A Survey on Opportunistic Channel Scheduling in Cognitive Radio Networks with QoS Guarantees

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Abstract- **An opportunistic scheduling policy is being employed in the cognitive radio networks wherein the applicable resources are allocated to the primary users and as well as secondary users by understanding their spectral activities and ranges. But major problem seen here is that secondary users have the capacity to transmit only if primary users are not transmitting. It is very much essential to provide the co-ordination between the primary and secondary users so that the channel is utilized efficiently. From the studies it is proved that a scheduling scheme is used that improve the services received by secondary users and at the same time aims to reduce the collisions with primary users. To effectively utilize the channel, a channel scheduling scheme is being used. Also to overcome delay tolerance(wherein maximum numbers of packet transmissions are done before exceeding the deadline).To keep track of this issue,dynamic priority queue scheduling mechanism is considered.Cognitive radio networks are basically used to improve the capacity of the network;researchers have also shown that these could be implemented from pure theory.**

Index terms: Cognitive radio networks,opportunistic channel scheduling.

I.INTRODUCTION

Cognitive radio networks are recent advances in wireless communications, where they aims to improve the radio spectrum that exists already. The key aspect used is the cognitive radio. The cognitive radio dynamically adjusts the operating points over a wide range depending on spectral availability. We know that cognitive radio is the special class of capacity wherein they aim to improve the total capacity of wireless networks. Opportunistic scheduling paradigm included in cognitive radio networks solves various issues such as:i)maximizing the throughput and minimizing interference to primary users.ii)aims to improve fairness among users.iii)co-ordinating channel access,wherein secondary users are allowed to transmit along with the primary users.iv)collisions among the secondary users and Between primary and secondary users should be minimized.v)To serve multiple secondary users within the same network that exhibit different network characteristics. In normal scenario, the primary users are called the licensed users and the secondary users are the unlicensed users, they have the opportunity to transmit only if the primary users are not transmitting.

There are two types of users:

(i)Primary users: These users have the priority access and are subject to QoS (Quality of service) constraints and those must be guaranteed. Primary users are the license holders of the spectrum of their interest.

(ii)Secondary users: These users use the unused spectrum and they have the cognitive ability to communicate while ensuring communication of primary users is kept at certain level.

Cognitive behavior networks that contain cognitive radios should achieve better performance than networks in which cognitive radios are absent. CRN's should achieve better performance because of the following reasons:(1) they are capable of sensing and adapting to their wireless environment and thus they exploit cognitive abilities.(2) exploits policies to enable secondary users to share the spectrum with the primary users. Performance basically depends upon the how the cognitive radios know about their environment and act accordingly.

The three types of cognitive behavior we consider are:

(i)Interference avoiding behavior (spectrum interweave):

Here the secondary users use the primary spectrum without interfering with the primary users. Also primary and secondary signals are said to be orthogonal to each other. They may access the spectrum in TDMA or FDMA fashion and they ensure that primary and secondary signals do not interfere with each other. The secondary users need to know this information.

(ii)Interference controlling behavior (spectrum underlay):

The secondary users transmit over the spectrum that the primary users use to transmit but they do so in a way that the interference seen by primary users from cognitive users is controlled to some acceptable level. This acceptable level is captured by primary QoS constraints. Cognitive radio transmit such that they appear to be noise under the primary signals. Particularly the knowledge with respect to acceptable levels are required for efficient transmission.

(iii)Interference mitigating behavior (spectrum overlay): In this scenario the secondary users transmits along with the primary users and uses same spectrum used by the primary users but the cognitive radios has additional information about the primary users and its operation.

Let us consider the simple example of the cognitive radio networks showing primary and secondary users.

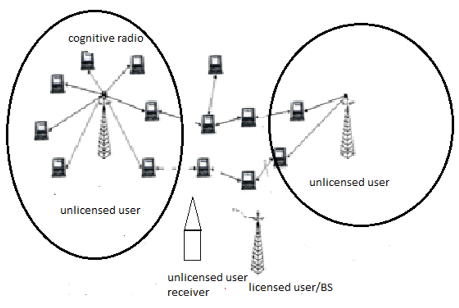

Fig 1:Cognitive radio networks

In cognitive radio networks, a dedicated channel is provided for each primary user. Reliability, safety and deadline guarantees of data are key features of advanced wireless communications and it should be ensured by the cognitive radio network. Also the main idea behind a cognitive network is for the secondary users to utilize the unused spectrum of the primary users and that should be done opportunistically. A dynamic reinforcement should be done with regard to utilize the spectrum holes and to reduce interference to primary users. The important consideration is done regarding the maximization of the available spectrum and schedule more number of packets.

