CHANNEL SELECTION IN COGNITIVE RADIO USING FUZZY LOGIC

M. Waheed ul Hassan[1,*] and Asrar ul Haq Sheikh[2], Zahoor Ahmad[3]
[1,2]Electrical Engineering Department, TheUniversity of Lahore, 1 Km, Raiwind Road, Lahore
[3]Centre for Advance Studies in Physics, Government College University Lahore, 1-Church Road, Lahore
Correspondent Email: engineer.waheed@msn.com

ABSTRACT: *Cognitive radio (CR) technology has been developed to improve spectrum utilization of underutilized licensed spectrum by allowing unlicensed users or secondary users (SU) to use the spectrum under the condition that such utilization will not interfere with licensed users or primary users (PU) that is the communication, quality of service (QoS) of primary users must not be degraded by the unlicensed users. The CR technology involves spectrum sensing, sharing and management under mobility etc. One of the issues in spectrum management is mechanism of deciding for channel selection for SU's. In this work a fuzzy logic control (FLC) based system is proposed for channel allocation decisions in spectrum management. The fuzzy logic control system (FLCS) proposed in this work is based on three inputs - signal strength, spectrum demand and signal to noise ratio (SNR). The FLCS outputsprobability of channel selection. Experiments are performed using fuzzy logic tool box in MATLAB. Results show improved performance of the proposed system.*

KEYWORDS: Cognitive radio, primary user, secondary user, spectrum management, Channel Selection,fuzzy logic

1. INTRODUCTION

Mitola introduced the term CR, which has emerged as a technology for increasing the utilization of the bandwidth while accommodating the more services in wireless networks [1].Cognitive radio (CR) allows transmission by unlicensed user without interference with the activities of the primary users. It detects the vacant spectrum and shiftsits transmission on the free spectrum called white space by intelligently changing the transmission and reception parameters in order to provide an efficient bidirectional communication. Cognitive radios can sense surroundings and allow secondary user to use unutilized spectrum. Development of suitable dynamic spectrum access techniques for different operating environments is essential as it is the key for implementation of cognitive radio [2].

A. Why Cognitive Radio

The wireless networks use assigned frequency spectrum, which has resulted in network congestion because of ever increase in the number of users. However, other networks such as TV broadcasts, military communications usethe spectrum assigned to them sparingly and an opportunity exists that this spectrum be shared with other communication modes. Earlier it was not allowed to use frequency spectrum assigned to a service provider whether empty or utilized to any other wireless user. The FCC in their Docket of November 2004 introduced rules to allow transmission of public users ofthe empty licensedspectrum frequencies without interference to the licensee [3]. Cognitive radio gives strategy for intelligent spectrum sensing, spectrum management and spectrum access to the unlicensed users. The cognitive radio learns from the existing radio environment and changes its characteristics by adjusting the transmission parameters in real-time. A cognitive radio network enables the establishment of communication linksby secondary users. The changes in communication parameters can be varied according to variations in the topology, radio spectrum usage, spectrum white spaces and user requirements [4]. Objectives of cognitive radio are to get efficient and reliable wireless communication in addition to realization of improved utilization efficiency of the spectrum.The CR consists of spectrum sensing for which a large literature is available in techniques [5]. The spectrum management consist of identification of radio resources and its utilization. Various methods of managing the identified spectrum have been discussed in the open literature. This aspect is also has been discussed in the literature including [9]. This paper discusses the application of fuzzy logic to the issue of channel assignment.

B. Fuzzy Logic Based Cognitive Radio

Loft Zadeh in 1965 introduced fuzzy set theory, which opened the doors to effective, easy and efficient ways of logical information processing in several fields of engineering particularly in image processing, mixing and grinding of materials, autofocus cameras, robots, diagnosis systems, automobile transmissions, machine learning, washing machines, automatic control systems and telecommunication [6]. The above list is not exhaustive; many more applications use fuzzy logic cognitive radio based networks is an example. Cognitive radio systems based on fuzzy logic presents a way to overcome emerging challenges and problems faced in wireless communication. Fuzzy logic provides a software and hardware based solutions to solve spectrum sensing and decision making in distributed environment of cognitive radio. Fuzzy logic does this dynamically and without too much complexity.

