Adaptive Power Allocation of OFDM Systems by using the Combination of Greedy and Gradient Methods in Cognitive Radio Networks

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Abstract: ***In this paper we will analyize the mixture of greedy and gradient primarily based technique is meant for power allocation in orthogonal-frequency-division-multiplexing (OFDM) -based psychological feature radio networks. the facility allocation drawback subject to a mutual interference constraint is taken into account. we tend to utilize the greedy and gradient descent approach to assign power to subcarriers in psychological feature radio (CR) networks. The planned greedy and gradient -based power allocation technique with a handy step size will approximate the optimum answer inside many iterations. underneath the condition of fairly smart system utilization, the planned algorithmic rule introduces a unique assignment technique referred to as approach of greedy and gradient primarily based distribution, that makes it doable to realize higher fairness. For comparison functions, a greedy power-loading technique and gradient loading technique requiring varied iterations is additionally designed for this power allocation drawback. Simulation results show that the planned algorithmic rules are able to do higher honestness compared with the existed greedy fair algorithm, whereas system utilization is close to or higher than that of honest algorithmic rule.***

Keywords: greedy and gradient method, OFDM, cognitive radio networks, power allocation, step size

1. Introduction

Cognitive radio (CR), built on software-defined radio, has been proposed as a means to improve the utilization of wireless spectrum resources (Ref). Spectrum sensing is a core technology upon which the entire operation of cognitive radio rests. It enables unlicensed users (also referred to as secondary users or cognitive users) to communicate with each other over licensed bands by detecting spectrum holes (Ref)[1].

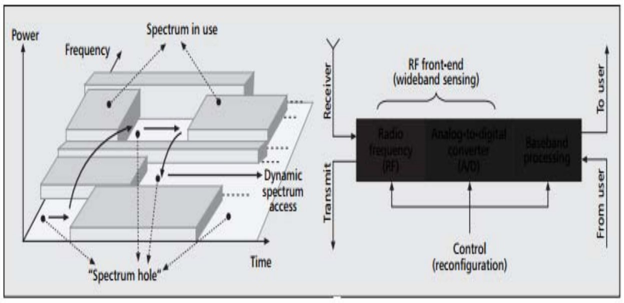


Figure: Overview of cognitive radio: a) the spectrum hole concept; b) cognitive radio transceiver architecture

Cognitive radio networks will provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques[2]. However, CR networks impose challenges due to the fluctuating nature of the available spectrum, as well as the diverse QoS requirements of various applications. To provide a better understanding of CR networks, this article presents recent developments and open research issues in spectrum management in CR networks. More specifically, the discussion is focused on the development of CR networks that require no modification of existing networks.

Current wireless networks are characterized by a static spectrum allocation policy, where governmental agencies assign wireless spectrum to license holders on a long-term basis for large geographical regions. Recently, because of the increase in spectrum demand, this policy faces spectrum scarcity in particular spectrum bands. In contrast, a large portion of the assigned spectrum is used sporadically, leading to underutilization of a significant amount of spectrum. Hence, dynamic spectrum access techniques were recently proposed to solve these spectrum inefficiency problems[2].

The rapid growth of wireless communication, the available resources of wireless spectrums are becoming scarcer, impeding the application of new techniques. Cognitive radio (CR) has been widely accepted as an effective method to improve wireless spectrum utilization. It can perceive and detect the dynamic changes of idle wireless spectrums, and make the unused spectrum available to cognitive users. The CR system must not affect the normal communications of the license users (LUs). The cognitive users (CUs) can communicate with each other by automatically searching and utilizing the idle spectrum. Therefore, CR is the most effective way of solving the problem of spectrum scarcity. Regarding to OFDM-based CR systems, the authors in studied the mutual interference caused by the non orthogonality between CUs and LUs using the convex optimization theory. The authors in examined the resource allocation plan in an OFDM-based CR network. According to the traditional power allocation scheme (such as water-filling algorithm), more power should be distributed to the sub carrier with a higher quality channel[3].

