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Dynamic Intra –network Spectrum Sharing for Cognitive Radio Networks

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Abstract. The swift expansion in the wireless technology has shaped the spectrum bandwidth scarce. This lack of spectra has pushed the spectrum management authorities to devise new ways for the efficient utilization of the existing spectrum. According to Federal Communication Commission (FCC) more than 70% of the available spectrum is not utilized optimally. Due to the shortage of available frequencies the bandwidth becomes a precious resource. For optimal and efficient usage of spectrum one possibility is to scan the whole spectrum to determine the opportunity for transmission (Dynamic Spectrum Access). The term Cognitive Radio refers to the intelligent radios that have spectrum scanning and parameter adjustment capability. This paper presents schemes for intra-network spectrum sharing in centralized cognitive radio networks. In such schemes a central entity called spectrum server is responsible to share the spectrum among the cognitive radio users. We assumed that all transmitters have fixed power and signal-to-interference determines the quality of a link. Dynamic Spectrum Sharing Scheme (DSSS) fulfills user's data requirement by utilizing the existing scheduling based spectrum sharing schemes. All of these techniques try to maximize different parameters with the sole objective of maximizing the utility of spectra.

Keywords: cognitive radio, software defined radio, spectrum sharing, primary user, secondary user etc.

1. Introduction

Cognitive Radio refers to the intelligent radios that have spectrum scanning and parameter adjustment capability. In [12] the authors measure the power spectral density (PSD) of the received 6 GHz wide signal. Fig.1 indicates the underutilization of spectrum that will demand a newer technology to enhance spectrum use. The power spectral density indicates the spectrum utilization behaviour of the primary users present in the radio environment. Dynamic spectrum access schemes permit CR user to use the best existing spectrum. The working of cognitive radios is illustrated through cognitive cycle. The cognitive cycle consists of following main components: spectrum sensing (finding spectrum holes), spectrum decision (characterization of spectrum holes), spectrum sharing (allocation of sensed spectrum) and spectrum mobility (vacate channel for primary user). The final step is necessary in order to avoid the interference with the licensed user.

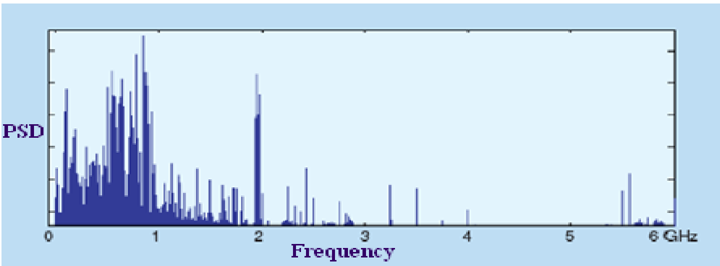

Fig. 1: Spectrum Utilization Measurement from 0-6 GHZ [12]

The remaining paper is organized as follows: Section 2 highlights the main characteristics of Cognitive

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Radios. The classification of spectrum sharing techniques is presented in Section 3. Section 4 presents the overview of existing scheduling based spectrum sharing schemes. Section 5 introduces the our Dynamic Spectrum Sharing scheme (DSSS). The results of DSSS are shown in Section 6. Finally the conclusion is presented in the Section 7.

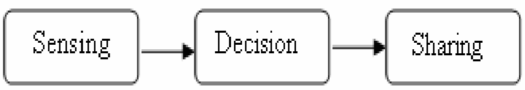
2. Distinct features of cognitive radio

2.1. Cognitive Capability

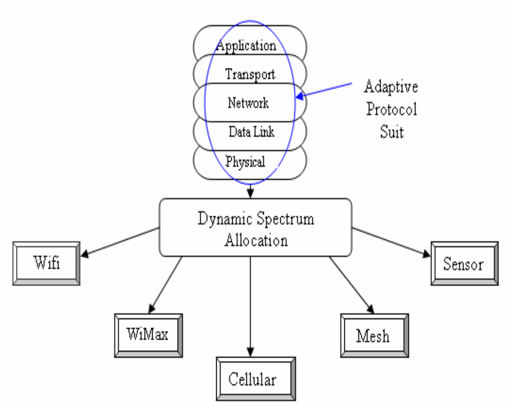
This feature allows cognitive radio to dynamically scan the whole spectrum and try to find out the opportunity for its transmission. The features consist of three components, sensing, decision and spectrum sharing as shown in Fig. 2(a).

2.2. Reconfigurability

Reconfigurability refers to the parameter adjustment capability without modification in hardware components. The parameters are operating frequency, modulation and transmission power etc. This feature requires dynamically changes in all layers of communication as shown in Fig.2 (b).



