Cooperative Cognitive Radio Sensing - Optimization: status, challenges and future Trends

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***Abstract*— Cognitive-Radio (CR) is a technique that has revolutionized the information technology market to improve the use of the electromagnetic spectrum. Spectrum sensing is an essential component of CR to avoid conflict problems with primary users and define available spectrum to maximize spectrum utilization. however, problems with multipath fading, shadowing, and uncertainty also undermine detection effectiveness. cooperative spectrum sensing has proven to be an Efficient tool for these problems by exploiting spatial diversity so improving detection efficiency. A literature review, framework and elements of cooperative sensing, classification of cooperative sensing, and various optimization of cognitive radio are discussed in this article.**

Keywords*— *cognitive radio, cooperative-sensing, sensing optimization

I. Introduction

Studies have found that the spectrum allocation policies that were used lead to ineffective use of spectrum and to solve This issue, cognitive-radio was used as a method that provides access for unused spectrum frequencies known as spectrum holes or white gaps and thus improve the effective use of the spectrum. There are 2 categories of users: primary users (PU), who are authorized and have a high priority, and secondary users (SU), who are unauthorized and have a low priority. A authorized band is one that is charged and can only be used by licensed organizations, while an unlicensed band is for the general public.

The primary goal of each CR user is In identifying authorized users or the so-called primary users if they are present or not, and determining the available spectrum ,this is typically done by sensing the radio frequency environment, using spectrum sensing techniques, The objectives of spectrum sensing are two parts: The first is that the cognitive radio users should not interfere with the authorized users either by moving to another band or reducing the interference process to an acceptable rate. The second is that the cognitive spectrum users must know the available spectrum and use it effectively to increase the productivity and the quality of the service.

Two parameters are used to measure the detection performance of primary users: the probability of a false alarms, which is the probability of an authorized user being present once the spectrum is empty, and the probability of detection, which is the probability of an authorized user being present once the spectrum is busy.

In CR, spectrum sensing is extremely important. Due to multipath fading, the shadow effect, and the receiver uncertainty problem, reliable spectrum sensing by a single secondary user is difficult to achieve (SU). To mitigate these effects, cooperative spectrum sensing (CSS) has been suggested as a way to increase spectrum sensing accuracy by applying spatial diversity, where multiple secondary users cooperate to perform spectrum sensing thus detection performance is optimize.[1][2]

II. LITRITURE REVIEW

In [3] to refine the weighting coefficient vector, the Enhanced particle swarm optimization (EPSO)' used by the author. EPSO picks the best weighting coefficients from the weighting coefficient vector.

In [4] to increase productivity in the use of telecommunications system resources, cooperative communications are presented using the game theory model. The main benefits and costs of collaboration, throughout the specific situation of cognitive radio networks, as well as security problems which may occur in such a scenario, are studied.

In [5] the author applied a survey on spectrum sensing, compressive sensing, machine learning, Recent Advances, New Challenges, and Future Research Directions.

In [6] the author explores the research methodology for a soft cooperative spectrum sensing (CSS) cognitive radio device's 'probability of spectrum hole use (PSHU) under a practical consideration of static structural frame.

In [7] a cognitive radio network (CRN) wherever several unauthorized users (SUs) collaborate, the researchers examine Deep cooperative sensing (DCS), which constitutes the first CSS framework based on a convolutional neural network (CNN).

In [8] the author uses deep learning to boost the precision of the primary user (PU) identification, as there is a memory in the channel and the state of the PUs in the network, Recurrent Neural Network is used to make it more realistic.

In [9] there is a suggestion based on compression sensing for a cooperative spectrum sensing (CSS) system. (SUs) are grouped as clusters in this system. In any cluster, SUs forwards their compact signals to the source node. The head of the clusters then send Local sensing data to the control center to make the final determination.

In [10] the sensing period of time is designed to decrease energy usage in a complex cooperative network using square law integrating decision theory. An important change in the sensing energy and time use of the sensing mission is verified by the results of the measurement.