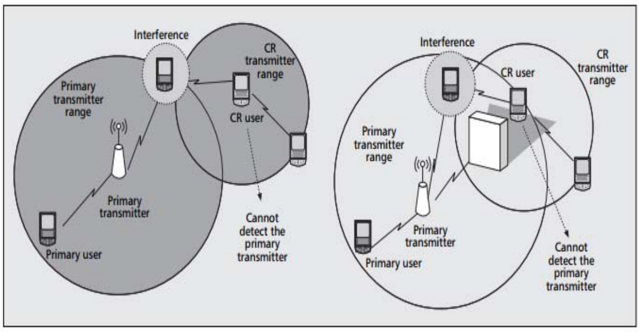


Figure: Transmitter detection problem: a) receiver uncertainty; b) shadowing uncertainty.

An unequal bit-loading algorithm for a non-contiguous OFDM-Based CR system. In fact, such an interference limited scenario limits the transmit power as well as the achievable transmission rate of CR users. Hence, the design problem is that, given an interference threshold prescribed by the primary users, how much power each CR user's subcarrier should have, so that the transmission rate of CR users could be maximized. An optimal power allocation scheme using Lagrange formulation. This scheme maximizes the downlink transmission rate of CUs, while keeping the interference induced to the primary users below a threshold. However, the total power constraint was not considered in this paper.

In order to address these challenges, each CR user in the CR network must:

- Determine which portions of the spectrum are available
- Select the best available channel
- Coordinate access to this channel with other users
- Vacate the channel when a licensed user is detected

These capabilities can be realized through spectrum management functions that address four main challenges: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility.

2. Cognitive Radio Network Architecture

A comprehensive description of the CR network architecture is essential for the development of communication protocols that address the dynamic spectrum challenges. The CR network architecture is presented in this section. NETWORK COMPONENTS The components of the CR network architecture, as shown in Figure, can be classified as two groups: the primary network and the CR network[4].

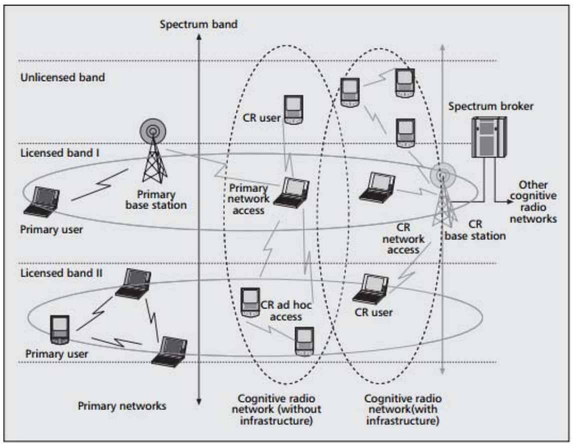


Figure: Cognitive radio network architecture.

The primary network (or licensed network) is referred to as an existing network[5], where the primary users have a license to operate in a certain spectrum band. If primary networks have an infrastructure, primary user activities are controlled through primary base stations. Due to their priority in spectrum access, the operations of primary users should not be affected by unlicensed users. The CR network (also called the dynamic spectrum access network, secondary network, or unlicensed network) does not have a license to operate in a desired band. Hence, additional functionality is required for CR users to share the licensed spectrum band. CR networks also can be equipped with CR base stations that provide single-hop connection to CR users. Finally, CR networks may include spectrum brokers that play a role in distributing the spectrum resources among different CR networks[6].

