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COMPRESSIVE SENSING BASED FUZZY OPPORTUNISTIC POWER CONTROL STRATEGY FOR COGNITIVE RADIO

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ABSTRACT

In spectrum sharing environment, transmit power control strategy has been implemented which enables cognitive secondary user to achieve its required transmission rate and quality, while minimizing interference to the primary users and other concurrent secondary users. In this paper, fuzzy logic is used which an intelligent decision is making tool for transmit power control. Transmit power control strategy is implemented using fuzzy logic system which can tolerate the imprecision and uncertainty of input data like spectrum sensing data and SINR measurements in this case. For the performance enhancement, compressive sensing is applied which lowers the number of samples in order to obtain the modified signal. Here the probability of missed detection and probability of false alarm is calculated which gives the information about active primary users.

Index terms— Fuzzy logic, Cognitive Radio, Dynamic Spectrum Access, Spectrum Sensing Methods.

I. INTRODUCTION AND LITERATURE REVIEW

In recent years, demand for wireless communication services has grown far beyond earlier predictions. Furthermore, in order to satisfy future market demand for mobile and broadband services, deployment of next generation mobile networks and services can envisaged which will need rapid and more flexible access to radio spectrum. Due to policy of exclusive frequency assignment, radio spectrum has become congested and scarce resource. Nevertheless, related surveys have proved that most of the allocated spectrum is underutilized. To deal with increasing conflict of spectrum congestion and spectrum underutilization, cognitive radio technique has been proposed as a flexible method which allows secondary users to utilize already licensed bands opportunistically.

Opportunistic radio spectrum access has the possibility to improve spectrum utilization and in perspective allowing next generation mobile networks access to the attractive radio spectrum bands.Cognitive radio is an intelligent technology that helps in resolving the issue of spectrum scarcity. Spectrum is a limited resource, hence the use of spectrum is regulated by government agencies like the Post and Telecom service (PTS) in Sweden, Federal Communications Commission (FCC) in United states, Telecom Regulatory Authority of India(TRAI) in India, Bangladesh telecommunications regulatory commission (BTRC) in Bangladesh. It has been found that most of the time the spectrum is underutilized even in highly populated urban areas. There are two types of users who use the spectrum. They are the Primary users (licensed) and the secondary users (Unlicensed). The Primary users (licensed) are those that have a license to use the spectrum. The secondary users (Unlicensed) are those who don't have a license to use the spectrum. When the assigned spectrum is not completely or if only partially utilized by the primary user, the unutilized spectrum is referred to as a spectrum hole or a white space. Cognitive radio identifies these spectrum holes and assigns them to the secondary users without causing any interference to the primary users. In a spectrum sharing network, where secondary user can communicate simultaneously along with the primary user in the same frequency band, one of the challenges is to obtain balance between two conflicting goals that are to minimize the interference to the primary users and to improve the performance of the secondary user. Primary link and a secondary link (cognitive link) is considered in a fading channel. To improve the performance of the secondary user by maintaining the Quality of Service (Qos) to the primary user, considering varying the transmit power of the cognitive user. For Cognitive radio users, optimal power control in spectrum sharing is one of the most important research issues. Opportunistic spectrum access and spectrum sharing are two types of mechanisms in cognitive radio networks. In opportunistic spectrum access either the primary user (PU) or the secondary user (SU) can use the spectrum. When the PU is idle, the SU will be able to use the spectrum. When the PU needs to use the spectrum again, SU has to vacate the spectrum. In Spectrum sharing both PU and SU can access the spectrum simultaneously as long as there is no interference to PU's Quality of service (QoS). The operation of the SU depends on the peak transmit power constraint and an average interference constraint at the primary receiver. It is important to balance the interference to the PU and improve the performance of the SU. Power control is one of the constraints to improve the performance of the secondary users.In the emerging paradigm of open spectrum access, cognitive radios dynamically sense the radio spectrum environment and must rapidly tune their transmitter parameters to efficiently utilize the available spectrum. The unprecedented radio agility envisioned, calls for fast and accurate spectrum sensing over a wide bandwidth, which challenges traditional spectral estimation methods typically operating at or above Nyquist rates. Capitalizing on the sparseness of the signal spectrum in open-access networks,