This paper is organized as follows: Section II describes the opportunistic scheduling and opportunism. Section III describes the cognitive radio networks. Section IV describes the CRN architecture. Section V describes the CRN capability and features. Finally, the paper is concluded in section VIII.

II.OPPORTUNISTIC SCHEDULING

In this section, we provide a brief of what is opportunistic scheduling and what is opportunism.

A. Opportunistic scheduling incentives

Opportunistic scheduling take into account information such as channel quality in terms of QoS metrics such as throughput, delay, jitter, allows the scheduler to find proper transmission resources for each user. This notion was introduced by Knopp and Humblet. Here the particular event is scheduled by taking advantage of situation and gives the priority to users with favorable channel conditions. This aims to provide favorable channel conditions to users, there by distributing resources in a wireless networks. Channel quality is a major criteria that is considered here. Multiuser diversity in scheduling process can significantly improve the capacity. In the best case opportunistic approach, scheduler always chooses user in best channel condition to use resources. Gain in opportunistic scheduling on multiuser diversity due to noiseless channel impairments such as fading and multipath. Let us consider the concept called multi-user diversity here.

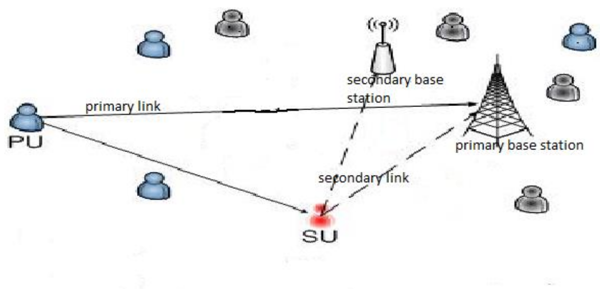

Fig 2:Multiuser diversity

Multiuser diversity is the ability to transmit a message securely in a dense wireless network. User scheduling allows base station to select high quality channel for transmission. Since there are many users here and each user requires the data out of the network, the transmitter must schedule the transmission independently. The rate at which each transmitter sends the data to each user differs because there exists variability in propagation environments and every user experiences varying channel conditions at different times. This is represented in the figure below:

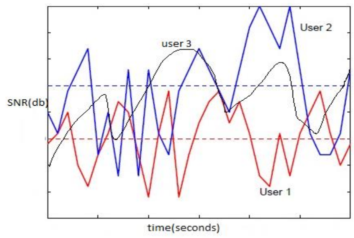

Fig 3:Channel conditions

There are three users here and each one of them experiences different channel conditions. User 1 is represented using red line; and it has got better channel condition compared to user 2 and user 3. Therefore we need to ensure that there exist favorable channel conditions for each and every users are provided. There must exist a mechanism to specify which user should transmit and at what time. Opportunistic scheduling schemes ensure this. They take into account channel in terms of QoS metrics such as bandwidth, throughput.

Aims to get good system throughput. It includes channel variability, multiple users share resources, exploits channel conditions. In opportunistic scheduling we include channel conditions or variability.

III. COGNITIVE RADIO NETWORKS

This subsection covers the opportunistic schedulers proposed for cognitive radio networks under the capacity category. In a cognitive radio network, secondary users have transmission opportunity only if primary users are not transmitting. It is desirable to design a scheduling scheme that improves the service received by secondary users while minimizing the collision possibility between primary and secondary users. The cognitive network control scheduling algorithm (CNC) maximizes the throughput of secondary users while bounding the maximum number of collisions with primary users. The authors of consider a network with primary and secondary users. There is a dedicated channel for every primary user. CNC consists of a flow control policy and a resource allocation policy. The flow control policy takes into account the current backlog of secondary users to decide whether a new packet must be admitted to the queue or not. A virtual collision queue is introduced that monitors how much a primary user experiences collisions more than a predefined threshold. Using Lyapunov drift and Lyapunov optimization, the authors prove that CNC maintains a worst case bound for both backlog queue and number of collisions. The authors also propose to use CNC in a distributed manner by using greedy maximal match scheduling. The distributed implementation supports any rate within 50% of the capacity region.

