Chapter 12
Genetic Algorithms for Decision-Making in Cognitive Radio Networks

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ABSTRACT

Efficient use of the available licensed radio spectrum is becoming increasingly difficult as the demand and usage of the radio spectrum increases. This usage of the spectrum is not uniform within the licensed band but concentrated in certain frequencies of the spectrum while other parts of the spectrum are inefficiently utilized. In cognitive radio environments, the primary users are allocated licensed frequency bands while secondary cognitive users dynamically allocate the empty frequencies within the licensed frequency band according to their requested QoS (Quality of Service) specifications. This dynamic decision-making is a multi-criteria optimization problem, which the authors propose to solve using a genetic algorithm. Genetic algorithms traverse the optimization search space using a multitude of parallel solutions and choosing the solution that has the best overall fit to the criteria. Due to this parallelism, the genetic algorithm is less likely than traditional algorithms to get caught at a local optimal point.

INTRODUCTION

Background and History of Cognitive Radios

Cognitive Radio can be defined as a radio that can adapt its transmitter parameters based on interactions with the environment in which it is operating. Cognitive Radio is an emerging technology aimed for the efficient use of the limited radio frequency spectrum.

The term "cognitive radio" was first used and defined by Joseph Mitola III in an article published in 1999 (Mitola, et al., 1999). He described the way a cognitive radio could enhance the flexibility of personal wireless services through a new language called Radio Knowledge Representation Language (RKRL). The idea of RKRL was further expanded

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in Mitola's doctoral dissertation, presented at the Royal Institute of Technology, Sweden, in May 2000 (Mitola, 2000). This dissertation presented a conceptual overview of cognitive radio as an exciting multidisciplinary subject. In 2002, FCC in the United States aimed at the changes in technology and the profound impact that those changes would have on spectrum policy. This report set the stage for a workshop on cognitive radio, held in Washington DC, in May 2003 (FCC, 2003). This workshop was immediately followed by a Conference on Cognitive Radios held in Las Vegas, NV, in March 2004.

Cognitive Decision Making

In cognitive radio, decisions have to be made, e.g., whether or not to stay on a specified carrier frequency or if the criteria is fulfilled move to another carrier frequency. This decision has to be made to facilitate a minimal interference policy and at the same time giving a high degree of spectrum efficiency. This approach could be extended to include decision on which type of modulation to use and also deciding on the configuration of a smart antenna system (e.g., SISO, SIMO, or MIMO) depending on what type of environment the transmission is propagating through.

Spectrum Sensing

The radio is searching for empty frequency bands in the licensed spectrum. These empty frequency bands constitute unlicensed slots inside the licensed frequency bands. The handling of these unlicensed bands is a coordinated effort among the equipments using these bands. All the transmitting units reports its own spectral usage and the distribution of these empty bands are decided upon based on some decision parameters. The secondary users can then acquire the usage of the empty bands until a primary user requires it.

Spectrum Reallocation

If a primary user is detected in a frequency band that is used by a secondary user, the secondary user will be allocated another frequency band to avoid interfering with the primary user. The hand over will be handled without affecting the communication.

Spectrum Management Policy

When the empty frequency bands have been detected the QoS (Quality-of-Service) of the secondary application is considered. This means that the secondary user should use these frequency bands if they meet the QoS requirement.

Spectrum Sharing

A scheme for scheduling will be required between the primary and secondary users of a frequency band. This is necessary to minimize the interference between the primary and secondary users. This is done by assigning a holding time to each user.

Overview of Genetic Algorithms

The Genetic Algorithm (GA) is a heuristic method of finding an approximate solution to optimization problems and belongs to a class of algorithms called Evolutionary Algorithms. These algorithms draw on the evolutionary theories of Charles Darwin's survival of the fittest by choosing the best solution from a set of evolved possible solutions. The history of evolutionary computation goes back to 1970s when Rechenberg first described it in his work "Evolution strategies" (Rechenberg, 1971). The GA was first developed by John Holland (1975) in 1975 and in 1992, John Koza (1992) introduced Genetic Programming (GP).

The genetic algorithm works by tagging each candidate solution with an array of bits, were each bit represents a parameter. A fitness function is