STUDY OF DIFFERENT SPECTRUM SCHEDULING IN COGNITIVE RADIO

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***Abstract*— Over the time, usage of wireless network has increased and lead the scarcity of spectrum problems. Cognitive radio (CR) is a key concept for the spectrum problems. Secondary users (SUs) can opportunistically use the licensed band in absence of primary user (PUs). In this paper, the study of different spectrum scheduling methods is conducted. Spectrum scheduling, refer as a spectrum sharing, is the challenging task and due to lack of management the throughput of the system decreases. One of the concern matters is power consumption while communication over network through secondary users. Secondary users are not allowed to transmit the data when primary user is busy. However, when the secondary user senses the status of primary user (Active or idle), harvest energy of transmission of primary user's in case of channel is busy. This indicates the degradation of energy efficiency and maximum throughput. This study presents of various spectrum scheduling of cognitive radio and different techniques used to increase the maximum throughput of the system.**

Keywords*— *Cognitive radio (CR), Spectrum sharing, Spectrum scheduling, Primary users (PUs), Secondary users (SUs), Cognitive radio network (CRN), Genetic algorithm, Quality-based Activation (QBA)

INTRODUCTION

Wireless communication is ever booming field. Consequently, spectrum demand increases due to enormous subscriber and leads to scarcity of spectrum. Cognitive radio (CR) is significant concept for the spectrum problems. It is an intelligent and an adaptive radio that can automatically detect unoccupied channels for transmission on data. Licensed user can use the allocated band without any interference. Nevertheless, secondary users are not licensed users. Cognitive radio technology provides the fair solution for both primary and secondary user. Secondary user opportunistically uses the free band. Spectrum scheduling is an important term in cognitive radio networks (CRNs). It is a process to enhance the communication with easiness. Licensed and unlicensed users are undetectable part of the network. The use of idle spectrum is as important as allocating the spectrum to user. The purpose of the utilization of idle spectrum through spectrum scheduling is to avoid the waiting list of users, unwanted interference between PU and SU, loss of unnecessary power. Spectrum sensing detects the idle/unused spectrum and share it with other users. Spectrum management is a paradigm to capture the best spectrum to meet user communication requirements. The purpose of this research paper is to analyze the performance of various scheduling method and find a better solution for increases throughput. According to FCC report, published in 2002, utilization of registered bands increased from 15% to 85% [1]. In this paper, the

Focus is on to achieve the performance analysis of spectrum scheduling of cognitive radio.

NOMENCLATURE

CR	Cognitive Radio
CRN	Cognitive Radio Network
PU	Primary User
CSS	Co-operative Spectrum Sensing
SU	Secondary User
FCC	Federal Communications Commissions
CCC	Common Control Channel
FC	Fusion Center
MTM	Mean Throughput maximization
DCH	Data Channel
RCH	Reporting Channel
TLM	Throughput loss minimization
EE	Energy Efficiency
QoS	Quality of Service
QBA	Quality-based Activation

QBR	Quality-based CQI Reporting
CQI	Channel Quality Information
CBS	Cognitive Base Station

Basic concepts in Cognitive Radio:

Licence User (Primary User): Genuine and rightful user of the spectrum with given services.

Unlicensed User (Secondary User): It is not valid user of the spectrum. [2] Secondary users are opportunistically given a chance to use licensed spectrum when the spectrum is idle.

This paper is organized in the manner as below. In section I, the sharing techniques are described. In section II, literature review is mentioned and then followed by performance in section III. In section IV, conclusion is portrayed based on the results and literature survey.

I. SPECTRUM SHARING TECHNIQUES

Spectrum sharing techniques based on network architecture.

1.Decentralized spectrum sharing: In this approach, master node concept does not exist. Instead of taking control of other node/radio, communication exits between the different nodes/radios and they share sense information. [3]

2.Centralized spectrum sharing: In this approach, master node collects all information sensed by all nodes or radio inside the network. It determines frequencies and analysis the information whether it can be used or not. [3] Central CR is called as fusion center (FS).

Spectrum sharing technique based on access behaviour.

1.Non-cooperative spectrum sharing: This technique known as non-collaborative spectrum sharing and in it cognitive radio users are not accountable for synchronising the cognitive functionalities. [3]

2.Cooperative spectrum sharing: In this method, cognitive radio users are accountable for synchronising the functionalities of cognitive radio network (CRN). It helps to improve network efficiency and optimize the spectrum utilization. [3]

Firstly, in against with non-cooperative spectrum sharing, cooperative spectrum sharing method requires the exchange of information. It is achieved with the help of common control channel (CCC) and required to enable the information exchange. On contrary, in non-cooperative approach, cognitive nodes work without need of any association from other users and achieve the network roles tasks on their own.

Spectrum sharing technique based on access technique.

1.Underlay spectrum sharing: This technique is manly meant and developed for cellular networks are used to access the network through observation by node. [3] Transmission starts once the spectrum allocation map is ready. Due to this it will interfere with the primary user and causes interferences. Expansion of bandwidth is the solution for this problem as oppose to overlay technique.