In [11] when two secondary users collaborate through the relay method, the author uses cooperative spectrum sensing two cooperative sensing techniques are studied, meaning that the secondary users share information locally and send it to a centralized control unit.

In [12] in terms of postponement, normal strength, SNR and BER, an overview of various strategies for advancement-based ISI (intersymbol interference) lessening systems, range detection techniques and FPGA arrangement procedures are examined. It is extremely probable that all methods perform admirably for different purposes. More references related to the topic of this paper can be found in [21- 35]

III. CLASSIFICATION OF COOPERATIVE SENSING

The cooperative sensing process begins with a spectrum sensing process that is performed on each secondary user and is called local sensing. Cooperative sensing is dealt with three groups in order to facilitate the process of understanding how the secondary users sharing the sensor information in the network to a Centralized, distributed and assisted-relay.

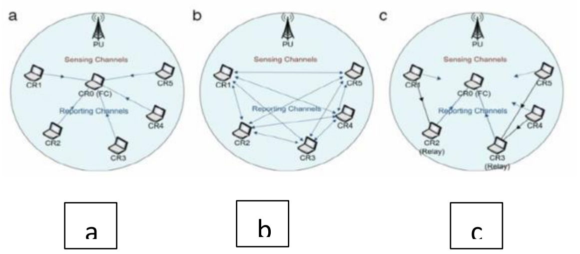

Fig.1. Classification of cooperative sensing

A. *Centralized cooperative sensing*

There is a central unit called the *base station responsible for the three steps of spectrum sensing, it selects a sensing channel or an interesting frequency range and directs all the cooperating secondary users to perform the local sensing process individually, then all the secondary users announce their sensor results via a controller channel, then the *fusion center collects the sensor results. The existence or non-existence of the primary user is decided and the result is published again to all cooperating users

All secondary users are connected to a controller channel for reporting data. The physical link between all collaborating secondary users and the base station is called the reporting channel.in fig.1 show the cenerlized cooperative sensing [13].

B. *distributed cooperative sensing*

Cooperative Distributed Sensing doesn't really rely on a single unit, cognitive radio users communicate with each other and arrive at a unified opinion about the existence or non-existence of the authorized user.

Figure.1b describes the distributed sensing method. The localized sensing data are exchanged with the users following the localized sensing process from CR1 to CR5. Each CR user sends other users their own sensor results, compares their data with the sensor data obtained, and uses a local parameter to decide whether or not the primary user is active [14].

C. *relay-assisted cooperative- sensing*

Collaborative sensing is used with relay assisted when both the sensor and report channels are inactive, a member of a cognitive radio network with a powerful sensor channel and a weaker report channel, as well as a member with powerful report channel and a poor sensor channel, can work together to optimize spectrum sensing. In fig.1c CR1, CR4 and CR5 have a powerful sensor channel and poor report channel in order to assist in transmitting CR1, CR4 and CR5 sensor results to FC. CR2 and CR3 with strong report channel will act as relays to FC [15].

IV. STRUCTURE AND COMPONENT OF COOPERATIVE SENSING

A. structure of cooperative sensing

The cooperative sensing system consists of the authorized user and all the unauthorized users cooperating with each other, including the integration center, all the cooperative sensing components, the radio frequency environment, the sensing and control channels, and an optional database.

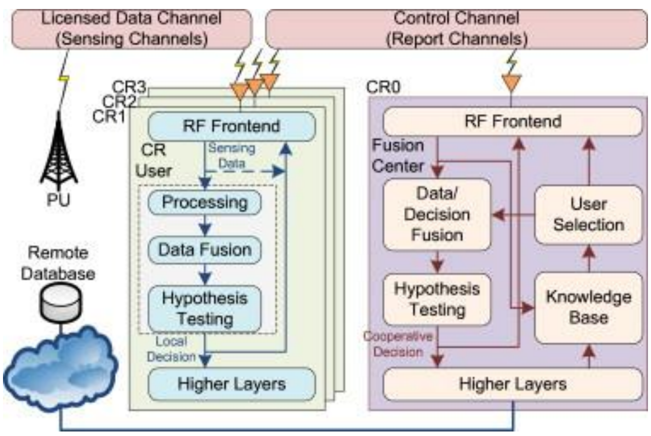

Fig. 2. Framework of centralized cooperative sensing.