3. Orthogonal Frequency Division Multiplexing (Ofdm)

OFDM is a wideband wireless digital communication technique that is based on block modulation. With the wireless multimedia applications becoming more and more popular, the required bit rates are achieved due to OFDM multicarrier transmissions. OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers on adjacent frequencies. In addition the sub-carriers in an OFDM system are overlapping to maximize spectral efficiency. Ordinarily, overlapping adjacent channels can interfere with one another. However, sub-carriers in an OFDM system are precisely orthogonal to one another. Thus, they are able to overlap without interfering. As a result, OFDM systems are able to maximize spectral efficiency without causing adjacent channel interference. Orthogonal frequency division multiplexing is commonly implemented in many emerging communications protocols because it provides several advantages over the traditional FDM approach to communications channels. More specifically, OFDM systems allow for greater spectral efficiency reduced inter-symbol interference (ISI), and resilience to multi-path distortion[11],[12],[13].

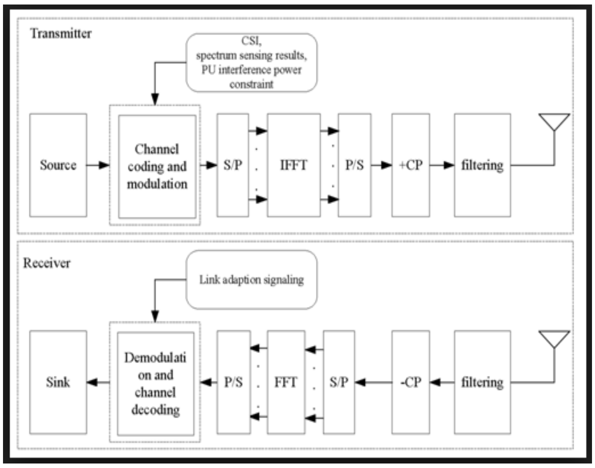


Figure: OFDM Block Diagram

Multicarrier modulation is commonly employed to combat channel distortion and improve the spectral efficiency. Multicarrier Modulation schemes divide the input data into bands upon which modulation is performed and multiplexed into the channel at different carrier frequencies so that information is transmitted on each of the sub carriers, such that the sub channels are nearly distortion less. In conventional OFDM system, IFFT (Inverse Fast Fourier Transform) and FFT (Fast Fourier Transform) are used to multiplex the signals together and decode the signal at the receiver respectively. In this system, the Cyclic Prefix is added before transmitting the signal to channel. But in wavelet based transmission technique has stronger ability of suppressing ISI and ICI than the conventional OFDM scheme[14],[15].

4. Adaptive Greedy Algorithm

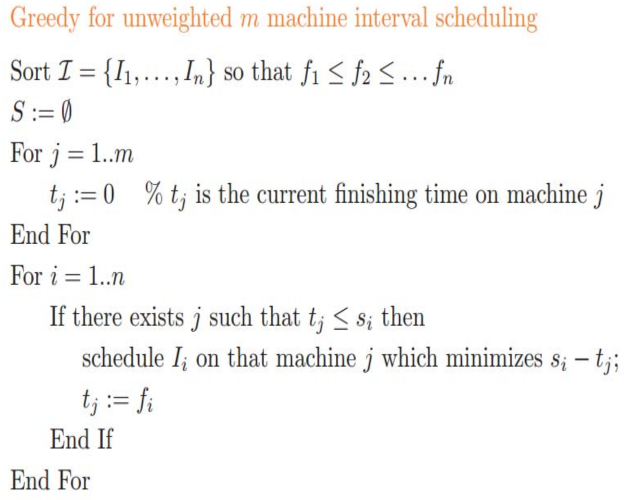
The sparsity form of both the channel impulse response (CIR) and the equalizer filters is properly exploited and two novel adaptive greedy schemes are derived. Greedy algorithms form an essential tool for compressed sensing. However, their inherent batch mode discourages their use in time-varying environments due to significant complexity and storage requirements[9].

This paper establishes a conversion procedure that turns greedy algorithms into adaptive schemes for sparse system identification. In particular, a Sparse Adaptive Orthogonal Matching Pursuit (SpAdOMP) algorithm of linear complexity is developed, based on existing greedy algorithms that provide optimal performance guarantees. Also, the steady-state Mean Square Error (MSE) of the SpAdOMP algorithm is studied analytically. The developed algorithm is used to estimate ARMA and Nonlinear ARMA (Auto Regressive Moving Average) channels. It is shown that channel inversion for these channels, maintains sparsity and that it is equivalent to channel estimation.

