A Proposal on Improving Frequency Spectrum Sensing Reliability in Cognitive Radio Using Genetic Algorithm

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***Abstract*-This research proposes a novel method for modifying, improving and deploying sensing techniques in cognitive radio on instruments in the oil and gas sector so as to improve the reliability of frequency spectrum sensing using genetic algorithm. Matlab/Simulink would be employed for the simulation.**

***Keywords*- sensing techniques, cognitive radio, instrumentation, frequency spectrum, genetic algorithm, simulation**

I. INTRODUCTION

In the past decade, there has been an intense growth in wireless communication due to the popularity of smart phones and other mobile devices. This has resulted to an astronomical increase in the demand for commercial spectrum. AT&T projected a 5000% increase in data usage from 2009 to 2012, Yankee Group predicted 29-fold increase in US mobile data traffic from 2009 to 2015, and CTIA estimated that U.S. cellular companies needed at least 800MHz more spectrum from 2009 to 2015 [1]. Wireless communication has created a revolution in our lives. New wireless devices are capable of offering higher data rates and innovative services. Licensed and unlicensed spectrum is available for different wireless services. But with the exponential increase in wireless devices and their usage, the unlicensed spectrum is becoming scarce. Licensed spectrum is used for specific service while the unlicensed spectrum (Industrial, Scientific and Medical (ISM) radio bands) are freely available for wireless services and research purposes. Currently static spectrum allocation policy is in practice due to which bandwidth in unlicensed bands is becoming scarce and for licensed bands it is either underutilized or unoccupied. Licensed spectrum specifically TV spectrum and cellular spectrum are underutilized.

Researchers have anticipated the current 'frequency spectrum scarcity' perception over the years and have attempted to proffer possible solutions to effectively and efficiently optimize the use of available frequency spectrum.

Cognitive radio (CR) refers to a new type of radio that uses real-time interaction with its environment to determine transmitter parameters such as centre frequency, symbol rate, transmit power, modulation type, pulse-shape filter (PSF) type, spread spectrum type, and spreading factor [3,4].

Cognitive radios are fully programmable wireless devices that can sense their environment and dynamically adapt their waveform, transmission channelaccess method, spectrum use, and networking protocols as needed for good network and application performance.

Basically, Cognitive Radio solves the spectrum underutilization problem in a tightly inter-coupled pair of ways:

i. Sense the radio environment to detect spectrum holes in terms of both time and location.

ii. Control employment of the spectrum holes by secondary users efficiently, subject to the constraint:

   The total power in each spectrum hole does not exceed a prescribed limit.

The three major tasks of the cognitive radio include [2]:

(1) radio-scene analysis,

(2) channel identification, and

(3) dynamic spectrum management and transmit-power control.

The radio-scene analysis includes the detection of spectrum holes by for example sensing the radio frequency spectrum. While the channel identification includes estimation of the channel state information which is needed at the receiver for coherent detection. Furthermore, the transmitter power control and dynamic spectrum management select the transmission power levels and frequency holes for transmission based on the results of radio scene analysis and channel identification.

Cognitive radio takes advantage of availability of white spaces in spectrum and allows its system (referred to as the secondary users) to opportunistically access the frequency spectrum held by licensed radio services (referred to as the primary users) using spectrum sensing [5].

Research in cognitive radio is categorized into four major branches as follows: spectrum identification, spectrum access, spectrum sharing, and spectrum management.

Spectrum sensing is one of the methods in the broad branch of spectrum identification that allow CR systems operate in spectrum bands licensed to other users without causing harmful interference. Other methods include Geo-location and Beacon; however, spectrum sensing has received more attention in literature because of its broader application areas and lower infrastructural requirement.

Beacon uses beacons transmitting on dedicated frequency or Cognitive Pilot Channel. This method did not receive much support from the international community due to the cost of deploying a network of beacons and the lack of sufficient spectrum for a pilot channel. In the same vein, Geo-location will work best when database contain information on a large scale for example on a regional basis.

