Optimal Subcarrier Power Allocation in OFDM Based Cognitive Radio Networks by Using Gradient Based Methods

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Abstract
The Power allocation in Orthogonal Frequency Division Multiplexing (OFDM)-based cognitive radio networks is designed by gradient based method. The gradient based method in which the power allocated between subcarriers by considering the interference constraint, capacity of CR users and channel gain. Utilize the gradient based descent approach to allocate power to subcarriers in Cognitive Radio (CR) networks. The gradient-based power allocation method with the Euclidean Projection technique is used for selection of step size and weighting factor. A well-designed step size can provide approximate optimal solution within little iteration. The analysis for the selection of the step size and weighting factor is required. The objective of this method is to use spectrum efficiency by allocating power between subcarriers. This method is required far less iteration. Gradient –based method with the adaptive step size has a fast rate to achieve a near –optimal solution within an extremely small number of iterations and has quite a low computational complexity.

1. Introduction

Wireless operations allow services, such as wide-range communications, that are unable or not practical to implement with the use of wires. Wireless communication is among technology's biggest contributions to mankind. Wireless communication involves the transmission of information over a distance without help of wires, cables or any other forms of electrical conductors. The transmitted range can be anywhere between a few meters and thousands of kilo meters. The most common wireless technologies use radio. Wireless communication involves no physical link established between two or more devices, communicating wirelessly. Wireless signals are spread over in the air and are received and interpret by appropriate antennas. The signal is transferred between transmitter and receiver which involve many processes.

A Cognitive Radio (CR) network means that a frequency band used by one or multiple primary users in a primary network can be operated by a secondary network which consists of one or multiple Secondary user. To ensure the Quality of Service (QoS) of the Primary User (PU) and to maximize the transmission rate of the secondary users are one of the most important design issues for a Cognitive radio system. Orthogonal Frequency Division Multiplexing (OFDM) is a promising candidate for Cognitive Radio systems. With OFDM, the SU has the ability to flexibly fill the spectral gaps left by PUs Cognitive radio may offer new opportunities for the wireless industry and consumers to cope with the continuously growing mobile data traffic. Cognitive technologies can significantly increase the overall utilization of spectrum, by allowing sharing in bands where it was previously not possible. A cognitive radio system can be intelligently programmed and dynamically configured. OFDM is a transmission technology used in cognitive radio. OFDM'S underlying sensing and spectrum shaping capabilities together with its flexibility and adaptively make it probably the best transmission technology for CR systems.

Mutual interference constraint problem is considered in [2]. There are two techniques are used for interference reduction. The first technique is windowing the transmit signal of the OFDM symbols and cyclic postfix is introduced to maintain the orthogonality within the OFDM signal. this interference reduction is reduced throughput. The second technique is the dynamic deactivation of subcarriers lying adjacently to allocated LS sub bands. This deactivation increased the throughput of the system. resource allocation problem is considered in [4]Sub bands are sensitive for channel quality, interference, transmission cost. risk return model include two method step ladder and nulling problem of this paper is required high iterations .In CR network two main type of interference is focused on [3].first type of interference is introduced by PUs into SUs which leads to signal to noise ratio loss in CR network and the other one is introduced by SUs into PUs which is less than the interference temperature level.

A fast algorithm is proposed to tackle the optimal power allocation for cognitive radio networks in [8]. The optimal solution is obtained by standard convex optimization techniques which have complexity of O(N^3). By using fast barrier method computational complexity is in the order of O(M^2 N) where M is number of primary user and major cost is spent in inversion of hessian matrix. By solving hessian matrix in Newton step treating them as sum of diagonal matrix the complexity is reduced. Time cost is high and there is large sum capacity of gain. In this paper we proposed a gradient based method is to be solved power allocation problem in OFDM subcarrier for cognitive radio networks .the main challenge of this method is to be find the step size. the selection of step size is determines the accuracy and the number of iterations .the proposed gradient based method is focused on the gradient descent based approaches with the Euclidean projection technique for the

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satisfaction of the interference constraint. And in this method have low computational complexity and requires less number of iterations.

