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AI Based Spectrum Allocation Approach in Cognitive Radio

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Abstract: With increase in demand in number of users using wireless communication technology, the study and implementation of cognitive radio comes into scenario. The radio resources can be more efficiently use with the emerging of cognitive radio. The paper presents an AI based spectrum allocation approach in cognitive radio. The paper focuses on how efficiently the secondary user use frequency channels of primary users without any interference caused at the primary user end. The paper shows an efficient spectrum allocation technique that will use fuzzy logic and Analytical Hierarchy Process for spectrum allocation decision making.

Keywords: Cognitive radio, fuzzy logic, fuzzification, defuzzification, artificial intelligence

I. INTRODUCTION

A basic problem facing the future in wireless systems is where to find suitable spectrum bands to fulfil thedemand of future services. While all of the radio spectrum is allocated to different services, applicationsand users, observation show that usage of the spectrum is actually quite low. To overcome this problemand improve the spectrum utilization, cognitive radio concept has been evolved. Wireless communication,in which transmitter and receiver can detect intelligently the communication channels which are in use and which are not in use are known as Cognitive Radio, and it can move to unused channels. This makespossible the use of available radio frequency spectrum while minimizing interference with other users. CRsmust have the capability to learn and adapt their wireless transmission according to the surrounding radioenvironment. The application of Artificial Intelligence approaches in the Cognitive Radio is very promisingsince they have a great importance for the implementation of Cognitive Radio networks architecture.

Dynamic spectrum access is a promising approach to make less severe the spectrum scarcity that wirelesscommunications face now. It aims at reusing sparsely occupied frequency bands and does not interfere tothe actual licensees.The design of future CRS will face new challenges ascompared to traditional cellular systems. The operationalenvironment is heterogeneous consisting of several accesstechnologies with diverse sets of terminals with the commongoal of providing high user satisfaction [1]. Moreover,an eclectic array of services will be provided. Distributednetwork architectures will appear alongside with centralizedstructures. The conventional network design by consideringonly one isolated network will no longer be sufficient.The cognitive radio is a technique that provides the capability for the unlicensed user or the secondary user (SU)to use or share the spectrum in an opportunistic manner from the auto-coexistence with the licensed user or primaryuser (PU), changing the transmission parameters allowing to operate in the best available channel depending onenvironmentbehaviour. The cognitive radio should determine which spectrum part does not have licensed users who are using it(detection of the spectrum). The cognitive radio can increase the spectral efficiency, because it allows SU to shareopportunistically the spectrum with PU [1].

In cognitive radio, the spectrum handoff can be defined as the process whereby a SU changes its operatingfrequency. The main problem in a change of frequency is the time it takes to find a new channel available, anddepending on the type of information that is being transmitted this may not be tolerable. The use of algorithms toavoid signal degradation and provide a time of satisfactory duration within the licensed bands are big challenges.If the selection of the channel is defective, then thetransmission may be paused because a channel may changefor various reasons such as, it is about to be occupied by a PU or it is already occupied and, when the channelpresents low quality. The multiple channel changes induced by the poor channel selection cause a significantincrease in the delay that directly affects the performance and quality of service for the SU communication [2].Therefore, to find a channel with the required characteristics for the continuous communication of the SU, it isessential for spectral mobility [3].The selection of the criteria is a fundamental task for proactive evaluation of the availability and optimalconditions to select a backup channel. Therefore, it is found in related documents that once the selection criteria areestablished, the development of the multiple criteria decision making (MCDM) methodology is widely used. ThisMCDM method is based on two processes, the weights assessment of each criterion using the AHP [4], and the rankingestimation of each possible solution by means of one of the following techniques, the Technique for OrderPreference by Similarity to Ideal Solution (TOPSIS), the Simple Additive Weighting (SAW), the MultiplicativeExponent Weighting (MEW) or the Grey Relational Analysis (GRA) [5-10].

II. RELATED WORK

In the research literature on the opportunistic spectrum access, different methods are applied using fuzzy logic to access spectrum efficiently. In [11], a novel approach using Fuzzy logic system provides the possibility of accessing spectrum band for secondary users and the user with the greatest possibility has to be assigned the available spectrum band. For enhancing the performance of Cognitive radio fuzzy logic based scheme is developed by AnileshDey et al., [12], where efficient spectrum utilization depends upon the link loss, hold time and interference temperature. With fuzzy controller, Cognitive radio opportunistically adjust its transmit power in response to the changes of the interference level to the primary user is discussed in [13]. A Fuzzy logic based algorithm [14] is used to reduce the spectrum handoff and improves the probability of PU's occupancy at a certain channel. In [15], Fuzzy rules are used to optimize the bandwidth allocation based on three antecedents as: arrival rate of both licensed and unlicensed users and the availability of unoccupied number of channels within the system. A decentralized method has been developed using fuzzy based techniques for both channel estimation and channel selection in [16]. The efficient decision making in the cognitive radio by fuzzy logic is also discussed by Matinmikko et al [17], which presented an overview of application of fuzzy logic to telecommunications. Our work is different from the above said works available on Cognitive radio based on fuzzy logic system. This paper presents a novel approach using Fuzzy logic system to utilize the available spectrum by the secondary users without interference with the primary user. The secondary users access the spectrum based on the highest possibility of the secondary users.