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compressed sensing techniques tailored for the coarse sensing task of spectrum hole identification is developed. Sub-nyquist rate samples are utilized to detect and classify frequency bands via wavelet-based edge detector. Because spectrum location estimation takes priority over fine-scale signal reconstruction, the novel sensing algorithms are robust to noise and can afford reduced sampling rates. Compressive sensing (CS) provided an exception to the lower bound on the sampling rate by exploiting sparsity in the signal. If a signal is sparse in some arbitrary basis, it may be sampled at a rate lower than Nyquist frequency in addition to this chapter.

II. FUZZY LOGIC

Fuzzy set theory is an excellent mathematical tool to handle the uncertainty arising due to vagueness. Fuzzy set may be viewed as an extension and generalization of the basic concepts of crisp sets. Figure 2.2 shows the structure of a fuzzy logic system.

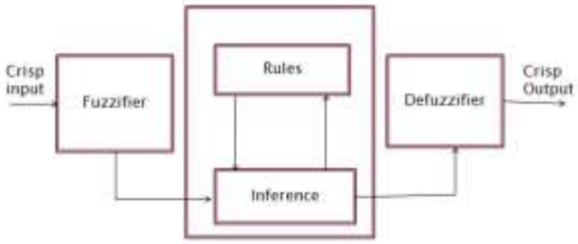

Figure 1: Structure of Fuzzy Control System.

Generally, fuzzy logic and fuzzy decision making is divided into three consecutive phases namely fuzzification, Fuzzy reasoning and defuzzification.

1. Fuzzification: The input variables are fuzzified using predefined membership functions (MF). Unlike in binary logic where only 0 and 1 are accepted, also numbers between 0 and 1 are used in fuzzy logic. This is accomplished with MF to which the input variables are compared. The output of fuzzification is a set of fuzzy numbers.

2. Fuzzy Reasoning: Fuzzy numbers are fed into the predefined rule base that presents the relations of the input and output variables with IF-THEN clauses. The output of the fuzzy reasoning is a fuzzy variable that is composed of the THEN clauses.

3. Defuzzification: The output of the fuzzy reasoning is changed into a non-fuzzy number that represents the actual output of the system.

The fuzzy logic for opportunistic spectrum access using cognitive radio is designed. It proceeds with selecting the best suitable secondary users to access the available users without any interference with the primary users. This is collected based on the following three antecedents i.e., descriptors. They are

Ant 1: Spectrum Utilization Efficiency

Ant 2: Degree of Mobility

Ant 3: Distance of Secondary user to the PU.

Fuzzy logic is used because it is multi-valued logic and many input parameters can be considered to take the decision.

III. POWER CONTROL STRATEGY

In order to fully exploit potential of opportunistic spectrum access, interference control is a crucial issue. It is essential to keep the transmission power of the cognitive SU at a minimum level while ensuring adequate signal quality at the receiving end. Power control strategy is based on balancing SU transmit power level between minimum required and maximum acceptable. Minimum required transmit power is obtained by adjusting it to satisfy targeted SINR at the SU receiver. Maximum acceptable transmit power is established considering permissible interference at the primary user's receiver. It is determined by spectrum sensing data and predefined regulatory constraints. As a result, TPC strategy tries to maintain required SINR at the cognitive SU receiver, while not causing excessive interference to the licensed primary users.

