Fuzzy Logic Based Negotiation Approach for Cognitive Radio Network in LTE-A

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***Abstract*- In this work, we focus on the spectrum mobility (also known as spectrum handoff) which manages the movements of secondary users to occupy the vacant unlicensed spectrum without interrupting the transmission of primary users. In this paper, we introduce fuzzy logic based negotiation approach based for spectrum handoff in CRN. It contains two Fuzzy Logic Controllers (FLC), namely, price negotiation and duration negotiation. The proposed system provides a good solution to avoid the communication interruption caused by the mobility of SU. It will reduce the handoff delay by 46 ~ 62% if the SU correctly selects the best PU.**

***Index Term*-- Spectrum handoff; fuzzy logic; cognitive radio**

I. INTRODUCTION

Currently, cognitive radio (CR) becomes one of the most research areas that offer solution for lack of spectrum in wireless communication due to increased demand of extra spectrum bands. Thus, IEEE 802.22 WRAN (Wireless Regional Area Networks) standard is standardized to allow the unlicensed users to utilize licensed spectrum bands while avoiding the interference with licensed users [1]. Meanwhile, there is a large portion of available spectrum which is not fully utilized by the licensed users such as some portions of TV VHF/ UHF bands, so called TV white spaces. CRNs have the capability of utilizing the vacant spectrum in fixed licensed bands. The basic concept of CR network is that the unlicensed users (also known as secondary users) occupy some portions of licensed spectrum band without interrupting the transmission of other licensed users (also called as primary users). The secondary users (SUs) need to be flexible in order to move from one spectrum to another if the licensed band occupied by the primary users (PU) so as to avoid the interference [2]. The process of moving SUs from one spectrum to another is called spectrum handoff or spectrum mobility. The dynamic use of the spectrum requires many functions such as spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility in CR network. However, spectrum mobility in CRN still has many research issues that should be focused in future.

Owing to the need of decision making techniques in order to select and utilize licensed bands, there are several of intelligent techniques for example fuzzy logic which are used in CR. The fuzzy logic is a useful technique which used to solve some problems that considered difficult to be solved using the traditional mathematical methods. Moreover, it is suitable for a multidimensional decision making problems due to the increase in dimensions of the operational environment [3]. The fuzzy logic system converts rule based on decision making to the mathematical equivalent which makes it suitable for dynamic and distributed environments [4].

We propose negotiation approach based spectrum handoff using fuzzy logic. The proposed algorithm provides a good solution to avoid the communication interruption caused by the mobility of SU. Besides, the SU able to switch from one channel to another smoothly based on the negotiation with PU. The rest of this paper is organized as follows. In Section 2, we provide the related works that have been done in spectrum mobility in the past years. Section 3 describes the method and implementation of negotiation method using fuzzy logic. Section 4, we describe the obtained simulation results from fuzzy system. Finally, Section 5 concludes the paper and provides recommendations for future work.

II. RELATED WORK

In spectrum mobility, it plays a critical role in improving the efficiency of spectrum utilization in cognitive radio network. Moreover, the throughput of cognitive radio networks depends on the scheme of channel selection. Fuzzy-based system was proposed by [3] to estimate the gain of available channels in order to select the most high channel gain. However, the decision of channel handoff depends on the Signal-to-Interference-plus-Noise Ratio (SINR) and interference caused by PU. The selection of high gain channel will not fully utilized the spectrum because there will be many vacant channels with medium and low gain.

Maheshwari, P.; Singh, A.K [4] introduced a fuzzy logic based spectrum handoff and assignment approach to enhance the utilization of vacant channels. Besides, avoiding the frequent channel switching that caused degrading of the throughput of CRN. The selection of channel quality depends on the signal strength level and bit error rate. Instead of selecting only high gain channel as discussed in [3], two gains of channels (high and medium) were selected to make a handoff discussion.

Thus, the spectrum utilization is slightly utilized although selecting the high and medium channel gain. Nevertheless, the consideration of channel quality leads to low spectrum utilization and also, the true states (occupancy by PUs) of each channel are never known to the SUs. Moreover, there are some errors in detecting the using of PU such as miss detect and false alarm.

Spectrum handoff scheme based on Hidden Markov Model (HMM) was presented by [5] to analyse and predict the channel status. Random channel selection applied in proactive spectrum handoff scheme to test the effective proposed model. However, it deduces the efficient of HMM in correcting the sensing sequence in CRN. A multi agent negotiation for spectrum sharing and handoff management was introduced by [6-7]. The negotiation mechanism is based on a pricing system for channel selection. However, the negotiation mechanism introduced in [6] was performed only with PU (with same frequency) while it is established in [7], even with the other preselected PUs. The number of spectrum handoffs was reduced by considering the frequency during the channel selection.

