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Optimization of cooperative spectrum sensing using Fuzzy logic

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ABSTRACT

One of the great challenges of implementing spectrum sensing is the hidden terminal problem, which occurs when the cognitive radio is shadowed .In this paper, a optimal selection of the secondary nodes has been intimated using fuzzy logic rule base. The selection of the secondary nodes plays a vital role in the enhancement of the throughput of the cognitive sensing spectrum. If the secondary node is not optimal the total error rate may increase and packet transfer would lead to some additional delay in the system which would further lead to damage in the data packet. In this work, Cognitive radios (CRs) utilize an improved energy detector for taking a decision. Probability of missed alarm P_m and probability of false alarm P_f In other recent works [10], [11], optimal sensing throughput tradeoff was studied. Using fuzzy logic total packet loss will reduced in cooperative spectrum sensing.

Keywords:-Cognitive Radio, Fuzzy logic, Fuzzy Rules, SNR, Cooperative Spectrum Sensing, Optimization, error rate

1.INTRODUCTION

Cognitive radio (CR) can be defined as a practice in the domain of unwired interaction in which a radio judiciously detects the usage of communication conduits, and thereby allocates empty station to the signal without interrupting unavailable ones. Energy costs are constantly increasing and energy expenditure of a wireless network is a significant fraction (20 to 30 per cent [1]) of total operator expenditures (site rental, licensing etc.). Hence, energy should be consumed effectively for cost-effective systems. Wireless technologies have grown rapidly from the last decade and more and more spectrum possessions are needed to bear indefinite number of emerging wireless services. All of the frequency bands are entirely allocated to specific services within the current spectrum regulatory framework and no encroachment from unlicensed users is allowed. Spectrum scarcity is the issue that troubles the wireless system designers and telecommunications policy makers. In the Federal Communications Commission (FCC) survey, the actual licensed band is mostly under-utilized in vast temporal and geographic dimensions [11] is stated. Cognitive radio (CR) technology has been recently put forward to solve the variance between spectrum scarcity and spectrum under-utilization. A cognitive radio is an intelligent device that aware of the radio frequency environment. Spectrum sensing is the vital component in cognitive radio technology. By sensing and transforming to the environment, a cognitive radio can fill in spectrum holes and provide to the desired users without cause deleterious interference to the licensed user. Executing spectrum sensing is the hidden terminal problem, which occurs when the cognitive radio is path in severe multipath fading or inside buildings with high saturation loss, while a primary user (PU) is operating in the environs [3] is one of the greatest challenges. Due to the hidden incurable problem, a cognitive radio may fall short to notice the existence of the PU and then will contact the licensed channel and source intrusion to the licensed system. In array to compact with the hidden terminal problem in cognitive radio networks, numerous cognitive user can help to carry out spectrum sensing. Spectrum sensing performance can be greatly enhanced with an increase of the number of cooperative followers [12]–[16]. Reducing energy consumption and energy-efficient operation are thereby at the interest of the operators. Characterized by large-scale and overlaid deployments, the emerging Cognitive Radio Sensor Networks (CRSN) [2] has attracted global attention recently. On the one hand, CRSN is required to aggregate application-specific data with limited energy. On the other hand, CRSN nodes should restrict the interference to Primary User (PU) systems with their intrinsic spectrum sensing capability. As a smart combination of Cognitive Radio Networks (CRNs) and WSNs, CRSN has yielded many open research issues which are distinct from existing ones. On the positive side, however, the CR technique could also reduce the energy consumed for communication by finding spectrum that is less congested. This would enable communication with less contention for the medium, another major factor of energy consumption in wireless devices. Higher contention for the medium typically results in more packet collisions, more time spent backing off when using CSMA protocols, and more overheard packets from other nodes. Thus, the CR technique's positive impact on energy consumption needs to be studied and quantified as well to understand how energy-constrained devices would fare in terms of operating life time cognitive radio Networks (CRNs) aCognitive radio is the emerging technology in the field of wireless communication. Cognitive radio is the model/system which can change its parameters in accordance to available environment. CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. This goal can be realized only through dynamic and efficient spectrum management techniques [8]. Fig. 1 show a cognitive radio network carrying two types of bands one is licensed and another is unlicensed . licensed band carry primary users and unlicensed band carry secondary users that send their data when primary user is not present. The main features of CR are listed are Spectrum Sensing, Spectrum Management ,Spectrum Mobility ,Spectrum Sharing . in this paper we will basically work on spectrum sensing.