Figure 2 shows the central cooperative sensing structure from the physical layer point of view, in this system with the RF frontend and the local processing unit, a set of SU perform the locally sensing process. the radio frequency frontend conversion of radio frequency signals and sampling by an "analog-to-digital converter (ADC)" at Nyquist rate. The RF frontend sensor data can be transmitted directly to the FC or processed for local decision making, to reduce the bandwidth of the controller channel there is a need for local processing, the processing includes the calculation of test stats and a threshold device for local decision, once the sensor data is ready, a medium access control (MAC) scheme required to access the control channel for transmitting local sensor results. Higher network layers can also use the sensing results for spectrum-aware routing selection [16].

B. COMPONENT OF COOPERATIVE SENSING

• Collaboration model is referred to as how unauthorized users collaborate to sense the spectrum. Currently popular models are parallel-fusion models and game-theoretical models.

•Sensing-techniques: they are used to sense the radio frequency environment, make observational measurements, and then use signal processing method to discover the authorized user signal or free spectrum. The choice of sensing technology affects how the secondary users co-operate with each other

• Hypothesis-testing: the presence or lack of a PU is a mathematical measure to be determined. This test can be carried out independently by each cooperating user for decisions locally or by the cooperative *integration *unit*.

• Control and reporting channel: is concerned with how to obtain the sensor results through the cooperation of secondary customer and transmit them to the integration *unit* efficiently and reliably.

• Data fusion: It is the mechanism by which reports or sensor outcomes are gathered and unified joint decision-making is taken based on their form of data. Sensor outcomes may be mixed using signal combination approaches or rules for decision-fusion • Selection of users: Selection In order to improve the cooperative benefit and reduce the cooperation overhead .It concerns what to do to choose collaborating CR users efficiently and how to define the appropriate scope for collaboration.

• Knowledge base: To enhance discovery performance, it keeps information and enhances the collaborative sensing process. The knowledge base information is either predefined or known by experience and includes authorized and unauthorized user places and forms of authorized user activity [1].

V. SENSING OPTIMAZATION IN COGNATIVE RADIO NETWORK

Many modern inferential algorithms are built to solve digital optimization problems. Depending on the factors which are taken into consideration, such as population-based, frequency-based, random-listed, etc., these algorithms can be divided into different classes. There are two basic sets of population-based algorithms: evolutionary algorithms (EA) and algorithms based on swarm intelligence.

A. Genetic-Algorithm

The most accurate evolutionary algorithm is the adaptive genetic algorithm to the radio environment. Among the proposed artificial intelligence techniques in the field of cognitive radio network research are expert systems, artificial neural networks, fuzzy logic, hidden tag models, and genetic algorithms. To achieve an optimal solution, these entire decision algorithms follow various forms of reasoning. But each algorithm has serious limitations that decrease its real-time operational value in the cognitive radio network. Fuzzy logic allows unpredictable inputs to find approximate solutions that do not allow the system to show Effective actions. In this field, neural-networks are the most relevant, but their difficulty is larger than that of other techniques. Genetic-algorithms are more general because of their speed to cover a wide variety of potential configurations and thereby find the most appropriate solution [17].

GA characterizes a radio as a chromosomes-and -genes provided as an input to the GA-procedure for the quality-of-service needs of users. Two parameters are evaluated, the available spectrum resource size specified by the GA as population-size and the number of defined chromosome-genes in the spectrum allocation efficiency. This technique begins with the description of a chromosome's-structure. A chromosome's-structure is a series of genes, i.e., 'frequency, modulation, bit error rate (BER)'.