2. Proposed System

As nowadays most of the licensed spectrum is not fully utilized and spectrum allocation is very big problem in wireless communication. The concept of Cognitive Radio (CR) based on software-defined radio and OFDM is to solve the problem of spectrum scarcity. And there is power allocation problem in OFDM subcarriers. There are many methods for power allocation. One such method is gradient based method in which power is allocated between subcarriers by considering the interference constraint, capacity of CR user and channel gain of users. The proposed method with well defined step size can provide optimal solution with a computational complexity of a O (N).

2.1 System Model

Consider the cognitive radio system with OFDM transmission technology having both primary users and secondary user with N OFDM subcarriers. The objective is to use spectrum efficiently by power allocating between subcarriers by gradient based method.

The spectrum in the frequency domain is distributed to PUs and SUs/CR users. M frequency bands with bandwidth B, in hertz, are sensed by the CR system, L bands have been used by pus. The unoccupied bands are assigned to CR users, which have N OFDM subcarriers. The bandwidth of subcarriers is ΔfHz. assume that LPU bands are active while one CR user is transmitting in frequency bands. objective is to maximize the capacity of the CR user while keeping the interference introduced to the PU bands below the interference temperature level. The capacity (in bits per second per hertz) of the CR user is defined as a convex optimization. The transmitter and receiver architecture of CR can be better and will improve the performance of cognitive radio spectrum Allocation and transceiver with adaptive power allocation. In the transceiver model, first we can take input of BPSK as modulated signal and transmit through the AWGN channel receiver .

At the part, to processing the spectrum allocation.

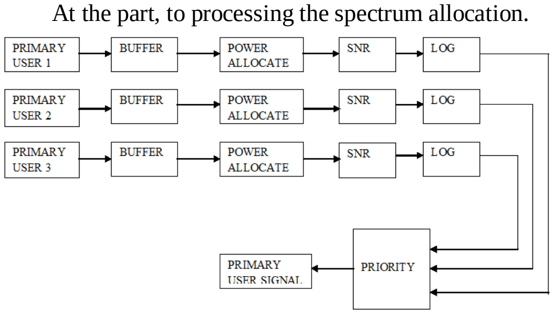

Fig: 1. Transmitter and Receiver Architecture with Power Allocation

In the first block, the input signal is given to the encoder and this is considered as secondary user signal and then modulated. During processing of channel, three primary user signals are considered and they are stored in buffer for bit by bit processing and for these signals energy is found.SNR value is evaluated and logarithmic value of signals is found. The priority block selects one primary user signal and is processed along with secondary user signal in channel. And in this channel gradient based method is performed for allocating between subcarriers by minimizing the interference and maximizing the capacity to use the spectrum efficiently.

2.2 Power Allocation

Secondary users will allow to use free primary user band .Cognitive radio consists of allocated users, primary user bands, primary user presents. Secondary users transmitted signals at OFDM protocols. It consist no of sub carriers These hole subcarrier is consider as signal. Power allocation processed at the channel. Power allocation is depend on the primary user interference Sense the interference and it will below the threshold means does not affect secondary user data Above the threshold means data will be loss. To overcome this problem using power allocation Power allocation is use for boost up this loss signals. To improve the capacity or signal strength of the secondary users.

In the frequency domain the spectrum is distributed to PUs to SUs. M frequency bands with bandwidth B in hertz, and it will sensed with CR system. the unoccupied primary user bands are assigned to the SUs/CR user which have N OFDM subcarriers .objective of this paper is to maximize the capacity of the CR user .To reduce data loss because of interference .and also requires minimum step size at less no of iterations.

