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Allocation of Resources in Radar Spectrum Sharing of Cognitive Networks for 5G Systems

G.T.Bharathy[1*] and V.Rajendran[2]
[1]Associate Professor, Department of Electronics and Communication Engineering, Jerusalem College of Engineering, Chennai, India
[2] Professor, Department of Electronics and Communication Engineering, Vels Institute of Science Technology & Advanced Studies, Chennai, India.
[1]bharathy@jerusalemengg.ac.in, [2] director.ece@velsuniv.ac.in

Abstract— Huge demand of wireless linked devices like IoT's, Machine to Machine Communication, Wireless Adhoc Networks, Multicast Networks, leads to the requirement of communication systems with larger bandwidth. Alternatively the spectrum resource is inadequate and is allotted to various services leading to insufficiency of the spectrum. The technology of CRN offers a possible solution to this issue of scarcity of spectrum by dynamically allotting the spectrum to cognitive users during the absence of primary users. Spectrum Sensing and Spectrum Sharing are the vital functions of CRN. The spectrum sensing can either be homogeneous or heterogeneous. In Homogeneous spectrum sensing there is a delay in the process of identification of spectrum holes. Spectrum sharing schema is a prospective technique to reduce the trouble of spectrum overcrowding by allowing the wireless communication providers to utilize additional spectrum to facilitate the continually mounting bandwidth requirements of commercial consumers. This paper aims in the study and comparative analysis of various spectrum sharing schemas like underlay, overlay and interweave as one of the category and dynamic & cooperative spectrum sharing as other category for comparison, also simulates a radar system model consisting of interfering and non interfering cell sectors with frequency reuse algorithm, depicted as a real time application with sigmoid utility function using Matlab software.

Keywords— Cognitive Networks, Cooperative Spectrum Sharing, 5G Systems, Sigmoid Utility Function, Radar Spectrum, Frequency Reuse

1. INTRODUCTION

Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), together perceived that the enormous portion of spectrum apprehended by federal bureau has lesser standard consumption, particularly in metropolitan regions. Conversely, spectrum apprehended by commercial mobile operators, have intense utilization in metropolitan regions than federal bureau. The demand for bandwidth from the wireless communication system service providers has made way for the sharing the spectrum allotted to the federal radar operations [1], [2]. With the intention of competently utilizing the spectrum occupied by federal bureau at present, FCC and NTIA are functioning on a project to distribute 150 MHz of frequency band, apprehended by federal bureau, in the frequency range of 3.55–3.7 GHz with wireless systems [3, 20]. Spectrum sharing amidst radars and communication networks is a significant multi-disciplinary thrust region of research among federal bureau and business concern. The frequency band 3.55-3.65 GHz, presently used employed in military and satellite purposes, is a potential contender for spectrum sharing among military radars and wireless networks [4, 20]. Wireless networks shares the government band like the Wi-Fi and Bluetooth in the frequency range of 2.45-2.49 GHz, Wireless Local Area Network (WLAN) in the frequency range of 5.25-5.35 and 5.47-5.725 GHz

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radar bands [5, 20], and in recent times the FCC has planned small cells, i.e. wireless base stations working on a less power, to function in the frequency range of 3.55-3.65 GHz radar band [3, 20]. FCC proposes to exploit the 3.5 GHz band in a hierarchical manner where federal incumbents, Primary Access License (PAL) holders, and General Authorized Access (GAA) customers coordinate through a Spectrum Access System (SAS) for channel assignment as shown in the figure 1.

