Optimal Power Allocation in Ofdm Based Cognitive Radio System

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Abstract

Efficient spectrum usage becomes critical issue when a variety of wireless communication device comes into wider use. The concept of cognitive radio based OFDM is used to solve the scarcity problem. To tackle the optimal power allocation problem in OFDM –based cognitive radio networks, the key is use gradient based power allocation method with well designed step size can approximate the optimal solution within a fewer iterations. The proposed gradient method taking into account the factors capacity of the user , interference constraints and channel gain which achieves optimal solution with low computational complexity of O(N).

Key terms: *Cognitive radio (CR), gradient descent, Orthogonal frequency- division multiplexing (OFDM), power allocation.*

I. INTRODUCTION

The limited availability of radio spectrum and high inefficiency in its usage, new insights into the use of spectrum have challenged the traditional approaches to spectrum management. This necessitates a new communication paradigm to harness the underutilized wireless spectrum by accessing it opportunistically. This new communication technology is referred as dynamic spectrum access (DSA) or cognitive radio (CR). A CR system relies on opportunistic communication between unlicensed or secondary users (SUs) over temporarily unused spectral bands that are licensed to primary users (PUs). The concept of cognitive radio (CR) based on software defined radio is first presented is to solve the problem of spectrum scarcity CR networks have been seen as a promising solution to improve the current spectrum underutilization while accommodating the increasing amount of services and applications in wireless communication. The Federal communication commission reports that most licensed spectrum are unutilised. This problem can be solved by allowing secondary users to access the spectrum holes, which are frequency bands assigned to primary users (PU), but not used at a same time. The spectrum utilization problem can be solved by allowing secondary users (SUs) to access the spectrum holes, which are bands of frequencies assigned to primary users (PUs) but not employed at a particular time. Orthogonal Frequency division multiplexing (OFDM) a competitive transmission technique has used in CR network. The problems that arise with high bit rate communications, and due to time dispersion are solved by multicarrier modulation technique called OFDM. The data bearing symbol stream is split into several lower rate streams and these streams are transmitted on different carriers. OFDM include high spectral efficiency, robustness against narrow- band interference (NBI), scalability, and easy implementation using fast Fourier transform (FFT) are the advantages. OFDM's underlying sensing and spectrum shaping capabilities together with its flexibility and adaptively make it probably the best transmission technology for CR systems

A major challenge is used to design efficient resource allocation algorithms that work well in OFDM based CR networks. The licensed PU spectrum should be accessed by secondary user without causing any interference to primary user. The optimal solution for power allocation problem of OFDM can be obtained by using water filling technique [1]. The water filling technique is employed for single user CR system without mutual interference, however as secondary user access the unused frequency bands by PU's mutual interference would affect primary user band. There are number of algorithm had used for single user case are bit and power loading schemes which is practical implementation of water filling algorithm. This problem is different with power constraint. So the total amount of mutual interference and interference on PU band should be considered. There are two main types of interference in CR networks. One is introduced by PUs into SUs which leads to signal to noise ratio loss in CR networks. The other one is introduced by SUs into Pus which should be less than interference temperature level. These are solved by several low complexity schemes but there is degradation of performance have been given in [2]. The next method which is used to tackle the power allocation problem for OFDM based CR network is fast algorithm [3] based on multiple interference constraints. The barrier method is used in this algorithm which is based on logarithmic barrier function. The optimal solution in barrier method is obtained by user specific parameters, however this method is not straightforward and where warm start is required for different problems. The resource allocation for SUs with constraints on interference level and subcarrier availability is considered in risk return model [4] where exhaustive search method is used. This approach is based on randomness in link capacity as a product of probability of sensing error activity and average rate loss function which is a function of allocated power in corresponding subcarriers. The greedy algorithms for multiuser OFDM-based CR networks are given in [5]. In this paper by considering the total power constraint, the transmit power constraint on the Sub channel, the total amount of the mutual interference or the mutual interference on each sub channel of PUs are used for power allocation. In addition, the resource allocation problem for SUs with the constraints on the interference level of each PU is further considered in multicast networks . In this paper gradient based method is used to solve the power allocation problem in OFDM based cognitive radio network. There are two main types of interference in CR networks. One is introduced by PUs into SUs, which leads to a signal-to-noise ratio loss in CR networks. The other one is introduced by SUs into PUs, which should be less than the interference temperature level used to ensure the quality of service for PUs. The extension of steepest descent method projection gradient algorithm is used where interference constraints are considered. The Euclidean projection technique is used for projection of power allocation of constraints. This method depends on step size. The step size determines the accuracy of the approximation and the number of iterations, so it should be carefully selected.The gradient-based method is slowly progresses for smaller value. A better performance may be achieved, but numerous iterations are required. Therefore, we may tend to find an adaptive method to adjust the step size in each iteration The proposed method has computational complexity of O (N).