The simulations results show that CNC can bound the total average congestion while delivering almost all the traffic. In a classic cognitive network, secondary users utilize the slots which are not used by primary users. In contrast, Khalil et al. consider a scenario in which secondary users in good channel state help primary users in bad channel to increase the channel capacity. The secondary users can be rewarded immediately.

Opportunistic channel scheduling in cognitive radio networks allocate resources to cognitive users by exploiting the spectral activities of primary users. In cognitive radio networks, secondary users are regulated to use channel when it is not used by primary users. Secondary users need co-ordination in order to utilize channel effectively, but there are not exists standard regulation how to co-ordinate the channel access among secondary users. In this paper, we consider an approach that co-ordinate channel access among secondary users along with primary users.

We propose a channel access scheduling scheme that assigns priorities values to users based on their maximum tolerable delay. This paper focuses on the real-time message scheduling in cognitive radio networks that maximizes the packet transmissions before they exceed their deadline (delay tolerance). In order to guarantee that the transmitted messages will not exceed their deadlines, dynamic priority queue scheduling mechanism has been considered. Through experimental results we show that the packets those are not able to meet their deadline has been reduced by using proposed dynamic scheduling as compared to static priority queue scheduling. Mobile users are the driving feature of future network architectures. Information will be accessed on move and a significant amount of increase is seen in utilization of information.

Wireless technology is essential in order to support the mobile User. Adaptive and efficient use of radio spectrum is an important aspect of developing futurenetwork architectures. Cognitive Radios (CRs) integrate radio technology and networkingtechnology to provide efficient use of radio spectrum, a natural resource, and advanced userservices.

We can infer that cognitive radio is one of the future wireless communication advancement and is evolved as a key technology. Cognitive radio networks are formed by cognitive radios by extending the radio link features to network layer and above layers. Cognitive radios could be categorized as CRN architecture into several structures and classify the unidirectional links in such structures, to pave the way for future systematic CRN research.

IV.ARCHITECTURE OF COGNITIVE RADIO NETWORK

A. CRN Architecture

An important feature of CRN is to sense available networks and the communication systems around it. We cannot conclude that a CRN is just another network that interconnects the cognitive radios but it is composed of various kinds of communication systems and networks and it could be a kind of heterogeneous network. The heterogeneity exists in network, user terminal, and also in the technologies used to access the network. The CRN architecture is for improving the entire network utilization and also the spectrum efficiency. Network utilization in terms of user perspective could be to fulfill their demands anywhere and at any time by accessing the CRNs. From an operator perspective, it provide better services to mobile users and allocates network resources to deliver more packets with the available bandwidth in an efficient way.

B. Network Architecture

CRNs could be deployed in distributed, ad hoc , mesh , network-centric architectures. They serve the needs of both licensed and unlicensed applications. The basic components of a CRN are mobile station (MS), base station or access point (BSs/APs) and the backbone or core networks.

These three basic components compose of three kinds of network architectures in CRNs:
Infrastructure, Ad-hoc, Mesh architectures.
(i)Infrastructure Architecture
In this scenario, a MS can access a BS/AP in one-hop manner. A MS that is under the transmission range of the same BS/AP will communicate with each other through the BS/AP. Backbone networks are used to ensure the communication between different cells. In order to fulfill

the demands of a MS a BS/AP executes one or multiple communication standards or protocols. By means of BS or AP a cognitive radio terminal can access different kinds of communication systems.

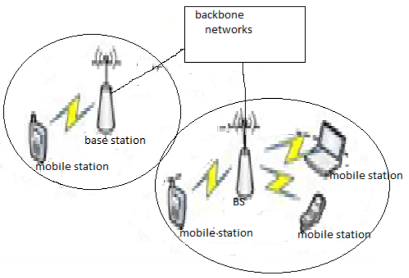

Fig 4: Infrastructure architecture

(ii)Ad-hoc Architecture

Here the infrastructure support is not available. If a MS recognizes that there are some other nearby MS then the MS connects with it through some communication standards or protocols available and thus can set up the link and form ad-hoc network. Links between the nodes could be set by different communication technology. Two cognitive radio terminals can communicate with each other by using protocols such as Wi-Fi or Bluetooth or by means of spectrum holes.