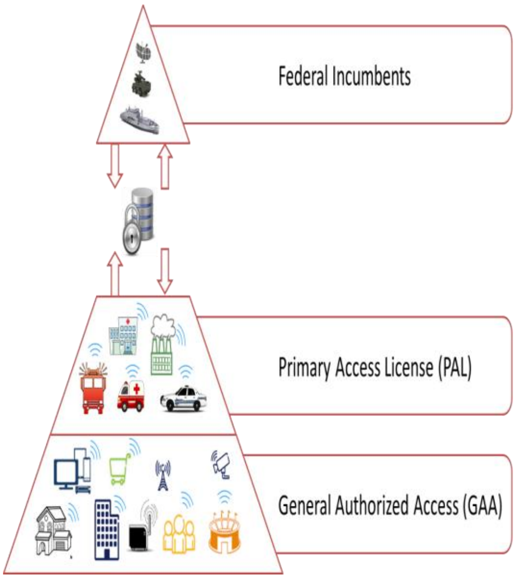

Fig. 1. Spectrum Sharing Hierarchy

A utility function helps in the depiction of Quality of Service of a consumer. At an instance, utility functions defines a parameter to exploit SINR [6], capacity of the channel [6], ratio of output power to the transmit power [7 , 8] etc. The optimum output of the network utility maximization issue is based on the contour of a utility function. For the maximization of the network utility, this paper uses sigmoidal- shaped utility functions with initial convex followed by concave shape, since the cumulative distribution function of the Quality of service criteria is triumphant packet transmission probability in addition is S-shaped with initial convex and followed by concave shape [9]. Spectrum sensing schemes and review of cognitive networks is explained in [10], [11], [12] & [13]. The sharing of the spectrum is executed by various techniques like sharing among same operator, among other wireless providers, sharing of licensed spectrum with cognitive consumers etc [14], [15], [16]. Open sharing scheme and hierarchical access scheme are the main categorization of scheme for sharing of the spectrum [17], [18], [23]. The spectrum sharing schemas are basically categorized as: interweave sharing, underlay sharing, and overlay sharing [19]. In interweave spectrum sharing; the cognitive network will with dynamism utilize the holes available in the spectrum. In spectrum underlay sharing, cognitive consumers are concurrently utilizing the spectrum along with the main licensed consumers.

2. LTE ARCHITECTURE

Control plane and the User Plane are the key elements of Long Term Evolution (LTE) as shown in the figure 2. User Plane Protocols forms a part of access stratum and transfers packets between UE and eNodeB on the radio interface. Control Panel Protocol forms a part of Non - Access Stratum (NAS) which takes care of the mobile management entity.

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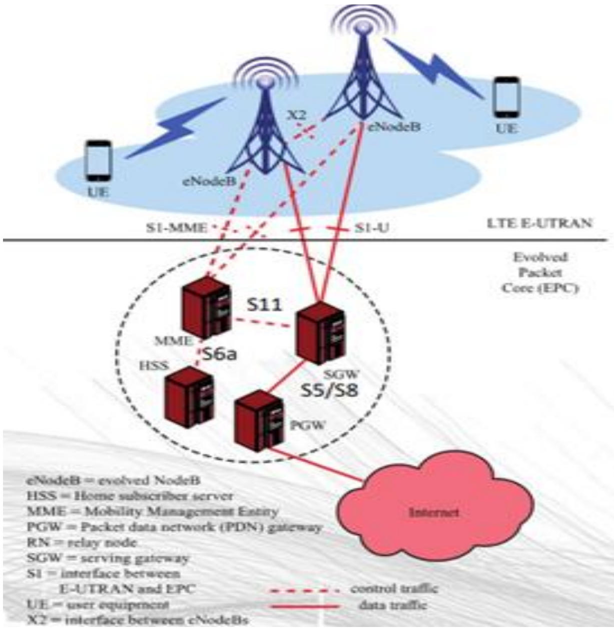

Fig. 2. LTE Architecture

2.1. MOBILE MANAGEMENT ENTITY

Mobility Management Entity (MME), provides an important management node for the LTE access network, handles UE access network and mobility. The MME also deals with the bearer activation/deactivation procedures. MME is accountable for the authentication of the customer and also creates and allocates provisional identification for all UEs. Additionally, it validates the authenticity for the UE to site on the wireless communication service provider's Public Land Mobile Network (PLMN) and also provides UE roaming limitations. The MME in addition manages mobility among LTE and 3G/4G access networks. Figure 3 depicts the structure of MME.