III. PROPOSED WORK

It is assumed that there exists an opportunistic spectrumaccess environment where each user is working to realize itsown benefit. However, the proposed system decides, on theavailable input characteristics, to which the available spectrumwill be allocated. Figure 1, shows the model of proposedsystem.As seen in diagram, FLC consists of four inputs for secondary user. These are defined as, Spectrum Demand (SD), SNR; SignalStrength (SS) and Mobility (M) ofSecondaryUser. Each input is described by three possible levels. These can be given as.

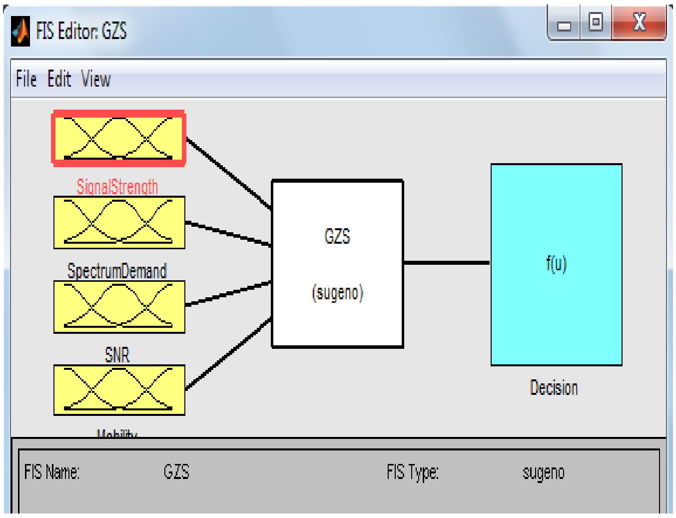

Figure 1 Proposed System Model

SD (Demand) = {Low, Medium, High} = {L, M, H}
SS = {Low, Medium, High} = {L, M, H}
SNR= {Low, Medium, High} = {L,M, H}
M= {Low, Medium, High} = {L, M, H}
Similarly channel selection probability as an output variable isa set of 5 membership values as:
Decision (D) = {Very Low, Low, Medium, High, Very High= {VL, L, M, H, VH}
The process of normalization is followed for every input parameter.

The membership functions for input and output parameter with their ranges are shown in Figure 2, 3, 4, 5 & 6 respectively.