Its multi-objective handling capacity is the key value of the GA. There are three key features of the genetic algorithm for every optimum solution:

Selection: It automatically chooses people named parents who contribute to the population's next generation.

Crossover: two parents are combined into the next generation to create an infant under the crossover rule.

Mutation: It is a random shift in the mechanism for individual parents to produce offspring [17][18].

B. Particle Swarm Optimization

Particle Swarm Optimization techniques ("PSO") is a popular technique that relies on swarm intelligence. PSO is a randomized population-based improvement strategy driven by a bird flow or fish education social activity. PSO has many similarities to advanced computational and research methods such as genetic algorithms (GA). PSO is an easy, fast and accurate computational technique that also improves the problem and aims to enhance the efficiency of detection and other parameters. The PSO utilizes the behavior of these social institutions or the algorithm of swarm intelligence. In PSO, in the search room, any unique solution to the problem is a "bird" and it is named a "particle". All particles in the region have fitness values that are calculated through the enhanced fitness function and have particle orientation velocities "fly. By following the current optimal particles, the particles travel through the problem space. PSO is initialized with a group of random particles (solutions) by upgrading generations and then looks for optimal ones. In every iteration, each particle is changed by using two "best" values. The first one is the best (fitness) approach that has been achieved so far. This attribute is called p-best. Another attribute of the "best" The best value obtained so far by any particle in the population is that which is monitored by the particle-swarm -optimizer. This, this, A global best, called g-best, is the best value. When a particle takes its topological neighbors as part of the population, the best value is a local best and is called l-best. The particle changes its velocity and locations after finding the two best values. The PSO has two primary characteristics: location and speed. These are altered according to the number of steps and assign the best position and velocity value to the actual particle value for each iteration. [19].

C. *Artificial-bee-colony*

The Artificial bee colony spectrum (ABC) sensing method was born by "Karabog" throughout the year -2005. Inspired by honey bee feed, it's a way to improve swarm intelligence. The ABC method is faster than the speed of other population models, with less control parameters. In the ABC method, an artificial bee colony is mainly composed of three classes of bees: worker bees - spectators - scouts, the one part of the colony is made up of worker bees, and the two part contains spectators. Each working bee is associated with a food source, ensuring that the number of bees used equals the food origin. The worker bee identifies a food source or place by changing the location in its mind and Computes the amount of nectar for each new source and saves the best one, i.e., the greedy variety. Worker bees share data about the essence of the food source they use for their dance floor. spectators' bees are classified by food sources based on the data. They come from worker bees. Onlookers are likely to prefer more profitable food sources. Based on this information, the spectator bees choose a food source and make a change to that source. The greedy filter is used in the ABC algorithm to identify better food sources. The ABC algorithm is very simple and versatile, especially with regard to suitable for hardware engineering [20].

D. *Result*

we compare the technique discussed above using different parameters illustrate in Table. I

TABLE. I DIFFERENT PARAMETERS FOR COMPARISON OF ARIOUS OPTIMIZATIONS IN CR

Parameter	GA	PSO	ABC
Control parameter	Generation rate, crossover rate, mutation rate	Cognitive, social factors, inertia weight	Maximum cycle number, colony size
Convergence Rate	Less	More than GA	Better than GA
Complexity	more	Less complex	Less than GA,PSO
Convergence speed	Less in large space	Better than GA	Better than GA
Flexibility	Flexible	More than GA	More Flexible than PSO
Computational time	More	Less than GA	Less than GA, but more than PSO

In Table. II we illustrate the status, challenges and future work of previous researchers

VI. CONCLUSION

cooperative sensing is an effective method to enhance detection efficiency by collaboration of spatially located CR consumers. CR users can share their sensor data through collaboration to make a more reliable decision than individual decision. In this paper we address classification of cooperative sensing, cooperative sensing component and the structure of cooperative sensing, as well as studying a various optimization method in cognitive radio for spectrum management.

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