The analytical framework was introduced by [8] to evaluate the effects of reactive spectrum handoff scheme on channel utilization and latency performances in CRN. This work proposed a Preemptive Resume Priority (PRP) M/G/1 queuing network model to characterize the channel usage behaviors of CR networks. It evaluates channel utilization under various traffic arrival rates and service time distributions. Furthermore, it investigates the transmission latency of the secondary users due to multiple handoffs.

III. FUZZY LOGIC SYSTEM

The fuzzy logic is a sophisticated control system which can be efficiently expressed the real world problems. Unlike the traditional mathematical models which are not sufficient to express the complex real world problems. Fuzzy Logic Controllers (FLC) consists of three main components: fuzzification, knowledge base inference and defuzzification as shown in Figure 1.

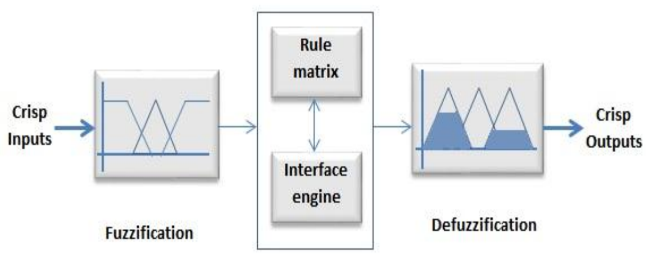

Fig. 1. Fuzzy logic controller

Fuzzification converts the crisp inputs variables into fuzzy values. Each crisp input labels by a linguistic term such as "low" ," medium" , " high", etc. Then, the fuzzy values used by the inference engine to trigger the rules stored in the fuzzy rule base to implement decision making processes. The set linguistic control rules are considered the main part of FLC which is based on a collection of logic rules in the form of IF-THEN statements. For example, IF (a set of antecedents), and THEN (a set of consequences). Finally defuzzification converts the fuzzy sets into crisp values.

Figure 2 shows the whole proposed negotiation approach based on the fuzzy logic system which consists of two FLCs. Flc1 has two linguistic variables inputs and one output linguistic variable while FLC2 has three linguistic variables inputs and two output linguistic variables.

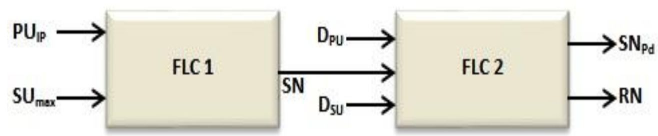

Fig. 2. Proposed negotiation approach based on the fuzzy logic system

FLC1 has been designed to estimate the probability of successful negotiation between PU and SU as shown in Figure 3. it consists of two linguistic variables inputs which are initial price of PU (PU_{ip}) and maximum price of SU(SU_{max}) while there is one output linguistic variable called successful price (SN). The linguistic terms of inputs and output are defined as:

$T(PU_{ip})$ = T(SUm)= T(SP)= { "low", "medium", "high"}

The fuzzy rules have totally 9 rules as given in Table 1. These rules are used to obtain the percentage of the successful price negotiation in FLC1.

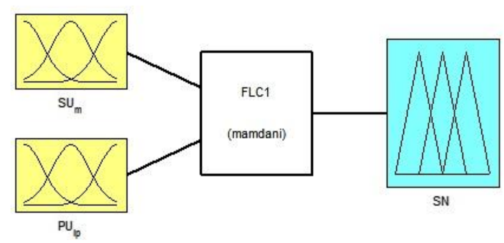

Fig. 3. Fuzzy logic controller of Price negotiation

Table I
Rule base for FLC1

No	SU_{max}	PU_{ip}	SP
1	L	L	Y
2	L	M	Y
3	L	H	Y
4	M	L	N
5	M	M	PY
6	M	H	Y
7	H	L	N
8	H	M	N
9	H	H	PY

The second FLC2 has been designed to estimate the probability of successful negotiation for pricing and duration between PU and SU. It consists of three linguistic variables inputs which are: initial duration of PU (D_i), required duration of SU(D_r) and successful price negotiation of FLC1 output (SN_P) while there are two outputs linguistic variable called successful (price and duration) negotiation (SN_{PD}) and repeat negotiation (RN). The linguistic terms of inputs and output are defined as:

T(SN)= T(D_{PU})= T(D_{SU}) = { "low", "medium", "high"}

Outputs:

T(SN_{Pd}) = T(RN_{Pd})= { "no", "pn", "py","yes"}

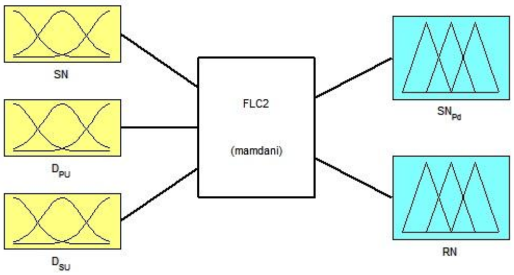

Fig. 4. Fuzzy logic controller of duration negotiation

The fuzzy rules of FLC2 have totally 27 rules which are given in Table 2. These rules are used to obtain the percentage of the successful negotiation of sharing spectrum band and failed negotiation. In case of failed negotiation, the SU searches for another PU and tries again the negotiation.

Table II
Rule base for FLC2

No	SN	D_{PU}	D_{SU}	SN_{Pd}	RN_{Pd}
1	L	L	L	N	Y
2	L	L	M	N	Y
3	L	L	H	N	N
4	L	M	L	N	Y
5	L	M	M	N	Y
6	L	M	H	N	Y
7	L	H	L	N	Y
8	L	H	M	N	Y
9	L	H	H	N	Y
10	M	L	L	PY	PN
11	M	L	M	N	Y
12	M	L	H	N	Y
13	M	M	L	Y	N
14	M	M	M	PY	PN
15	M	M	H	N	Y
16	M	H	L	Y	N
17	M	H	M	Y	N
18	M	H	H	PY	PN
19	H	L	L	PY	PN
20	H	L	M	N	Y
21	H	L	H	N	Y
22	H	M	L	Y	N
23	H	M	M	PY	PY
24	H	M	H	N	Y
25	H	H	L	Y	N
26	H	H	M	Y	N
27	H	H	H	PY	PN

The SU selects the licenced channel offered by PU according to its requirements. In other words, it tries to find an acceptable price with sufficient duration offered by PU to continue or begin the transmission.

The process of SU to find a suitable vacant channel is divided into two phases: pricing phase and duration phase. In the pricing phase, the SU searches the lowest initial price offered by the PU where the offered price should be less than or equal to the maximal price proposed by SU.

$$P(SU_{\max}) \leq P(PU_i) \quad (1)$$

If the SU dose not accepts the initial price due to high price offered by PU, the SU proposes a new negotiation price to PU in the second phase according to the following equation:

$$P(SU_{\text{new}}) = PPS_{max}(SU) * TTI_i \quad (2)$$

where $PPS_{max}(SU)$ and TTI_i are the maximum price per second proposed by SU and initial transmission time interval, respectively.

IV. PERFORMANCE EVALUATION

The Fuzzy logic based negotiation approach is proposed. Input parameters are determined as; SU and PU price, duration of SU and PU. The proposed system is simulated using MATLAB FIS software editor. To evaluate the response of fuzzy logic system in CRs, we randomly generated normalize sequence value of all descriptors in proposed fuzzy system with a random value in the interval [0 1]. We used a linguistic knowledge of 9 and 27 rules for FIL1 and FLC2, respectively.

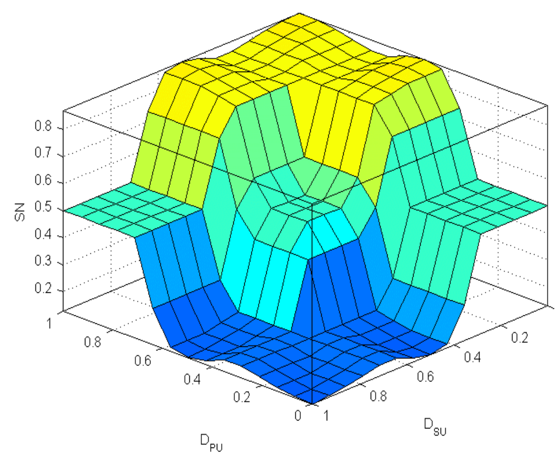

Fig. 5. Percentage of the successful negotiation

Figure 5 shows the percentage of the successful negotiation for sharing spectrum band. The successful negotiation rate represents the average percentage of successful negotiations between SUs and PUs. Recall that a successful negotiation is achieved when the selected PU accepts the US proposed price or use duration. The high percentage obtained when the PU offers price or duration less than the maximum of SU price.