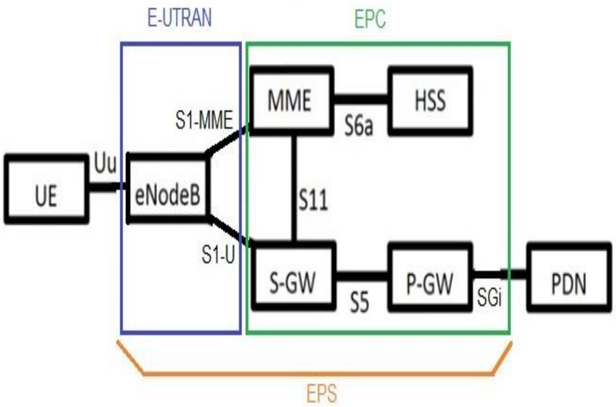

Fig. 3. MME Structure

2.2. UTILITY FUNCTION

For simulating the real world applications, sigmoid utility function is used. It is represented in mathematical expressions as

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$$U(r) = c\left(\frac{1}{1+e^{-a(r-b)}} - d\right) \quad (1)$$

$$c = \frac{1+e^{ab}}{e^{ab}} \quad (2)$$

$$d = \frac{1}{1+e^{ab}} \quad (3)$$

The delay - tolerant applications utilize the logarithmic utility function represented in mathematical expression given by

$$U(r) = \log(1+kr)/(\log(1+kr^{\wedge}mc \quad (4)$$

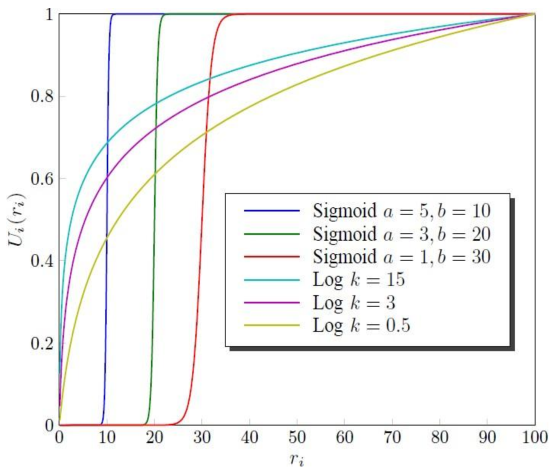

Fig. 4. Plot of Sample Utility Function

3. SPECTRUM SHARING

The spectrum sharing is an important function of the cognitive radio networks where the sensed spectrum is shared among the licensed user and the cognitive user. Figure 5 depicts the types of spectrum sharing schemes.

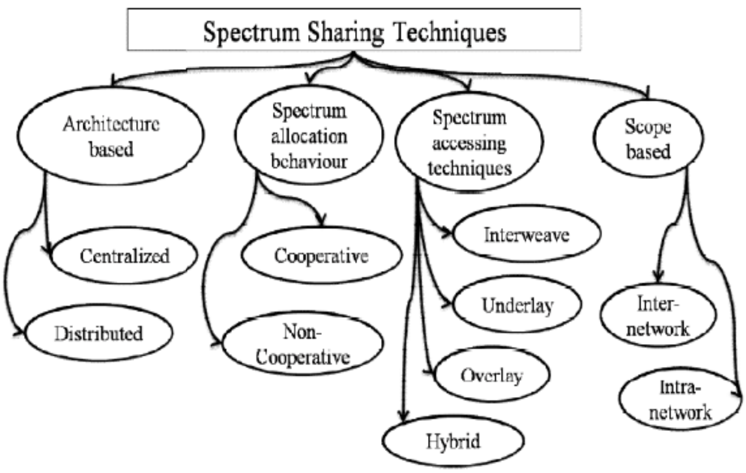

Fig. 5. Classification of Spectrum Sharing Techniques

Underlay spectrum sharing, Overlay spectrum sharing and Interweave spectrum sharing are one of the classifications of spectrum sharing schemes. The table 1 provides the comparative chart of all the three spectrum sharing schemes.

