,

$$T_{sc} = QCTho\sum_{geG} N_g \tag{4}$$

Where C is the cost introduced by channel switching Ng is the number of ring-participating Gs found in channel g. Thus a channel with best CQI is chosen as the common control channel (CCC) and dynamically changed in each round

D. Weight based Channel Assignment

The different weight values with channels are allocated to the SUs based on their category. For each and every incoming stream, the priorities of packets are depending on the service type and queuing delay. Then CQI is estimated for each stream by multiplying the priority with channel gain. The streams can be sorted in the descending order of the weighted values in the queue. Then the weights with the channels are allocated to the respective type of SU.

During the transmission the Secondary Base Station (SBS) gains the channel information. Let we consider the following assumptions.

- K1: SUs with minimum rate guarantee
- K2: SUs with best effort service.

The two categories of SUs should be signified as KA and KB respectively. During the resource and channel allocation, we consider N channels are available in the given CRN. Also assume that the SBS couldn't know the best quality channel information for these K SUs on N channels.

The minimum rate (MR) guarantee can be calculated during the channel allocation, (threshold guarantee (MRkmin))

$$MR_k \geq MR_k^{\min} \forall k \in K_A \tag{5}$$

The best effort service can be calculated as

$$\frac{MR_k}{\sum_{i\in K_B} MR_i} = \delta_k \forall k \in K_B \tag{6}$$

where δk, ∀k∈KB is the predetermined value.

The stream with highest objective function is allocated to the MRDG, followed by MRG and MDG. The stream with least objective function is assigned to BE.

E. Omni-directional TDMA based Slotted Cognitive Function (SCF)

This phase illustrates control transmission:

Here, TDMA slots are divided into fixed size frames (1, 2, 3, …,K). Each frame has S slots (T0, T1, T2,…,Tk) with a frame duration of 'Tfr =ST'.

T0 is used to run the clock synchronization. T1 is always reserved for transmitter (G0) to broadcast its network beacons and PU free Channel list (PCL). T2 is used to tune CR transmitter into receive mode and listen its PU free channel list (PCL) from higher to lower priority.

Neighbor CR nodes (CR1, CR2,…, CRk) who has common channel with CR transmitter will tune to transmit mode at T2 period and broadcast its PCL list to sender (CR0). When two neighbor nodes has same common PU free channel with G transmitter, then the neighbor node with higher priority will be selected first for control message exchange. When CR transmitter (CR0) has data to its next-hop from higher layers, then it broadcast its data channel request (D_REQ) in selected common channel at T3 period. Once, the D_REQ is reached to receiver, it estimates the Angle of Arrival (Θ) of CR transmitter and CR transmit power. Θ estimation helps for directional RTS/CTS and data transmission during DCF period whereas G transmit power level helps to calculate power level to avoid interference for edge PU receiver hidden terminal packet drops as shown in the figure 1.

F. Directional Antenna based Distributed Co-ordination Function (DCF)

In this technique, an antenna index number (Z) is added in RTS and CTS message formats. This helps neighbor nodes to block its Network Allocation Vector (NAV) in corresponding antenna directions during data transmission.

When the directional RTS and CTS messages are broadcasted, the node will initiate its data transmission and wait for acknowledgment in directional antenna. Also, nodes within the network will broadcast its application data in their selected legitimate channels. With directional antennas, link aggregate throughput gets enhanced with minimal channel contention delays.

The main advantages of this technique are as follows:

- Data transmission with directional antennas helps to minimize node and network energy consumption with interference suppression.
- The D_REQ and D_RES in SCF operation helps to find collision free data channel for directional data transmission.