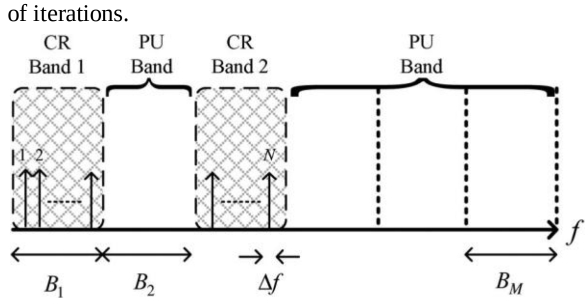

Fig: 2. Spectrum Distribution of PUs and SUs user in Frequency Domain

The capacity of CR system is given by

$$Min C_{cr} = \frac{1}{N}\sum_{n=1}^{N} -log_2\left(1 + p_n|h_n^{ss}|^2/\left(\sigma^2 + J_n\right)\right)$$

$$= \frac{1}{N}\sum_{n=1}^{N} f_n(p_n) \quad (1)$$

Where $p_n \geq 0, forn = 1,2 \ldots \ldots \ldots N$

N denotes the total number of OFDM subcarriers

h_n^{ss} Denotes the channel gain of subcarrier n

σ^2Denotes the noise power on subcarrier n

J_nDenotes the interference introduced by the l_{th}PU to the nth subcarrier, which is related to channel gain

h_l^{ps} between the l_{th} PU transmitter and the CR user's receiver

$\sum_{n=1}^{N} k_n p_n \leq I_{th}$ (2)

$k_n p_n$ denotes the interference introduced by the CR users to PU bands, which is related to channel gain h_l^{ps} between the CR user's transmitter and the lth PU receiver; K is a vector whose nth element is the mutual interference between PUs and SUs.

3. Gradient Based Power Allocation Method

The gradient based method is used to solve power allocation problem with the interference constraint. Because of the interference constraint, the gradient-based method needs to project the gradient vector on the constraint vector to obtain a feasible direction. In this method initially some subcarriers are would be assigned zero power and these subcarriers are not considered. To maximize the capacity while satisfying the interference constraint, the Euclidean projection operation is performed for the power allocation onto the interference constraint. In this, the step size should be carefully determined. The step size can be predetermined or adaptively adjusted in iterations. This gradient based method include gradient descent approach and Euclidean projection.

In proposed gradient based method consist of number of subcarriers. Zero power would be assigned with some subcarrier it means that these subcarriers does not considered. The Euclidean projection operation is performed for the power allocation is depend on interference constraint and it would be maximize the capacity while satisfying the interference constraint. in this method selection of step size is important. Step size should be carefully determined.

3.1 Gradient Descent Approaches

The gradient depends on partial derivative of $f_n(p_n)$ with respect to p_n. The gradient is given by

The gradient with respect to the power vector is

$$\nabla F(p) = \left[\frac{\partial f a(p_a)}{\partial a} \frac{\partial f_b(p_b)}{\partial b} \ldots\ldots \frac{\partial f_N(p_N)}{\partial N}\right] \quad (3)$$

Where,

P = $[p_1 \, p_2 \ldots . p_N]^T$

Each element is evaluated by using the current power allocated to that selected subcarrier. To satisfy the interference constraint, the specific structure of the constraint set allows us to computethe projection operator using the orthogonal projector.

The orthogonal projection of any vector onto the null space of **K** involves multiplication by the following matrix **J** as an orthogonal projector

$$J = I_{NXN} - K^T (KK^T)^{-1} K \quad (4)$$

Where, I_{NXN} Denotes the identity matrix.

Power vector P is updated by $\nabla F(p)$ and premultiplied by orthogonal projector matrix J

$$\tilde{p}(t+1) = p(t) - \frac{\alpha j(t) \nabla F p(t)}{\sqrt{(J(t)\nabla F(P(t))^T (J(t)\nabla F(P(t))}} \quad (5)$$

Where, *t* Denotes the iteration index, *α Denotes* the positive step size.

Some subcarriers may be assigned Negative $\tilde{p}(t+1)$ during iteration; do not allocate power to these subcarriers. Step size is to give fixed values in advance for the gradient-based method. While considering the performance and the number of iterations required in the proposed method, the value of the step size and the weighting factor should be appropriately determined. The main criterion is to make the step size value as large as possible but not to make the allocated power become no positive. So the proposed gradient-based method can achieve a solution in a fast rate.

