A Novel Opportunistic Spectrum Access for Applications in Cognitive Radio

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ABSTRACT

Today's wireless networks are characterized by fixed spectrum assignment policy. The limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to exploit the existing wireless spectrum opportunistically. This new networking paradigm is referred to as Dynamic Spectrum Access (DSA) and cognitive radio networks. Cognitive radio is a paradigm for wireless communication 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 practice, the spectrum allocated to licensed primary users is not utilized properly. The secondary unlicensed users can sense and utilize the unutilized spectrum. In this work, a fuzzy logic based system is proposed where the secondary user can opportunistically use the spectrum. The descriptive factors for choosing the proper secondary unlicensed user are distance of secondary user from primary user, velocity of the secondary user and ratio of spectrum to be utilized by secondary user to the total unutilized spectrum. The proposed system is found to give satisfactory results and the user with highest possibility of spectrum access decision is allowed to use the spectrum.

Key words : Cognitive radio, fuzzy logic, opportunistic spectrum access, primary user, secondary user

1. INTRODUCTION

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 thought of as an ideal goal towards which a software-defined radio platform should evolve: a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demands.

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], 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 opportunistic spectrum access and is a feature of 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).

The main functions of Cognitive Radios are [4]:

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.

Cognitive radios have the capability to sense surroundings and allow intended secondary user to increase QoS by opportunistically using unutilized spectrum holes. If a secondary user sense available spectrum, it can use this spectrum after the primary licensed user vacates it.

2. BACKGROUND OF THE PRESENT WORK

So from the previous section is may be seen that the main functions of cognitive radio are spectrum sensing, spectrum mobility and spectrum sharing. With these functions it will be able to utilize radio spectrum efficiently. Keeping this in mind a novel fuzzy logic based opportunistic spectrum access system is proposed in the present work where the unlicensed user can utilize available licensed spectrum in dynamic manner depending on the possibility of access based on external parameters.

3. PROPOSED SYSTEM

A fuzzy logic based system for taking decision to use unused spectrum is proposed and studied. Fuzzy logic is used because it is a multi-valued logic and many input parameters can be considered to take the decision. The model of the fuzzy based system is shown in Fig 1.

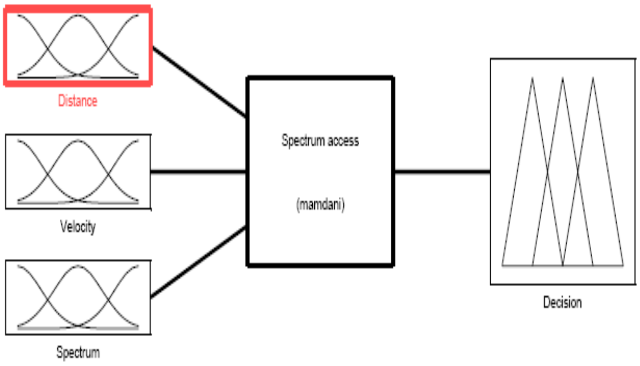

Figure 1: Model of the proposed system

The distance between the primary and secondary user has been considered to be one determining parameter because the secondary user at a closer distance should be given priority to access spectrum by a licensed primary user. The secondary user's velocity is also one input parameter here because more is the velocity more will be the chance for a secondary user to change position and hence quality of service degradation due to nonavailablity of desired channel. Ratio of the required spectrum by the secondary user to the total available spectrum has been kept to be the third determining parameter because in this dynamic spectrum access policy radio will use unused vacant spectrum. The linguistic variables are kept to be LOW, MEDIUM and HIGH and the membership functions for distance between secondary and primary user, velocity of the secondary user and the ratio of required spectrum by secondary user to total available spectrum are shown in Fig 2, 3 and 4 respectively. Trapezoidal membership functions are used in this work. Based on the knowledge on the linguistic variable 27 IF THEN ELSE fuzzy rules are used to take decision for opportunistic spectrum access. At a particular time and place, the unlicensed secondary user with maximum possibility of decision will be allowed to use spectrum.

More priority is given for secondary user which are close to primary users and at the same time secondary users with high velocity is given preference because they may require quick spectrum access otherwise quality of service may degrade. It is also obvious that priority is given when the ration of spectrum requirement to total available spectrum is low. Mamdani rule is used here and the weight is kept to be 1. Mamdani type 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 decision of dynamic spectrum access at a particular location is calculated as

Spectrum access possibility = weight x min value of the membership functions.