(a)

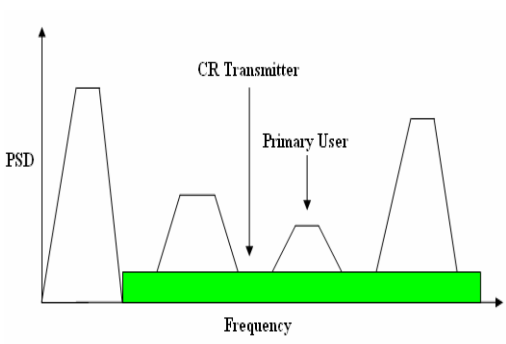


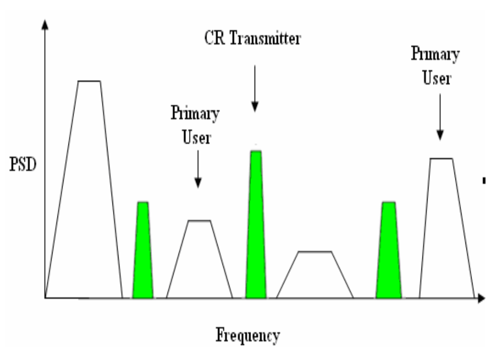
(b)

Fig. 2: (a) Cognitive Capability Components (b) Adaptive Protocol Suit

3. Classification of Spectrum Sharing schemes

The main challenge after the detection of available spectrum is to coordinate the access among the secondary or Cognitive Radio (CR) users. There are two basic approaches from the sharing perspective i.e. under and overlay as shown in Fig. 3. We utilize the overlay spectrum sharing approach to transmit data on the available spectrum. In underlay approach the communication go side by side with the transmission of primary users. [5].The spectrum sharing techniques can also be classified on the basis of architecture as Intra and Inter-network spectrum sharing.





(a)

(b)

Fig.3 Spectrum Sharing approaches (a) Underlay (b) Overlay

The centralized spectrum sharing schemes rely on single entity while distributed approach takes input from CR users to form a schedule for spectrum sharing. In centralized Intra-network spectrum sharing, spectrum server coordinates the sharing of spectrum among the CR users as shown in the fig. 4(a) [19].The arrow heads show the exchange of control information between CR user and spectrum server and thus exhibiting the cooperative nature. The circle on particular entity shows its participation in the sharing.

Fig. 4(b) exhibits the centralized inter- network spectrum sharing. All the dynamics are similar to intra network with the only difference that central entity called spectrum broker shares the spectrum among the CR users of two or more than two different networks. The spectrum sharing decision is taken from the input of the of more than one CR user networks.

