Allocation of Power for Secondary Users in Cognitive Radio Network

G. Sivaranjani and S. Sarika

Abstract: **Most of the power allocation schemes rely on centralized server to resolve resource allocation problem, provided the server must have a global knowledge about the Channel State Information and interference information of every receiver. Due to this, computational ability of server becomes tedious as it create interference to other Secondary users. The major contribution of this paper is to allocate power for secondary users in distributed manner using Frequency Division Multiplexing Access within the node power budget. A power allocation algorithm is proposed to maximize throughput of secondary users by calculating pay off function. The pay off function determines the spectrum utilization of each secondary users by using pricing method. Meanwhile the interference between secondary users and primary users is reduced by the proposed distributed algorithm.**

Keywords: CR network, game theoretical approach, pay off function. Overlay spectrum sharing.

I. INTRODUCTION

Among diverse wireless technology supporting Internet access and other stream traffic services [7], a different vision is to integrate different wireless systems/networks and to appropriately use one of them based on the communication environments and the application requirements, based on reconfigurable communication and networking. Cognitive radio is considered to improve spectrum utilization by minimizing the interference between the users. A cognitive radio consists of a licensed users (Primary Users or PUs) and unlicensed users (Secondary Users or SUs). Radio Resource Management is an important module of a CR node, the aim of which is to evaluate the available resources (power, time slots, bandwidth, etc) and assign them to meet the QoS objectives of the SU, within some constraints on factors (typically interference) which limit the performance of the licensed user or the PU.

The power allocation could be done using various methods which is studied from [3]-[5].One of the methods involves a centralized server that includes all the state information about the entire network. The server must contain the information about each and every primary user and secondary users. It also contains the capability of the users to withstand the service that is being requested to the Access point (AP).The evaluation of such a type of tedious network is a complicated one because if the server fails at any instant, the entire system goes down. It becomes unusable for future justifications. In order to overcome such a drawbacks, this method is modified into de-centralized technique, where the power allocation is done using a modified game theoretical approach. As a result the power control is done with minimum reduction of interference. The literature review says that most of the power allocation schemes uses underlay spectrum sharing approach in which same frequency band is accessed by both PU and SU.

The main objective of is the use of overlay spectrum sharing approach in order to minimize the interference between the two PUs and between PU and SU, thereby increasing the SU throughput within the power budget.

II. RELATED WORK

A. A general power allocation in OFDM based cognitive radio networks

Power allocation in OFDM based CRN system have used the adaptive sub-carrier configuration considers not only Channel State Information but also the sensing results of SU and interference limits of PUs[5]. Here a band of SU is divided into several sub channels, each sub channel corresponds to a licensed band of one PU system. As interference limit of each PU introduces the sub channel transmit power constraints for SU, the power allocation in OFDM based CRN must satisfy the sum transmit power constraint and the sub channel transmit power constraints. The transmit power in each sub channel is comprised of the power allocated to the subcarriers inside the sub channel and the side lobes power of the subcarriers in the other sub channels. In this method ,in the power allocation problem, if the effect of side lobes is ignored, then there is a sufficient guard band between any two neighboring sub channels. In order to maximize the capacity and to provide optimal power allocation by satisfying both sum and sub channel transmit power constraints, iterative water-filling algorithm has been used by ignoring the side lobes. Another method is to decouple the sub channel power constraints phase by phase by considering the side lobes. The power allocation problem can be classified into two categories in conventional

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OFDM-based systems. The first one is to optimize the power allocation across the subcarriers such that the sum rate is maximized with a given sum transmit power constraint.

B. Mutual interference in OFDM systems based on spectrum pooling systems

Interference in OFDM [3] aims at enabling public access to these spectral ranges without sacrificing the transmission quality of the actual license owners. Unfortunately, using OFDM modulation in a spectrum pooling system has some drawbacks. There is an interaction between the licensed system and the OFDM based rental system due to the non-orthogonality of their respective transmit signals. The author describes the interaction mathematically which provides quantitative evaluation of the mutual interference that leads to an SNR loss in both systems. However, this interference can be mitigated by windowing the OFDM signal in the time domain or by the adaptive deactivation of adjacent subcarriers providing flexible guard bands between licensed and rental system. It is obvious that both approaches sacrifice bandwidth of the rental system. A quantitative comparison of both approaches is given as a trade-off between interference reduction and throughput in the rental system. A potential rental system (RS) needs to be highly flexible with respect to the spectral shape of the transmitted signal. Here, the case of an FDMA/TDMA-based licensed system (LS) is considered. Thus, spectral ranges that are accessed by licensed users (LUs) have to be spared transmission power originating from the RUs. OFDM modulation is a candidate for such a system as it is possible to leave a set of subcarriers unused, thus providing a flexible spectral shape that fills the spectral gaps without interfering with the LUs. This interference is caused by the side lobes of the OFDM signal. This method focuses on parasitic losses in SNR of both LS and RS due to the non-orthogonality of their respective transmit signals. It is possible to reduce the mutual interference of both systems and increasing the throughput of RS can be done by using raised cosine windowing. By using windowing techniques number of transmissions could be increased in a system.

