ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 10, October 2014

Optimal Fuzzy Logic Power Control in cognitive Radio: A Comparative Study

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Abstract: This paper presents the spectrum sharing network consisting of a pair of primary users (PUs) and a pair of cognitive users or secondary user (SUs) in fading wireless channels. Cognitive radio networks are the spectrum utilizing networks. When both the links (primary user link and secondary user link) utilized the spectrum simultaneously networks are called the spectrum sharing networks. During the spectrum sharing, the interference will occur at the primary user link and secondary user degrades the QoS of the primary user link due to same frequency band utilization from the PUs and SUs. The priority of the primary user's spectrum utilization will be higher than secondary user's spectrum utilization. This study discussed about the QoS assurance of primary users, improved the performance of the secondary users and minimization of bit rate in the spectrum sharing cognitive radio network.

Keywords: Cognitive radio networks, Fuzzy control, Power control, Spectrum sharing, Quality of services.

I. INTRODUCTION

Cognitive radio is a technology for wireless communication in which either wireless network or a wireless node changes its reception or transmission parameters to communicate efficiently avoiding the interference with primary (licensed) or secondary (unlicensed) users.

The concept of cognitive radio was first proposed by Joseph Mitola III in a seminar at KTH (the Royal Institute of Technology in Stockholm) in 1998 and he published that in an article by Mitola and Gerald Q. Maguire, Jr. in 1999 [1] . It was a novel approach in wireless communications at that time , which was also described by Mitola later 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].

Now a day's research is going on to reduce the interference at the spectrum sharing networks by optimal power control strategies. Research area bon the cognitive radio network are consisting of two types of mechanisms: the opportunistic spectrum access and the spectrum sharing. In opportunistic spectrum access, the primary user (PU) link and cognitive user (CR) link utilize spectrum exclusively. The CR link senses the spectrum to seek spectrum holes for opportunistic spectrum access. In spectrum sharing, the PU and CR links utilize spectrum simultaneously.

Section II explains fuzzy inference systems, in section III System model presented, In IV Comparative study of optimal fuzzy logic power control in cognitive radio and conclusions are given in section VI.

II. SYSTEM MODEL

This paper considered the spectrum sharing cognitive radio network in Rayleigh fading wireless channel .the system model can be explained as follow.

A. Channel Model

Figure-1 shows the spectrum sharing network which consisting a pair of PU's called a PU link and a pair of SU's called a CR (SU) link in a Rayleigh fading channel. Inside the spectrum sharing network, all channel state information (CSI) on each side is also available to the other. This assumes the additive white Gaussian noises are independent at PU-RX and CR-RX with the same variance of No. The instantaneous channel gains on the PU direct link (PU-PU), PU Interference link (PU-SU), CR direct link (SU-SU)and CR interference link (SU-PU)are denoted by- g_{pp} , g_{cp}, g_{cc} and g_{pc} respectively. The values of all instantaneous channel power gains are assumed to be independent random variables with a continuous probability density function (PDF).

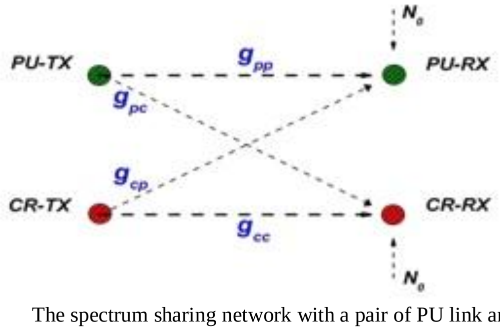

Fig. 1. The spectrum sharing network with a pair of PU link and a pair of CR link [10]

B. The SNR and SINR

When SU's are not utilized the spectrum then considered as signal-to-noise ratio (SNR) and when both the links are communicated the extra interference sensitive at the links

