IMPLEMENTATION OF ANFIS ALGORITHM FOR EFFICIENT SPECTRUM HANDS-OFFS IN COGNITIVE RADIO NETWORKS

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ABSTRACT

The advancements in wireless communication in the recent times have raised the demand for wireless radio spectrum. Thus, Cognitive Radio Network (CRN) is introduced as it has the capability to sense the available channels and radio-frequency (RF) spectrum in order to minimize the interference to primary users. Basically, Cognitive Radio (CR) is the network that alters the parameters of transmission and enables more users to communicate concurrently. However, unnecessary handovers in the wireless network lead to the rise of ping pong effect. This effect reduces the efficiency of the network in terms of providing continuous call to the users. The conventional fuzzy model used two fuzzy controllers to implement the entire process. Although, it is efficient but this model is very complex as Fuzzy rules are generated manually. Thus, a novel approach is presented in this dissertation in which amalgamation of fuzzy inference system and neural network is carried out. The main purpose of designing this approach is to reduce the probability of Spectrum Hands-off (HO) which in turn will reduce the ping pong effect. The proposed approach includes two ANFIS controllers and the implementation is performed in terms of different parameters such as Signal Strength from primary to secondary user (SSps), Signal to noise ratio (SNRpu), power of secondary user (P_{su}), Channel hold time (HT), Velocity of secondary user (V_{su}). Simulation is carried out in MATLAB and the comparative analysis is performed which ensured the effectiveness of the proposed ANFIS model. It is observed that the outcome of proposed model surpassed the efficiency of conventional fuzzy logic controller.

Key words: Cognitive Radio, Ping Pong, Fuzzy, ANFIS, Spectrum Handoff.

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1. INTRODUCTION

The development in wireless correspondence and systems administration has expanded the interest for the accessibility of additional spectrum bands. Research in the domain has envisaged that the issue of spectrum scarcity can be addressed by Cognitive Radio (CR). Cognitive Radio Networks (CRNs) are comprised of multiple technologies and networks which permits the dynamic use of spectrum. Spectrum Handoff (HO), is thus a major necessity of Cognitive Radio Network and if not properly executed, might cause ping-pong effect [1]. When mobile users move between the boundaries of adjacent cells, it leads to needless Spectrum HOs that leads to rise of Ping pong effect. Fuzzy Logic based framework is recommended that is fit for settling on proficient choices about executing Spectrum HOs along these lines, and diminishes the odds of the ping-pong impact. It is commonly believed that there is a spectrum scarcity at frequencies that can be economically used for wireless communications. The strong competition for spectra use at frequencies less than 3 GHz has given rise the concern for seamless HO. Licensed user or Primary user (PU), is a licensed user who has the priority to use the spectrum, Cognitive user or Secondary user (SU), accesses the network opportunistically in the absence of licensed user, it is thus important for the SU to be intelligent enough to sense the availability of spectrum bands. Spectrum sensing involves sensing the surrounding RF frequencies which are not currently in use of PU [2]. The spectrum handoffs, is the process where a SU switches its operating frequency because of the many reasons including channel occupation by the PU, sudden arrival of PU, quality of service degradation, interference to the transmission of PU etc. Cognitive Radio (CR) is a flexible, smart radio and network technology that senses available channels dynamically within a wireless spectrum and adjusts transmission parameters to make it possible for more communication to function simultaneously, as well as enhanced radio operating behaviour. There are no active primary users for these elements, called white space as shown in figure 1, within these parts of the spectrum, secondary users can freely detect and communicate and the method is referred to as an overlay approach which is taken into account in many radio systems [3]. The power level is also very small in the other areas of the continuum. By adding cognitive radio capabilities, spectrum can be used as a basis, provided it is regulated under a predefined threshold level of the transmitting power of the secondary users has no effect on Primary users. To solve non regular distribution of spectrum hands off back channel selection method has been suggested basically spectrum hands off occur when the PUs arrive in the channel, therefore the cognitive user has the leave the channel, the transmission will be interrupted hence the backup channel approach is suggested, it will give the another free channel to resume the cognitive user transmission [4]. Proactive spectrum hands off is mainly used to avoid the interference between the PUs and SUs by detecting the mobility of the PU and initiating the spectrum hands off before the Pus reappear hence it helps achieving the personal gain [5]. For increasing the efficiency of the network probability-based spectrum hands off with centralized method are used, it provides the accuracy for sensing the right channel for hands off also reduces the energy required, hands off and speed up the transmission of the data [6]. Spectrum management is the important task of the CRN, it helps the SUs to get benefit from the spectrum without interference with the Pus by using the pure reactive hands-off method [7].