2.Overlay spectrum sharing: As oppose to underlay spectrum sharing technique, in this method, node access network by means of spectrum hole which is not used by the licence user. It reduces interference to the primary user. [3]

II. LITERATURE REVIEW

Fig.2 Shows *Zubair Ahmed et al. [4]* discuss about "spectrum scheduling in cognitive radio between licensed and unlicensed user" with the help of collision rate. Spectrum utilization depends on time and geographical location. In this research paper, the hybrid approach of underlay spectrum and overlay spectrum sharing technique is used. If the collision rate is high, then underlay spectrum sharing will be chosen and if collision rate is low then overlay spectrum sharing will be implemented. The objective of this proposed literature is to use the licensed band when it is not used without causing any interruption. As fixed spectrum cannot be used by secondary users even if it is rarely used by the licensed users. This spectrum scheduling method gives the idea and help to share the unused band to secondary users but, lack in proper selection of suitable channel at extent level. Communication over network compromise the security as it cannot be guaranteed. It does not give privacy at amount level. On the other hand, this

approach provides the opportunistic manner to secondary user to use the licensed band.

Raouia Masmoudi et al. [5] discuss about "the joint scheduling and power allocation in cognitive radio systems". The objective is to minimize the overall SU system power consumption with described constraints in paper. Quality of Service (QoS) and interference are hard to achieve together. It is not suitable for symmetric case. Non-convexity problem is solved by lagrangian relaxation and varying the topmost interference. It has a discrete spectrum scheduling policy. This literature gives essential and enough conditions for the optimal solution.

M. Tahir et al. [6] discuss about "spectrum scheduling and consider it as the key factor for maximum throughput and optimal resource utilization in cognitive radio network". This literature introduces the numerous scheduling methods. The striking challenge is to decide when and which user can access the allocated spectrum bands or channels to transmit their packets. In this method, for designing online flow control, Lyapunov optimization technique is used. Each unlicensed user checks the channel condition, channel status and quality of channel. It depends on queue size and experimental channel status. The packet scheduler is important for resource management. Simulation results of this paper clearly shows that maximum throughput and optimal resources utilization are relies on the scheduling technique.

Shabnam et al [7] discuss about "the real-time scheduling for cognitive radio networks". In this research paper cognitive radio network opportunistically take advantage of white spaces of primary users (PUs). A white space is an unusual radio resource that can depend on time, frequency, and geographical location, and its utilization should not cause interference to PUs. Protocols take into considerations. Efficiency computational complexity is high due to various factors. Scheduling is performed at each time slot from the beginning. The proposed mean throughput maximization (MTM) scheduling protocol schedules the CRs available in the current time slot considering past channel allocations and possible future demands without introducing the delay for further CR resource demands to be revealed. Throughput loss minimization (TLM) is introduced to reduce the delay in MTM scheduling. TLM is a variation of MTM. This method prevents interference to PUs from SUs.

Soumen Mondal et al [8] discuss about "primary behaviour-based energy harvesting multi-hop cognitive radio network" paper. In this research paper, decode and forward relays are deployed between the secondary source and secondary destination. In wireless communication, the received signals attenuated due to various interferences. Decode relay and forward relay are used to overcome this problem. Few nodes were brought to improve the performance. The simulation results show that optimum duration of harvesting which maximises throughput. The outage performance of secondary network decreases when the CSI is in between primary receiver and secondary transmitter. It is not matched with perfect case.

Junaid Imtiaz et al [9] provides the base for this research paper. It discusses about "Energy-Efficient Management of Cognitive Radio Terminals with Quality-Based Activation". The cooperative cognitive radio system (CRSs) is opted. In CRS, to sense and report the existence of primary and spectrum hole the battery-powered cognitive radio terminals (CTs) are used to exploit the spectrum hole. Report is sent back to the centralized fusion center (also known as cognitive base station (CBS)) by cognitive terminals. The decision is made on the base of received report at CBS. When the spectrum hole is unoccupied then, cognitive base station feeds back about the best suitable cognitive terminal which can actively exploit the spectrum [10]. The process of selecting best cognitive terminal is achieved through the greedy scheduling. The sensing and reporting for every time slot demand for better energy management. Energy efficiency can be improved with by selecting only quality cognitive terminals and let remains other in sleep mode [11]. Disadvantage of this kind of selective activation could limit the participation of cognitive terminals and end up in losing multi-user diversity gain. On contrary, number of reports from all cognitive terminal could lessen the diversity gain by declining the successful reports due to congestion in reporting channel (RCH) [12],[13]. This paper proposes quality-based activation (QBA) for cognitive user pairs. It works only with cognitive terminals with equal or higher values in magnitude of DCH and RCH compared to given threshold. To conclude, in a large network with number of cognitive terminals quality-based activation is a promising approach.

