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Cluster Based Spectrum Sensing Technique for Cognitive Radio Networks Using Fuzzy Logic Controller

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Abstract— As many kind of spectrum sensing techniques have been introduced for various wireless technologies. These spectrum sensing models have been improved the spectrum usage and have also opened up new opportunities for the different wireless applications to utilize the radio spectrum more effectively. To exploit these opportunities, the wireless transceivers need to be more intelligent to access the radio spectrum. Such an intelligent wireless transceiver is referred as a "cognitive radio". In this paper, we proposed efficient cluster based spectrum sensing technique using fuzzy logic controller for cognitive radios network (CRN).

Keywords— energy detection, cluster, spectrum sensing, cognitive radio, fuzzy logic

I. Introduction

Cognitive radio(CR), as one of the emerging communication technologies in recent years, is proposed[1] to solve the spectrum scarcity. CR users access the licensed spectrum dynamically and guaranteed to the primary signals not to be interfered. Consequently, CR users can be aware of the existence of primary users. The detection of primary user presence is most important and challengeable task in CRN. Primary User(PU) is a Licensed User, has a license to operate in a certain spectrum band, Secondary User(SU) is a Unlicensed User, has no spectrum license. Hence, SUs are required additional functionalities to share the licensed spectrum band. The main functions are are (i) Spectrum Sensing (ii) Spectrum Management (iii) Spectrum Mobility (iv) Spectrum Sharing. In this paper, cluster based spectrum sensing technique using fuzzy logic control is proposed also compared with the existing (Leach-C) system. The rest of the paper is organised as follows, section II describe about the system model, section III discuss about the fuzzy logic system and Section IV discuss about the results and finally we conclude the proposed system.

II. System Model

In our system model, we consider a cognitive radio network with N cognitive radio users (CRs) that act as local sensing devices are assumed to be organized into clusters, where each cluster has a cluster head that makes a cluster decision based on the local decisions received from its cluster members and report the result to the cognitive base station that acts as a fusion centre FC. We assume that the primary user signal at CRs is not initially known, therefore, we adopt an energy detector to conduct the local sensing, which is suitable for any signal type. In this energy detection algorithm, only the transmitted power of the primary system is known. Therefore, this power will be detected firstly, and then compared with a predefined threshold to determine whether the spectrum band is available or not [1]. When the energy of the received signal is greater than the desired threshold γ the detector will indicate that the primary user is present, which will depicted by exist hypothesis H_1, otherwise, the primary user is absent, which will be represented by null hypothesis H_0.

First, all CRs are grouped into clusters, which proposed for wireless sensor network [3]. This protocol provides an efficient clustering configuration algorithm, in which the cluster heads CHs are selected by the fuzzy logic system. by using this method, data transmission energy between a CH and other members in a cluster is minimized, due to this the life time of the SUs will be increased.

In our scheme following assumptions are made: [5]:

(i) A CR network is stable and consists of one fusion centre FC, one primary transmitter and N no of cognitive radio users .
(ii) The FC has the location information of all CRs, possibly determined using Global Positioning System (GPS).
(iii) The instantaneous channel state information of the reporting channel is available at the CRs.
(iv) The channel between any two CRs in the same cluster is perfect since they are close to each other.

Cluster formation

The cluster formation process is made up of many rounds, each round consists of two phases: setup phase when the CHs and cluster formation are made, followed by a steady state phase when cluster members begin send their data to CH and on to the FC, as shown in Figure 1.