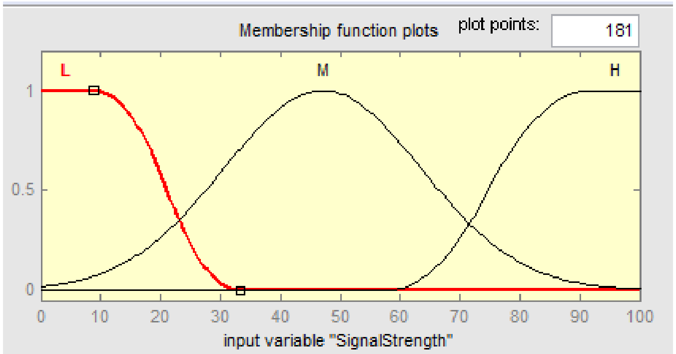

Figure 2 Membership function plot for Input variable Signal Strength

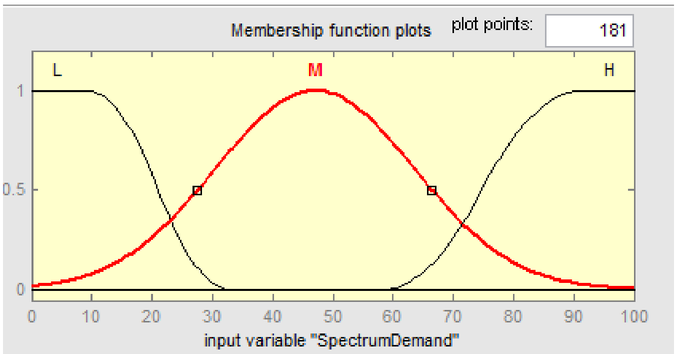

Figure 3 Membership function plot for Input variable Spectrum Demand

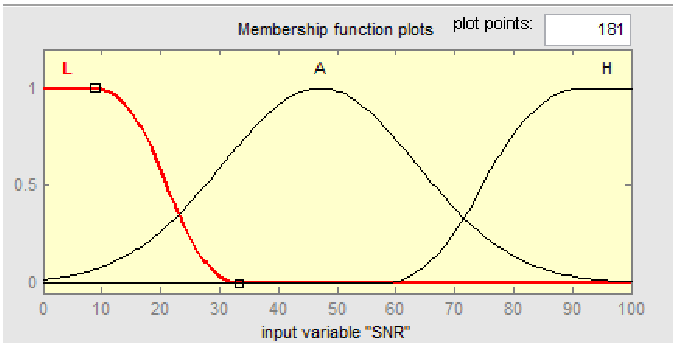

Figure 4 Membership function plot for Input variable SNR

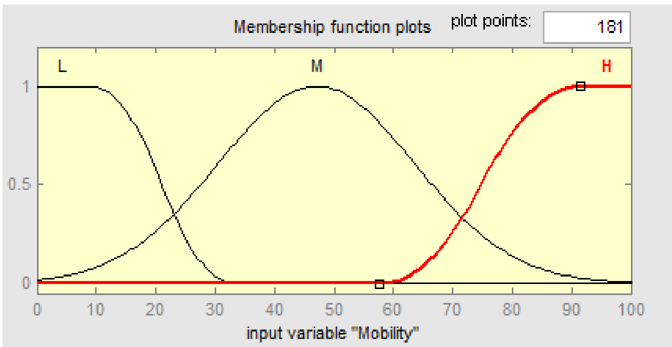

Figure 5 Membership function plot for Input variable Mobility

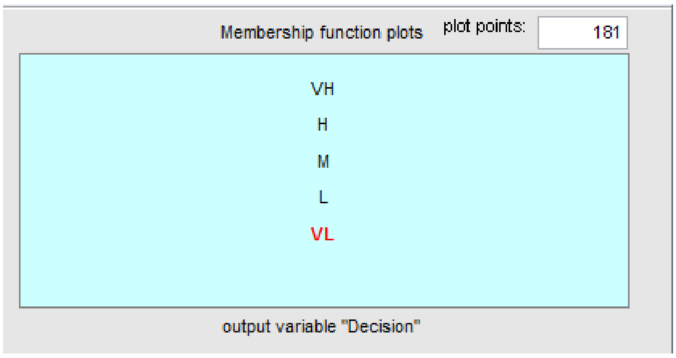

Figure 6 Constant Membership function plot for Output variable Decision

The decision of selecting a channel for secondary user toaccess spectrum is calculated using formula:

$$\text{Channel Selection Possibility} = \frac{\sum_i (Mi * Si)}{\sum_i Mi} * 100 \quad (1)$$

Rules are of the form to find out the decision. The rule blocks contain the control strategy of a fuzzy logic system. Each rule block confines all rules for the same context. A context is defined by the same input and output variables of the rules.The rules' 'if' part describes the situation, for which the rules are designed. The 'then' part describes the response of the fuzzy system in this situation. The degree of support (DoS) is used to weigh each rule according to its importance.The processing of the rules starts with calculating the 'if' part. The operator type of the rule block determines which method is used. The operator types MIN-MAX, MIN-AVG and GAMMA are available. The characteristic of each operator type is influenced by an additional parameter.A total of 81 rules are made to designthe inference engine. Out of total 81 rules fired by fuzzy inference engine some of the rules are given in Table 1. Fuzzy logic toolbox of MATLAB 7.8.0 was used for simulation of theproposed algorithm.

TABLE 1 Set of Rules for the Proposed System

IF				THEN	
SD	**SNR**	**SS**	**M**	**DoS**	**Decision**
Low	low	low	low	1.00	very_low
Low	low	low	medium	1.00	very_low
Low	low	low	high	1.00	Low
Low	low	medium	low	1.00	very_low
Low	low	medium	medium	1.00	Low
Low	low	medium	high	1.00	Low
Low	low	high	low	1.00	Low
Low	low	high	medium	1.00	Low
Low	low	high	high	1.00	Medium
Low	medium	low	low	1.00	very_low
Low	high	medium	low	1.00	Low
Low	high	medium	medium	1.00	Medium
Low	high	medium	high	1.00	High
Low	high	high	low	1.00	Medium
Low	high	high	medium	1.00	High
Low	high	high	high	1.00	High
Medium	low	low	low	1.00	very_low
IF				**THEN**	
Medium	medium	high	high	1.00	high
Medium	high	low	low	1.00	low
Medium	high	low	medium	1.00	medium
Medium	high	low	high	1.00	high
Medium	high	medium	low	1.00	medium
Medium	high	medium	medium	1.00	high
Medium	high	medium	high	1.00	high
Medium	high	high	low	1.00	high
Medium	high	high	medium	1.00	high
Medium	high	high	high	1.00	very_high
High	low	low	low	1.00	low
High	low	low	medium	1.00	low
High	low	low	high	1.00	medium
High	low	medium	low	1.00	low
High	low	medium	medium	1.00	medium
High	low	medium	high	1.00	high
High	low	high	low	1.00	medium
High	low	high	medium	1.00	high
High	medium	high	medium	1.00	high
High	medium	high	high	1.00	very_high
High	high	low	low	1.00	medium
High	high	low	medium	1.00	high
High	high	low	high	1.00	high
High	high	medium	low	1.00	high
High	high	medium	medium	1.00	high
High	high	medium	high	1.00	very_high
High	high	high	low	1.00	high
High	high	high	medium	1.00	very_high
High	high	high	high	1.00	very_high