2. PREVIOUS WORK

Decision making problems are usually multivariate in resource management where optimal solutions may not exist because of complexity or is very difficult to find. Thus, instead using complex mathematical solutions, fuzzy provides an alternative, which provides a solution at relatively very little cost without losing on the accuracy of the solution [7]. Pehand others in 2007 presented a work based on detection of spectrum to give frequency bands to secondary and primary users in CR ensuring best performance using indicator of false alarm with cooperation of users. False alarm is indicative oth the presence of a PU by SU when PU actually did not exist. The results that detection is increased and false alarm is decreased were supported by simulation experiments [8].

In 2008,Akyildizand others gave a new solution of sensing white spectrum, keeping in view the QoS of CR. In this work of surveying architecture of CR, issues in spectrum management, spectrum mobility and decision to share spectrum are discussed [9]. Giupponi and others in 2008 worked to propose a technique for handoff in CR networks using fuzzy logic(FL)in search for optimal decision. Their algorithm implemented by adaptation of frequency channel to SU automatically and reducing the interference [10]. Ly and others in 2008 proposed a scheme for selection of a secondary user suitable to control access of spectrum by using FL. Analysing the mobility of the SU and the Doppler produced gives out the possibility for the secondary user to use spectrum [11].

Kaur in 2010 proposed a strategy for bandwidth allocation to cognitive SU using FLC system. In their work they used two FLC modules, one for spectrum access computation and other for allocation of free bandwidth to users [12]. In 2012 Yao presented an algorithm for decision making using fuzzy logic in cognitive radio environment for selection of channels. This algorithm showed better results and its working was based on information of competing level by SU for the spectrum and activity level of the primary users [13].

3. RESEARCH METHOD

It is assumed that there exists an opportunistic spectrum access environment where each user is working to realize its own benefit. However, the proposed system decides,on the available input characteristics, to which the available spectrum will be allocated. Figure 1, shows the model of proposed system.As seen in diagram, FLC consists of three inputs, namely, secondary user spectrum demand, its SNR, and signal strength.

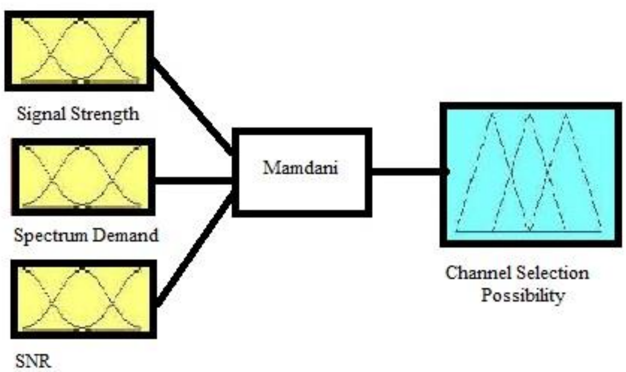

Figure 1 Proposed System Model

Each input is described by three membership functions or fuzzy characteristics.

D (Demand) = {Low, Moderate, High} = {L, M, H}

S (Signal Strength) = {Low, Medium, High} = {L, M, H}

S_n (Signal to noise ratio-SNR) = {Low, Average, High} = {L, A, H}

Similarly channel selection probability as an output variable is a set of 5 membership values as:

Pd (Probability of decision) = {Very Small, Small, Medium, Large, Very Large} = {V_s, S, M, L, V_l}

Ranges of input membership function are given in table 1 below.

TABLE1
Ranges of Input Membership Functions

Membership Functions	Ranges	Signal Strength	Spectrum Demand	SNR
MF1	0-50	Low	Low	Low
MF2	0-100	Medium	Moderate	Average
MF3	50-100	High	High	High

Ranges for output membership functions are given in table 2 below.