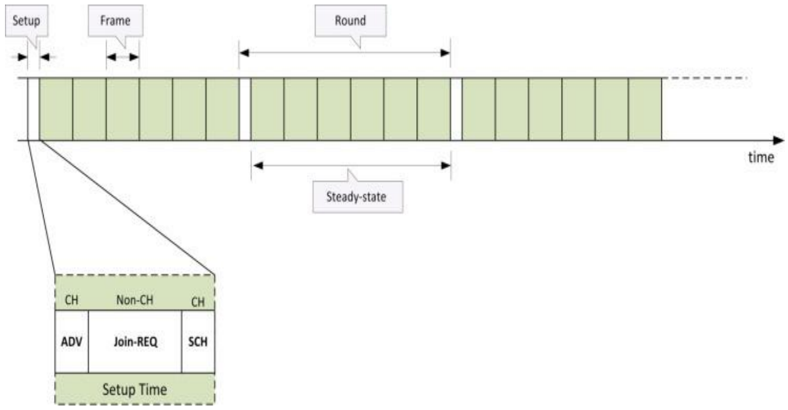

Fig 1. Cluster formation.

A. Setup Phase

During the setup phase of our clustering protocol, each CR user sends information about its current location, current energy level and SNR of reporting channel to the FC. Based on energy level and channel uncertainty, using the fuzzy logic , the FC will be desired the which cluster to be CH for the current round while the remaining CR users will act as cluster members. The FC determines the optimal number of clusters based on minimizing the energy consumed by cluster members to transmit their results to the CH, by minimizing the total sum of squared distances between the cluster members and the closest CH [3].

1. Cluster Head Formation

   After the CHs are assigned , the FC broadcasts a message that contains not only the cluster head ID for each CR user but also the information of tie synchronization. If a CR user's cluster head ID matches its own ID, the CR user is a CH; otherwise, the user is a cluster head ID matches its own ID, the CR user is a CH , otherwise the user is a cluster member and goes to sleep based on its time division multiple access (TDMA) slot time which determined by the selected CH

2. Cluster formation

   The cluster formation is done by CHs, where each CH broadcasts an advertisement message(ADV) using a carrier sense multiple access (CSMA) MAC protocol, which instructs the CR users to select their CHs. After receiving the messages from all CHs, each CR user sorts the received power signal of each message and selects the largest one as its selected CH. Then, each CR user should inform the CH that it will be a member of the cluster by sending back a join-request message to the selected CH using CSMA MAC technique. This join message contains the cluster head's ID and the CR user's ID. Each CH compares its ID with received one, and if the cluster head's ID matches its own ID, the CH will accept the join request; otherwise, the request is rejected.

After completing the cluster formation, each CH knows which CRs are in its cluster and creates a TDMA schedule assigning each member a time slot to transmit its sensing result, and then informs all members in its cluster a CSMA code which is used for communication among them. After the TDMA schedule is known by all members in the cluster, the set-up phase is complete and the data transmission can start.

B. Steady State Phase

In this phase, the CRs start to transmit its results to the CH during their allocated time slots. As shown in Figure 1, this phase is divided into frames which depend on the number of clusters. The time to send a frame of data is constant and depends on the number of cluster members. During each frame, all the cluster members send their results to the CH in respect to the TDMA schedule, and then the CH collects the local decisions and makes the cluster decision about the presence of the primary signal and sends it to the FC in accordance to its time slot. Afterword, the FC combines the received clustering decision to make the final decision then broadcasts it back to all CHs, which in turn send it to its cluster members.

The energy expended during transmission (E_{TX}) and reception (E_{RX}) for a k bit message to a distance d between transmitter and receiver CR user is given by (1) and (2)

$$E_{TX}(k,d) = E_{elec} * k + E_{amp} * d^{\alpha} \quad (1)$$

$$E_{RX}(k) = E_{elec} * k \quad (2)$$

Where α is a path loss exponent

III. FUZZY LOGIC CONTROLLER

Fuzzy Logic is convenient way to map input space to output space[2][4]. It is a multi valued logic that allows intermediate values to be defined between conventional evaluations like true/false, yes/no, high/low etc. The fuzzy logic controller block diagram is shown in figure 2.

