EFFECTIVE SPECTRUM SHARING METHOD USING POWER ALLOCATION ALGORITHM IN COGNITIVE RADIO NETWORKS

***Dr. E.D.Kanmani Ruby*, Professor**
S.Nithya
N.Saranya
PG Scholars, Kongu Engineering College,Tamil Nadu, India

Abstract

Major problem in cognitive radio network is frequent handoff between the spectrum bands which is sensed to be idle for the usage of the secondary users. Whenever the spectrum is utilized by the primary users the secondary user has to be looking for the free idle band in order to avoid the interference between the licensed and unlicensed user because of which the handoff between the secondary have been increasing between the idle spectrum bands. To avoid the frequent handoff and the efficient usage of spectrum of bands we propose a new power allocation algorithm. This algorithm not only adjusts the transmission power of the secondary user but also provides interference constraint between the primary and secondary user, through which the secondary user can obtain more spectrum for the usage. Finally the simulation result of the power allocation algorithm is illustrated and demonstration of the proposed scheme is shown.

Keywords: Handoff, power allocation algorithm, interference constraint, licensed, unlicensed

Introduction

The spectrum is a scarce natural resource and its efficient use is the utmost importance. In the development of future wireless systems the spectrum utilization functionalities will play a key role due to the scarcity of unallocated spectrum. Recent studies reveal that radio spectrum licensed to primary users is underutilized and the problem of "spectrum scarcity" is actually a problem of "spectrum access" [1]. Most spectrum bands are allocated to certain services but worldwide spectrum occupancy measurements show that only portions of the spectrum band are fully used. It has become essential to introduce new licensing policies and co-ordination infrastructure to enable dynamic and open way of utilizing the available spectrum efficiently. One promising solution to such problems is the Cognitive Radio. A ''Cognitive Radio" is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. The ultimate objective of the cognitive radio is to obtain the best available spectrum through cognitive capability and reconfigurability. Since most of the spectrum is already assigned, the most important challenge is to share the licensed spectrum without interfering with the transmission of other licensed users [3].

A typical cognitive radio consists of a sensor, a radio, a knowledge database, a learning engine, and a reasoning engine. A cognitive radio continuously learns from its surroundings and adapts its operational parameters to the statistical variations of incoming radio frequency (RF) stimulus. A cognitive radio selects a set of parameters based on knowledge, experience, cognition, and policies. The parameters chosen optimize some objective function. In the cognitive domain, knowledge or cognizance is obtained from awareness of surroundings, based on input statistics from sensory observations and other network parameters [11].

The cognition cycle consists of three stages: observe reason and learn, and act. In the observe stage, the radio takes input statistics from the RF environment, updates the knowledge base, and tries to learn the trends with an ultimate aim to optimize a certain objective function during the act stage. It can be noted that, false input statistics in the observe stage can induce incorrect inference, which when shared might propagate throughout the network. As far as learning is concerned, several algorithms based on machine learning, genetic algorithm, artificial intelligence, etc., can be used. With the accumulated knowledge, the radio decides on the operational parameters in such a way that maximizes the objective function at any time instance. At times, different combination of inputs are tried to see if there is a significant change in the objective function. The results are stored in the knowledge base and also fed to the learning algorithms for them to evolve over time.

Spectrum Decision: Cognitive radio networks have to decide on the availability of channels before they can use them. The entity deciding on the occupancy compares the energy detected on a channel with a threshold; if energy is greater than the threshold, the channel is inferred to be occupied by a primary or a secondary. This process is termed as local sensing as it is done by a stand-alone cognitive radio. In an infrastructure based cognitive radio network, the local sensing results are sent to the central fusion center which combines the local results in accordance with a suitable fusion algorithm. The local sensing result may also be raw energy values; in which case the fusion center has to normalize the energy vectors from each node. Generally for larger networks, the local sensing result is a binary vector of 1’s and 0’s, where 1 denotes channel is occupied by a primary and 0 denotes absence of primary [11]. In contrast, in the ad hoc mode, the local sensing results are sent to all neighbors. A radio fuses the local sensing of its neighbors data before it can decide on the usage. The process of fusing data from other radios usually entails cooperation, and thus collaborative or cooperative sensing is usually employed. However, there is always a difference (both temporal and spatial) between the collected data and the result of the fusion. The possibility of this difference can be exploited by the malicious nodes.