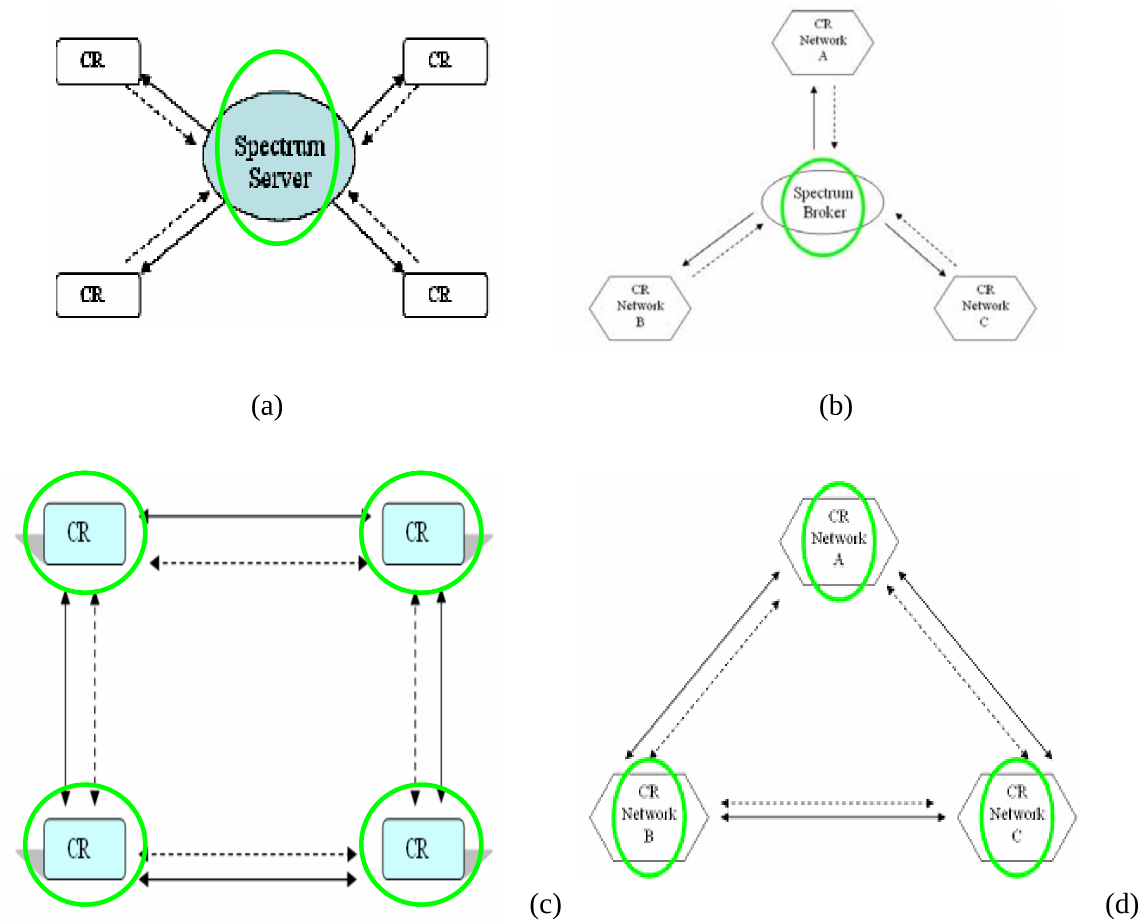


Fig. 4: Spectrum Sharing: Centralized Intra-network (a) Centralized Inter –network (b) Distributed Intra –network (c) Distributed Inter-network (d) [19]

The distributed spectrum sharing approach in intra and inter network is depicted in fig.4. (c) and fig.4.(d). It is clear from the block diagram that no single entity holds the sharing decisions. Each CR user in Intra-network and each CR network in Inter-network play its role in the sharing process.

4. Scheduling based Spectrum Sharing Schemes

There are three scheduling based spectrum sharing schemes discussed in literature in the context of cognitive radio networks.

4.1. Maximum Sum Rate Scheduling (MSRS)

This main objective of this scheme is to maximize the sum of the average data rates on all available links. It does not take into account the fairness criteria [3].

4.2. Max-Min Fair (MMF)

The MSRS scheme selects the best quality (i.e., least interference) links for transmission. The max-min fair is the global fairness scheduling scheme that provides the equal data rate to all links by adjusting the scheduling time (Sec) given to each link. It can be thought of as best scheme for those applications that require equal data rate to all available users in order to maintain consistency in the given data rate [3].

4.3. Proportional Fair (PPF)

The MMF scheme provides the fairness to all links equally that is unfair to the best quality links. The proportional fair scheduling scheme provides fairness on the basis of quality of individual link [3].

The existing three scheduling schemes make a way to devise new schemes for the efficient utilization of the sensed spectrum in cognitive radio networks.

5. Scheduling based Spectrum Sharing Schemes

Our proposed Dynamic Spectrum Sharing Scheme (DSSS) is an efficient spectrum sharing scheme that utilizes the existing scheduling based schemes to fulfil the data requirement of individual user. DSSS has the following capabilities.

- Incorporate Changes in the Radio Environment
- Mobility Support
- Throughput
- Segmentation

As we know that the radio environment is changing continuously so there is a strong need to map this behavior within the spectrum sharing scheme. Secondly, the mobility behavior is also important factor for the cognitive radio networks because if the primary user will arrive to the same band than CR user must have to leave that band in order to avoid the interference from the primary users. Thirdly, the throughput is also an important consideration for any sort of network. In the last segmentation is necessary step in order to maximize the throughput by sending the different packet of same users on different available links. All these four factors demand the robustness of sharing scheme for the cognitive radio networks. The DSSS by taking into account all the above mentioned four factors shares the available spectrum in optimal way by using one of the three techniques mentioned in the literature.

6. Results and Comparisons

The simulation results of DSSS are presented in this section. Though results are true for general cases, the present simulation provides results for some specific case. The simulation set-up consists of five users that are requesting for the spectrum according to their data need. There are three links available to the spectrum server for sharing among CR users. The dynamic maximum sum rate scheduling (DMSRS) scheme fulfils the data requirement of five (5) users in optimal way by considering all the important factors mentioned in section 5. The changes in the radio environment are mapped within the DSSS which you can visualize through the variations in the data rates of links in different time units (Sec). The data rate during the 1st sec is 3.65 bits/sec which reduces to 2.39 bits/sec during the second time unit as shown in Table 2.

The Dynamic MSRS encompasses the mobility support which is easily shown by the activity of single user on multiple links. For example in the Dynamic MSRS scheme the user 3 is transmitting on link number 3 during the 1st time unit while in the second time unit it shows the mobility behaviour and starts going its transmission on Link 1. The throughput is maximized by utilizing the segmentation process. The data of user 1 is segmented into two parts and transmitted over two links during the same time unit in order to provide the maximum throughput as shown in Table2. The sharing behaviour of Dynamic Max-Min Fair (Dynamic MMF) and Dynamic Proportional Fair (Dynamic PPF) is depicted in Table 3 and Table4.