The greedy matching pursuit algorithm and its orthogonal zed variant produce suboptimal function expansions by iteratively choosing dictionary waveforms that best match the function's structures. A matching pursuit provides a means of quickly computing compact, adaptive function approximations[10].

5. Adaptive Forward-Backward Greedy Algorithm

The main strength of forward greedy algorithm is that it always works with a sparse solution explicitly and thus computationally efficient. Moreover, it does not significantly over fit the data due to the explicit sparsity. However, a major problem is its inability to correct any error made by the algorithm. On the other hand, backward greedy steps can potentially correct such an error, but need to start with a good model that does not completely over fit the data — it can only correct errors with a small amount of over fitting. Therefore a combination of the two can solve the fundamental flaws of both methods. However, a key design issue is how to implement a backward greedy strategy that is provably effective. Some heuristics exist in the literature, although without any effectiveness proof.



Greedy for unweighted m machine interval scheduling

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Sort $\mathcal{I} = \{I_1, \ldots, I_n\}$ so that $f_1 \le f_2 \le \ldots f_n$
$S := \emptyset$
For $j = 1..m$
    $t_j := 0$   % $t_j$ is the current finishing time on machine $j$
End For
For $i = 1..n$
    If there exists $j$ such that $t_j \le s_i$ then
        schedule $I_i$ on that machine $j$ which minimizes $s_i - t_j$;
        $t_j := f_i$
    End If
End For
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6. Adaptive Gradient Algorithm:

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[7],[16].

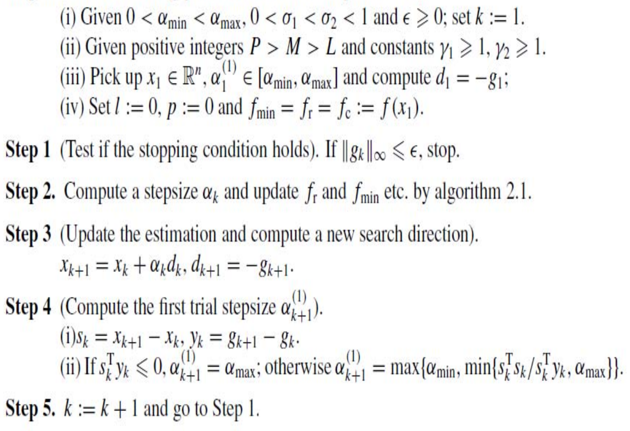
The proposed gradient based method with Euclidean projection technique and adaptive selection of step size and weighting factor is used to solve the problem of power allocation in OFDM based CR network. To obtain optimal solution in fast rate the step size and weighting factor should be adaptively set 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. The algorithms attempt to maximize the total throughput of the CR system (secondary users) subject to the total power constraint of the CR system and tolerable interference from and to the licensed band (primary users).

Adaptive critics As stated previously there is a difference between adaptive critics and techniques from optimal control using back propagation of utility In optimal control one often poses an optimization problem that is solved for optimal feedback parameters given a system model The solution is then fed with the estimated system parameters to give optimal parameters for the system at hand Adaptive critics on the other hand try to model the value function or one of its relatives describing the long term reward This estimate can then be used to add optimal feedback in a number of ways as will be described later. Another difference is that some of the adaptive critics do not need to estimate an explicit model of the environment and that stochastic systems can be treated within the framework. Adaptive decision feedback equalization (DFE) has been widely used in single-carrier transmission systems as an effective technique for reducing the introduced Inter symbol Interference (ISI). Moreover, it has been shown that for the particular class of channels we consider here, and under reasonable assumptions concerning the filter sizes, both the DFE filters[8].

