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RESEARCH ARTICLE

A New Fuzzy Logic Rule Based Power Management Technique for Cognitive Radio

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Abstract*— *The limited available spectrum and the inefficient use of spectrum necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically. Cognitive radio is a wireless communication system in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. In our work, a fuzzy logic rule based control system is proposed where the cognitive radio can change its transmission power depending on distance between transmitter and receiver, node density and interference. The proposed system is simulated and found to give satisfactory results.

Indexed Terms: - Cognitive radio, fuzzy logic, dynamic spectrum access.

I. INTRODUCTION

Cognitive radio is a kind of wireless communication system in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. It was thought of as an ideal goal towards which a software-defined radio platform should evolve to a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demand. It is considered to be an intelligent wireless communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier frequency, and modulation strategy) in real-time, with two primary objectives in mind:

· Highly reliable communications whenever and wherever needed;
· Efficient utilization of the radio spectrum.

The idea of cognitive radio was first presented officially in an article by Joseph Mitola III and Gerald Q. Maguire, Jr in 1999 [1]. It was a novel approach in wireless communications that Mitola later described as: The point in which wireless personal digital assistants (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to detect user communications needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs [2].

Regulatory bodies in various countries (including the Federal Communications Commission in the United States, and Ofcom in the United Kingdom) found that most of the radio frequency spectrum was inefficiently utilized [2]. For example, cellular network bands are overloaded in most parts of the world, but amateur radio and paging frequencies are not. Independent studies performed in some countries confirmed that observation [3-6], and concluded that spectrum utilization depends strongly on time and place. Moreover, fixed spectrum allocation prevents rarely used frequencies (those assigned to specific services) from being used by unlicensed users, even when their transmissions would not interfere at all with the assigned service. This was the reason for allowing unlicensed users to utilize licensed bands whenever it would not cause any interference. This paradigm for wireless communication is known as cognitive radio.

More specifically, the cognitive radio technology will enable the users to determine which portions of the spectrum is available and detect the presence of licensed users when a user operates in a licensed band (spectrum sensing), (2) select the best available channel (spectrum management), (3) coordinate access to this channel with other users (spectrum sharing), and (4) vacate the channel when a licensed user is detected (spectrum mobility)..

Applications of Spectrum Sensing Cognitive Radio include emergency networks and WLAN higher throughput and transmission distance extensions. The main functions of Cognitive Radios are [7-9]:

i) Spectrum Sensing: It refers to detect the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes, detecting primary users is the most efficient way to detect spectrum holes. Spectrum sensing techniques can be classified into three categories:
   - Transmitter detection: Cognitive radios must have the capability to determine if a signal from a primary transmitter is locally present in a certain spectrum, there are several approaches proposed:
     - matched filter detection
     - energy detection
   - Cooperative detection: It refers to spectrum sensing methods where information from multiple Cognitive radio users are incorporated for primary user detection.
   - Interference based detection.

ii) Spectrum Management: It is the task of capturing the best available spectrum to meet user communication requirements. Cognitive radios should decide on the best spectrum band to meet the Quality of Service requirements over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios, these management functions can be classified as:
   - spectrum analysis
   - spectrum decision

iii) Spectrum Mobility: It is defined as the process when a cognitive radio user exchanges its frequency of operation. Cognitive radio networks target to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during the transition to better spectrum.

iv) Spectrum Sharing: It refers to providing the fair spectrum scheduling method, one of the major challenges in open spectrum usage is the spectrum sharing.

II. PROPOSED SYSTEM FOR TRANSMISSION POWER CONTROL

Energy management is one of the key issues in CR because of limited resources and longer lifetime expectation. Moreover, interference between licensed and unlicensed users also needs to be minimized. The model of the fuzzy controlled energy management system is shown in Figure 1.