Channel selection probability is determined by holding oneparameter constant and viewing the surface plot of theremaining two input parameters against channel selectionprobability. In figure 7, surface plot is shown when SNR and Spectrum Density are kept constant at the medium level and channel selection decision possibility is plotted against signal strength and mobility. Similarly in figures8 signal strength and spectrum demand is kept constant and in figure 9 Mobility & signal strength are kept constant at medium level while remaining two parameters are used to plot surface plot against channel selection decision possibility.

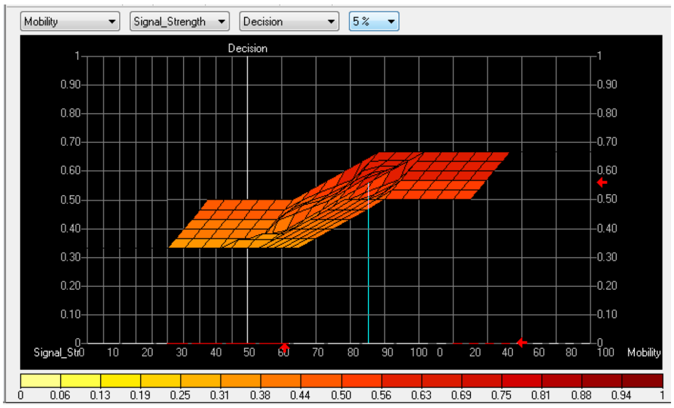

Figure 7 Surface Plot between Mobility, Signal Strength & Decision

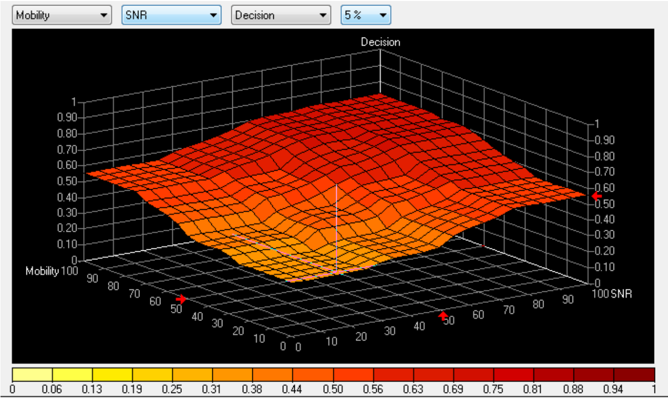

Figure 8 Surface Plot between Mobility, SNR& Decision

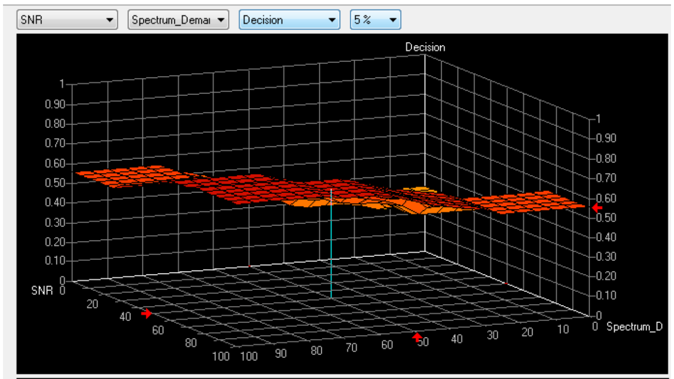

Figure 9 Surface Plot between SNR, Spectrum Density& Decision

IV. CONCLUSION

In this paper an overview of application of fuzzy logic in communication is presented. The characteristics of Cognitive Radio offer a great potential for applying fuzzy logic into the system. It is concluded that system is performing well under given set of rules with minimum error in results. Hence a new scheme for channel selection in cognitive radio has been proposed and simulated using MATLAB fuzzy logic tool box. The proposed scheme can be used efficiently to assign free channels to secondary users according to defined input parameters.

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