Chapter 80

Fuzzy Systems for Spectrum Access, Mobility and Management for Cognitive Radios

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ABSTRACT

This chapter addresses the issues in air interface designs for Cognitive Radios. Fuzzy logic system is used as one of the soft computing techniques to learn to sub optimality and vagueness. Many good, simple, and quick fuzzy based solutions have been developed since few decades in many diverse domains. Through this chapter, the authors first discuss the significance and need of soft computing techniques in designing such solutions and then present fuzzy based solutions for spectrum access, mobility, and management. Hierarchical fuzzy systems have been used to get over to the problem of curse of dimensionality. The proposed solutions consider an architecture, similar to the one proposed by IEEE 802.22 working group, for spectrum sharing and management. Models have been designed using fuzzy logic toolbox in MATLAB, and the system performance is checked using SIMULINK.

1 INTRODUCTION

Lack of spectra has emerged as a unanimous problem among all countries. Researchers throughout the world are focusing to increase the spectrum efficiency to mitigate spectrum scarcity. Cognitive radio (CR) is looked as one of the promising proposals for improving spectrum utilization. Many efforts are being put up in standardizing the architecture and air interface parameters for

CR. To optimize resource use, next generation networks require smart devices like CR to be able to model their location, their users, networks and the larger environment. Based on monitored set of these parameters, CR can adapt to appropriate frequency bands, protocols and interfaces.

2 SOFT COMPUTING AND COGNITIVE CYCLE

CR was first coined by Mitola (1999) who represented its major functions to adapt the transmission parameters in changing environments through a cognitive cycle. This six stage cognition cycle is briefed as follows.

- **Observe**: Know the information of operating environment through sensing and signaling mechanisms.
- **Orient**: Evaluate this information to determine its significance and relevance.
- **Plan**: Based on this evaluation, the radio determines its options or alternatives for resource optimization.
- **Decide**: An alternative is chosen that evaluates more favorably than other options, including the current ongoing action.
- **Act**: The radio implements the decisions taken for resource optimizations. These changes are then reflected in the interference profile presented by the cognitive radio in the outside world.
- **Learn**: Throughout the process, the radio uses its observations and decisions to improve its own operation, creating new modeling states and alternatives.

Cognitive cycle as briefed above, forms the heart of a Cognitive Radio. Out of the six stages of cognitive cycle, the stages *"decide"* and "act*"* is important functionalities that may work efficiently using soft computing techniques. Thus, artificial intelligence and soft computing techniques form important en-

abling techniques for the success of CR. Some of the key functionalities (Mitola 1999), (Linda 2009) supported by these techniques are as follows:

1. **Optimization of Resources:**
   - CR to make best use of use of resources it has been given or it has identified for itself while protecting the rights of others
   - Auto reconfigurability of transmission profile and operating parameters and redirecting resources around the network e.g. *"who gets what"*

   Thus the purpose is to evaluate all choices or solutions to find the one with highest rank and adapting to the "best" parameters. Thus, this amounts to the cross layer optimization largely focussing on physical (PHY) and medium access control (MAC) layers.

2. **Signal Shaping:** CR needs to represent, organise, store and analyse the collected knowledge so that appropriate optimization routines can be evoked. Some uniform mechanism for knowledge representation to be selected and then a suitable form of reasoning could be used. The operating parameters that need manageable decisions are: waveform type and antenna usage. The decisions are to be taken from the choices available as shown in Figure 5.1. Regulatory policies like any other knowledge need to be represented in a machine readable manner and the CR needs to reason about the policies and make decision.

3. **Knowledge Gain through Learning:** Learning is crucial when dealing with unknown and unplanned scenarios and thus can be of great benefit to a CR in improving the overall performance. There are many learning techniques ranging from very simple memorising techniques to complex ones e.g. artificial intelligence and machine learning.

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