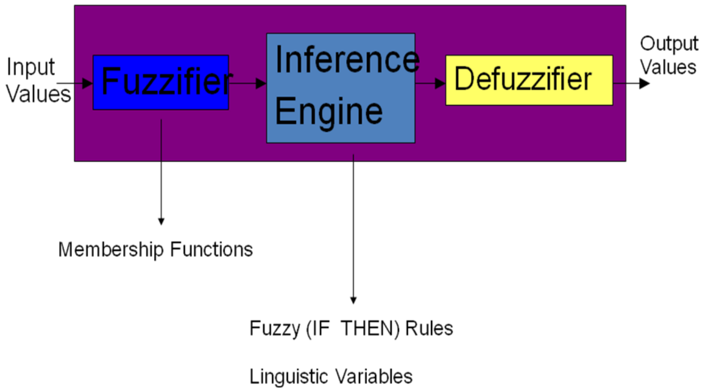

Fig 2: Block diagram of Fuzzy logic controller

The functions of Fuzzy logic controller are,

- Fuzzifier (Fuzzification) **-** the process of translating input measurements into their fuzzy representation.
- Inference Engine –rule based control and decision making
- Defuzzifier (Defuzzification) **-**the process of determining the actual output value

In this fuzzy system, We have used the Mamdani technique to calculate the implication value, and the Centroid defuzzification method used to find the CH election chance value to form a cluster formation, inputs are energy level of the SUs and distance to the base station, the output will be probability of the cluster become CH for the current round. In this paper, we used radio model same as given [3]. Table 1 represents the values are used for simulation and table 2 presents rule base for the fuzzy combining. There are total 9 rules. e.g. case(i) if energy level is low and uncertainty is low then chance for getting CH for that SU is low for that current round.

Table1: Parameter values used for simulation

Parameter	**Values**
Network size	$(100X100)m^2$
Number of SUs	100
Initial Energy	0.5pJ
Maxi. Energy	1.5pJ
E_{TX} aJ/and R_{TX}	50nJ/bit
Data Packet Size	4000 bits
Probability of CH	0.1
Data Aggregation energy	5nJ/bit/message
Path loss exponent(α)	2
Free space model	$10pJ/bit/m^2$
Multipath propagation model	$0.0013pJ/bit/m^4$
No of rounds	1300

Table 2: Rules used for fuzzy system

Energy level	Dist to BS	Output level
Low	Low	Low
Medium	Low	Medium
High	Low	High
Low	Medium	Medium
Medium	Medium	Medium
High	Medium	High
Low	High	High
Medium	High	High
High	High	High

IV. Simulation Results

We have modelled the system using Fuzzy logic toolbox in Matlab7.9.The descriptive linguistic input variables are energy level and uncertainty and output is the probability of SU become CH, linguistic values are low, medium and high. Figure 3 shows the random distribution of SUs in the area of 100 X 100 m. In this, the non-CHs are represented by circle and CHs are represented by +, the FC located in the centre of the network coverage area.

