AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Spectrum Sharing in the Cognitive Radio Communication Networks

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Yara Ashraf Kamel Mohammed

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering , 2012

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Cognitive Radio (CR) is a technology which can solve the scarcity and inefficient of spectrum usage. It achieves this target by enabling the primary users and cognitive users share the same spectrum under the condition that the cognitive user must minimize the power interference produced on the primary user through using multiple antennas for the transmitters and receivers. Thus, this thesis introduces the interference management problem for underlay spectrum sharing approach of the MIMO cognitive and primary users. This study has been introduced for two different cases: single unlicensed users and multiple unlicensed users. In case of single unlicensed user, the interference management problem of a CR networks has proposed for minimizing the interference power introduced to the licensed receiver while satisfying capacity and power constraints for unlicensed user transmission. A solution for the interference management problem of a single primary user and cognitive user in MIMO system is proposed. The problem was formulated as interference minimization problem under both transmission capacity and transmit power constraints for obtaining a closed form solution. Low complexity algorithm is proposed for designing the optimal covariance matrix based on the Lagrangian duality method which convey the cost function and its constraints into a weighted sum form. Numerical results are performed to corroborate our theoretical results, where a near optimal capacity and interference power are achieved with a low complexity. This study has been extended for multiple cognitive users where the competition over the utility maximization between the secondary transmitters is occurred. This problem has been modeled as a cooperative and non-cooperative game where game theory is an effective mathematical tools for analyzing the confliction between secondary transmitters to achieve the optimal behavior derived algorithm. Numerical results approved the effectiveness of the cooperative scenario that minimizes the network interference power. Thesis organized as following:

- Chapter(2):Concept of the Cognitive Radio

  This chapter introduces overview about the spectrum limitation and inefficient spectrum usage problem as a result to a strategy of static spectrum allocation and proposed a CR as a solution for this problem. Different spectrum access approaches of a CR networks are clarified where the underlay approach is a basic of this study.

- Chapter(3): Interference Minimization with Power-Capacity Constraints for Cognitive Radio Networks
  The interference management problem is studied for MIMO CR networks. The scenario of the conflicting problem consists of single primary user coexist with single cognitive user on a same frequency band where cognitive user try to balance between minimizing the interference which produced on licensed primary user and maximizing the transmission capacity.

- Chapter(4): Game theoretic approaches for Interference Management in MIMO Cognitive Radio Networks
  Network interference management (NIM) problem is studied from game-theoretic point of view with the aim to minimize overall network interference in case of multi-cognitive users MIMO CR network. Non-cooperative and cooperative solution are proposed.

- Chapter(5): Simulation Results
  In this chapter, the numerical results are performed to corroborate our theoretical results. The numerical results for a two different cases single cognitive user and multiple cognitive users are introduced and discussed.

- Chapter(6): Conclusion and Future work
  This chapter summarized thesis and predict the possible direction of the future researches.

Key words:
Cognitive radio, spectrum sharing, dynamic spectrum allocation, Multiple antennas wireless system (MIMO), convex optimization problem, channel capacity, Lagrangian duality, Game Theory, Nash equilibrium, Nash bargaining solution.

Abstract

Over the last two decades, the spectrum has become limited and inefficient due to static spectrum allocation while services of wireless communications have grown. Cognitive radio (CR) is concerned recently due to its radio spectrum efficient usage where it make a network adapt its transmission or reception parameters to effectively communicate by avoiding interference among the primary users and cognitive users. The primary users and cognitive users are enable to use dynamically primary user frequency band under the condition that the cognitive users should minimize the power interference produced on the primary users through using transmitters and receivers have been equipped by multiple antennas.

This thesis introduces the interference management problem of MIMO CR network for minimizing the interference power introduced to a single primary receiver while satisfying capacity and power constraints for cognitive users transmission in two different cases: single cognitive user and multiple cognitive users as deduced in chapter three and four. In chapter three, interference management problem in MIMO CR network is provided for a single cognitive user. Interference power effected on the primary user has been formulated as a convex optimization problem. The original problem which is the non-convex problem is reformulated to be a convex problem for finding the global optimal solution. This is done by designing the secondary transmitter covariance matrix to solve the conflict problem. An algorithm is developed that converge to the optimal solution after a few several iterations.

For more general, cooperative and non-cooperative game theoretic approaches are proposed for interference management in MIMO cognitive radio (CR) networks in chapter four. The cognitive users compete to maximize their payoff function under transmission

capacity and power constraints. Cognitive users' transmit covariance matrix is designed to minimize network interference power. Two different multi-user scenarios are derived. The first one, non-cooperative game converges to equilibrium by using the best response iteration method. The second, cooperative game is proposed depending on dual decomposition method to converge to Nash bargaining solution. In addition, to estimate the CR network performance based on game theoretic solutions, two new metrics are proposed.

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