TABLE2
Ranges for output membership function

Membership Functions	Ranges	Channel Selection Possibility
MF1	0-25	Very small
MF2	0-50	Low
MF3	25-75	Average
MF4	50-100	High
MF5	75-125	Very High

TABLE 3
Set of Rules for the Proposed System

Rule #	Input 1 (Signal Strength)	Input 2 (Spectrum demand)	Input 3 (SNR)	Decision
1	High	Low	Low	Average
2	High	Low	Average	High
3	High	Low	High	Very High
4	High	Moderate	Low	Low
5	High	Moderate	Average	Average
6	High	Moderate	High	High
7	High	High	Low	Very small
8	High	High	Average	Low
9	High	High	High	Average
10	Medium	Low	Low	Average
11	Medium	Low	Average	High
12	Medium	Low	High	Very High
13	Medium	Moderate	Low	Low
14	Medium	Moderate	Average	Average
15	Medium	Moderate	High	High
16	Medium	High	Low	Small
17	Medium	High	Average	Low
18	Medium	High	High	Average
19	Low	Low	Low	Low
20	Low	Low	Average	Average
21	Low	Low	High	Very High
22	Low	Moderate	Low	Small
23	Low	Moderate	Average	Very small
24	Low	Moderate	High	Low
25	Low	High	Low	Very small
26	Low	High	Average	Low
27	Low	High	High	Average

The decision of selecting a channel for secondary user to access 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 like, if signal to noise ratio (SNR) is S_n and the demand of spectrum of the secondary user is d and signal strength is S then the Possibility (Pd) of assigning the available spectrum or channel selection for cognitive users is the consequence of rule. A total of 27 rules are made to design the inference engine and are given in table 3. Fuzzy logic tool box of MATLAB 7.10 was used for simulation of the proposed algorithm.

Channel selection probability is determined by holding one parameter constant and viewing the surface plot of the remaining two input parameters against channel selection probability. In figure 2, surface plot is shown when SNR is kept constant at the medium level and channel section possibility is plotted against signal strength and spectrum demand. Similarly in figures3 and 4, signal strength and spectrum demand respectively are kept constant at medium level while remaining two parameters are used to plot surface plot against channel selection possibility. Surface plot in figure 2 shows that when spectrum demand is increases and signal strength decreases, channel selection possibility decreases. However, when signal strength and the spectrum demand are increased, channel access probability still decreases. Channel selection probability increases only when signal strength increases and spectrum demand decreases.

Figure 3 shows the surface plot of channel selection probability againstSNR and spectrum demand while signal strength is kept constant at medium level. It is seen that the channel selection probability decreases when spectrum demand is increased and SNR is decreased.

When both the SNR and the spectrum demand are increased then channel selection possibility is also increased but relatively slowly. If SNR is increased and spectrum demand is decreased then channel selection probability increases rapidly.

Figure 4 shows the surface plot of channel selection possibilityagainstsignal strength and SNR. It shows that when both signal strength and SNR are increased channel selection possibility increases rapidly and the opposite is true when both are decreased. When signal strength increases and SNR decreases or when SNR increases and Signal strength decreases then channel selection possibility also decreases.

4. RESULTS & CONCLUSION

Finally observations regarding simulations will be discussed using following table no.4 having comparison between actual values and calculated results of possibility of channel selection for three cognitive users.