Table 1. Comparison of various Spectrum Sharing Schemes

Underlay Sharing	Overlay Sharing	Interweave Sharing
The channel strength of the licensed users is available to the cognitive users	The gain of the channel and the codebooks of the licensed users is available to the cognitive users	When the licensed spectrum is unoccupied then the cognitive users identifies the holes in the spectrum
Licensed users and the cognitive users utilize the spectrum simultaneously when the infringement is below the threshold value	Licensed users and the cognitive users utilize the spectrum simultaneously when the infringement is below the threshold value	Licensed users and the cognitive users will utilize the spectrum simultaneously if and only if the spectrum hole is identified

Dynamic sharing of spectrum and Cooperative sharing of spectrum are another category of the spectrum sharing schemes. Table 2 provides the comparative analysis of the two schemes.

Table 2. Comparative Analysis of Dynamic and Cooperative Spectrum Sharing Schemes

Dynamic Spectrum Sharing	Cooperative Spectrum Sharing
Opportunistic sharing between main and the cognitive user	The main user spectrum is shared with the cognitive user
To control the intervention the frequency bands of main user and the cognitive user is disjoint	A part of the licensed user is given to the cognitive user for the management of the interference
The intervention constraint limits the transmitter power of the cognitive user	The cognitive user can transmit signal with any power
The cognitive users access the spectrum using CSMA/CA or CSMA/CD techniques	The cognitive users access the spectrum using ALOHA techniques

4. RADAR SPECTRUM SHARING MODEL

The system model is designed to have cells with sectors which are both interfering and non interfering with the transmission of radar. The model is depicted in the figure 6.

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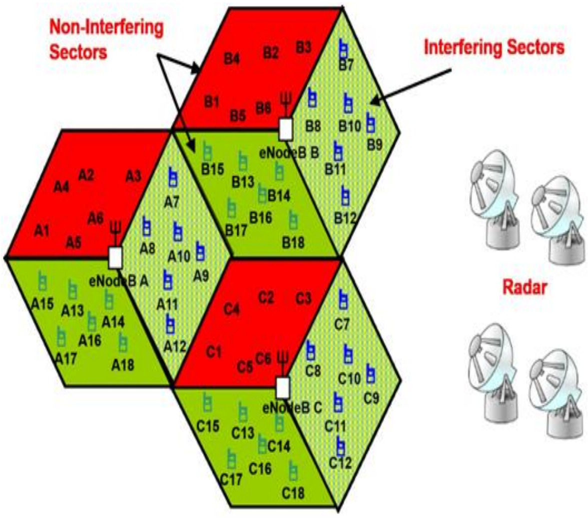

The non-interfering sectors uses the radar spectrum. The model has f k = 3 eNodeBs' in k = 3 cells. L = 3 sectors per cell and M = 54 mobile customers are available in these cells. The allotment of the resources from the MME to eNodeBs' sectors depending on the UEs' applications. The frequency reuse algorithm is separated into an i^{th} UE algorithm as depicted in the figure 7, an l^{th} eNodeB sector algorithm as depicted in the figure 8 and MME algorithm in the figure 9.