The proposed FRBS thus takes decision based on three key parameters according to a predefined rule base. A decision value close to 1 is considered to take decision in favor of getting permission for spectrum access. Matlab 7.0 is used for the simulation.

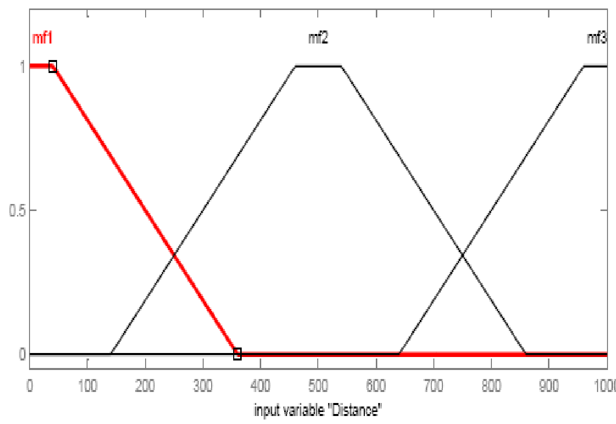

Figure 2: Membership function for distance of secondary user from primary user (meter)

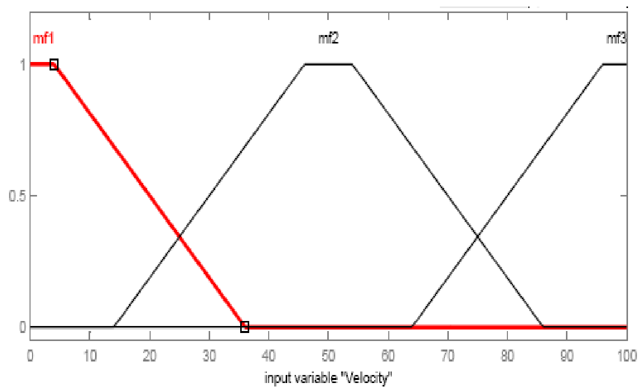

Figure 3: Membership function for velocity of secondary user (Km/hr)

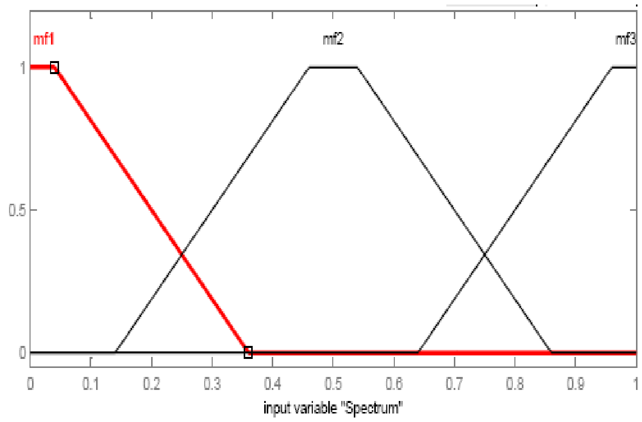

Figure 4: Membership function for ratio of required spectrum by secondary user to the available spectrum

4. RESULTS AND DISCUSSION

The simulation results are shown in Fig 5, 6 and 7. It may be seen from the results that the chance of taking decision increases if the distance between licensed and unlicensed user is low and velocity of the secondary unlicensed user is more (Fig 5). Similarly, the chance is getting increased when required spectrum is low compared to available spectrum (Fig 6 and Fig 7).

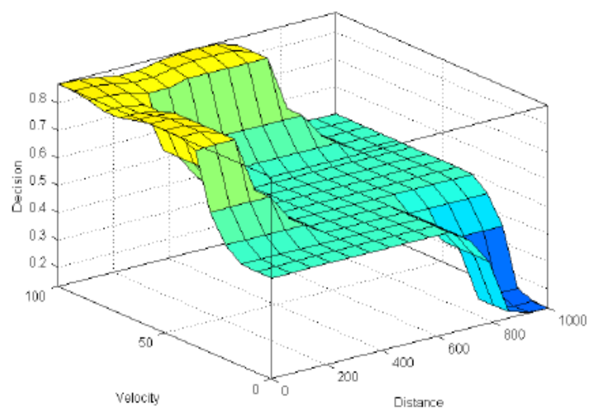

Figure 5: Opportunistic spectrum access decision possibility (ratio of required spectrum to available spectrum = 0.5)