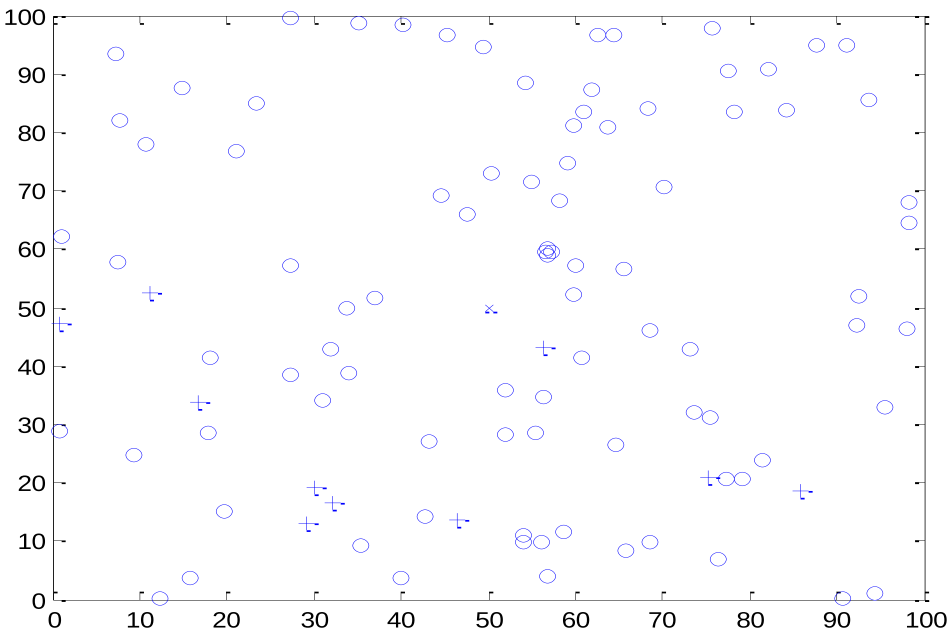

Fig.3 Random distribution of SUs.

In figure 4 shows that, in this proposed system, only few SUs are become dead due to very poor energy level after maximum no of rounds, that SUs are denoted by dot(red colour).

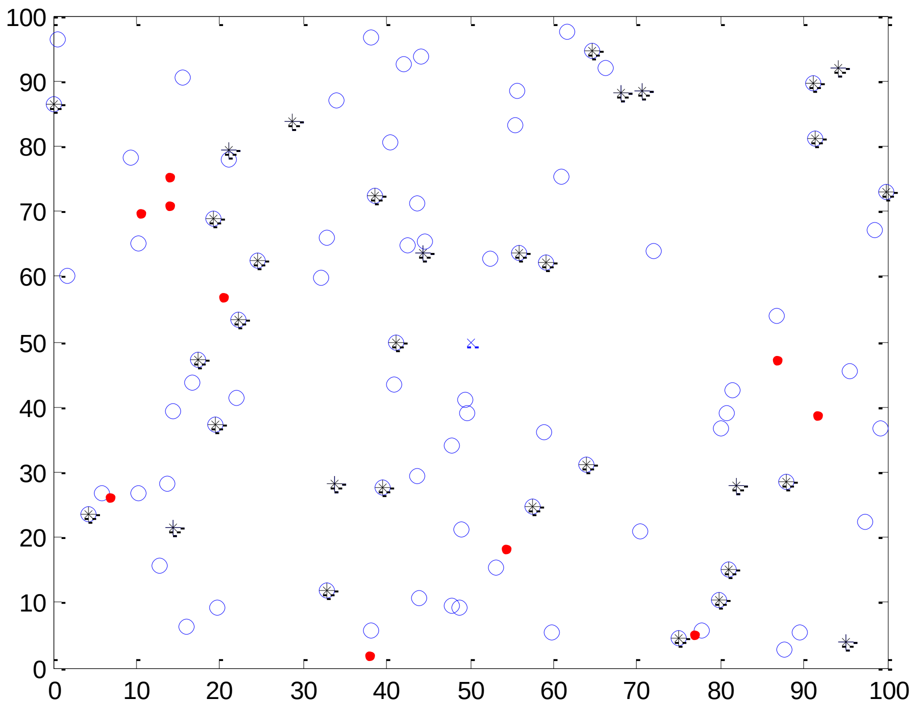

Fig.4 Active (Blue circle) and Inactive SUs(dot) for proposed system

Figure 5 shows that, in the existing system, the most of the SUs are become dead due to very poor level of energy. Compared to our proposed system, the existing system network life time become less and it is proved by our simulation results.