7. An Adaptive Two-Point Step Size Gradient Algorithm

Combined the two-point step size gradient method and our adaptive non-monotone line search, we then obtain a new gradient algorithm for unconstrained optimization. Due to its adaptivity in choosing its reference value, we call the new algorithm as adaptive two-point step size gradient (ATSG) algorithm in this paper. A full description of the algorithm is given as follows.

Algorithm (An adaptive two-point stepsize gradient algorithm).



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Step 0 (Give the starting point and initialize the parameters).
    (i) Given $0 < \alpha_{\min} < \alpha_{\max}$, $0 < \sigma_1 < \sigma_2 < 1$ and $\epsilon \geqslant 0$; set $k := 1$.
    (ii) Given positive integers $P > M > L$ and constants $\gamma_1 \geqslant 1, \gamma_2 \geqslant 1$.
    (iii) Pick up $x_1 \in \mathbb{R}^n, \alpha_1^{(1)} \in [\alpha_{\min}, \alpha_{\max}]$ and compute $d_1 = -g_1$;
    (iv) Set $l := 0, p := 0$ and $f_{\min} = f_{\mathrm{r}} = f_{\mathrm{c}} := f(x_1)$.

Step 1 (Test if the stopping condition holds). If $\|g_k\|_\infty \leqslant \epsilon$, stop.

Step 2. Compute a stepsize $\alpha_k$ and update $f_{\mathrm{r}}$ and $f_{\min}$ etc. by algorithm 2.1.

Step 3 (Update the estimation and compute a new search direction).
    $x_{k+1} = x_k + \alpha_k d_k, d_{k+1} = -g_{k+1}$.

Step 4 (Compute the first trial stepsize $\alpha_{k+1}^{(1)}$).
    (i)$s_k = x_{k+1} - x_k, y_k = g_{k+1} - g_k$.
    (ii) If $s_k^{\mathrm{T}} y_k \leqslant 0, \alpha_{k+1}^{(1)} = \alpha_{\max}$; otherwise $\alpha_{k+1}^{(1)} = \max\{\alpha_{\min}, \min\{s_k^{\mathrm{T}} s_k / s_k^{\mathrm{T}} y_k, \alpha_{\max}\}\}$.

Step 5. $k := k + 1$ and go to Step 1.
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8. Simulation Results

In this section, simulation is executed to analyze the performance on both spectrum utilization and allocation fairness of the proposed algorithms, and compare them with greedy, gradient and combination *greedy and gradient* algorithms. The channel availability is assumed to be fixed during the executions of the algorithms. Although the system utilization is measured by *frequency use efficiency* is more generally, the more channels each node is assigned, the better utilization the system owns. The fairness metric is the variance of channel allocations among nodes in each assignment.

Emerging wireless technologies, such as sensor and relay networks[15], have found applications in cooperative communications. In fact, users of a wireless network can cooperate by relaying each other's messages thus improving the communications reliability. However, the limited communication resources, such as battery lifetime of the devices and the scarce bandwidth, challenge the design of such cooperative communication schemes.