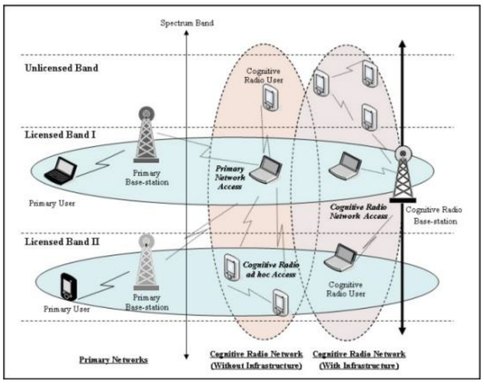

Fig.1. Cognitive radio network architecture

The paper is organized as follows: the related work is discussed in section II, section III describes the problem formulation and system model, then the section IV provides insights into the proposed solution, in section V the proposed protocol is analyzed and in section VI the paper is concluded.

2.RELATED WORK

In this section, the prior research on various spectrum sensing schemes for CRs is reviewed. Spectrum sensing is a key function of cognitive radio to prevent the harmful interference with licensed users and identify the available spectrum for improving the spectrum's utilization. IanF.Akyildiz [1] stated that detection performance in practice is often compromised with multipath fading, shadowing and receiver uncertainty issues. To mitigate the impact of these issues, cooperative spectrum sensing has been shown to be an effective results. While cooperative gain such as improved detection performance and relaxed sensitivity requirement can be obtained, cooperative sensing can incur cooperation overhead. The overhead refers to any extra sensing time, delay, energy, and operations devoted to cooperative sensing and any performance degradation caused by cooperative sensing. Jun Ma [2] has been discussed "the state of-the- art survey of cooperative sensing is provided to address the issues of cooperation method, cooperative gain, and cooperation overhead. Robert W. Brooders Berkeley [3] proposed a technique to consider cooperative spectrum sensing based on energy detection in cognitive radio networks. In their work , they observed soft combinations of energies coming from CR users. Based on the Nyman-Pearson criterion, they obtained an optimal soft combination scheme that maximizes the detection probability for a given false alarm probability .In addition, he proposed a way to further improve the sensing reliability, the advantage of a MAC protocol that exploits cooperation among many cognitive users was investigated. Dong-Chan Oh [4] investigated a technique to optimize of threshold level with energy detection to improve the spectrum sensing performance. Determining threshold level to minimize spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum, resulting in improving total spectrum efficiency. VahidJamali [5] proposed a technique in which a secondary user report about the presence of primary user in cooperative environment .Most of the previous work assumed a control Channel for the reporting transmission; however, he assume that the secondary network utilizes the same primary band to send their observations (data fusion) toward the fusion centre while by controlling the transmit power the secondary users, it is assured that the outage probability of the primary transmission remains below a predefined threshold.Ajay Singh[6] proposed the scheme that by using multiple antennas at the CRs, it is possible to significantly improve reliability of spectrum sensing with extremely low interference levels to the PU at very low (much less than 0 dB) signal-to-noise ratio of the PU-CR link. Jiming Chen [7] employ Greedy Degradation to degrade it into a linear integer programming problem, and propose three approaches namely Implicit Enumeration (IE), General Greedy (GG) and λ-Greedy (λG) to solve the sub problem for spectrum sensing .Xin Liu [8]proposed a results to show that compared with the previous algorithms, the optimal sensing period can improve the spectrum utilization of the CRU and decrease the interference to the PU significantly, the optimal sensing time can make the CRU achieve the largest throughput, and the optimal searching time can make the CRU find an idle channel with the least time .