Problem Formulation

In this paper, to reduce the frequently handoff among idle spectrum bands and fully utilize the spectrum resource for secondary users, we propose a new spectrum sharing scheme for the secondary user and focus on the problem of power allocation for secondary users. This new spectrum sharing scheme allows the secondary users to utilize all the spectrum bands (i.e. the spectrum bands occupied by primary users and the idle spectrum bands). And the secondary users firstly sense the state of spectrum bands before the data transmission. For the spectrum bands occupied by the primary users, the secondary users just only consider the interference constraints and adjust the transmit power in the spectrum bands, instead of handoff to idle spectrum bands. And for the idle spectrum bands, the secondary users can utilize them freely and only consider the total transmission power constraint. Under this new spectrum sharing scheme and the constraint conditions, we study the problem of distributed power allocation for secondary users and formulate the optimization problem as a Nash equilibria problem (NEP). Then we solve the NEP based on the variational inequality approach.

Assume P primary user and S secondary user with single transmitter receiver pair for each user. The frequency spectrum band is divided into T sub-channels. First the spectrum is sensed to determine whether it is idle or active then the power allocation is according to the sensing result. Let us consider T1 idle and T2 active sub-channels in a time slot where T=T1+T2 respectively.

Then NEP problem is formulated with of maximizing the transmission rate under the constraint condition. Therefore the NEP with prices can be formulated as follows

$$\max_{P_i} R_i(P_i, P_{-i}) - \sum_{p=1}^{P} \sum_{n=1}^{T_1+T_2} \alpha_{P,n|G_{pi}(n)|^2 P_i(n)}$$

Show that,

$$\sum_{n=1}^{T1} P_i(n) + \sum_{m=1}^{T2} P_i\,(n) \leq P_i^{tot}; \quad \forall\, i \in \{1,2, \dots S\}$$

$$P_i(n) \leq P_i^{mask}(n);\ \forall n \in \Delta1 \cup \Delta2, \forall i \in \{1,2, \dots, S\}$$

$$\sum_{i=1}^{S} P_i(n)\left|G_{pi}(n)\right|^2 \leq P_p^{peak}(n);\ \forall n \in \Delta1$$

Where

$$R_i(P_i, P_{-i}) = \beta_{\omega1} + \beta_{\omega2}$$

$$\beta_{\omega1} = \sum_{n=1}^{T1} lb\left(1 + \frac{P_i(n)|h_{ii}(n)|^2}{\mu_i^2(n) + \sum_{j\neq i} P_j(n)\left|G_{ij}(n)\right|^2}\right)$$

$$\beta_{\omega2} = \sum_{m=1}^{T2} lb\left(1 + \frac{P_i(m)|h_{ii}(m)|^2}{\mu_i^2(m) + \varphi_i(m) + \sum_{j\neq i} P_j(m)|G_{ii}(m)|^2}\right)$$

In this formula, $P_i^{tot}, \forall\, i \in \{1,2, \dots, S\}$ denotes the total power available for the *i*th secondary user, $P_i(n)$ denotes the transmit power for secondary user *i* in sub-channel *t*. $P_i^{mask}(n), \forall\, n \in \Delta1\ \cup \Delta2$ denotes the spectral mask constraints that maybe imposed by radio regulatory bodies to limit the maximum power spectral density (PSD) that each secondary user can use over a specified band. $G_{pi}(n)$ denotes the channel gain in sub-channel *n* from the transmitter of secondary user *i* to the receiver of primary user *p*.

Power Allocation Algorithm

1. Sense the sub-channel state of primary users.
2. Based on the sensing results, the SU's take a transmission strategy with an iteration process.
3. In each iteration process, the PU updates its prices according to the interference.
4. Then SU estimate the prices and do the power allocation.
5. Until the prices satisfy a certain criterion, the power allocation for SU's is realized.
6. And when the set of prices is fixed, the power allocation for secondary users is determined.

This algorithm gives that at each time slot, the secondary users firstly take the spectrum sensing techniques to sense the sub-channel state of primary users. Then based on the sensing results, the secondary users take a corresponding transmission strategy with an iteration process. And in each iteration process, for those sub-channels occupied by the primary users, the primary users update its prices according to the interference and broadcast their prices to the secondary users [6]. Then the secondary users estimate the prices and do the power allocation.