However, the initial cost of having a database of all existing users of a given band on a large scale is high, and non-existing, especially in Africa.

In this study however, emphasis will be on spectrum identification, and particularly on improving frequency spectrum sensing sensitivity and reliability. This is because secondary users need to have cognitive radio capabilities, which will enable them sense frequency spectrum reliably to check whether it is being used by a primary user and to change the radio parameters to exploit the unused part of the spectrum.

A. Motivation

There is a soaring frequency spectrum demand, much more than the current fixed spectrum access technique can handle. Not long ago, at the World Radio Communication Conference held in Geneva, Switzerland, the European Conference of Postal and Telecommunication (CEPT) administrator opposed Africa's bid for more spectrum allocation [6]. The simple solution to frequency spectrum congestion is the invention of cognitive radio. The ability of this system to sense its environment and adapt so as to enhance its performance and that of the network has allowed for more intensive use of frequency spectrum. However this new technology still suffers some set back owing to some challenges in its implementation and deployment.

B. Problem Statement

Current Spectrum Sensing Techniques in Cognitive Radio Systems are plagued with the problem of false alarm, hence reducing their reliability. The higher the Probability of detection (Pd) of a Primary User the better the quality of Spectrum sensing. Also the lower the Probability of false alarm (Pf) of a Primary User the better the quality of Spectrum sensing.

C. Aim and objectives

The aim of this research work is to improve spectrum sensing reliability in Cognitive radio. To achieve this, the following objectives are highlighted:

1. To study as many available sensing techniques as possible.
2. To use the most efficient technique as a basis for improving the reliability of spectrum sensing in Cognitive Radio research using Genetic Algorithm.
3. Implementation of the applicable network in Matlab/Simulink environment.
4. To validate the effectiveness of this technique using and existing model of cognitive radio network.

II. LITERATURE REVIEW

Extensive work has been done on frequency spectrum sensing techniques, and the reliability of these methods, however like every research work, these works are not exhaustive of the topic. Topics involving obtaining the spectrum usage characteristics across multiple dimensions such as time, space, frequency, and code are still issues that have not been well tackled [7]. Issues which also involve determining what types of signals are occupying the spectrum including the modulation, waveform, bandwidth, carrier frequency are still being researched.

This section presents previous work done in frequency spectrum sensing in Cognitive radio. In [8] Khalaf et al proposed a sensing technique with a low complexity detector based on a combination of two well-known and complementary spectrum sensing methods namely energy and cyclostationary detection. The cyclostationary detector is used to estimate the noise N, which is then used to fix the threshold of the energy detector. Results in [8] show promising performances of the proposed detector in low Signal to Noise Ratio (SNR) level. Khambekar and Spooner in [9] proposed a signal-processing perspective on signal-statistics; for spectrum sensing in Cognitive radio. These techniques were view in [9] as ways of estimating an RF environment map (RFEM), which characterizes the position, directivity, power, and modulation type of all relevant RF emitters in a geographical region of interest.

In [10], cooperative spectrum sensing based on blind source separation, suggest that this approach will improve reliability of cooperative spectrum sensing. Numerical analysis and computer simulation in [10] confirm that proposed algorithm achieved the vacant spectrum sensing and overcomes effect of noise uncertainty to statistical decision. In [11] however, improved on [10] by proposing a probabilistic graphical model to represent and fuse multi-prior information from one hop neighbouring secondary users. [11] Use Belief propagation (BP) for the statistical inference of the spectrum occupancy. Numerical simulation results in [11] demonstrate that the proposed BP based cooperative compressed spectrum sensing effectively achieve cooperation in heterogeneous environments and improve performance of compressed spectrum sensing under a low sampling rate and low signal-to-noise ratio (SNR), compared with the other distributed cooperative compressed sensing methods. [12] Posited that hidden nodes problem in spectrum sensing in Cognitive radio is alleviated by cooperative sensing using multiple cognitive radio (CR) sensors. To improve radio sensitivity and reliability of the sensing function through processing gain [13] and [14] investigated three digital signal processing techniques in literature which are matched filtering, energy detection, and cyclostationary feature detection.