3.SYSTEM MODEL AND PROBLEM FORMULATION

The system is assumed to be a medium to large scale cognitive radio network. We consider a CR network composed of k CRs (secondary users) and a common receiver, as shown in Fig.2 We assume that each CR performs spectrum sensing independently and then the local decisions are sent to the common receiver which can fuse all available decision information to infer the absence or presence of the PU. The essence of spectrum sensing is a binary hypothesis-testing problem:[15]

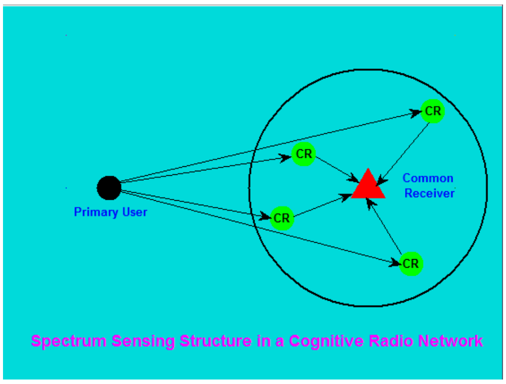

Fig.2. Cooperetive Spectrum Sensing in Cognitive radio Network[15]

Ho: primary user is absent

H1 : primary user

In the following we only consider the spectrum sensing at CR_i The sensing method is to decide between the following two hypotheses:

$$Xi\ (t) = wi\ (t), \qquad Ho,$$

$$Xi\ (t) = hi\ (t)\ s\ (t) + wi\ (t), \qquad H1,$$

Where xi (t) is the received signal at the ith CR in time slot t, s(t) is the PU signal, wi(t) is the additive white Gaussian noise (AWGN), and hi (t) denotes the complex channel gain of the sensing channel between the PU and the ith CR. In this section, problem is defined that how to overcome the problem of interference that occurs in the network due to hidden terminals. In order to deal with the problem of hidden terminals a cooperative spectrum sensing is employed. The problem formulation therefore involves firstly the creation of Cooperative Spectrum Sensing structure so that the problem of hidden terminal (shadowing) decreases. Next the way of locating Secondary User on the basis of angle of incidence is being described. Then comes the problem that in case spectrum sensing, it is desired to minimize spectrum sensing error (i.e., sum of false alarm and miss detection probabilities) since minimizing spectrum sensing error both reduces collision probability with primary user and enhances usage level of vacant spectrum probability of false alarm detection and missed alarm detection So some technique is to be employed to detect the interference and to reduce total error rate. In the proposed technique main focus in on the minimum packet loss, that has not been focused earlier. . In past years many techniques has came but none of this focused to minimize the packet loss along with optimization.

4.PROPOSED SOLUTION

In this section, the details of Fuzzy logic are described. The proposed solution provides better selection of secondary users and reduces the total error rate (false and missed detections)message in the cognitive radio network having k number of CRs. It also helps in resolve the problem of interference which is caused due to hidden terminals by using cooperative spectrum sensing as discussed in previous step. In our work we use a cognitive radio network is which uses cooperative spectrum sensing to know the presence and absence of primary user in network. In cognitive radio networks the secondary users send data or utilize the unused spectrum when primary user is not present but while selecting sometime it cause interference to primary users . cooperative spectrum sensing is a technique in which all the cognitive users made their independent decisions and then send it to a common receiver. Presence or absence of primary user in network is concluded by common receiver fusing all the received decisions from independent CRs. These properties can be employed with the idea of forming a optimized spectrum sensing technique to detect the presence or absence of primary user. The idea of Opportunistic spectrum access approach is enabled by cognitive radios which are able to sense the unused spectrum and adapt their operating characteristics to the real-time environment. However, a naive spectrum access for secondary users can make spectrum utilization inefficient and increase interference to adjacent users. In this work, we propose a novel approach using Fuzzy Logic System (FLS) to control the spectrum access. The linguistic knowledge of spectrum access based CR is very helpful. Various fuzzy rules are set up based on this linguistic knowledge. The output of the FLS provide the possibility of accessing spectrum band for secondary users and the user with the greatest possibility will be assigned the available spectrum band.