User ID	Max. Need	d_{min}/ Sec
1	4	0.5
2	1	1.00
3	2	0.5
4	3	0.5
5	1	1.00

Table: 1

Links	Time Unit 1		Time Unit 2		Time Unit 3	
	User	Data Rate	User	Data Rate	User	Data Rate
Link 1	1	0.5	3	0.5	5	1.00
					3	0.5
Link 2	2	1	1	0.84	4	1
	1	2.65	4	1.55		
Link 3	3	0.5	4	0.5	3	0.5

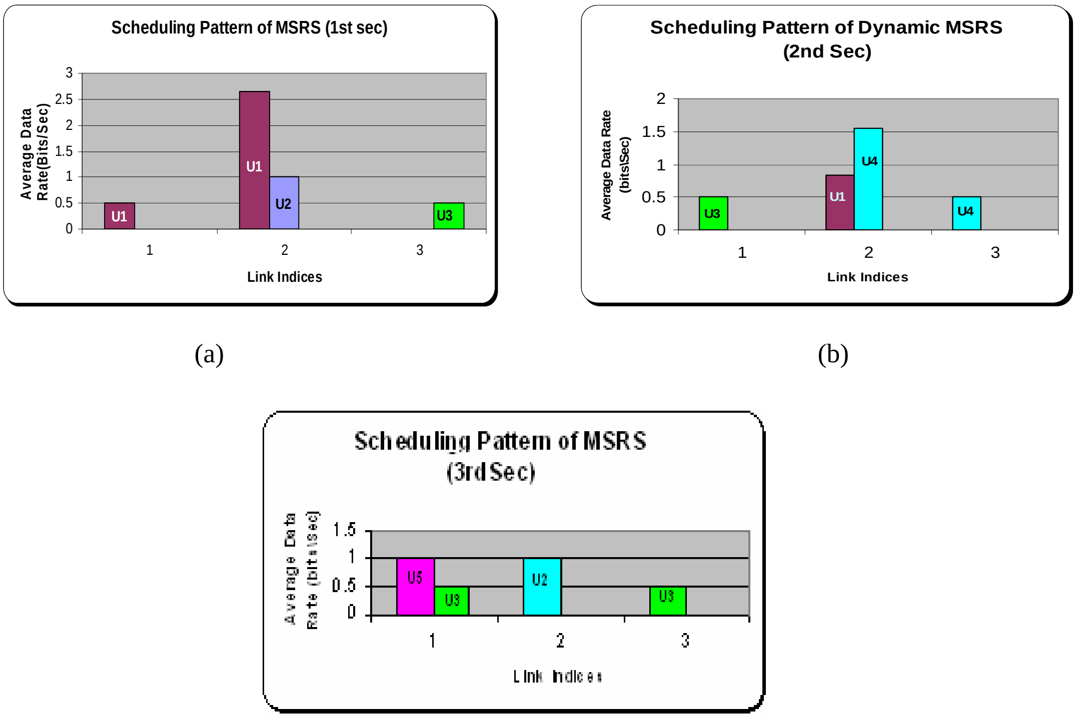
Table: 2

Links	Time Unit 1		Time Unit 2		Time Unit 3	
	User	Data Rate	User	Data Rate	User	Data Rate
Link 1	1	1.31	3	0.75		
			4	1.00		
			5	1.00		
Link 2	2	1.00	1	0.5		
	1	0.65				
Link 3	3	1.24	4	1.98	1	1.31

Table: 3

Links	Time Unit 1		Time Unit 2		Time Unit 3	
	User	Data Rate	User	Data Rate	User	Data Rate
Link 1	1	1.38	3	0.61	4	0.95
			4	0.72		
Link 2	2	1.00	1	1.34	5	1.00
	1	0.38				
Link 3	3	1.38	4	1.34	1	0.90

Table: 4



(a) (b)

(c)

Fig.5: Scheduling Pattern of Dynamic MSRS during 1st Sec (a) 2nd Sec (b) and 3rd Sec (c)

7. Conclusion

The efficient spectrum sharing scheme is like heart for the cognitive radio networks. The optimal utilization of the sensed spectrum totally relies on the sharing scheme. The current Dynamic scheme assumes that all transmitters are transmitting with the same power. An interesting thing to enhance the efficiency of the DSSS is to reduce the power of transmission. Secondly, we have assumed that the spectrum server is aware of the link gains. In order to increase reliability the link gains are calculated by considering all the factors that can influence the quality of links. From the application point of view, the Dynamic Maximum Sum Rate Scheduling (DMSRS) scheme is suitable scheme in order to provide priority to some particular users according to their data need. In certain application if there is a need to maintain consistency in the given data rate allocated to user then the Dynamic Max-Min Fair (DMMFS) is the best choice in that scenario. And in order to provide fairness to the user according to their link quality Dynamic Proportional Fair (DPPFS) scheme is the optimal choice.

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