Figure 1 The free and occupied spectrums [1]

When Spectrum Allocation is performed, most of the time 90% of the Spectrum Remains unused hence in the CRN, Licensed user who has the priority on the spectrum band, in the absence of the licensed user, unlicensed user can sense the availability of the spectrum band for transmission [8]. The sudden arrival of the primary user (licensed) disrupts the Secondary user (unlicensed) transmission, it will cause the degradation of the quality of the service (QoS), hence in order to avoid this problem, spectrum handoff's (SH) are required. The four main functions of the SH are Spectrum Sensing, Channel Selection, Spectrum Sharing and Spectrum Mobility.

2. SYSTEM MODEL

This section discusses about the ping pong effect and two algorithms to overcome this effect in cognitive radio. The algorithms are conventional fuzzy model used two fuzzy controllers to implement the entire process and a novel approach which uses amalgamation of fuzzy inference network and neural network.

2.1. Ping Pong Effect in Cognitive Radio

The Ping-pong effect happens when a mobile station (MS) performs HOs frequently and rapidly between base stations (BS) when the signal strength from the previous BS is sufficient. For the purpose of resource management and due to unpredictable nature of wireless communication, some intelligent technique is required that can facilitate in deciding about carrying out of Spectrum HOs. One such technique is the Fuzzy logic and ANFIS Algorithm. Fuzzy logic helps in modelling problems where traditional mathematical methods cannot be applied effectively or where the information about the problem is not complete. From the figure 2, CR Network is considered which is assumed to be composed of two networks, i.e. UMTS and WLAN, furthermore, SUs are assumed to have the ability to sense the presence of PUs nearby. The system consists of two sets of Fuzzy inference Logic Controllers such as FLC-1 and FLC-2 respectively. The first system i.e. FLC-1 is designed to control the power of SU, so that interference to PU can be controlled and kept to its minimum. The second system i.e. FLC-2 is designed to take decision in order to execute Spectrum HOs. Inputs to FLC-2 are Channel Hold-time (HT), Velocity of SU (V_{SU}) and power of SU (P_{SU}) [9]. The occurrence of Spectrum HOs in an environment. Where conditions and situations of the network are ambiguous and unknown, the range of transmitting power of SU is kept between that of WLAN and UMTS i.e. 30dBm and 43dBm respectively [10]. The method of Defuzzification used is centroid.

2.2. Fuzzy Inference Algorithm

Fuzzy Inference algorithm is developed by using fuzzy if-then rule, and these fuzzy if-then rule are also called the linguistic variables using if X and Then Y, where X and Y represents the Fuzz sets characterized by the Membership variables, mainly these rules are used to identify the non-accurate and unknown variations that exists when the decision has be taken at the output and its flowchart as shown in the figure 3.

Figure 2 Fuzzy Logic Controller [3]

2.3. ANFIS Algorithm

Table 1 Rule base for FLC

Inputs				Output
Rules	HT	PSF	VSF	HO _{prob}
1	Low	Low	Low	Medium
2	Low	Low	Medium	High
3	Low	Low	High	Very High
4	Low	Medium	Low	Medium
5	Low	Medium	Medium	High
6	Low	Medium	High	High
7	Low	High	Low	High
8	Low	High	Medium	High
9	Low	High	High	Very High
10	Medium	Low	Low	Medium
11	Medium	Low	Medium	Medium
12	Medium	Low	High	High
13	Medium	Medium	Low	Low
14	Medium	Medium	Medium	Low
15	Medium	Medium	High	High
16	Medium	High	Low	Very Low
17	Medium	High	Medium	Low
18	Medium	High	High	Medium
19	High	Low	Low	Medium
20	High	Low	Medium	High
21	High	Low	High	Very High
22	High	Medium	Low	Very Low
23	High	Medium	Medium	Low
24	High	Medium	High	Medium
25	High	High	Low	Very Low
26	High	High	Medium	Low
27	High	High	High	Medium

ANFIS algorithm is based on FIS and it is additionally known as Adaptive Neuro-Fuzzy Inference System and it could be a Hybrid system that can merge the Artificial Neural Network & Conventional Fuzzy logic system by upsurging the performance of each ways of AI then reduces the drawback of technique to get an adaptive System that gives the higher result and intelligence compared with both of the Method one by one. Due to Incalculability of the handshaking procedure in the mobile network and improper nature of those factors, ANFIS methodology being employed to check the changes with those paraments over a amount of time then train the network to form the hands-off probability decision based on the changes Identified while training the data [13]. ANFIS is associate adaptive network of ANN and FIS integrating the power of neural network to supervise learning technique and it works on live input and output knowledge to get fuzzy membership rules.