II. SYSTEM MODEL

The proposed method involves OFDM transmission technology for cognitive radio network. The OFDM reduces inter symbol interference due to its orthogonality of subcarriers. Consider a CR system where frequency domain spectrum is divided among Primary users and CR or secondary users. M frequency bands are used by CR users and L frequency bands are used by primary users whose bandwidth B. The bands unoccupied are considered for CR users which N OFDM subcarriers. The bandwidth is $\Delta f\ Hz$. L PU bands are active when one CR user is transmitting. The capacity of secondary user is maximised while keeping interference of the primary user below the interference temperature level. The capacity of the CR user is defined as convex optimisation problem (bits per second per hertz). The capacity is given by

$$Min - C = \frac{1}{N}\sum_{n=1}^{N} -\log(1 + p_n\,|h_n|^2/(\sigma^2 + J))$$

$$= \frac{1}{N}\sum_{n=1}^{N} f_{n(P_n)}$$

Where $p_n \geq 0$ for n= 1,2,3..........N

Here N denotes the number of subcarriers of OFDM, h_n denotes the channel gain of subcarrier, σ^2 represents the noise power, p_n and represents the power allocated to subcarrier, interference introduced to the PU subcarrier is denoted by J which is related to primary user transmitter and CR user receiver channel gain. The algorithm used here is gradient based method.

A. Power Allocation by Gradient based Method

The power allocation problem with interference constraint is solved by gradient based method. In this method the gradient vector on the constraint vector is projected to obtain a feasible direction. Some subcarriers are assigned with zero power and this subcarriers are not considered for power allocation. The Euclidean projection operation is performed for the power allocation onto the interference constraint. The step size is predetermined or adaptively adjusted in iterations. This gradient based method contains two components gradient descent approach and the Euclidean projection technique.

B. Gradient Descent Approach

The gradient is given by partial derivative of $f_{n(P_n)}$ with respect to p_n .This is given by

$$\nabla f_n(p_n) = \frac{\partial f_n(p_n)}{\partial p_n}$$

The power vector with respect to gradient is

$$\nabla F(p) = \left[\frac{\partial fa(p_a)}{\partial a}\ \frac{\partial f_b(p_b)}{\partial b} \dots\dots \frac{\partial f_N(p_N)}{\partial N}\right]$$

Each element is evaluated by using the current power allocated to that selected subcarrier. To satisfy the interference constraint in , the specific structure of the constraint set allows to compute the projection operator using the orthogonal projector. The orthogonal projection of any vector onto the null space of K involves multiplication by the matrix J as an orthogonal projector.

Power vector P is updated and premultiplied by

$$p(t+1) = p(t) - \frac{\alpha j(t)\nabla Fp(t)}{\sqrt{(J(t)\nabla F(P(t))^T (J(t)\nabla F(P(t))}}$$

Where $\propto$ is the step size, t is iteration index, some subcarriers have negative power vector during iteration, and these subcarriers are not considered for power allocation.

The equal interference method are used for allocating power initially to each subcarriers

$$p^n = I_{th}/N\widetilde{K}$$

By appropriately setting step size and by using above equations interference constraints for each subcarrier is calculated. If sum of caused interference is equal to or less than the interference constraint the capacity of the CR user is calculated. The aim of the proposed gradient-based power allocation method is used to find the amount of power allocated to each subcarrier directly. The computational complexity of the gradient-based method is O(N) in each iteration, where the matrix-related operations can be manipulated to achieve this complexity. The choices of the step size and the weighting factor determine the behaviour of the proposed gradient-based power allocation method. For a small value, the gradient-based method slowly progresses. A better performance may be achieved, but numerous iterations are required. If a large value is selected, a fast rate is revealed to achieve a solution. The method for determining the step size and the weighting factor is to give fixed values in advance for the gradient-based method. The value of the step size and the weighting factor should be appropriately determined by considering the performance and the number of iterations required in the proposed method.