Fuzzy Logic systems

In fuzzification, the two input variables are used as the antecedents and the output variable is used as the consequence in the Mamdani fuzzy control. [13], [14], [15]. A fuzzy relation is characterized by the same two items as a fuzzy set. First is a list containing element and membership pairs,$\{\{ v_1, w_1\}, R_{11}\}, \{\{v_1, w_2\}, R_{12}\}, \ldots \ldots, \{\{v_n, w_m,\}, R_m\}\}$.Note that the elements of the relation are defined as ordered pairs, $\{v_1, w_1\}, \{v_1, w_1\}, \ldots \ldots, \{v_n, w_m\}$.. These elements are again grouped with their membership grades $\{R_{11}, R_{12}\}, \ldots \ldots, R_{nm}\}$., which are values that range from 0 to 1, inclusive. The second item characterizing fuzzy relations is the universal space. For relations, the universal space consists of a pair of ordered pairs, $\{\{v_{min}, v_{max}, C_1\}, \{w_{min}, w_{max}, C_2\}\}$. The first pair defines the universal space to be used for the first set under consideration in the relation, and the second pair defines the universal space for the second set. Universal spaces for fuzzy sets and fuzzy relations are defined with three numbers in this package. The first two numbers specify the start and end of the universal space, and the third argument specifies the increment between discrete elements.

Rule Set Applications

The fuzzy logic rule set decides the scenario of the selection of the secondary node . Here in this research work the fuzzy logic has been used to select a secondary node on the basis of the angle of incidence which is explained in the below sections . The rule set classifies that if the search has to be set on the different angles what has to be the outcome of the result being a secondary node. Different angle of incidence or rotation angles have been configured like 0 to 100 degrees and then optimal selection rule has been utilized. The optimal selection rule depicts specific angles on which the transmission is possible . The fuzzy set has been drawn using the ANFIS tool which is easily available with MALAB 2010 and upper version selection of MATLAB.

The rule set has been designed in such a manner that if the node has to search the secondary node in either left , right , up or down direction it should only move with a marginal difference based on the angles set in the rule base.

Four directions have been configured namely

a)right

b)left

c)vertical up

d)vertical down

First of all the rule set is checked against the direction , if the direction is found to be ok then further optimization function is called . The load against each angle is calculated and the node with least load is utilized as a secondary node en the virtual backbone structure is formed afterwards the nodes send requests to the owner node for data items on the backbone nodes.

No Cooperation

The fuzzy logic scenario is implemented with the following contrast .

No cooperation is the rule set where no bar over the data set is applied that means the data set is free to move any where in the network . The no cooperation system will not look into what a secondary node should possesses and what it should not . It is not concerned with any angle of incidence and any bit loss.

8 Bit Cooperation

8 bit cooperation is the system where always a limit of 8 bit is transferred through the secondary node . It is an easy way of data transfer but it consumes a lot of time in this scenario as only 8 Bits are transferred at a time . No doubt the routing over head with this approach gets reduced but the when it comes to fast data transmission , 8 bit cooperation is not feasible

The rule set has been also tested with the packet loss rate like 5% packet loss and 10 % packet loss.

Angle Of Incidence

The Primary Receiver (PR) contaminated by the signals from the Secondary Transmitter (ST) and Secondary Receiver (SR) are interfered by the Primary Transmitter (PT) approximately due to spectrum sharing. In a cognitive radio network the weight vector of the transmit beam-forming is given as w = ww1. Wwm } HH .The beam-forming gain in the direction of Q can be written as:

G (Q) = V(Q) W

And we suppose that the path loss via a factor α is in a large scale wireless channel, so the channel state information for a consumer in the direction of Q can be articulated as:

$H = d^{-1} V (Q)$

In this algorithm we utilize the four most wanted signal sources and estimate it in the desired directions. The desired angles may be 20°, 40°, 90°, 140° and 160° in the directions of primary users while the estimated angles having peaks values.

5.ANALYSIS

The performance of the proposed protocol is analyzed by determining the parameters like Probability of False alarm detection (Pf) against the Probability of Detections to overcome the problem of false and missed detections using Fuzzy Logic. It is shown in Fig. 3, that the probability of False alarm rate decreases with the use of Fuzzy Logic. Then by analyzing the Fig.4 , we found that that the packet loss occurred obtained is only 5% in the proposed CR network. Fig .5 shows total error rate of cooperative spectrum sensing versus number of collaborating cognitive radios in a network with 50 CRs when Fuzzy logic is used. Proposed method that is based on Fuzzy logic requires fewer than the total number of cognitive radios in cooperative spectrum sensing while satisfying a given error bound.