Figure 3 Flowchart of the Fuzzy inference network

From the table 1, the rule base for Fuzzy logic controller, the probability of Spectrum HOs with respect to P_{SU} and V_{SU} . Figure shows that probability of Spectrum HOs remains very low even for high values of P_{SU} . When the value of V_{SU} is maximum, means that probability of Spectrum HOs is high only when the value of P_{SU} is low and that of V_{SU} is high [14]. probability of Spectrum HOs decreases and velocity of SU (V_{SU}) increases, the probability of Spectrum HOs also increases but that increase in HO_{prob} depends on the status of Channel hold-time thus, HO_{prob} is controlled by HT therefore, chances of ping-pong effect at high velocity becomes less.

Hence the conventional Fuzzy logic controller and ANFIS algorithm are used for efficient execution of spectrum handoff in the CRNs, thereby reduces the ping pong effec

3. IMPLEMENTATION AND MECHANISM

The novel technique is designed to compute the handover probability in order that ping pong effect can be reduced. In the previous work, two fuzzy logic controllers are used to determine the HO probability. And the performance was analysed using different parameters for each case. In the proposed work, fuzzy systems are replaced by ANFIS model due to its following advantages:

- ANFIS is the amalgamation of neural network and fuzzy inference system which makes it an intelligent model. The features of neural network enable this model to analyze the data deeply and precisely.
- It eliminates the rule generation for different situation as ANFIS offers the feature of self-optimization.
- It performs operation better than that of fuzzy logic

Moving toward its implementation, the entire process was performed in two phases. Two ANFIS controllers are designed. These phases are delineated below for both previously designed fuzzy logic systems and Proposed ANFIS model.

3.1. Implementation of First Controller

In the first phase, two inputs –SSps and SNRpu are given to the fuzzy system to compute Psu. These parameters are as explained as follows, SSps is the signal strength of primary user (PU) as measured by secondary user (SU). SNRpu is the signal to noise ratio of primary user. This controller is designed to achieve the output Psu. The output is attained in term of power of the secondary user. The GUI designed for phase 1 has two options to compute the output i.e. power of SU. The output is determined for both existing model (Fuzzy) and proposed model (Neuro Fuzzy). Different values are taken into consideration to determine the power of secondary user. Strength from secondary to primary user varies from -92 to 0 and for signal to noise ratio of primary user it has the range from 0 to 28. These values are kept same for both existing and proposed model in order that the performance of the systems will be determined on this basis. The design of ANFIS model is represented in figure 5. Sugeno type fuzzy is used for the ANFIS model. The inputs SSps and SNRpu are given to the ANFIS where 9 rules are generated. These rules are generated by ANFIS according to the different data retrieved by it. Eventually, the output is received in terms of power of secondary user Psu.

Figure 4 Proposed ANFIS model for first phase

3.2. Implementation of Second Phase

The out obtained by the first ANFIS model is taken as the input for second phase. It is further used to compute the handover probability of the Cognitive Radio network. In order to do so, two more parameters are taken along with P_{su} . These are as follows:

HT is the channel hold time. It is referred to the time when the channel is not being utilized by the primary user (PU).

V_{su} Is the velocity of the secondary user and P_{su} is the output of first controller.

These three parameters act as the input to the second controller.

Figure 5 Proposed model for ANFIS used for second controller

The architectural design for proposed ANFIS controller is presented in figure 5. It can be seen that three inputs are given for the Sugeno Fuzzy type-based controller. Neural network enabled the model to generate 27 rules and eventually Hprob is obtained as the final output. The above diagram explains the flow of data in the ANFIS controller. In order to calculate the HO probability for proposed model, the GUI is used where the output is computed just by clicking the button. Figure 6 displayed the snapshot while computing probability of HO. Different iterations are performed to obtain the values in different scenarios. The GUI to compute the HO probability (HOp_{rob}) has the values of the input can be attuned according to the requirement, however, to compute the values for existing system and proposed system, two buttons are given. Firstly, the membership functions are generated to use than as the input to fuzzy based controller. The degree of membership is defined in low, medium and high level. The range of each parameter is recorded in the following table

Table 2 Range of parameters

Sl. No	Parameter	Range
1	HT	0-1
2	P_{su}	0-45
3	V_{su}	0-100 Km/h

Figure 6 GUI to compute output for proposed model

4. RESULTS

The simulated results are discussed for the conventional fuzzy model and an algorithm which uses amalgamation of fuzzy inference system and neural network.