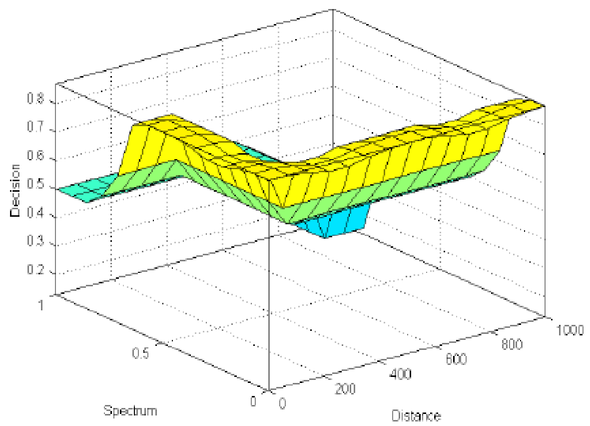

Figure 6: Opportunistic spectrum access decision possibility (velocity of secondary user = 50 Km/hr)

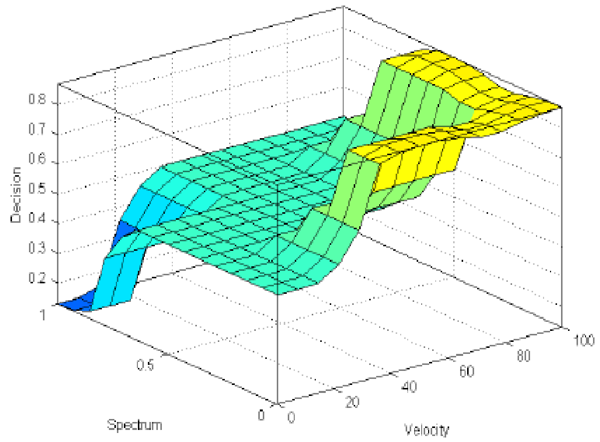

Figure 7: Opportunistic spectrum access decision possibility (distance between primary and secondary users = 500 meters)

The same simulation is repeated with bell shaped membership functions as shown in Fig 8, 9 and 10. The results are shown in Fig 11, 12 and 13. With bell shaped membership functions, the fluctuations are minimized and the rise time is also low.

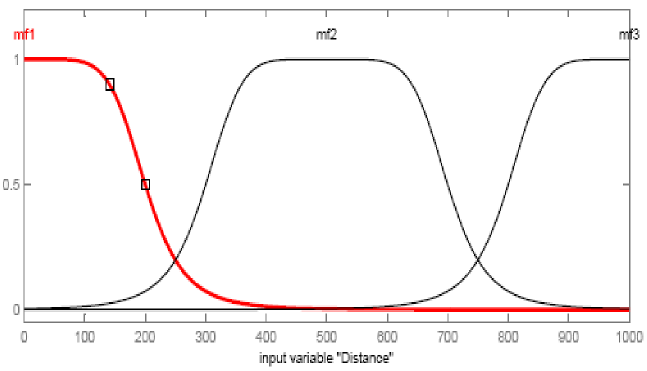

Figure 8: Membership function for distance of secondary user from primary user (meter)

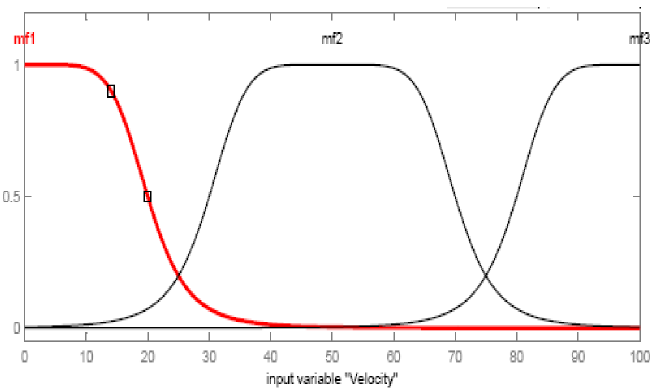

Figure 9: Membership function for velocity of secondary user (Km/hr)