C. A game theoretic approach to interference management in cognitive networks

A game theoretic solution [21] for channel selection and power allocation was proposed in cognitive radio networks. The author enforced the cooperation among nodes in an effort to reduce the overall energy consumption in the network. For designing the power control, the author considered both the case in which no transmission power constraints are imposed and the maximum transmission power is limited.An iterative algorithm for channel scheduling and power allocation has be implemented, which converges to a pure strategy Nash equilibrium solution, i.e., a deterministic choice of channels and the transmission powers for all users.

To tackle the problem, the author proposed a game theoretic formulation, in which the adaptive channel allocation and power control problem is modeled as a potential game. The radios are modeled as a collection of agents that distributive act to maximize their utilities in a cooperative fashion. The radios' decisions are based on their perceived utility associated with each possible action which is related to the transmission power and to the channel selection. Two scenarios (power control with and without maximum transmission power limitation) are considered, and the effect of various maximum power levels on the system performance is investigated. By using this method, both channel allocation and power control can independently improve the system performance, in order to achieve a significant gain for the joint algorithm.

III. SCHEMATIC MODEL OF NETWORK

In cognitive radio networks, there are large number of secondary users compete to access the spectrum. There may be occurrence of interference between two SUs or between one PU and one SU. Such a problem could affect the network performance to a large extent. Instead of using a centralized power allocation, in which there is a centralized server. The server must have knowledge about the global information about the network. The distributed algorithm has been formulated in order to improve the spectrum utilization of SU.

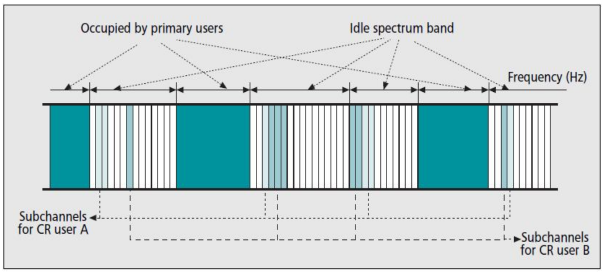

Fig. 1 Spectrum Allocation

Compared to OFDM based power allocation in cognitive where the effect of side lobes in sub channels are considered, the proposed distributed algorithm reduces the interference between the SU pairs. The interference from the licensed system occurs in the OFDM receivers of the Rental systems is reduced by windowing scheme which is very poor performance. If the windowing scheme is used number of transmissions could be increased and there is a chance for occurrence of interference. The overall performance of the network is degraded. The proposed model considers an overlay spectrum sharing approach for PU and SUs to shares spectrum using FDMA technique to maximize throughput of SU by formulating a game theoretical approach. The overlay spectrum approach is interference avoidance scheme which is better in which the SU have to identify and exploit the spectrum holes defined in space time, and frequency, when compared to underlay spectrum approach.

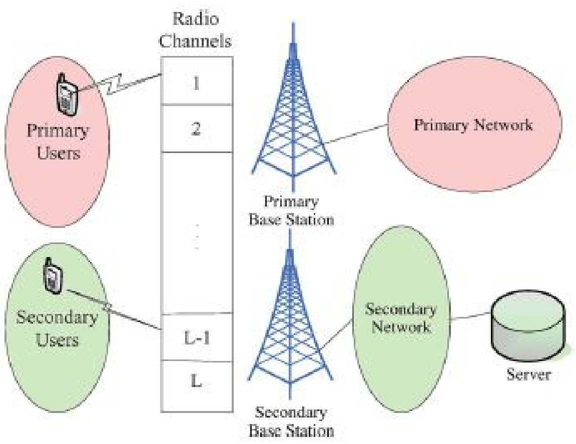

Fig. 2 Network model for CRN

The sequential steps are as follows.