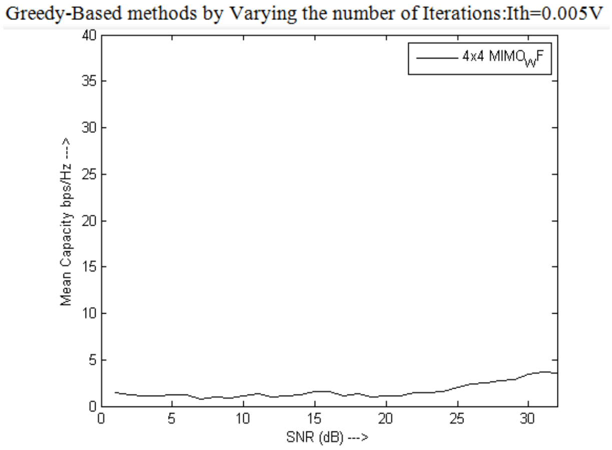

Figure: Greedy Method analysis

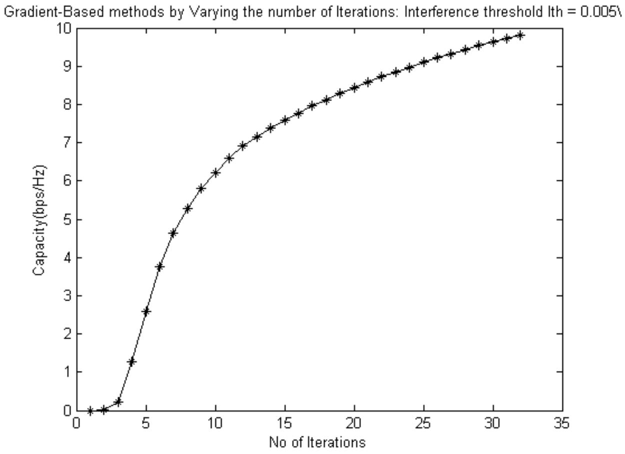

Figure: Gradient Method analysis

Therefore, while ensuring that each user receives a certain quality of service (Quos), one is often confronted with the challenge that communication resources are subject to stringent constraints. The communication system of a conventional multi-node decode-and-forward cooperative scheme is shown in Fig.

The simulation result of Figure shows that the utilization of cognitive radio networks is nearly the same with that of the greedy based algorithm and gradient based method but lower than that of greedy algorithm when the number of step size less value, and decreases as the number of secondary users increases, the greedy algorithm makes the worst performance, and fairness of these three algorithms all increases as the number of secondary users increases.

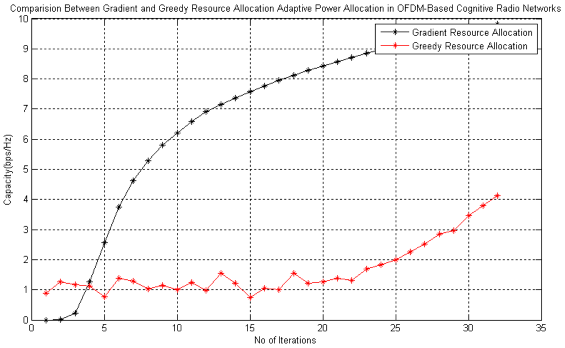

Figure: Comparison of Greedy and gradient methods

As shown in Figure, the simulation result shows that the utilization of cognitive radio networks in between the combination of *greedy and gradient based* algorithm, and is better than that of greedy and gradient method which is near fair algorithm.

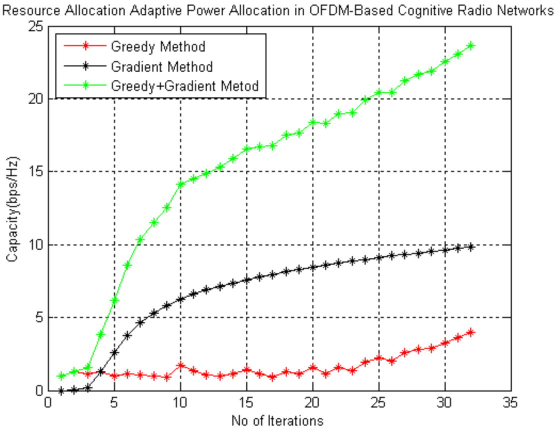

Figure: Comparison of Existing and Proposed method

9. Conclusion

In this paper, we have proposed two algorithms on the basis of the previous work on greedy based spectrum allocation algorithms. The power allocation problem with the mutual interference constraint in OFDM-based CR networks is resolved by using the proposed *greedy and gradient* -based method with the Euclidean projection technique and the method of the adaptive selection for the step size and the weighting factor, which has been proposed. Under the condition of fairly good system utilization, a novel assignment method called *approach of greedy and gradient based distribution* is introduced, by which better fairness has been achieved in CR networks. Simulation results show that the proposed algorithms can achieve better fairness compared with *greedy and gradient method ofr better* fair algorithm, while system utilization is equal to or more than that of the existed fair algorithm.