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considered as signal-to-interference-plus-noise ratio (SINR) are used to evaluate to the QoS.
When only PU link utilized the spectrum the PU's SNR without the CR link is:

$$\alpha = \frac{\mathrm{Pp} \times \mathrm{gpp}}{\mathrm{No}} \qquad (1)$$

When both the links utilized the spectrum and during spectrum sharing, the PU's SINR with the CR link is:

$$\beta = \frac{\mathrm{Pp} \times \mathrm{gpp}}{\mathrm{Pc} \times \mathrm{gcp} + \mathrm{No}} \qquad (2)$$

For maintaining the QoS , the model assume that the SU has a peak power scale P_{cmax} and the SU allocates the peak power scale ratio K to assure the desired QoS on the PU link. Now the above equation can be rewritten as follows:

$$\beta(K) = \frac{\mathrm{Pp} \times \mathrm{gpp}}{\mathrm{K} \times \mathrm{Pc} \times \mathrm{gcp} + \mathrm{No}} \qquad (3)$$

The peak power control scale ratio K is determined by using mamdani fuzzy inference system model and assure the QoS at the primary user when PU and SU share the spectrum simultaneously or in other words QoS are not degraded when SU and PU share the spectrum simultaneously.

III.COMPARATIVE STUDY OF OPTIMAL FUZZY LOGIC POWER CONTROL IN COGNITIVE RADIO

In any system power control plays an important role in the performance of that system. Likewise in Cognitive radio, power control has a major role in its performance.
In [3], proposed the fuzzy rule based power control strategy in which CU is able to opportunistically adjust its transmit power and responsible to changes of interference level to primary user. In this fuzzy based power control strategy the CR user's link considers three input variables - The interference level caused by the SU to the reclaiming PU, The distance from the SU to the reclaiming PU, The received power difference of the SU at base station. In this strategy, decreases the average transmits power consumption and achieve lower average outage probability compared with the fixed-step power control scheme. The outage probability of this power control scheme increases with the number of active SUs but more slowly than the corresponding outage probability of fixed-step power control scheme. There is need of proposed transmit power constraints to reduce the outage probability.
In [4] the authors proposed a new transmit power control constrained (peak/average power constrained) to assure the optimal outage probability of the PU, when SU is also utilize the spectrum in the spectrum sharing network. In this method the SU transmit power can not be larger than the pre-defined threshold. To achieve the opportunistic ergodic capacity of the SU link, it has been derived under these new constraints. Also author has been considered the PU outage loss constraint $\Delta E=0.1$ then the capacity gain becomes large. For large value of ΔE the SU capacity gain gets saturated. There is need of some new constraints which can increase capacity gain and reduce the outage probability.
In [5] the authors have been considered the peak power constraint at the secondary transmitter and the average interference constraint at primary receiver. Authors have characterized the SNR and capacity optimal power adaption strategy to maximize the SNR and capacity of the secondary users. The SNR optimal power adaptation policy makes sure that transmissions take place only at the peak power regardless of the knowledge of the secondary channel and type of sensing metric. The binary power adaption at the secondary transmitter ensures that the interference seen at the primary receiver is varying. Continuous power adaption ensures that the SU capacity is maximized.
In [6] to maximize the ergodic capacity of secondary users, optimal power control strategies under four different power constraints have been derived via convex optimization. In this paper the authors have considered the interference power constraint and the transmission power constraint in the four cases, which affects the capacity of the secondary users. The simulation results shows that, with increasing the transmit power of PU the ergodic capacity of SU has decreased. This scheme reflected that the power control strategy is still better than that proposed in [5].
To improve the SUs performance, the transmission rate of SUs should be high. In [7], authors proposed a scheme to increase the transmission rate of cognitive user. In this scheme cognitive radio network used a time varying spectrum in which SUs (CUs) monitors the dynamic usage of licensed frequency band of PUs, allowed to utilize the spectrum when it is not a cause of interference with PUs. This scheme matches the transmit power of SU with the non interfering probability at each data samples through the statistical information of the licensed frequency band occupancy. In this strategy CU utilized the spectrum only when PU is not utilized the spectrum effectively. There is need of strategy in which SUs and PUs can utilize the spectrum simultaneously or a spectrum sharing networks.
Yan chen et at [8] proposed a strategy for spectrum sharing networks in which the secondary user can adopt the transmit power opportunistically to maximize its trans mission rate without degrading the outage probability of the primary user. The result shows that the protection gap is inversely proportional to the ergodic rate of the cognitive users. The work presented in this paper is based on the channel state information and thus the requirement of the synchronization between the PU and SU is significantly relaxed.
Tabakovic et at [9] presented a new strategy for fuzzy logic transmit power control which enables cognitive secondary user to achieve its required transmission rate and QoS , while minimizing interference to the primary users and concurrent secondary users. In this strategy, SU sets the required signal to noise plus interference ratio (SINR) to assure the Qos of the cognitive radio network. Comparison of measured and required SINR at SU receiver determines transmit power control ratio and minimum required SU transmit power. This scheme shows that the smaller interference potential and reduction of frequency .This scheme also valid in other next