Fuzzy logic transmit power controller for opportunistic radio spectrum access contains fuzzy logic processor, performance evaluator and regulatory database as shown in Fig. 2. Regulatory database contains regulatory rules defining maximum permissible radiated power or power spectral density of cognitive SU transmitter in geographic area of interest. Spectrum sensing data collected at cognitive SU determines level of spectrum activity and potential influence of cognitive SU to the primary network. These two elements define maximum acceptable transmit power of cognitive SU. Performance evaluator compares measured SINR at SU receiver with required SINR. Based on SINR difference fuzzy logic processor determines transmit power adjustment for estimating minimum required transmit power of cognitive SU.

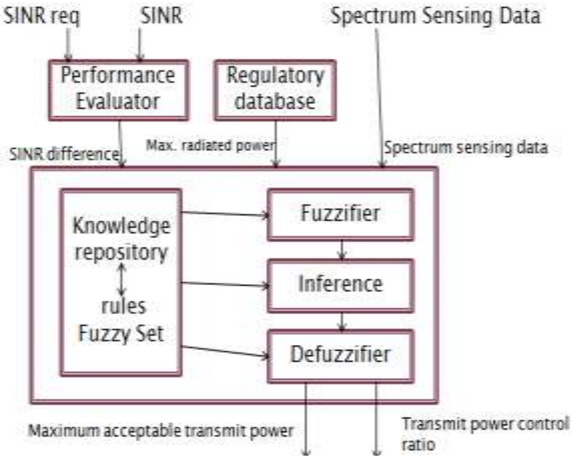

Figure 2: Fuzzy Logic Transmit Power Controller

The advantage of proposed TPC strategy is in minimizing mutual interference and reduction of frequency reuse distance for PU and other SU. This leads to radio spectrum utilization improvement and increasing overall networks capacity with available radio spectrum. Additionally, reduction of SU transmitter power results in minimizing battery consumption of mobile terminals for next generation mobile networks and services.

IV. COMPRESSIVE SENSING

In recent years, compressed sensing (CS) has attracted considerable attention in areas of applied mathematics, computer science, and electrical engineering by suggesting that it may be possible to surpass the traditional limits of sampling theory. CS builds upon the fundamental fact that it can represent many signals using only a few non-zero coefficients in a suitable basis or dictionary. Nonlinear optimization can then enable recovery of such signals from very few measurements. Compressed sensing has emerged as a new framework for signal acquisition and sensor design. CS enables a potentially large reduction in the sampling and computation costs for sensing signals that have a sparse or compressible representation. While the Nyquist-Shannon sampling theorem states that a certain minimum number of samples is required in order to perfectly capture an arbitrary bandlimited signal, when the signal is sparse in a known basis it can vastly reduce the number of measurements that need to be stored. This is the fundamental idea behind CS: rather than first sampling at a high rate and then compressing the sampled data.

V. SIMULATION RESULTS

To demonstrate the adequacy of proposed work, some numerical results of fuzzy logic transmit power control strategy is given. There are 10 number of cognitive radio users are generated and the various parameters that we have used in the coding is shown in table 1.

TABLE I :Various Paramters Used In Coding

S No.	Parameters	Values
1	Number of Cognitive Radio Users	10
2	Time Bandwidth Factor	100
3	Signal Length	200
4	Channel	Additive White Gaussian Noise
5	SNRdB	15
6	Number of Sampling Points	243

By using fuzzy logic the transmit power is controlled in intelligent manner by its decision making capability and hence balance the transmit power level between PU and SU. Figure 3 shows the performance of the detection algorithm with two probabilities: probability of missed detection (PMD) and probability of false alarm (PFA). When a missed detection arises, the CR may unwittingly transmit over the same channels used by active primary users, causing detrimental interference to legacy services. Probability of false alarm (PFA) is the probability that the test incorrectly decides that the considered frequency is occupied when it actually is not. Probability of false alarm (PFA) should be kept as small as possible in order to prevent underutilization of transmission opportunities.