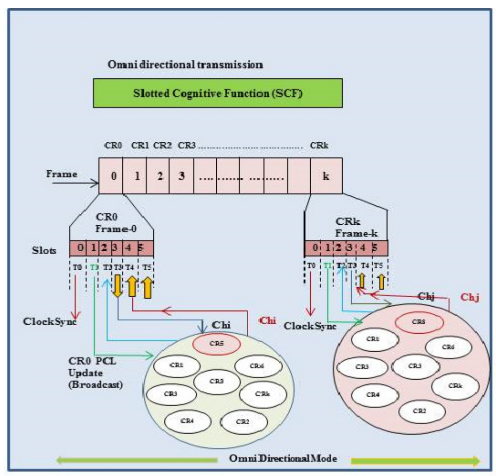

Fig.1 Operation of Slotted Cognitive Function

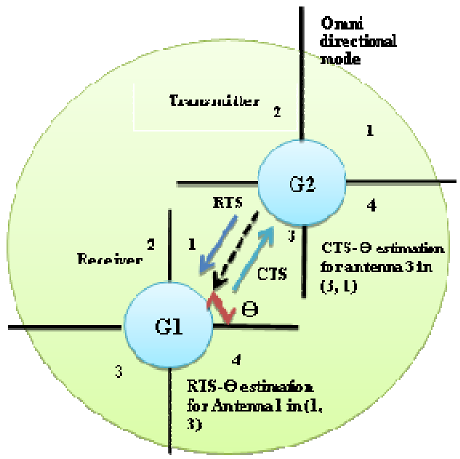

Fig.2 AOA Estimation

G. *Simulating setting*

The proposed CQHMAC Protocol is simulated in NS2 and compared with Interference Aware Hybrid MAC (IAHMAC) [23] and Cognitive MAC with mobility support (CMMAC) [24] protocols. The simulation settings are summarized in Table 1. The performances of these protocols are evaluated in terms of the metrics CBR-throughput, EXP-throughput, Video-throughput, packet delivery ratio.

TABLE I

SIMULATION PARAMETERS

Number of Nodes	50
Topology Size	1000 X 300 m
MAC Protocol	IEEE 802.22 contention based MAC
Simulation Time	100 sec
Traffic Model	CBR, Exponential and Video
Packet Size	512 Bytes
Transmission Range	75m
Propagation Model	Two Ray Ground
Antenna Type	Omni Antenna
Number of channels	4
Number of network interfaces	3
Number of secondary transmissions	6,12,18 and 24
Data sending rate	100 to 500Kbps

H. *Results and Analysis*

1) *50 nodes Scenario*

In 50 nodes scenario, the data sending rate and number of secondary transmissions are different.

I. *Varying the Data sending Rate*

In this experiment, the data transmission rate is varied from 100 to 500kb.

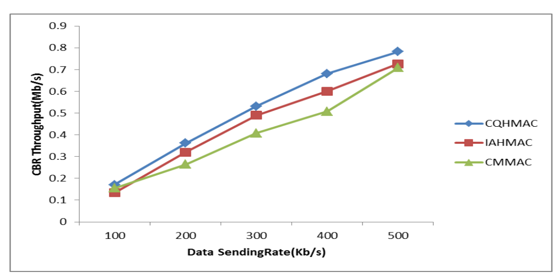

Fig.3 CBR-Throughput for varying rate

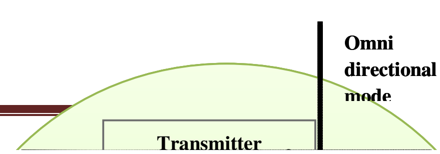

Fig.3 shows the CBR-Throughput measured for CQHMAC, CMMAC and IAHMAC when the rate is varied. The rate is increased from 100 to 500Kb, throughput of CQHMAC increases from 0.17 to 0.7, the throughput of IAHMAC increases from 0.13 to 0.72 and the throughput of CMMAC increases from 0.15 to 0.7. Henceforth the throughput of CQHMAC is 12% of higher once compared to IAHMAC and 18% of higher than CMMAC.

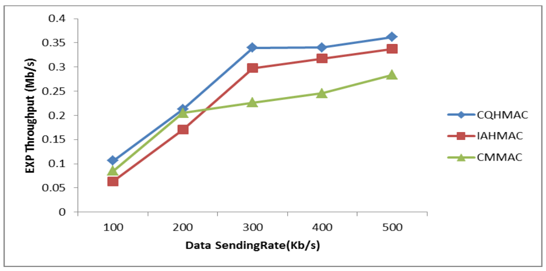

Fig. 4 EXP Throughput for varying rate

Fig.4 shows the EXP-Throughput measured for CQHMAC and IAHMAC when the rate is varied. The rate is increased from 100 to 500Kb, the throughput of CQHMAC increases from 0.10 to 0.36, the throughput of IAHMAC increases from 0.06 to 0.33 and the throughput of CMMAC increases from 0.08 to 0.28. Hence the throughput of CQHMAC is 17% of higher when compared to IAHMAC and 21% of higher than CMMAC.

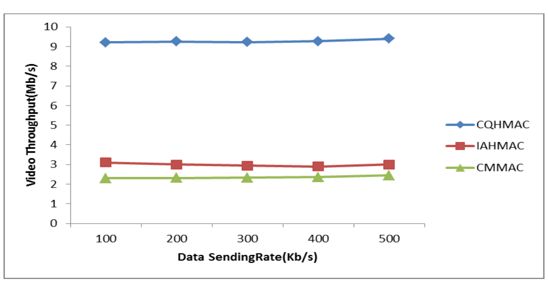

Fig.5 Video Throughput for varying rate

Fig.5 shows the video-throughput measured for CQHMAC and IAHMAC when the rate is varied. The rate is increased from 100 to 500Kb, the throughput of CQHMAC increases from 9.2 to 9.3, the throughput of IAHMAC decreases from 3.1 to 2.9 and the throughput of CMMAC goes from 2.35 to 2.44. Hence the throughput of CQHMAC is 68% of higher when compared to IAHMAC and 75% of higher than CMMAC.