generation mobile networks (5G, 6G) to improve the overall performance of SU, spectrum utilization and maximized the PUs and SUs network capacity with respect to different parameters like bit error rate, data rate in spectrum networks.

In [10] the authors have considered a spectrum sharing network with a pair of primary users and secondary users in a fading channel to reduce the bit error rate of data transmission. The primary user has the higher priority to utilize the spectrum than cognitive user. Cognitive user can share the spectrum as long as the desired Quality of service is maintained for the primary user. Using three input parameters: the PU's SNR, the PU's interference channel gain and the relative distance between PU's link and CR's link. A fuzzy based opportunistic power control strategy using Mamdani fuzzy control has been proposed. There is need of an intelligent network strategy as like adaptive neural fuzzy inference system ANFIS based power control strategy to improve the SU;s performance and reduce the bit error rate in the spectrum sharing cognitive radio network.

In [11] the author proposed the fuzzy decision making and cognitive radio access selection scheme to improve the Qos of cognitive radio network. The fuzzy decision making is based on cross layer information, past history and shared knowledge. This scheme is suitable for multi technology scenarios; results show that the throughput of user is optimal. It can also elaborate in spectrum sharing and information sharing networks.

Le and Ly et at [12] in this paper modify the membership functions of the inputs in according to the requirements of the primary networks and spectrum utilizing policy. Based on Mamdani fuzzy control model, the CR link considers three input variables: spectrum utilization efficiency, degree of mobility and relative distance, and selects an optimal spectrum band to utilize.

It can also solve the mobility management problems in order to keep high quality of services of cognitive radio networks. There are 27 fuzzy rules which are more complex as compare to [13]. It should be to balance the trade-off between spectrum sharing accuracy and interference 81 rule based model in [13].

In [13] The effect of CR parameters like spectrum utilization efficiency, degree of mobility, strength of received signal and distance to the primary user have been used as fuzzy inputs on the basis of which the secondary users can be scheduled as per the rule base of spectrum assignment. The proposed 81 rule base model is an improvement over the earlier 27 rule base as it has incorporated the PU-SU distance and signal strength inputs in a logical reasoning to balance the tradeoff between spectrum sensing accuracy and interference. Also, four types of membership functions namely Triangular, Trapezoidal, Gaussian and Bell have been used to compare the scheduling decision surfaces for a given spectrum sharing model and interestingly trapezoidal membership function is seen to give higher values of decision possibility for almost the whole range and combinations of inputs. To improve the overall performance of cognitive radio environment, it can be used in spectrum or information sharing networks to efficient spectrum utilization.

IV. CONCLUSION

The fuzzy inferences systems are used to automatic control, decision analysis, optimize the parameters, adaptive techniques, and intelligent systems. This study shows that using fuzzy logics many parameters has been improved in the cognitive radio systems. Hence from this comparative study it can be concluded that the results are improving but need more enhancement at secondary user link in the above considered spectrum sharing cognitive radio network. So, there is need of a new opportunistic power control strategy to increase the bit error rate in this network.

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