4.1. Results of Conventional Fuzzy Logic Controller

The results obtained by the designed model are explained in detail and comparative analysis is performed in order to validate the efficacious performance of the proposed ANFIS controller to reduce unnecessary HOs and rising of the ping pong effect. The results are presented in the 3D graphical view for easy demonstration.

Figure 7 HO probability in terms of Psu and Vsu using fuzzy model

Figure 7 presents the 3D graph for HO probability in terms of Psu and Vsu. The graph reveals that HO probability is obtained for 11 iterations i.e. 11 different values of Psu and Vsu. The maximum HO probability constituted to 0.46 at 100km/h and minimum HO

probability accounted to 0.27 at 50.3km/h velocity of secondary user. The corresponding values of the parameters are recorded in table 3. The value of HO probability for conventional work varies from 0.27 to 0.46. It is observed as for most of the cases, the probability remains between 0.43 to 0.46.

Figure 8 HO probability in terms of HT and Vsu using fuzzy model

Figure 8 demonstrates the graph showing the HO probability in terms of hold time and velocity of secondary users. The graph shows the probability of HO is high in the beginning and it reduced till 6th iteration. After this, the probability experiences a gradual increase in its value. The retrieved values of Ho probability are presented in the table 3. The HO probability for the conventional fuzzy controller is observed to be better. Further, in the subsequent section, the likelihood of HO for the proposed system is explained.

4.2. Results of the ANFIS Controller

The proposed ANFIS controller reduced the complexity of computing the HO probability in terms of different factors. The analysis of output is presented with respect to the (P_{su}, V_{su}) and (HT, V_{su}). In figure 9, the representation of 3d graph is displayed for power and velocity of the secondary user. The obtained probability suggests that when power and velocity is 0 then the likelihood of the handover occur accounted to 0.4. This number is the maximum probability of HO and the minimum HO probability constituted to 0.17. The output is taken for 11 iterations in which the power and the velocity is always different. The obtained data is recorded in a tabular form shown in table 4.

Table 3 HO probability for conventional fuzzy system in terms of P_{su} and V_{su}, HT and V_{su}

Sl. no.	PSU fuzzy	VSU	Fuzzy ho
1	22.5	0	0.45
2	11.3	10	0.45
3	13	20	0.433
4	16.5	30	0.444
5	18.1	40	0.3
6	20.7	50.3	0.27
7	21	60	0.3
8	22	70	0.45
9	23	80	0.44
10	23	90	0.45
11	22.5	100	0.46

Sl. no.	HT	VSU	Fuzzy HO Probability
1	0	0	0.45
2	0.1	10	0.45
3	0.2	20	0.433
4	0.3	30	0.444
5	0.4	40	0.3
6	0.5	50.3	0.27
7	0.6	60	0.3
8	0.7	70	0.45
9	0.8	80	0.44
10	0.9	90	0.45
11	1	100	0.46

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Figure 9 HO probability in terms of Psu and Vsu using ANFIS model

Table 4 HO probability for proposed ANFIS system in terms of Psu and Vsu, HT and Vsu

Sl. no.	HT	VSU	ANFIS HO
1	0	0	0.4
2	0.1	10	0.4
3	0.2	20	0.34
4	0.3	30	0.23
5	0.4	40	0.17
6	0.5	50.3	0.2
7	0.6	60	0.236
8	0.7	70	0.3
9	0.8	80	0.31
10	0.9	90	0.36
11	1	100	0.4

Sl. no.	PSU Anfis	VSU	ANFIS HO
1	0	0	0.4
2	3.3	10	0.4
3	5.7	20	0.34
4	11.54	30	0.23
5	14.7	40	0.17
6	22	50.3	0.2
7	24	60	0.236
8	29	70	0.3
9	35	80	0.31
10	41	90	0.36
11	45	100	0.4

Figure 10 HO probability in terms of HT and Vsu using ANFIS model

Similarly, for HT and V_{su} , the HO probability is demonstrated in the above graph (figure 10). The values of HO are shown in table 4. The results reveal that the Ho probability experience a downward parabola shape i.e. high in the beginning that gradually decreased when coming to the iteration in the middle and further, increase is experienced till last iteration.