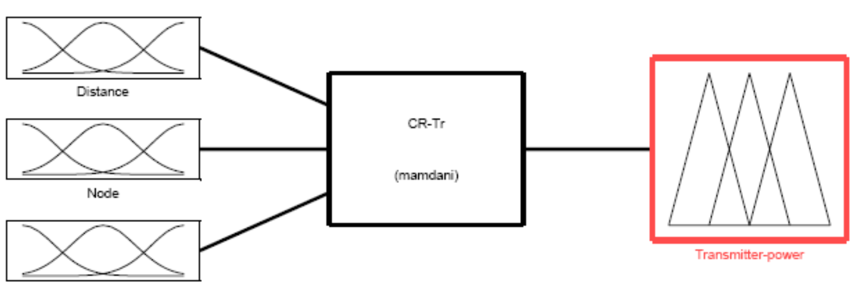

Figure 1. Model of the proposed fuzzy control system

The distance between the transmitter and receiver has been considered to be one determining parameter because for larger distance more transmission power is required. The node density is also one input parameter here. Interference temperature has been kept to be the third determining parameter because more is the interference more is the requirement of high transmitted power. The linguistic variables are kept to be LOW, MEDIUM and HIGH and the membership functions are shown in Figures 2, 3 and 4 respectively. Trapezoidal membership functions are used here. Based on the knowledge on the linguistic variable 27 IF THEN ELSE fuzzy rules are used to take decision for transmitter power selection.

Mamdani rule is used here because this type of fuzzy rule based system (FRBS) provides a natural framework to include expert knowledge in the form of linguistic rules. This knowledge can be easily combined with rules that describe the relation between system input and output. Moreover, Mamdani type FRBS possesses a high degree of freedom to select the most suitable fuzzification and defuzzification interface components as well as the interface method itself. Mamdani type FRBSs also provide a highly flexible means to formulate knowledge, while at the same they remain interpretable. The selection of power at a particular location is calculated as

Power selection = weight x min value of the membership functions.

A decision value close to 1 is considered to take decision in favor of increasing transmission power to its maximum possible value. Matlab 7.0 is used for the simulation. The proposed FRBS thus takes decision based on three key parameters according to a predefined rule base, as in Figure 5.

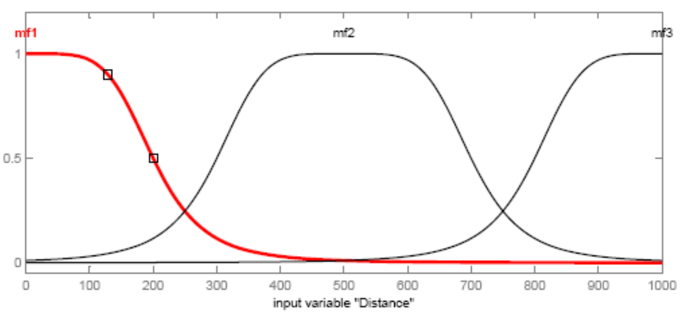

Figure 2. Membership function for distance between the transmitter and receiver (meter)