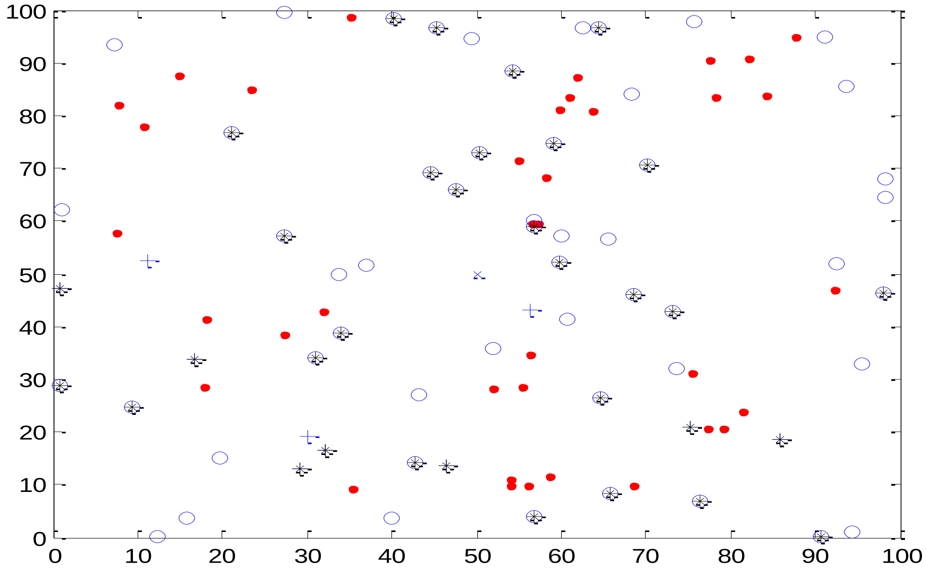

Fig. 5 Active(Circle) and Inactive(dot) SUs for existing system

we can see from Figure 6 the energy of the SUs in existing system quite variable with some SUs having a high energy level and some nodes being dead. In the proposed system, SUs energies do not have these extremes. From this graph, the network life time is increased compared to existing system.

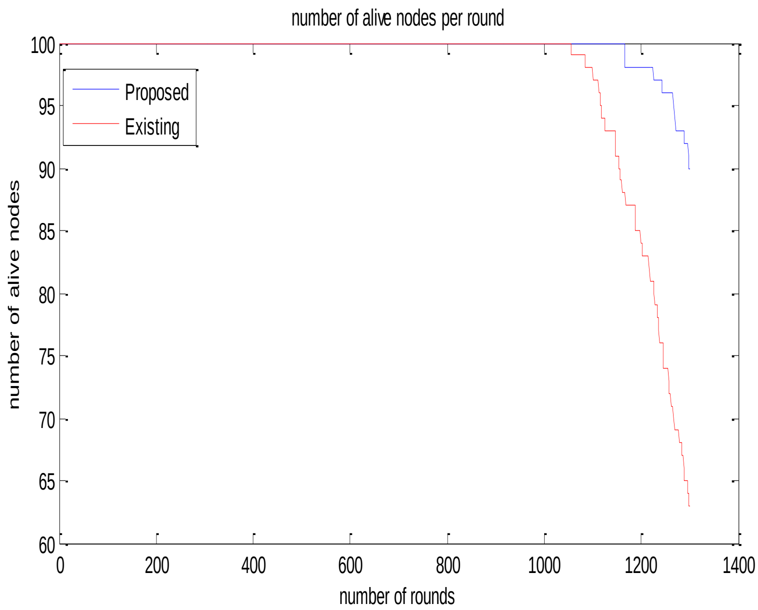

Fig. 6 No of alive SUs per round

V. Conclusion

Fuzzy Logic provides a different way to approach a control or classification problem. Fuzzy approach requires a sufficient expert knowledge for the formulation of the rule base, the combination of the sets and the defuzzification. The employment of fuzzy logic might be helpful, for very complex processes, when there is no mathematical model for highly non-linear processes or if the processing of expert knowledge is to be performed. The simulation results show that only 10 SUs become dead in the proposed system and 40 SUs (approx) are dead in the existing system, from that we concluded our protocol improved the network overall lifetime significantly

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