C. Flowchart of Gradient Based Method

The gradient based algorithm procedure is given in below figure 1. In the algorithm initially power is allocated between subcarriers and by appropriately setting the step size the power vector is updated. The caused interference is calculated. If this interference is less than or equal to interference constraint then the next step is to calculate the capacity. If the sum of caused interference is greater than the interference threshold, then Euclidean projection technique is employed. When the capacity improvement becomes negative in the iteration, the processing of iterations is stopped.

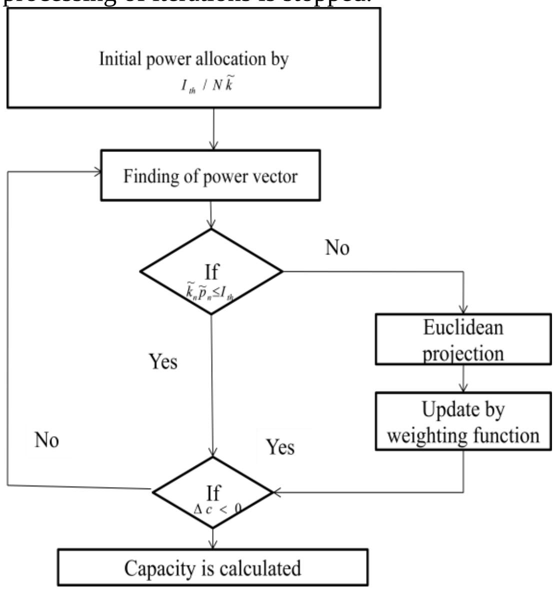


Fig 1. Flowchart of gradient based method

D. Euclidean Projection

The Euclidean projection technique is used to perform a projection of the power allocation onto the constraint set so that interference constraint is satisfied. Only N^+subcarriers are selected for projection technique. The Euclidean projection is given by

$$\bar{P}(t+1) = \hat{p}(t+1) - \frac{\breve{K}.|K_{1*N} + \tilde{P}(t+1) - I_{th}|}{\sum_{n=1}^{N} |K|^2}$$

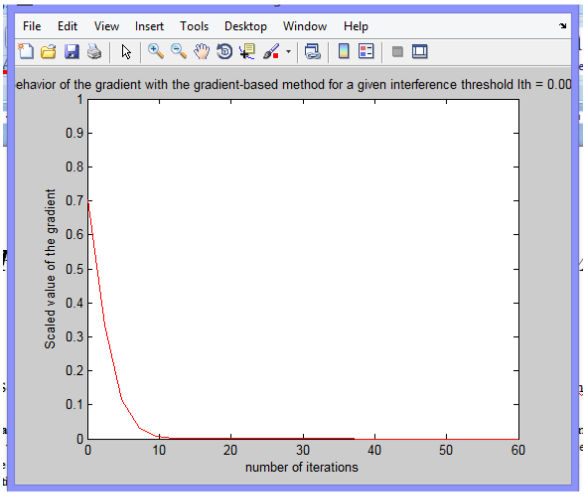
To obtain the improved performance the allocated power is adjusted by introducing weighting function which consists of projected power and allocated power in previous iteration. The weighting function is given by

$$P_n(t+1) = (1-\delta)p_n(t) + \delta\bar{P}(t+1)$$

The weighting factor belongs to (0, 1) which satisfies the interference constraint. The capacity improvement is obtained due to weighting function. If the achievable capacity is improved, the proposed gradient-based method continues to update the allocated power.

III. RESULT

There are six bands with a bandwidth of 180 kHz are assumed. Two bands are unoccupied by PUs are assigned to CR users. Each band contains 12 subcarriers with a bandwidth of 15 kHz. Channel gain is considered as Rayleigh distribution. The step size is defined to be greater than zero and to to find a step size that would improve the performance for each iteration. For a small value, the gradient-based method slowly progresses. A better performance may be achieved, but numerous iterations are required. If a large value is selected, a fast rate is revealed to achieve a solution, but the performance may not be near the optimal performance. The proposed gradient based contains step size and weighting factor in the order of 0.2,0.5 and 0.7,the same values are for weighting function. The step size behaviour for a given interference threshold is



IV. CONCLUSION AND FUTURE WORK

The proposed gradient based method with Euclidean projection technique and adaptive selection of step size and weighting factor is used to solve the problem of power allocation in OFDM based CR network. To obtain optimal solution in fast rate the step size and weighting factor should be adaptively set in iterations. The optimal solution is obtained by gradient based with step size and adaptive weighting factor is also used to obtain optimal solution. The proposed gradient based method with low computational complexity of O(N) achieves a good performance in small iterations. This work is extended by including time factor along with gradient based method to solve power allocation problem.

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