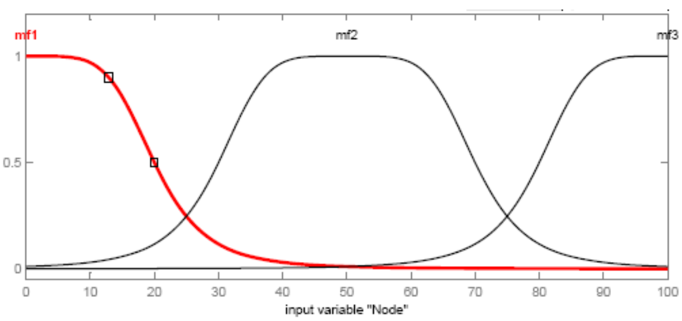

Figure 3. Membership function for number of nodes

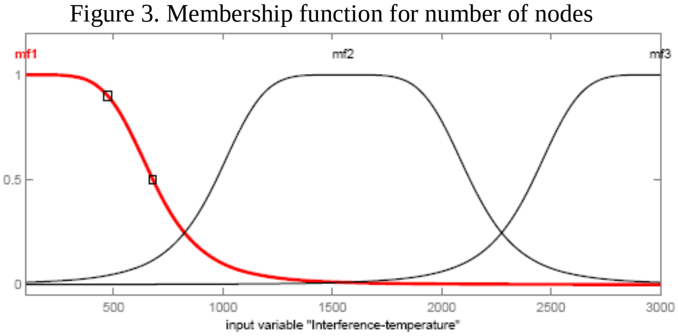

Figure 4. Membership function for interference-temperature

Distance	Number of nodes	Interference-temperature	Transmission power
Low	Low	Low	Low
Low	Low	Medium	Low
Low	Low	High	Low
Low	Medium	Low	Low
Low	Medium	Medium	Low
Low	Medium	High	Medium
Low	High	Low	Medium
Low	High	Medium	Medium
Low	High	High	Medium
Medium	Low	Low	Low
Medium	Low	Medium	Medium
Medium	Low	High	Medium
Medium	Medium	Low	Low
Medium	Medium	Medium	Medium
Medium	Medium	High	High
Medium	High	Low	Medium
Medium	High	Medium	High
Medium	High	High	High
High	Low	Low	Medium
High	Low	Medium	Medium
High	Low	High	Medium
High	Medium	Low	High
High	Medium	Medium	High
High	Medium	High	High
High	High	Low	High
High	High	Medium	High
High	High	High	High

Figure 5. Fuzzy IF-THEN-ELSE rules

III. RESULTS AND DISCUSSION

The results are shown in Figures 6, 7 and 8. It may be observed from Figure 6 that the chance of increasing transmission power increases as the distance between nodes and number of nodes increase. The result is desirable because more transmission power is required if the distance increases and node density increases. Similarly, the chance increases as the interference temperature increases (Figures 7 and 8) because if interference increases more transmission power is required.

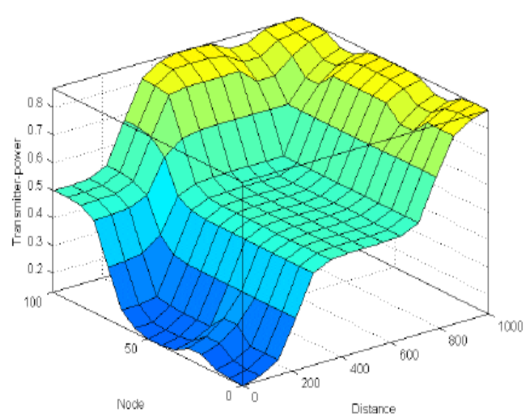

Figure 6. Decision for using maximum transmission power

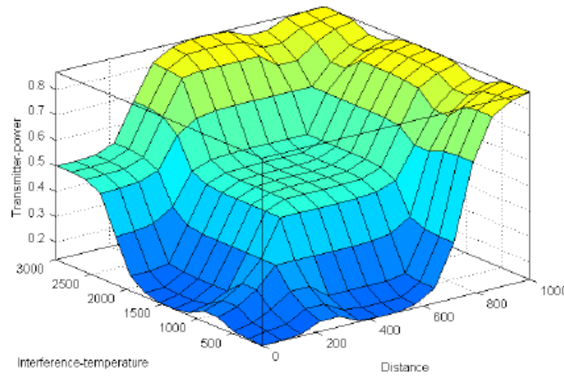

Figure 7. Decision for using maximum transmission power

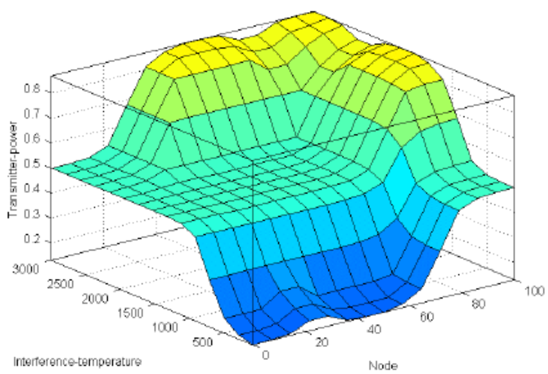

Figure 8. Decision for using maximum transmission power

IV. CONCLUSION

Researchers throughout the World are trying to develop a radio communications system that would be able to fulfill the requirements for a Cognitive radio system. In this paper, fuzzy logic based power control method is proposed which work satisfactorily. The simulation software programs for the proposed system are not complex and do not consume much time to respond. Hence, it can be easily implemented in real systems.

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