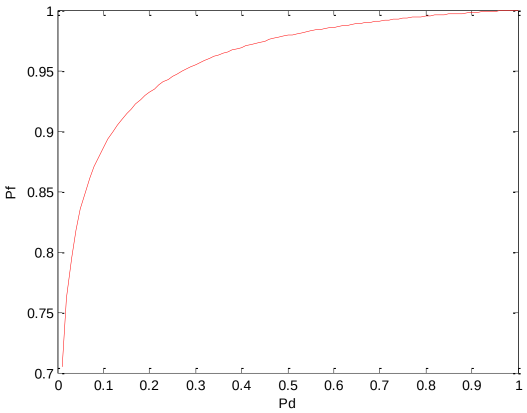

Figure. 3: Probabilty Of False Alarm And Missed Detection

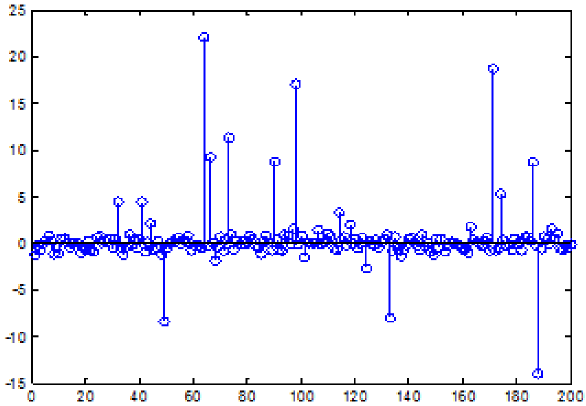

Figure 4: Compressed Signal

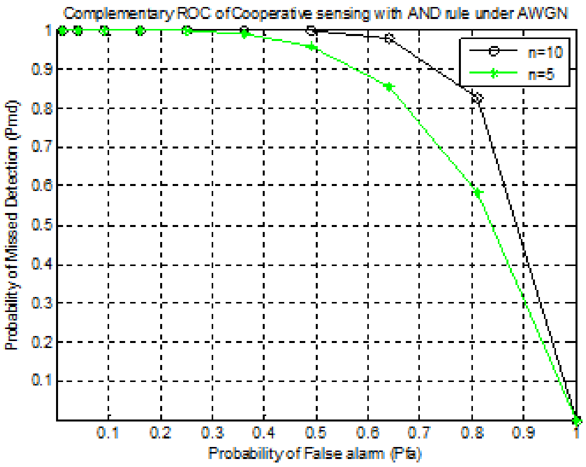

Figure 5: Fuzzy Logic Transmit Power Controller Simulation Result.

From above figures, it is clearly shown that the performance of detection algorithm is enhanced by using compressive sensing technology and fuzzy logic with transmit power control strategy. Compressive sensing lowers the sample index from n = 10 to n = 5. By lowering the sample index from 10 to 5, the capacity of the system is enhanced because it can easily detect the active PUs even in fading environment and reduce the probability of missed detection and probability of false alarm.

VI. CONCLUSION

In this paper, an alternative transmit power control strategy is presented for cognitive secondary users applying opportunistic spectrum access. Transmit power control is realized using fuzzy logic system which enables simple and low cost implementation of TPC function. Presented TPC strategy allows cognitive secondary use to achieve its required transmission rate and quality, while minimizing interference to the primary users and other concurrent secondary users. Fuzzy logic is basically used as an intelligent decision making tool for transmit power control. Transmit power control strategy is implemented using fuzzy logic system which can tolerate the imprecision and uncertainty of input data like spectrum sensing data and SINR measurements in this case. Advantage of presented cognitive SU TPC scheme is that it is following altruistic approach which results in smaller interference potential and reduction of frequency reuse distance. This allows also other next generation mobile network users to benefit from available radio spectrum, leading to the improvement of overall spectrum utilization and maximizing overall PU and SU networks capacity Also applying compressive sensing to cognitive radio for the performance enhancement by lowering the number of samples to obtain the desired signal. The compressed sensing technique is developed for detecting wideband signals at reduced signal sampling and acquisition costs. The performance of detection algorithm is enhanced by using compressive sensing technology and fuzzy logic with TPC strategy.

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