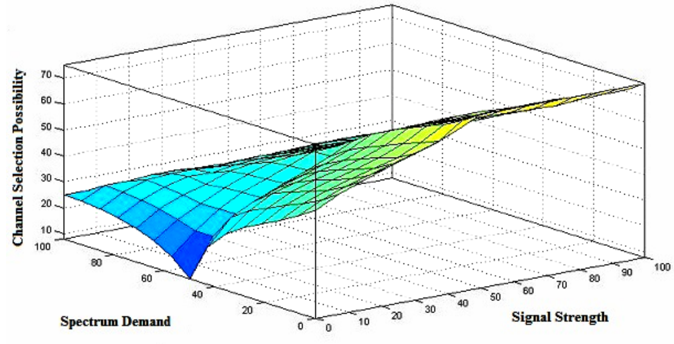

Figure 2 Surface Plot Between Signal Strength & Spectrum Demand

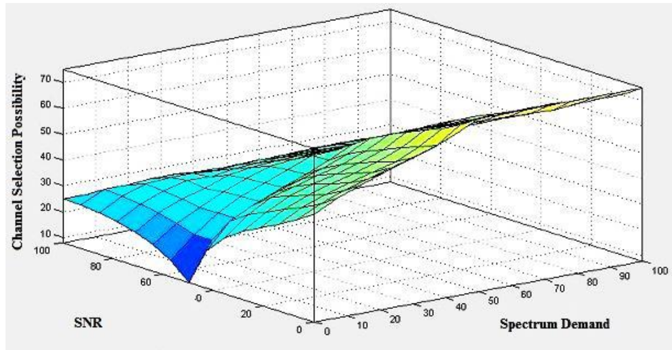

Figure 3Surface Plot Between SNR & Spectrum Demand

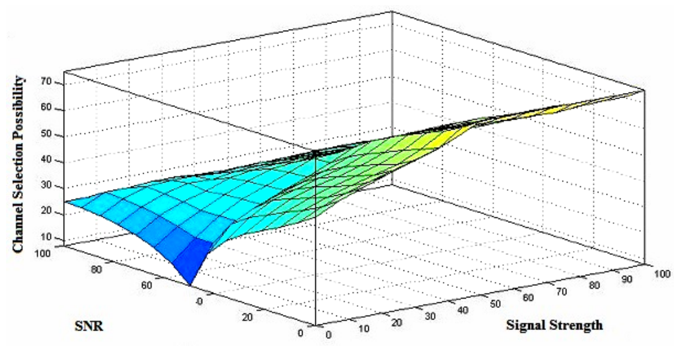

Figure 4 Surface Plot Between Signal Strength & SNR

TABLE 4; Results

Cognitive User	Actual Value	Calculated value	Difference	Percentage error
1	54.5	52.71	1.79	3.3%
2	31.6	29.83	1.77	5.6%
3	68.3	69.7	1.4	2.04%

It concludes that system is performing well under given set of rules with minimum error in results. Percentage of error between designed and simulation results are low so this error is negligible. 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.

REFERENCES

1. J. Mitola III, "Cognitive radio for flexible mobile multimedia communications,"Mobile Networks and Applications, vol. 6, no. 5, Sep 2001.
2. S. Haykin, "Cognitive radio: brain-empowered wireless communications," IEEE Journal on Selected Areas in Communications, vol. 23, no. 2, pp. 201–220, 2005.
3. FCC, "Facilitating Opportunities for Flexible, Efficient,and Reliable Spectrum Use Employing CognitiveRadio Technologies,"FCC Docket 03-322, December 17, 2003. Available [Online].
4. R.V. Prasad, P. Pawlczak, J. A. Hoffmeyer, and H. S. Berger, "Cognitive functionality in next generation wireless networks: standardization efforts," IEEE Communications Magazine, vol. 46, no. 4, pp. 72–78, 2008.
5. G. Ganesan and Y. Li, "Cooperative Spectrum Sensing in Cognitive Radio Networks, Part I: Multiusers Networks," IEEE Transactions On Wireless Communications, Vol. 6, June, 2007.
6. L. A. Zadeh. "Fuzzy sets," Information and control, vol. 8, pp.333-353,1965.
7. T. Rauma, "Fuzzy modeling for industrial systems," Ph.D. Dissertation, VTT Publications 382,ISBN 951-38-5367-5, Espoo, Finland, 1999.
8. E. Peh, and Y.C. Liang, "Optimization for Cooperative Sensing in Cognitive Radio Networks," IEEE Wireless Communications and Networking Conference on Communication, Networking & Broadcasting, ISBN:1-4244-0658-7, March 2007.
9. Akyildiz, I.F., Won-Yeol Lee, Vuran, M.C., andMohanty S., "A survey on spectrum management in cognitive radio networks," BrowseJournals Magazines, Communications Magazine, IEEE Volume:46, Issue:4,2008.
10. L. Giupponi, and A. I. P. Neira, "Fuzzy-based spectrum hand off in cognitive radio networks,"3rd International Conference on Cognitive Radio Oriented Wireless Networks and Communications (Crown Com.) Singapore, 2008.
11. H.D.Ly,"Opportunistic spectrum access using fuzzy logic for cognitive radio networks," Second International Conference on Electronics (ICCE), (pp. 240-245) HoiAn, Vietnam, 2008.
12. P. Kaur, M. Uddin, and A. Khosla, "Fuzzy based adaptive bandwidth allocation scheme in cognitive radio networks," Eighth International Conference on ICT and Knowledge Engineering, (pp. 41-45). Bangkok, 2010.
13. Y. Yao, S. R. Ngoga, D. Erman and A. Popescu, "Competition-Based Channel Selection for Cognitive Radio Networks," IEEE Wireless Communications and Networking Conference: MAC and Cross-Layer Design,2012.