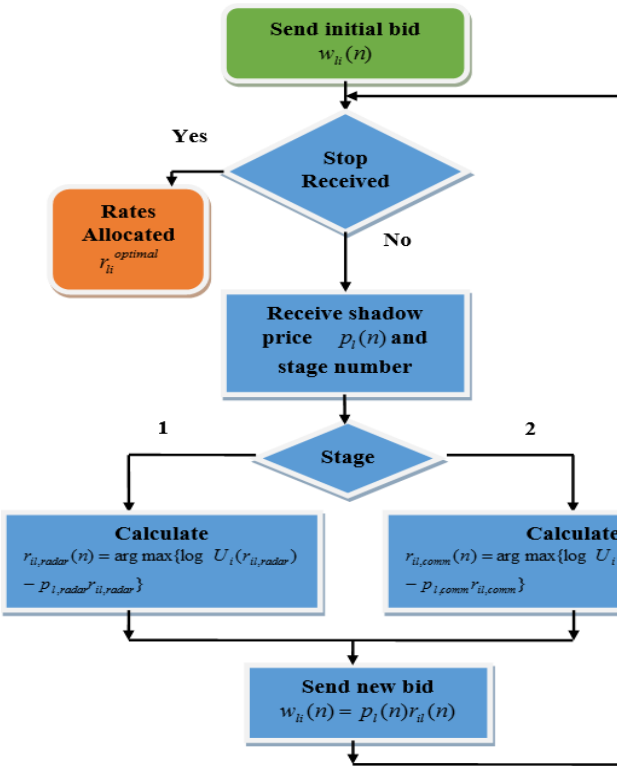

Fig. 7. Flowchart of an i^{th} UE algorithm

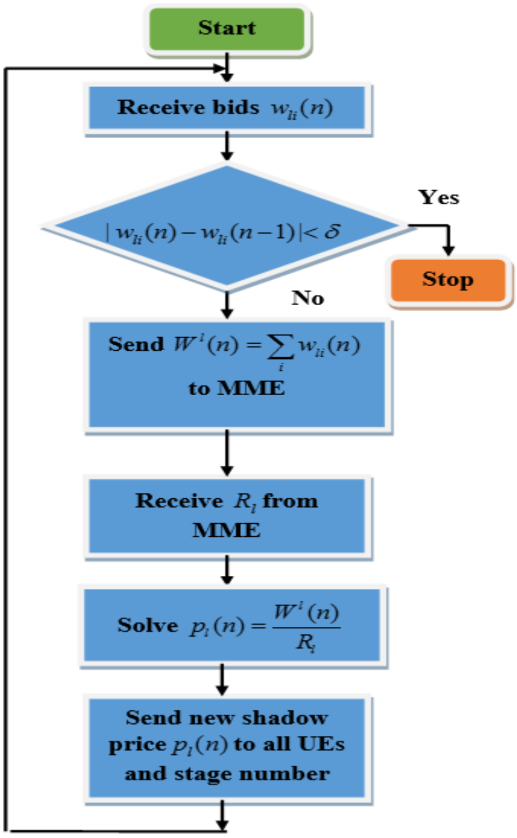

Fig. 8. Flowchart of an l[th] eNodeB

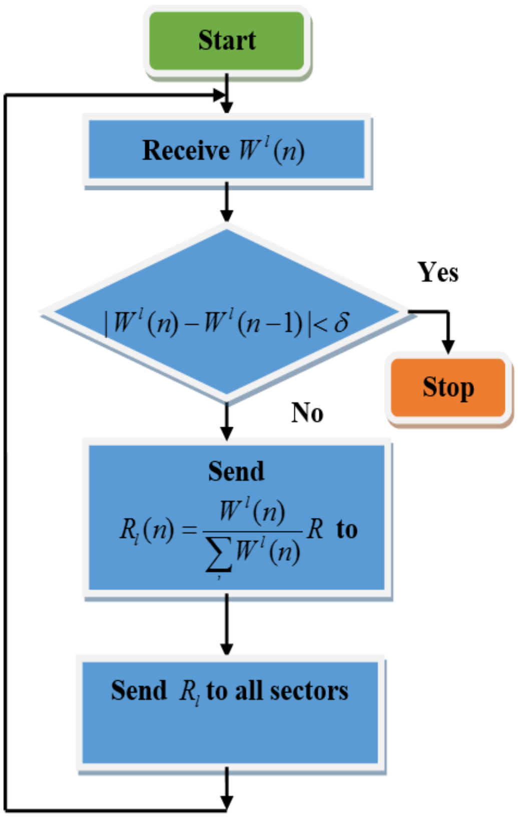

Fig. 9. Flowchart of MME algorithm

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wli(1) is the initial bid of the ith UE that is transmitted to the lth sector. The difference between the present bid wli(n) and the previous bid wli(n − 1) is calculated and is present if the value is smaller than the threshold value δ and transmits the data to all the user in its coverage area.

