Chapter 26

Cross-Layer Optimization and Link Adaptation in Cognitive Radios

Ali H. Mahdi
University of Baghdad, Iraq & Technische Universität Ilmenau, Germany

Mohamed A. Kalil
Suez University, Egypt

ABSTRACT

Cognitive Radio (CR) systems are smart systems capable of sensing the surrounding radio environment and adapting their operating parameters in order to efficiently utilize the available radio spectrum. To reach this goal, different transmission parameters across the Open Systems Interconnection (OSI) layers, such as transmit power, modulation scheme, and packet length, should be optimized. This chapter discusses the Adaptive Discrete Particle Swarm Optimization (ADPSO) algorithm as an efficient algorithm for optimizing and adapting CR operating parameters from physical, MAC, and network layers. In addition, the authors present two extensions for the proposed algorithm. The first one is Automatic Repeat reQuest-ADPSO (ARQ-ADPSO) for efficient spectrum utilization. The second one is merging ARQ-ADPSO and Case-Based Reasoning (CBR) algorithms for autonomous link adaptation under dynamic radio environment. The simulation results show improvements in the convergence time, signaling overhead, and spectrum utilization compared to the well-known optimization algorithms such as the Genetic Algorithm (GA).

INTRODUCTION

Cognitive Radio (CR) is an intelligent wireless communication system, which is aware of its surrounding radio environment. Based on the observation of statistical variations in the incoming radio frequency stimuli, CR can adapt its internal states in order to optimize spectrum usage. In the optimization process, CR should consider different link objectives (such as, minimizing packet error rate, maximizing throughput, minimizing packet transmission delay, etc.) from different layers of the protocol stack/OSI.
Cross-Layer Optimization and Link Adaptation in Cognitive Radios

(PHY, MAC, Network, etc.) to optimize all the transmission parameters that are related to those objectives (e.g. modulation scheme, transmit power, packet length, etc.). This process is called Cross-Layer Optimization (CLO). Adjusting the cross-layer parameters empowers the wireless devices with the flexibility, re-configurability, awareness and adaptability which are characteristics required in CR networks.

In literature, many Artificial Intelligence (AI) approaches have been proposed and developed for link adaptation and optimization of CR systems. However, few previous works discussed autonomous link adaptation during the communication process and under dynamic environmental observations, and how the changes in the environmental observations and Primary User’s (PU) activity could affect the error rate at the receiver (CR-Rx) side.

In our previous work (Mahdi, Mohanan, & Kalil, 2012), we developed an Adaptive Discrete Particle Swarm Optimization (ADPSO) algorithm to minimize the effect of the local optimum problem in (Zhao, Xu, Zheng, & Shang, 2009). ADPSO is a CLO algorithm that adapts parameters from different layers to achieve the desired Quality of Service (QoS) for CR nodes. Simulation results showed that ADPSO outperforms DPSO and GA in terms of the fitness value and the convergence time.

The main contribution of this chapter is two-fold: 1) we present Automatic Repeat reQuest-ADPSO (ARQ-ADPSO) as an AI-based CLO approach for efficient spectrum utilization to achieve QoS requirements of user application, and 2) we propose an efficient solution for achieving autonomous link adaptation (dynamic packet length control and energy consumption optimization) in CRN. The proposed solution is based on merging the ARQ-ADPSO algorithm and Case-Based Reasoning (CBR). CBR uses past experience in the form of state-action pairs to speed up the convergence (Reddy, 2010). This merging aims at: 1) controlling the packet length dynamically according to the varying channel condition; 2) autonomously increasing or decreasing the transmit power according to the changes of path loss and noise in the channel, in order to minimize energy consumption; 3) reducing the computation time, hardware resources and signaling overhead.

This chapter is organized as follows: First, we present an overview of the existing optimization algorithms developed for CR. Second, we give a detailed description of the ARQ-ADPSO algorithm and how it achieves CLO. Third, we describe the combination of ARQ-ADPSO and CBR aimed at improving the convergence time and achieving dynamic packet control and power consumption control under different channel conditions. Finally, the simulation results are shown.

LITERATURE SURVEY

In this section, we present a survey of the optimization algorithms which can be used for CLO and link adaptation in CR. In order to study the previous work with their strengths and weaknesses, we classify the previous work into three classes: 1) Optimization Algorithm, 2) Expert System, and 3) Multi-algorithm System.