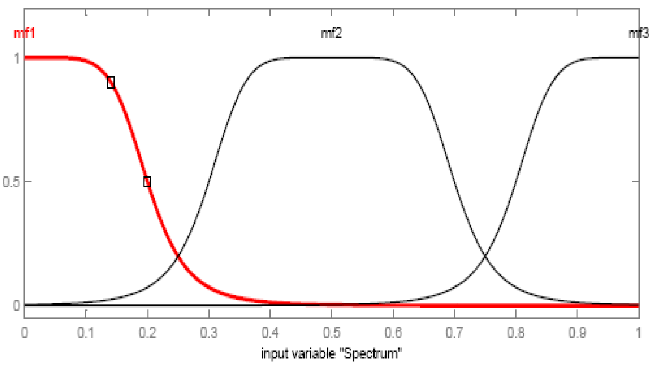

Figure 10: Membership function for ratio of required spectrum by secondary user to the available spectrum

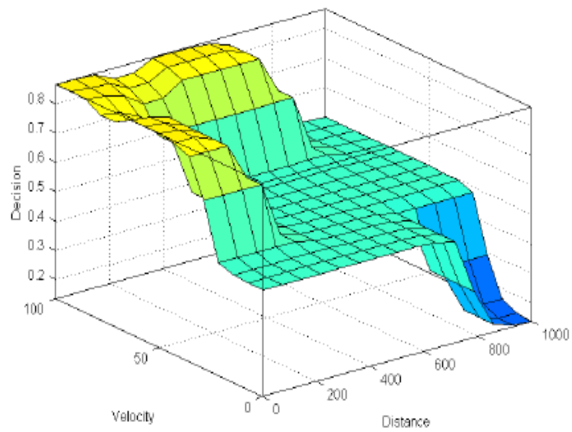

Figure 11: Opportunistic spectrum access decision possibility (ratio of required spectrum to available spectrum = 0.5) with bell shaped membership function

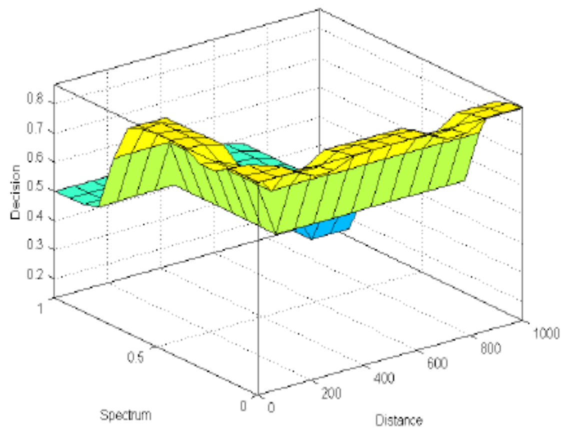

Figure 12: Opportunistic spectrum access decision possibility (velocity of secondary user = 50 Km/hr) with bell shaped membership function

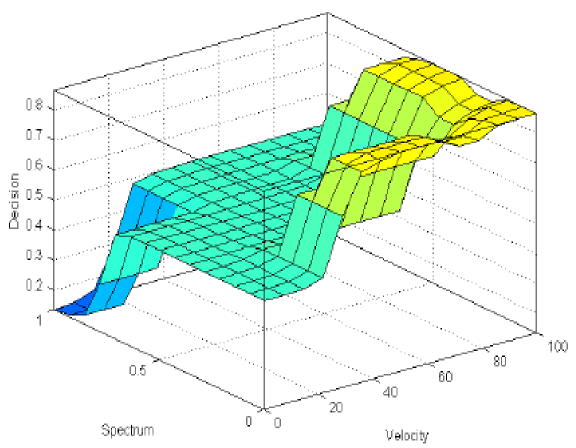

Figure 13: Opportunistic spectrum access decision possibility (distance between primary and secondary users = 500 meters)

So it is clear that the results are desirable, fluctuations are low and can be used to take decision in practical systems. Future systems would sense free spectrum and estimate its velocity using the available standard techniques such as level crossing rate, zero crossing rate, etc. [5]. Since all the necessary information will be available, the proposed system can be implemented in Cognitive Radio applications.

5. CONCLUSION

Researchers throughout the World are trying to find out the best methods to develop a radio communications system that would be able to fulfill the requirements for a cognitive radio system. It has been seen that cognitive radio is the emerging spectrum sharing technology and can be the best option for future generation wireless networks because of present spectrum crisis and uneven use of spectrum. In this paper, a fuzzy logic based opportunistic spectrum access method is proposed which is found to work well. The author is trying to enhance spectrum aware communication by this system to fulfill the present demand. The simulation software programs for the proposed system are neither complex nor consume much time to respond. Hence, it can be easily embedded into application programs and can be implemented in real systems.

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