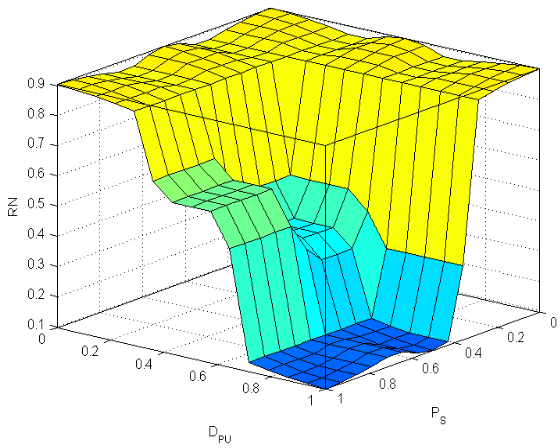

Fig. 6. Percentage of return negotiation

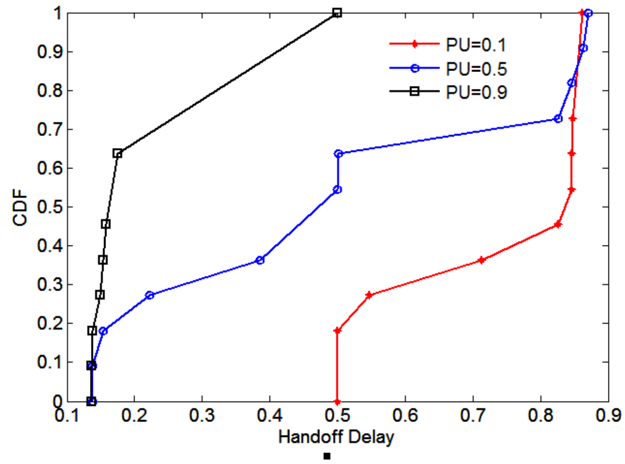

Fig. 8. Handoff delay of different rate of PU

Figure 6 shows the probability of return negotiation between PU and SU. It can be seen that the percentage rate of return negotiation is high when the PU does not accept the proposed SU duration. Thus, the repeating of negotiation leads to high handoff delay of SU.

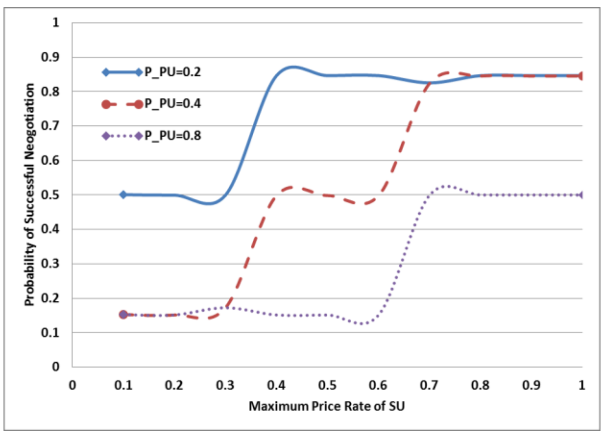

Fig. 7. Probability of successful negotiation with three different price rate of PU

Figure 7 shows the probability of successful negotiation with three different price rates of PU (PU= 0.2, 0.4 and 0.8). It can be generally seen that when the maximum price rate of SU increases and PU rate is close or greater than SU rate, the probability of successful negotiation increases gradually. However, if PU rate less than SU rate as shown Figure 7, when PU=0.4 and PU=0.8 along with US rate (0.1 to 0.3) and (0.1 to .0.5), respectively, the probability of successful negotiation has very low rate in order to share the spectrum band. Hence, SU tries to search or sense another PU to start gain the negotiation process which causes long handoff delay.

Figure 8 shows the rate of SU handoff delay due to unsuccessful negotiation and sharing PU band. It can be shown that the PU duration has a great effect on SU handoff delay. In other words, when PU offers long duration with the low price which causes SU to accept the offer and start sharing the PU bands. Thus, the handoff delay will be short as long as the SU correctly selects PU with long duration.

V. CONCLUSION

The fuzzy logic system has a great potential and represent a vast field for research. In this paper, we proposed negotiation approach based on spectrum handoff using fuzzy logic system. We considered two main input parameters (price and duration) for sharing band negotiation. The handoff delay can be minimized by reducing the return negotiation process in which SU selects a long duration offered by PU. Furthermore, when SU correctly selects the best offer by PU it will reduce the handoff delay by 46 ~ 62%. Besides, the proposed system provides a good solution to avoid the communication interruption caused by the mobility of SU. In the future work, the proposed fuzzy logic can be integrated with other optimized algorithm to enhance the PU selection as well as reducing the handoff delay to minimal value.

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