Simulation Results

In this area the simulation result of the algorithm is been demonstrated. In this section we assume that the secondary user is having two ray propagation model with different channel fading in different channel. We assume that the total number of primary and secondary as P and S, so that P=20 and S=125 with 4 frequency spectrum and each spectrum has 100 sub-channels totally. The total power of the user has been considered as 0.8 with the transmitting and receiving power.

In fig.1 the performance of the peak power with the average capacity has been shown. Here the capacity of the user increases with respect to the peak power. Also the interference between the primary user and secondary user reduces according to the peak power.

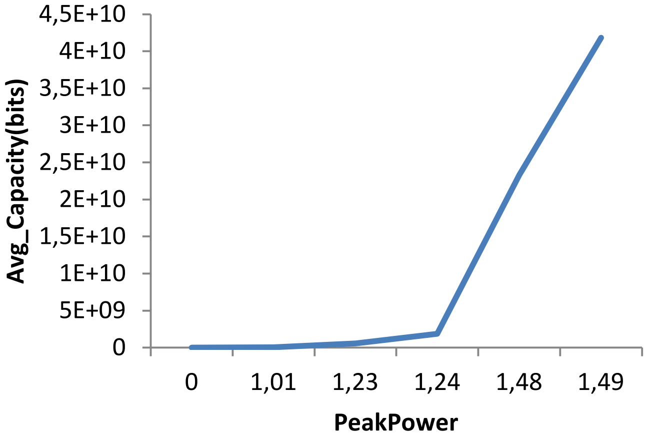


Fig. 1 Average Capacity vs Peak Power

In the fig.2 the convergence iteration count of prices of update for different number of secondary user. From the fig we see that the convergence iteration count of price with respect to interference increases with the increase of the number of secondary user.

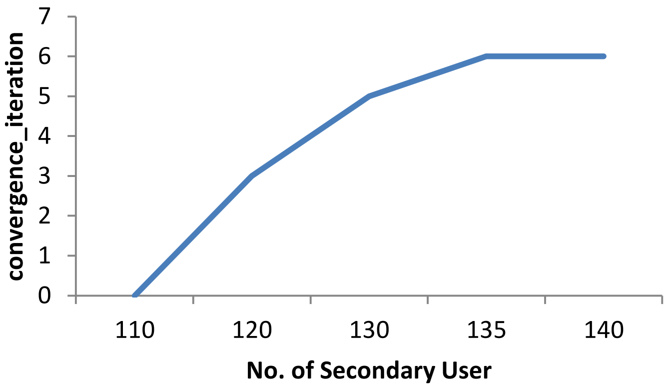
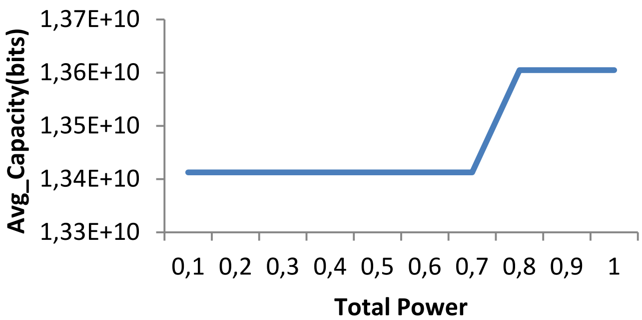


Fig. 2 Convergence iteration count vs Number of Secondary Users

In fig.3 we estimate the capacity of the secondary user with the increase of total power of the user and it is proven that the total power increases then the average capacity of the secondary user increase. It is proven by estimating the result with the different amount of total power and the simulation result is shown in the below figure.



The Above simulation result shows that the power allocation algorithm of the new spectrum sharing has an effective utilization of the spectrum through the power allocation scheme to the secondary user.

Conclusion

In this paper, we have seen the optimal power allocation algorithm for a new spectrum sharing scheme. Here we have introduce the power allocation for the secondary user so that it reduces the interference between the primary user and secondary also allows the secondary user to utilize the spectrum even during the presence of primary user so that the spectrum is fully utilized and also the capacity of the user increases. The Nash Equilibrium Problem is also formulated and a variational inequality approach is been used to solve this problem. Finally the simulation result of the proposed scheme is demonstrated and the performance of the cognitive system also improved.

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