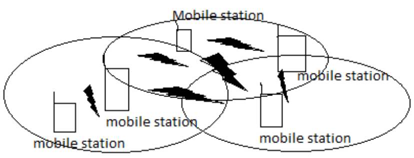

Fig 5: Ad-hoc architecture

(iii)Mesh architecture

This architecture is a combination of Ad-hoc and infrastructure architectures and thus enables connections between BS/AP. Here BS/AP works as wireless routers and form wireless backbones. A MS can access a BS/AP directly or by using another MS. Some BS/AP may connect to backbone or core networks to function as gateways. A BS/AP can be deployed without connecting to wired backbone, so it is more flexible and cost is significantly less. A BS/AP having cognitive radio capability use spectrum holes to communicate with each other. There is a lot of spectrum holes available and thus capacity of wireless communication links among BS/AP is enough to serve as a wireless backbone.

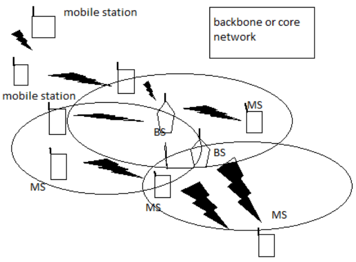

Fig 6: Mesh architecture

Primary System and Cognitive Radio System:

The two kinds of wireless communication systems in CRNs

Primary System and Cognitive Radio System, and this classification is based on the priorities on frequency bands.A primary system is referred to an existing system which operates in frequency bands that has one or many fixed bands. A primary system works in either licensed or unlicensed bands.

(i)Primary System in Licensed Bands: It has the highest priority to use the frequency band (Ex-2G /3G networks). During this scenario other unlicensed users cannot interfere with the primary system nor occupy the license band.

(ii)Primary System in Unlicensed Bands

Primary systems operating in an unlicensed band (Ex- ISM band) are called as unlicensed band primary system. Various primary systems should use the band efficiently. Primary systems operating in same unlicensed band will coexist with each other. Primary systems will have different levels of priorities and that depends on the regulations. A CR system neither has fixed operating frequency band nor has privilege access to that band. Entities communicate by means of spectrum holes.

The two components in CR systems: Cognitive Radio Base Station (CR-BS) and Cognitive Radio Mobile Station (CRMS).

(i)Cognitive Radio Base Station (CR-BS)

A CR-BS is a fixed component in cognitive radio system and has cognitive radio capabilities. A CR-BS represents the infrastructure side of CR system and provides the support (Ex- mobility, security) to CR-MS. Also provides a gateway for CR-MSs to access backbone networks (Ex-Internet).CR-BSs can form a mesh wireless backbone network by allowing the wireless communications between them and also some of them act as gateway routers if they are connected with wired backbone networks.

(ii)Cognitive Radio Mobile Station (CR-MS)

A CR-MS is a portable device associated with cognitive radio capabilities. It has the capability to reconfigure itself to connect to different communication systems. It can also sense spectrum holes and use them dynamically to communicate with CR-MS or CR-BS.

V.TERMINAL CAPABILITY OF COGNITIVE RADIO NETWORKS

The capabilities of cognitive radios are classified according to their functionalities.
A cognitive radio shall:
(i)Sense the environment (cognitive capability)
(ii)Analyze and learn sensed information (self-organized capability)
(iii)Adapt to the environment (reconfigurable capabilities)

Cognitive Capability
Spectrum Sensing
A cognitive radio can sense spectrum and detect spectrum holes that are not used by licensed users.

Spectrum Sharing
A cognitive radio can incorporate means of sharing the spectrum under the terms of an agreement with a third party.

Location Identification
The ability to determine a nodes location and also the location of other transmitters, later select the operating parameters such as the power and frequency allowed at specified location. Location technology is an appropriate method to avoid interference because technology pertaining to sensing will not be able to identify the locations of nearby receivers.

Network/System Discovery
A cognitive radio in order to communicate will first discover the available networks around it. These networks could be reached in one hop or through multi hop relay nodes. If a CRN wants to make a phone call, it will first discover if there is any Wi-Fi APs nearby. The ability to discover one hop or multi hop access networks is important.

Service Discovery
This concept will accompany with network and system discovery. System operators will provide their services through their access networks. A CR terminal will find appropriate services to fulfill its demand.

Reconfigurable Capability
Frequency Agility
It could be quoted as the ability to change its operating frequency. This method dynamically selects the appropriate operating frequency based on sensing of signals from other transmitters or based on some method.
Dynamic Frequency Selection
It is a mechanism that detects the signals dynamically from other radio frequency systems and avoids co-channel interference with those systems. Methods used by methods to determine when to change frequency includes spectrum sensing, location monitoring geographically.