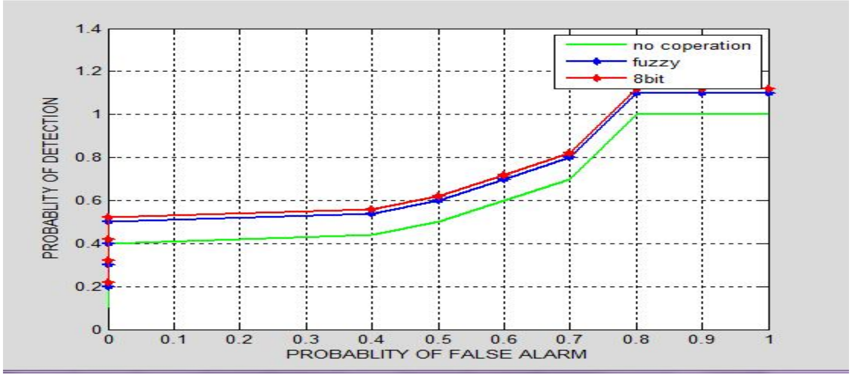

Fig.3.Probability of False alarm detections vs Probability of Detections.

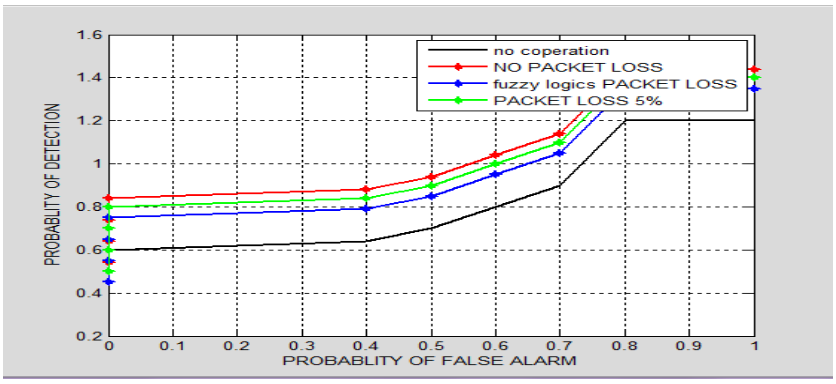

Fig.4. Probability of False Alarm Detections vs Probability of Detections with data loss

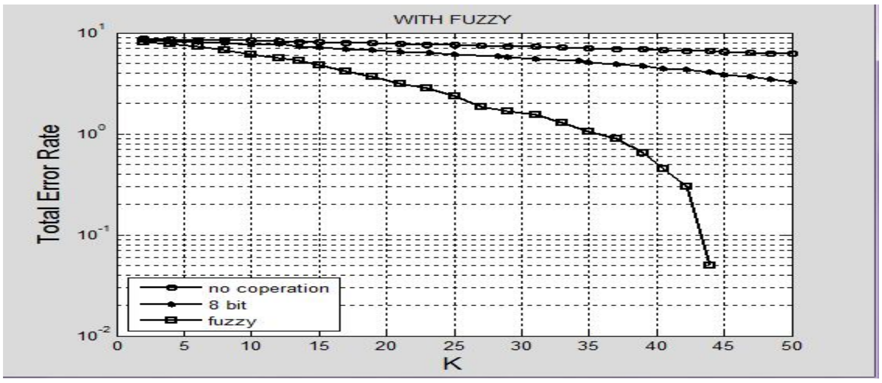

Fig. 5 Total error rate versus Collaborating Cognitive radios

6.CONCLUSION

In a cognitive radio network with a large number of CRs, cooperative spectrum sensing may become impractical because in a time slot only one CR should send its local decision to the common receiver so as to separate decisions easily at the receiver end. Hence, it may make the whole sensing time intolerably long. To address these issues, we propose next an efficient sensing algorithm which relies on the transmission of decision in one time slot for one CR but guarantees a target error bound by requiring a few CRs in cooperative spectrum sensing instead of all of them. Also we have studied the performance of cooperative spectrum sensing with energy detection in cognitive radio networks. It has been found that the optimal decision voting rule to minimize the total error probability is the half-voting rule. A method of numerically obtaining the optimal detection threshold has been presented. In addition, an efficient spectrum sensing algorithm has been proposed which requires fewer than the total number of cognitive radios in cooperative spectrum sensing while satisfying a given error bound.

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