5. COMPARATIVE ANALYSIS OF PROPOSED AND CONVENTIONAL TECHNIQUES

This section presents the comparative analysis of handover probability with respect to velocity (V_{su}), power (P_{su}) of secondary user and channel hold time (HT). For different values of velocity, the graph is plotted for HO probability that is delineated in figure 11. The graph presents the velocity on x axis ranging from 0-100 km/h and probability on Y axis. The outcome of proposed ANFIS model is observed to be less as compared to that of the conventional method. When velocity is 100 km/h the likelihood of HO for proposed work is 0.4 whereas for conventional technique it accounted to 0.46 which is higher.

Figure 11 Comparative analysis of HO probability in terms of V_{su}

The more the probability the more will be ping pong effects. A great difference can be seen in the probability for proposed and existing system which ensured the effectiveness of NFIS model. The values are recorded in the following table (Table 5).

Table 5 Comparison of proposed and existing system HO probability wrt V_{su}

VSU	Fuzzy HO	ANFIS HO
0	0.45	0.4
10	0.45	0.4
20	0.433	0.34
30	0.444	0.23
40	0.3	0.17
50.3	0.27	0.2
60	0.3	0.236
70	0.45	0.3
80	0.44	0.31
90	0.45	0.36
100	0.46	0.4

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Figure 12 Comparative analysis of Ho probability in terms of Psu

Table 6 Comparison of proposed and existing system HO probability wrt Psu

PSU fuzzy	PSU Anfis	Fuzzy HO	ANFIS HO
22.5	0	0.45	0.4
11.3	3.3	0.45	0.4
13	5.7	0.433	0.34
16.5	11.54	0.444	0.23
18.1	14.7	0.3	0.17
20.7	22	0.27	0.2
21	24	0.3	0.236
22	29	0.45	0.3
23	35	0.44	0.31
23	41	0.45	0.36
22.5	45	0.46	0.4

Similarly, the graph is obtained for power of secondary user and it is shown in figure 12. The values achieved for this parameter is different for proposed and conventional technique. The graph shows the Psu on x axis that has a range from 0 to 24. However, Psu is achieved by giving same values of SSps and SNRpu to ANFIS and fuzzy controller. In the graph, the differences between the outputs can be seen. The highest probability of HO is 0.46 for conventional, however it is 0.4 for proposed technique. Low HO probability makes it more effective than that of previously existing technique.

Figure 13 Comparative analysis of HO probability in terms of HT

Further, the last comparison is performed between conventional and proposed technique with respect to the channel hold time. HT is presented on x-axis and has range from 0-1 second and it is shown in figure 13. The HO probability doesn't exceed 0.5 in both the cases. The minimum likelihood of HO accounted to 0.17 for proposed ANFIS model where for fuzzy controller it constituted to 0.27. For every iteration of HT. The probability for the proposed work is less than that of conventional technique. From this comparison, it is observed that the proposed technique is capable of reducing the HO probability in cognitive radio network. The remaining values got hold time are shown in table 7.

Table 7 Comparison of proposed and existing system HO probability wrt V_{su}

HT	Fuzzy HO	ANFIS HO
0	0.45	0.4
0.1	0.45	0.4
0.2	0.433	0.34
0.3	0.444	0.23
0.4	0.3	0.17
0.5	0.27	0.2
0.6	0.3	0.236
0.7	0.45	0.3
0.8	0.44	0.31
0.9	0.45	0.36
1	0.46	0.4

The probability of HO in traditional and composed technique is presented with respect to HT and V_{su} , V_{su} and P_{su} . Eventually the comparative analysis is shown for each parameter and it is observed that the proposed system is capable of reducing the HO probability in terms of velocity, power and channel hold time. The average probability is reduced by 0.1 by and the overall performance in CRN is enhanced with the reduction in unnecessary handover occurrence.

6. CONCLUSION

In CRN the ping pong effect is overcome by novel strategy, the technique implemented is Fuzzy Inference System and Neural networks are amalgamated to utilize their advantages.

The proposed model resulted into two ANFIS controllers which are used to compute the network parameters. The comparative analysis of conventional fuzzy logic controller and proposed ANFIS controller ensured the efficacy of the proposed work and the handover probability experienced overall reduction of 0.1 in the total average probability. Reduced probability indicated the effectiveness of the proposed ANFIS in terms of better handoff and low ping pong effect.

Though the proposed approach is proved to be better in reducing the HO probability but still there is a scope of enhancing this mechanism. Following aspects can be taken into consideration to improve the performance and efficiency of ANFIS model, the complexity of using two ANFIS model can be reduced and reliance on parameters can be increased by introducing the concept of mobility.

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