Adaptive Modulation/Coding
These techniques modify the transmission characteristics and waveforms to provide opportunities for improved spectrum characteristics. To permit interoperability between the systems an appropriate modulation type is used for particular type of transmission.

Transmit Power Control
This feature enables a device to switch dynamically between several transmission power levels in data transmission process. Also reduces transmitter power to a lower level for greater sharing of spectrum.

Dynamic System/Network Access
A cognitive radio terminal must have the reconfigure capability when necessary in order to access multiple communication networks which runs different protocols.

Self-Organized Capability
Spectrum/Radio Resource Management
Good spectrum management is necessary to manage and organize spectrum holes information among the cognitive radios.

Mobility and Connection Management
Routing and topology information is more complex due to heterogeneity of CRNs. A good mobility and connection management is required to detect available Internet access and support vertical handoffs which help CRs to select route and networks.

Trust/Security Management
CRNs are heterogeneous in nature, a lot of security issues should be considered. CRNs are designed to improve the entire network utilization rather than link spectral efficiency. From users perspective they can fulfill their anywhere and anytime.

VI. OPEN ISSUES

1. With respect to the global internet, how richly connected mobile wireless networks affect the architecture, design and implementation?
2. How do resource allocation algorithms interact with fixed infrastructure resource allocation?
3. How to sense the radio spectrum environment sensibly? How one could detect the weak signals with respect to constrained processing capacity?
4. How operating parameters are set up? How information exchange is done reliably peer –to-peer?
5. How regulatory policies are set up? How multiple radio networks collaborate with each other? How are settings exchanged across the network?
6. How one can ensure that techniques are secure against intruders?

VII. CONCLUSION

Opportunistic scheduling criteria in cognitive radio networks allocate resources to cognitive users by considering the spectral activities of primary users. An opportunistic approach is considered to co-ordinate channel access among secondary users along with the primary users and also to minimize the interference among the secondary users. Also we have elaborated on the cognitive radio architecture and also the terminal capability of CRNs.

REFERENCES

[1] X. Liu, E. Chong, and N.Shroff, "Optimal opportunistic scheduling in wireless networks," in Proc. IEEE Vehi. Tech. Conf. (VTC'03), Vol. 3, pp. 1417-1421, Oct. 2013.

[2] D. Zheng, W. Ge, and J. Zhang, "Distributed opportunistic scheduling for ad-hoc networks with random access: An optimal stopping approach," IEEE Trans. Inf. Theory, Jan. 2012.

[3] S. Chakrabarti and A. Mishra, "QoS issues in ad hoc wireless networks," IEEE Communications Magazine, Vol. 39, Issue 2, pp. 142-148, Feb. 2011.

[4] R. Ramanathan and Martha Steenstrup, "Hierarchically organized multihop mobile wireless networks for qualityof- service," Special Issue: Mobile multimedia communications, ACM, Vol. 3, Issue 1, pp. 101-119, Jun. 2011.

[5] H. Zhai and Y. Fang, "Distributed flow control and medium access in multihop ad hoc networks," IEEE Trans. Mobile Computing, Vol. 5, No. 11, pp. 1503-1514, Nov. 2010.

[6] S. Kulkarni and C. Rosenberg, "Opportunisitc scheduling: Generalizations to include multiple constraints, multiple interfaces, and short term fairness," Wireless Networks, Vol. 11, Issue 5, pp. 557-569, Sept. 2012.

[7] Q. Zhang, Q. Chen, F. Yang, X. Shen, and Z. Niu, "Cooperative and opportunistic transmission for wireless ad hoc networks," IEEE Networks, Vol. 21, Issue 1, pp. 14-20, Feb. 2013.

[8] Y. Cao and V. Li, "Scheduling algorithms in broadband wireless networks," IEEE Proceedings, Vol. 89, Issue. 1, pp. 7687, Jan. 2001. 162 JOURNAL OF COMMUNICATIONS, VOL. 7, NO. 2, FEBRUARY 2011

[9] R. Knopp and P. Humblet, "Information capacity and power control in single cell multiuser communications," in Proc. IEEE International Conference on Communications (ICC), Seattle, USA, pp. 331-335, Jun. 2010.

[10] L. Yang and M. Alouini, "Performance analysis of multiuser selection diversity," in Proc. IEEE InternationalConference on Communications (ICC), Paris, France, pp.3066-3070, Jun. 2012.