The available spectrum is divided into different subcarriers.Each subcarrier is allocated with power that could be updated, if necessary. If in case the adjacent carrier reduces power, then based on the users and carriers, power allocation is done. In order to calculate throughput of SU, pay off function is to be measured. Pay off function is the utility function that describes how well the spectrum is utilized more by SU. Based on the utilization factor, the interference between two SUs, and the interference between one PU and one SU, throughput is measured. By minimizing the interference, throughput could be maximized. The available spectrum is divided into different sub carriers. Each sub carrier is allocated with power that could be adjustable if necessary. If adjacent carriers reduce power, then based on the number of users & carriers, the power is allocated. The allocated power is stored in the vector form. Initially the vector is stored with zero values. After allocation, the current power is stored & compared with the previous power. Based on the values, variation is identified and CINR value is calculated. If there is no power management, then throughput will reduce.A vector is created in which the initial value is zero. As and when the power is allocated by base station to each user, that power is stored in the vector. Each time the current power is stored and compared with the previous power. Based on this value, identify the variations. If there is no power management, then throughput will reduce. After the throughput estimation it is essential to calculate the utility function & pricing function. The utility function is nothing but the pay off function for p^{th} secondary users. The utility function is given by the following expression.

$$U_n(P_p, P_{-p}) = T_p - I_{p1} - I_{p2} \qquad (1)$$

Where $U_n(P_p, P_{-p})$ is the utility factor of p^{th} secondary users,

T_p is the SU throughput.

I_{p1} is the interference occurred between the PU and SU.

I_{p2} is the interference occurred between the secondary users.From the expression it is very clear that by reducing the interference between the PU and SU, we could maximize the throughput ot some extent. The maximum spectrum utilization of SU is given pricing 1 and the minimum utilization of SU is given zero pricing value. Based on the pricing function, channel is allocated to the SU so as to access the service. If two SUs access the same service,the base station will check the capability of SU whether it could access the service requested by SU. If the user doesn't have the sufficient capacity, the service will not be provided to that SU.

If the service requested by primary user, the free band available service is immediately allocated and the requested packet is sent by the base station. If in case the secondary users request the service, then the cognitive starts to sense the free band availability. If free band is available, then the corresponding frequency is allocated to secondary users. If there is no free band in that particular channel, then channel switching takes place.

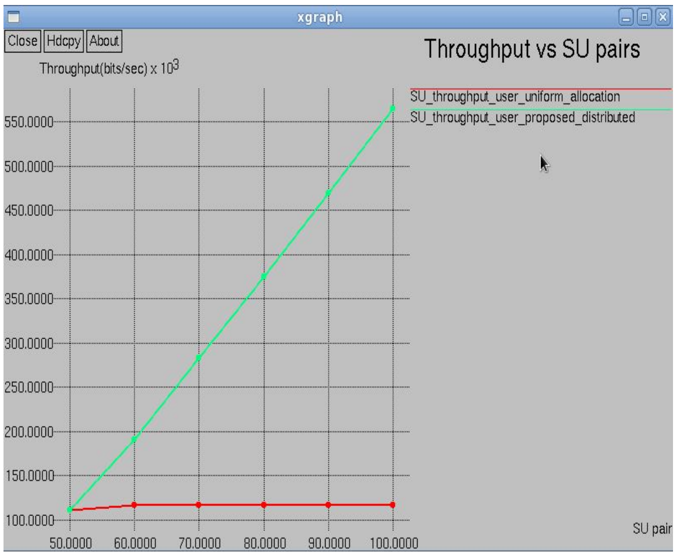

Fig. 3 Throughput versus SU pairs in Cognitive Radio Network

Fig.3 shows the throughput measurement..Here a network has been created with 50 primary users and 100 secondary users and the graph for the number of packets transmitted per second (Throughput) versus secondary user pairs has been obtained and the proposed distributed power allocation is compared with the uniform power allocation is plotted. Throughput comparison is made between the distributed power allocation and uniform power allocation. The simulation results shows that throughput achieved using distributed power allocation algorithm is better.

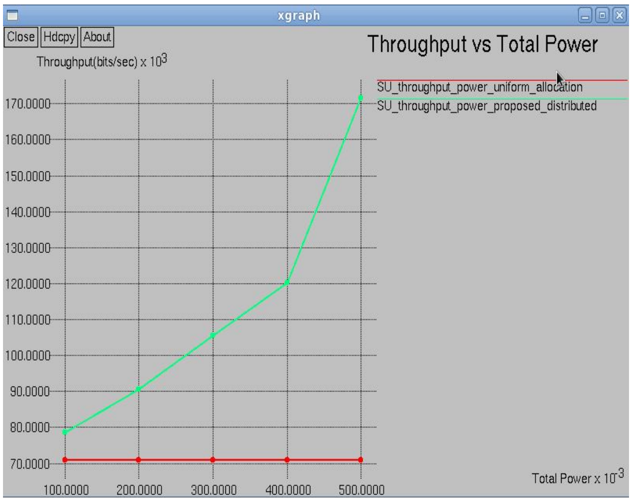

Fig. 4 Throughput versus Total Power.