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

$$p_n = I_{th}/N\overline{k_n} \quad (6)$$

Where, p_n Denotes the power allocated to subcarrier

After step size *α* is appropriately set, the power $\hat{p}_n(t+1)$ is updated by projector matrix. The interference caused by allocated power $\hat{p}_n(t+1)$ can be calculated by $k_n p_n$. If the sum of the caused interference is less than or equal to interference constraint I_{th} then the achievable capacity is evaluated. If the sum of the caused interference exceeds interference constraint, the nonnegative power assignment should be reallocated to satisfy the interference constraint, for this Euclidean projection technique is used.

3.2 Euclidean Projection

The Euclidean projection technique is used to perform a projection of the power allocation onto the constraint set. Therefore, the interference constraint can be satisfied. Only those *N*+ subcarriers with nonnegative power assignment are selected to perform the Euclidean projection on a polyhedron.

The Euclidean projection of

$$\overline{P_n}(t+1) = \hat{p}(t+1) - \frac{\overline{K_n}|K_{1*N} + \tilde{P}(t+1) - I_{th}|}{\sum_{n=1}^{N} |K|^2} \quad (7)$$

Projected power is obtained and satisfies the ınterference constraint. To obtain an improved performance the allocated Power is adjusted by introducing weighting function composed of projected power and the allocated power in the previous iteration $P_n(t)$ to update power.

The weighting function is given by

$$P_n(t+1) = (1-\delta)p_n(t) + \delta \overline{P}(t+1) \quad (8)$$

Where, $\delta \epsilon (0,1)$ Denotes a weighting factor. Interference constraint is to be satisfied for updated power. After weighting factor is appropriately set, the achievable capacity improvement Δ*C* can be calculated. If the achievable capacity is improved, the proposed gradient-based method continues to update the allocated power. The gradient based algorithm procedure is given in below figure. In the algorithm initially power is allocated between subcarriers and by appropriately setting the step size to updating the power vector. To calculate the cause of interference. 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. The process of the iteration terminates if the capacity improvement ΔC becomes negative, which means the capacity starts to decrease in the iteration.

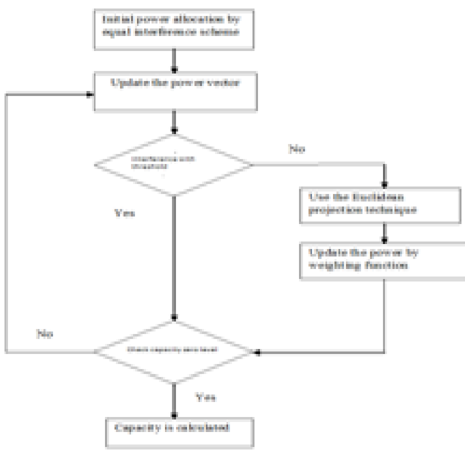

Fig: 3. Flowchart of the Proposed Gradient-Based Power Allocation Method

The proposed gradient-based power allocation method tends to find the amount of power allocated to each subcarrier directly. The computational complexity of the gradient-based method is in each iteration. If the sum of the caused interference is less than or equal to interference constraint Ith, the next step is to evaluate the achievable capacity improvement if the sum of the caused interference ˜Knˆ on exceeds interference constraint Ith, the allocation power ˆpn(t+ 1) for those N+ subcarriers with nonnegative power assignment should be reallocated to satisfy the interference constraint.

The step size is defined to be greater than zero. our aim is to find a step size that would be improve the capacity for each iterations. the range of step size is not guaranteed to improve the capacity in every iterations. however the capacity performance may be improve if the step size is selected within the range .selection of weighting factor in gradient based method, the allocated power multiplied by the caused interference should be equal to interference constraint. The aim of selection of weighting factor is to make as large as possible but not to create allocated power become non positive. The value of weighting factor between 0 and 1. If the value is out of range ,the weighting factor is adjusted by multiplying a factor.

4. Result

This paper introduced an implementation of subcarrier power allocation in OFDM based cognitive radio networks by using gradient based methods Power allocation using adaptive gradient based method with an adaptive selection of the step size and weighting factor and the capacity will compare with different temperature level. The performance of the method with the adaptive step size and the adaptive weighting factor is near the optimal performance.