Dongwoo Kim et al [12] gives detail research about "On capacity of Quality-Based Channel-State Reporting in Mobile Systems with Greedy Transmission Scheduling". This paper proposes QBR scheme. In this scheme (Quality-based CQI reporting (QBR)), receivers with only best signal quality greater than predefined threshold value are fed back to transmitter through CQIs. Greedy transmission scheduling attain great capacity by means of greatly exploiting independent time-varying channels. The capacity is given in terms of the threshold and feedback-error rate. In this method the trade off problem between uplink and downlink capacities was prevalent.

Paper	Year	Summary	Research Gap
"Spectrum scheduling in cognitive radio between licensed and unlicensed user"	2016	Based on Collision rate. Underlay spectrum is chosen in case of high collision rate else overlay spectrum sharing is chosen for low collision rate.	Privacy of the users is the concern. Security of the data over transmission can not be guaranteed.
"Joint scheduling and power allocation in cognitive radio systems"	2015	Iterative water-filling algorithm is proposed. It converges at an optimal scheduling and power allocation policy Apart from this interleaved allocation and block-wise allocation is also implemented to get the result.	QoS and interference constraints are hard to get together. It is not suitable for symmetric cases and has discrete spectrum scheduling policy
"Real-Time Scheduling for Cognitive Radio Networks"	2017	Opportunistically use white spaces. A white space depends on time, frequency, and geographical location. Utilization of white space should not cause interference to primary users.	Efficiency Computational Complexity due to various factors.
"Primary behavior-based energy harvesting multi-hop cognitive radio network by opportunistically serving the delay-tolerant data only when enough spectrum is available".	2017	A multi-hop transmission in cognitive environment is examined. Impact of imperfect channel state information of interfering links between secondary transmitting nodes and primary receiver is investigated.	Outage performance of secondary network degrades when CSI of the channel between secondary transmitting nodes and primary is imperfect in compared with the perfect case. At a primary receiver, the maximum transmit power of secondary node is limited by interference constraint.
"Spectrum scheduling: The key factor maximum throughput and optimal resources utilization in cognitive radio	2014	This paper offerings different scheduling techniques and evaluated the results. It focuses on one of the challenges that is how the users can access the allocated	The simulations result apparently reveal that maximum throughput of cognitive radio and optimal utilization of thee resources are dependent on the scheduling technique

network".		spectrum bands and when the channels to transmit their packets.	used for the CRN's users.
"Energy-Efficient Management of Cognitive Radio Terminals with Quality-Based Activation".	2017	The number of participations of cognitive terminal is reduced with QBA (quality-based activation). It is gain through the quality of DCH and RCH to preserve the multiuser diversity.	As number of users decrease the certain multi-user diversity gain also lose and followed by system throughput. To put in nut shell, work can be done on how to optimize the all cognitive terminals without losing multi-user diversity gain to contribute in system throughput.
"On capacity of Quality-Based Channel-State Reporting in Mobile Systems with Greedy Transmission Scheduling".	2006	The capacity is determined on the base of feedback error rate and threshold value. The QBR (quality-based CQL reporting) is implemented.	The capacity gain is dependent in the uplink CQI BER. Gain decreases with increasing CQI reports. It leads in difficulty of trade-off between downlink and uplink capacities.

III.PERFORMANCE ANALYSIS

There Spectrum scheduling with various method is observed. Unlicensed user starts the transmission of data when licensed user is unavailable. While the spectrum is having idle state, secondary user takes the advantage of the licensed band and start transmission over network. It should not cause any interference to primary user. Secondary user must release the band when primary user come back for the transmission. Primary user must have the highest priority over band as they are legally allocated to the band. Secondary user must sense the available band without any delay. While sensing the available idle band secondary user lose some energy. In cognitive radio systems, cognitive radio terminal works on battery. It senses existence of primary user and report about the status (occupied/unoccupied). This research paper works on how to choose suitable scheduling method to increase the maximum throughput with adequate proposed technique. To increase more throughput with energy efficiency the quality-based activation is proposed. QBA improves EE is dual: lets QBA a subset of cognitive terminals turns into sleep mode and save the energy and, same time increases throughput. Consequently, Energy efficiency also increased. Throughput and energy efficiency are derived in terms of thresholds [9]. This value will be compared with the output in further study with proposed algorithm.

IV.CONCLUSION

In this paper we have reviewed different spectrum scheduling technique and research on various methods to achieve maximum throughput available in literatures. Maximum output without compromising in system performance with the use of all available recourses is the concern. In case joint scheduling if the conditions are not met, it is hard to know priori whether algorithm converges or not. In real-time scheduling paper, the schemes consider short-lived idle primary channels. Furthermore, the uncertainty about primary and secondary user's future activities. In regards of scheduling between licensed and unlicensed user, the achieved output is almost identical to input rate for small values. On the other hand, in study of maximum throughput and optimal resource utilization, throughput gradually increases till it reaches its maximum level and after that different input values it become identical. In this research paper after performance analysis of various spectrum scheduling, the proposed genetic algorithm is implemented and, quality-based activation also increase throughput. QBA method seems promising to achieve maximum throughput. The further study will include the comparison of the achieved results and will comment throughput results according to the respective outputs.

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