J. Varying the Secondary Transmissions

In this experiment, the numbers of secondary user transmissions are varied from 6 to 24.

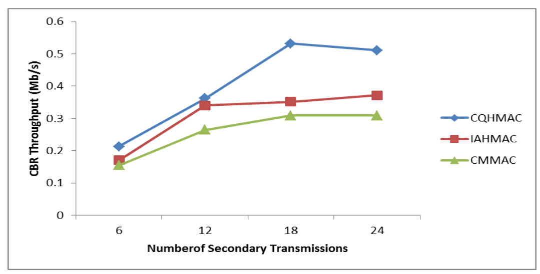

Fig.6 CBR Throughput for varying Secondary transmissions

Fig.6 shows the CBR-throughput measured for CQHMAC, CMMAC and IAHMAC when the flows are varied. The flows are increased from 6 to 24, the throughput of CQHMAC increases from 0.2 to 0.5, the throughput of IAHMAC increases from 0.1 to 0.3 and the throughput of CMMAC increases from 0.15 to 0.30. Hence the throughput of CQHMAC is 22% of higher when compared to IAHMAC and 34% of higher than CMMAC.

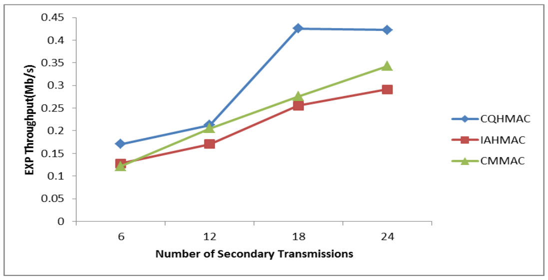

Fig.7 EXP Throughput for varying secondary transmissions

Fig.7 shows the EXP-Throughput measured for CQHMAC, CMMAC and IAHMAC when the flows are varied. The flows are increased from 6 to 24, the throughput of CQHMAC increases from 0.17 to 0.42, the throughput of IAHMAC increases from 0.12 to 0.29 and the throughput of CMMAC increases from 0.12 to 0.34. Hence the throughput of CQHMAC is 29% of higher when compared to IAHMAC and 22% of higher than CMMAC.

V. Conclusion

In this paper, we have proposed to design a channel quality based MAC protocol cognitive radio networks. Here a channel quality indicator (CQI) is used as a utility function for each channel. Then a channel with best CQI is chosen as the CCC and dynamically changed in each round. Omni-directional TDMA based Slotted Cognitive Function (SCF) is used for control transmission and directional antenna based Distributed Co-ordination Function (DCF) is used for data transmission The channels with higher weights are assigned to higher priority SU. By simulation results, we have shown that the proposed technique minimizes congestion and delay.

References

[1] Pushp Maheshwari and Awadhesh Kumar Singh, "A Fuzzy Logic Based Approach to Spectrum Assignment in Cognitive Radio Networks," in 2015 IEEE International Advance Computing Conference (IACC), IEEE, 978-1-4799-8047-5/15/$31.00©2015 IEEE pp.278–281. July 2015.

[2] Anil Carie, Mingchu Li, Satish Anamalamudi, Syed Bilal Shah, and Wahab Khan, "An Internet of Software Defined Cognitive Radio Ad-hoc Networks based on Directional Antenna for Smart Environments", Sustainable Cities and Society, vol. 39, pp. 527-536, may 2018.

[3] Zaw HTIKE, Choong Seon HONG and IIKwon CHO, "DYN-MAC: A MAC protocol for cognitive radio networks with dynamic control channel assignment", IEICE TRANS. COMMUN, Vol. E97-B, no. 8, pp. 1577-1585, August 2014.

[4] J.Arun and M.Karthikeyan, "Optimized cognitive radio network (CRN) using genetic algorithm and artificial bee colony algorithm", springer, cluster computing, March 2018.

[5] Long Zhang, Fan Zhuo and Haitao Xu, "A cross-layer optimization framework for congestion and power control in cognitive radio adhoc networks under predictable contact", EURASIP Journal on wireless communication and networking, Vol. 2018, no. 57, pp. 1-23, 2018.