From the Figure 4 shown above, for various powers of secondary users, the throughput is measured. From the simulation results, it is observed that using uniform power allocation method, we can't view the power variation in secondary users as it remains constant throughout the simulation time. But in distributed power allocation, there is a power variation of secondary users with some degradation and the throughput versus total power is plotted.

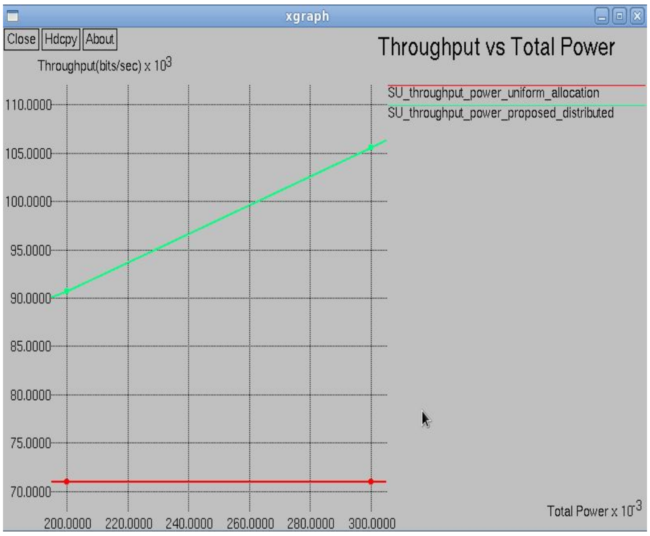

Fig. 5 Throughput versus Total Power using distributed scheme

From the Figure 5 shown above, for various powers of secondary users, the throughput is measured. From the simulation results, it is observed that using uniform power allocation method, we can't view the power variation in secondary users as it remains constant throughout the simulation time. But in distributed power allocation, there is no degradation in power of secondary users and the throughput versus total power is plotted.

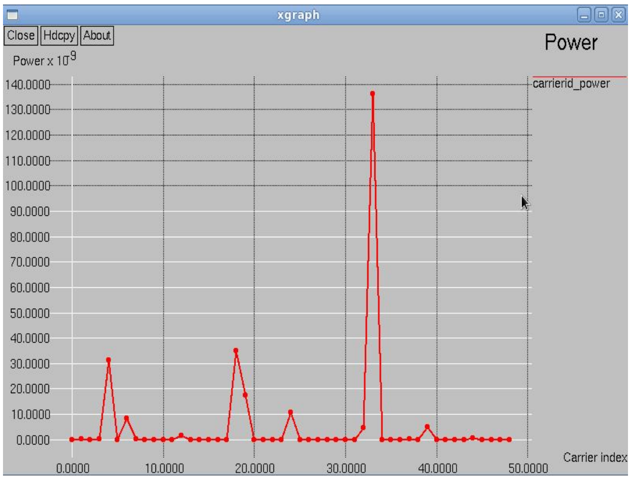

Fig. 6 Power Vs Carrier Index

From the Figure 6 shown above describes about the power consumption of the entire network. Carrier index refers to the division of subcarrier. The above graph explains that which subcarrier utilizes maximum power that is shown as peaks and the flat response shows that underutilization of the spectrum.

From the Figure 3, it has been observed that the throughput of secondary users using distributed power allocation scheme is improved to four times when compared to the uniform power allocation. It is observed that the distributed power allocation is better with respect to throughput performance.

From the Figure 5, it is observed that the throughput is uniform for the total power of secondary users in case of uniform power allocation, whereas the throughput varies linearly with respect to power of secondary users.

IV. CONCLUSIONS

The conventional centralized power allocation method involves a server that must have knowledge about global information of the network, which controls all the nodes. So by using the distributed power allocation scheme involves a pricing method that determines the utilization of spectrum based on the power level of each secondary user. Meanwhile the interference between one primary user and one secondary user as well as the interference between two secondary users is reduced by allocation of power based in distributed manner. This scheme provides maximum throughput and node power could be measured for all secondary users in cognitive network In cognitive radio network, the number of secondary users per channel could be increased in order to reduce interference and avoiding channel wastage within a threshold limit, without affecting the primary users.

V. SIMULATION PARAMETERS

The total system bandwidth assumed is to be 8MHz of which 7MHz is occupied by SU, while PU occupies 1MHz.The type of channel used is wireless channel having 100 primary nodes and 150 secondary users. The simulation time is 100s.Here we use two ray ground propagation model. The transmitted power is 1Watt.

VI. FUTURE WORK

In cognitive radio network, the power allocation could be done by using Pareto distribution in cognitive radio network using shadowing propagation model. Also the interference between the secondary users could be reduced to an extent using Full Duplex Relay System and the performance could be compared might be the future work.

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