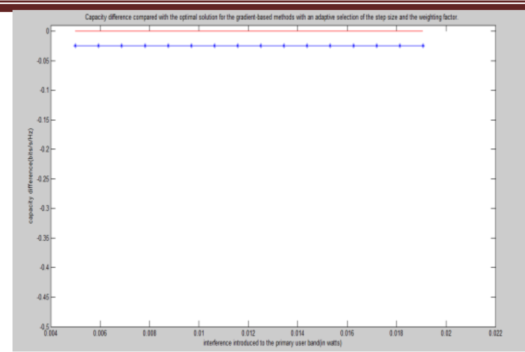

Fig: 4. Capacity Difference Compared with the Optimal Solution with an Adaptive Selection of the Step Size and the Weighting Factor

Fig 4.shows the performance of the gradient based method with a proposed adaptive method is setting the step size and the weighting factor in the iteration. The upper limits of the step size and the weighting factor are set for their values. The performance of the method with the adaptive step size and the adaptive weighting factor is near the optimal performance. The result is compare with optimal solution.

Behaviour of step size

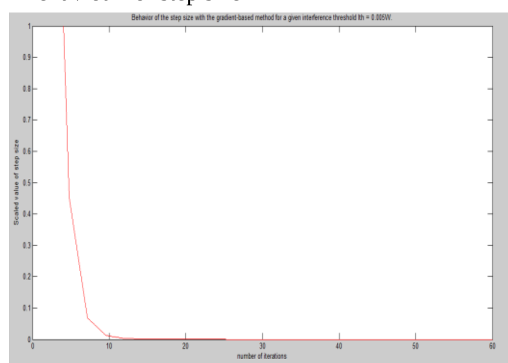

Fig: 5. Behaviour of the Step Size with the Gradient-Based Method for A Given Interference Threshold Ith=0.005w

Fig. 5 shows the scaled value of the step size by averaging from 500 trial runs with a given interference threshold, i.e., Ith= 0.005W. In this method the value of the step size related to the number of selected subcarriers with allocating power. The scaled value of the step size decreases as the number of iterations increases.

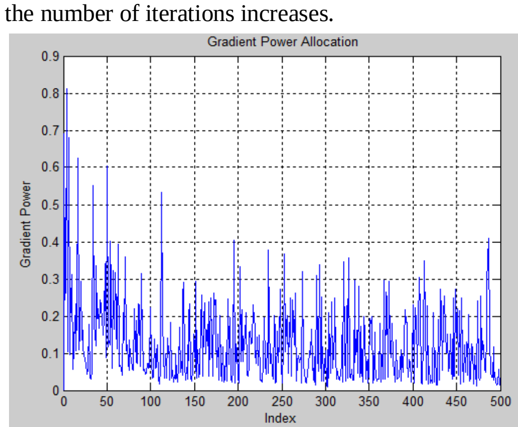

Fig: 6. Gradient Power Allocation

Fig 6 shows the no of bits power allocation. it shows the 500 trial runs with given interference Consider this interference allocating the power with the 10 channels which channel with have minimum interference. When the power allocation is depend on the interference. When the interference is high means the power allocation will not be processed. When the low interference means power allocation will be processed in the minimum interference channel.

5. Conclusion

Gradient based power allocating method is used for allocating power in subcarriers. The power allocation problem with the mutual interference constraint in OFDM-based CR networks by using the gradient-based method with the Euclidean Projection technique is used for selection of step size and weighting factor. The effect of the selection of the step size and the weighting factor has been analyzed. The values of the step size and the weighting factor should be adaptively set in iterations to achieve a near-optimal solution in a fast rate. Channel state information is used for allocating power between subcarriers by using gradient based method. With the help of the adaptive selection scheme for the step size and the weighting factor, the gradient-based method with a low complexity and achieves a good performance in a quite small number of iterations.

Based on this work to solve the power allocation in OFDM based Cognitive Radio networks by using gradient based method and sensing the primary user presence by using dynamic Bayesian network It will provide sensing efficiently

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