References

[1] J. Mitola and G. Q. Maguire, ―Cognitive radio: Making software radios more personal," *IEEE Pers. Commun.*, vol. 6, no. 4, pp. 13–18, Aug. 1999.

[2] S. Haykin, ―Cognitive radio: Brain-empowered wireless communications," *IEEE J. Sel. Areas Commun.*, vol. 23, no. 2, pp. 201–220, Feb. 2005.

[3] I. F. Akyildiz,W.-Y. Lee, and S.Mohanty, ―A survey on spectrum management in cognitive radio networks," *IEEE Commun. Mag.*, vol. 46, no. 4, pp. 40–48, Apr. 2008.

[4] X. Hong, Z. Chen, C.-X. Wang, S. A. Vorobyov, and J. S. Thompson, ―Cognitive radio networks," *IEEE Veh. Technol. Mag.*, vol. 4, no. 4, pp. 76–84, Dec. 2009.

[5] G. Chung, S. Vishwanath, and C. S. Hwang, ―On the limits of interweaved cognitive radios," in *Proc. IEEE Radio Wireless Symp.*, 2010, pp. 492–495.

[6] S. Srinivasa and S. A. Jafar, ―Soft sensing and optimal power control doe cognitive radio," in *Proc. IEEE Global Telecommun. Conf.*, 2007, pp. 1380–1384.

[7] G. Ding, Q. Wu, N. Min, and G. Zhou, ―Adaptive resource allocation in multi-user OFDM-based cognitive radio systems," in *Proc. Int. Conf. Wireless Commun. Signal Process.*, Nov. 2009, pp. 1–5.

[8] Y. Zhang and C. Leung, ―Resource allocation in an OFDM-based cognitive radio system," *IEEE Trans. Commun.*, vol. 57, no. 7, pp. 1928–1931, Jul. 2009.

[9] Y. Ma, Y. Xu, and Y. Sheng, ―A greedy algorithm for cognitive network resource allocation based on minimum remaining constraint space," in *Proc. Int. Conf. Wireless Commun. Signal Process.*, 2009, pp. 1–5.

[10] S. Wang, ―Efficient resource allocation algorithm for cognitive OFDM systems," *IEEE Commun. Lett.*, vol. 14, no. 8, pp. 725–727, Aug. 2010.

[11] P. Wang, M. Zhao, L. Xiao, S. Zhou, and J. Wang, ―Power allocation in OFDM-based cognitive radio systems," in *Proc. IEEE Global Telecommun. Conf.*, 2007, pp. 4061–4065.

[12] P. Wang, X. Zhong, L. Xiao, S. Zhou, and J. Wang, ―A general power allocation algorithm for OFDM-based cognitive radio systems," in *Proc. IEEE Int. Conf. Commun.*, 2009, pp. 1–5.

[13] Z. Hasan, G. Bansal, E. Hossain, and V. K. Bhargava, ―Energy-efficient power allocation in OFDM-based cognitive radio systems: A risk-return model," *IEEE Trans. Wireless Commun.*, vol. 8, no. 12, pp. 6078 6088, Dec. 2009.

[14] Y. Zhang and C. Leung, ―An efficient power-loading scheme for OFDMbased cognitive radio systems," *IEEE Trans. Vehicular Technol.*, vol. 59, no. 4, pp. 1858–1864, May 2010.

[15] D. T. Ngo, C. Tellambura, and H. H. Nguyen, ―Resource allocation for OFDMA-based cognitive radio multicast networks with primary user activity consideration," *IEEE Trans. Veh. Technol.*, vol. 59, no. 4, pp. 1668– 1679, May 2010.

[16] G. Bansal, Md. J. Hossain, and V. K. Bhargava, ―Adaptive power loading for OFDM-based cognitive radio systems," in *Proc. IEEE Int. Conf. Commun.*, Jun. 2007, pp. 5137–5142.