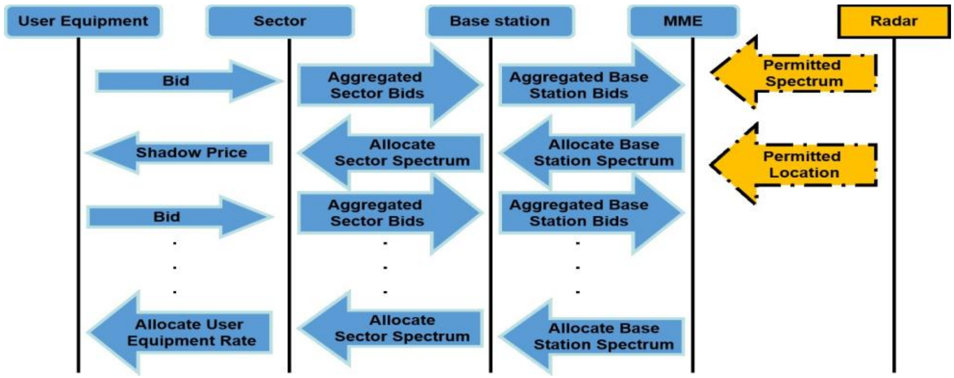

Fig.10. Frequency Reuse Algorithm Transmission

5. SIMULATION RESULTS

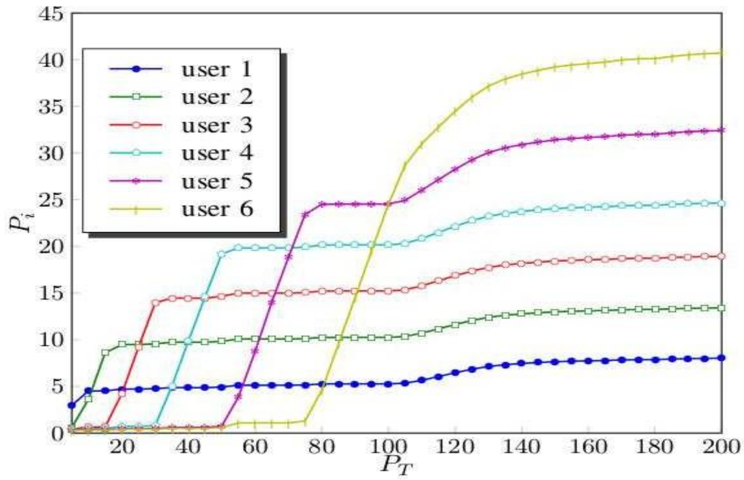

Fig. 11. Plot of P_T versus P_i

Figure 11 shows the plot of allotted power P_i for various base station power values of P_T. The plot shows that the power is allotted to all the users depending on the modulation techniques.

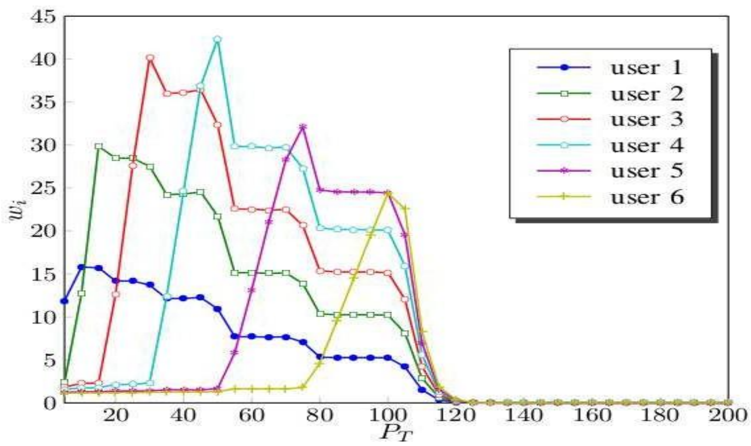

Fig. 12. Plot of W_i versus P_T

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Figure 12 depicts the plot of W_i versus P_T and the plot shows that larger base station power P_T is allotted to the user with larger bid value W_i.

6. CONCLUSION AND FUTURE SCOPE

Spectrum sharing schema is a prospective technique to reduce the trouble of spectrum overcrowding by allowing the wireless communication providers to utilize additional spectrum to facilitate the continually mounting bandwidth requirements of commercial consumers. This paper has presented a study and comparative analysis of various spectrum sharing schemas like underlay, overlay and interweave as one of the category and dynamic & cooperative spectrum sharing as other category for comparison, also describes a radar system model consisting of interfering and non interfering cell sectors with frequency reuse algorithm, depicted as a real time application with sigmoid utility function using Matlab software. As a future scope this model can be implemented for the wireless applications in 5G systems.

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