[6] Mahfuzulhoq Chowdhury, Asaduzzaman, Md.Fazlul Kader and Mohammad Obaidur Rahman, "Design of an efficient MAC protocol for opportunistic cognitive radio networks", International journal of computer science & information technology (IJCSIT), Vol. 4, no. 4, pp. 233-242, October 2012.

[7] Claudia Cormio and Kaushik R. Chowdhury, "A survey on MAC protocols for cognitive radio networks", Ad Hoc Networks, 7(2009), pp. 1315-1329, Feb 2009.

[8] Anargyros J. Roumeliotis, Stavroula Vassaki and Athanasios D. Panagopoulo, "Joint Power and Time Allocation Scheme with QoS Constraints in Overlay Multi-user Cognitive Radio Networks", Springer, Wireless Personal Communication, August 2017.

[9] Le Thanh Tan and Long Bao Le, "Distributed MAC protocol for cognitive radio networks: Design, Analysis and Optimization", IEEE Transactions on vehicular Technology, Vol. 60, no. 8, pp. 3990-4003, Oct 2011.

[10] Sedat Atmaca, Omer Sayli, Jin Yuan and Adnan Kavak, "Throughput maximization of CSMA in cognitive radio networks with cooperative spectrum sensing", Wireless pers Commun, springer publication, Oct 2016.

[11] Mir Mehedi Ahsan Pritom,Sujan Sarker,Md. Abdur Razzaque, Mohammad Mehedi Hassan, M. Anwar Hossain and Abdulhameed Alelaiwi, "A Multiconstrained QoS Aware MAC Protocol for Cluster-Based Cognitive Radio Sensor Networks", International Journal of Distributed Sensor Networks, Hindawi, pp. 1-24, 2015.

[12] S.Tamilarasan and Kumar P, "Dynamic Resource Allocation and Priority Based Scheduling for Heterogeneous Services in Cognitive Radio Networks", International Journal of intelligent Engineering Systems, Vol.9, no.3, pp. 127-136, 2016.

[13] S. M. Kamruzzaman,"An Energy Efficient Multichannel MAC Protocol for Cognitive Radio Ad Hoc Networks", International Journal

of Communication Networks and Information Security (IJCNIS) Vol. 2, No. 2, pp. 112-119, August 2010.

[14] Saptarshi Debroy, Swades De and Mainak Chatterjee," Contention Based Multichannel MAC Protocol for Distributed Cognitive Radio Networks", IEEE Transactions On Mobile Computing, Vol. 13, no. 12, pp. 2749-2762, December 2014.

[15] Irfan Latif khan, Riaz Hussain, Atif Shakeel, Adeel Iqbal, Junaid Ahmed, Shakeel Alvi, Qadeer ul Hasan and Shahzad A. Malik, "Efficient idle channel discovery mechanism through cooperative parallel sensing in cognitive radio network" ,EURASIP Journal on Wireless Communications and Networking (2018) 2018:75, pp. 1-15, 2018.

[16] J.Arun and M. Karthikeyan, "Optimized cognitive radio network (CRN) using genetic algorithm and artificial bee colony algorithm", Springer, Cluster Computing, 2018.

[17] P. Reba, Govindaswamy Uma Maheswari, and Moses Satheesh Babu, "Multiple Antenna Selection for Underlay Cognitive Radio Systems with Interference Constraint", Springer Wireless Pers Commun, September 2017.

[18] Aghus Sofwan, and Salman A. AlQahtani, "Cooperative and fair MAC protocols for cognitive radio ad-hoc Networks", Springer Wireless Netw, May 2016.

[19] Paulo M. R. dos Santos, Mohamed A. Kalil, Oleksandr Artemenko, Anastasia Lavrenko, Andreas Mitschele-Thiel," Self-Organized Common Control Channel Design for Cognitive Radio Ad Hoc Networks" , IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications: Mobile and Wireless Networks, pp. 2419-2423, 2013.

[20] Satish Anamalamudi, Minglu JIN and Jae Moung Kim," Interference-Aware Hybrid MAC protocol for Cognitive Radio Ad-Hoc Networks with Directional Antennas', EAI Endorsed Transactions on Wireless Spectrum, Vol. 1, no. 3, pp. 1-10, July 2015.

[21] Le Thanh Tan and Long Bao Le," Joint cooperative spectrum sensing and MAC protocol design for multi-channel cognitive radio networks", EURASIP Journal on wireless communications and networking, Springer, pp. 1-24, 2014.

[22] Peng Hu and Mohamed Ibnkahla," A MAC protocol with mobility support in cognitive radio ad hoc networks: Protocol design and analysis", Ad Hoc Networks, Elsevier, 17 (2014), pp. 114–128, 2014.