Analysis in [13] and [14] shows that cyclostationary feature detection has advantages due to its ability to differentiate modulated signals, interference and noise in low signal to noise ratios. In addition, to further improve the sensing reliability, [14] investigated the advantage of a MAC protocol that exploits cooperation among many cognitive users.

[15] introduced a novel concept known as Multi-stage sensing which divides the sensing process into a number of sequential stages. [15] Proposed that the number of sensing stages and the sensing technique per stage can be used to optimize the performance with respect to secondary user (SU) throughput and the collision probability between primary user (PU) and SU.

[16], explained the cooperative sensing concept and its various forms. [16] Also discussed external sensing algorithms and other alternative sensing methods. Furthermore, statistical modelling of network traffic and utilization of these models for prediction of primary user behaviour is studied.

Other literatures reviewed include [17], [18], [19], [20], [21], [22], [23], [24] and [25] the authors all agree that Spectrum is a very valuable resource in wireless communication system. Therefore, authors evaluated Spectrum opportunity and spectrum sensing concepts by considering different dimensions for spectrum space.

A. Genetic Algorithm (GA)

This is a stochastic universal search method that imitates the metaphor of natural biological evolution that have been applied in solving various problems in different fields of human endeavour. The strength of GA comes from its simplicity and style as a strong search algorithm in addition to the power to realize good solutions speedily for complex high-dimensional problems. GA is helpful and proficient when, the search space is big and/or complicated, domain knowledge is rare, mathematical analysis is lacking and traditional search methods fall short of requirements.

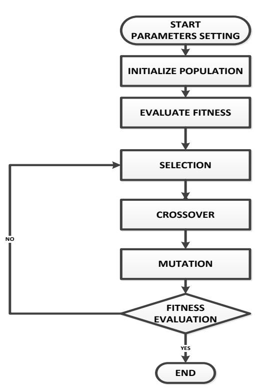

Figure 1. A typical GA flowchart

B. Spectrum Assignment using genetic Algorithm

The computation of the GA starts from the assortment of the chromosomes which are randomly generated. Configurable radio parameters viz. transmit power, modulation, coding rate, symbol rate, packet size etc. represent genes of chromosomes. Size of population is taken according to number of cognitive users.

1. *Initialization:* A random initial population of n chromosomes is generated. This population contains the available solutions for the specified problem.
2. *Fitness measures:* Evaluation of the fitness of an initial population's chromosomes.
3. *Construction of a new population:* Try the following steps to reproduce, until the production of the next generation completes:
    - *Selection:* A selection of chromosomes will be done in a way such that these chromosomes have the better level of fitness in the current available population.
    - *Crossover:* The crossover is done to make new individuals for the incoming generation. So with the defined probability of crossover, selected chromosomes reproduce to form new individuals.
    - *Mutation:* The new created individual will be mutated at a definite point.
4. *Stopping Criteria:* The process is repeated with all the above-mentioned steps until a desired optimum solution is obtained or a set of maximum numbers of the population are generated. To implement the GA there are still several factors to consider, like creation of chromosomes, types of encoding used to perform the genetic algorithms, selection of the optimum chromosomes, and different criterion such as defining the fitness measure.

III. METHODOLOGY

It is envisaged that the research will include practical research element to investigate questions raised in the study, primarily targeted at Improving Spectrum Sensing reliability in Cognitive Radio.

Research methods include:

1. Exhaustive literature review to identify which spectral usage characteristics and specification are of interest.
2. Formulate a Mathematical model for the Genetic Algorithm using four genes Frequency, Power, BER and Modulation.
3. Use Genetic Algorithm to improve the reliability of spectrum sensing.

4. Employ applicable simulation tools such as MATLAB to run this technique.
5. Comparison of simulated performance characteristics with existing techniques.
6. Publication of results.

IV. CONCLUSION

In conclusion, the proposal is being made with a timeline that fits the duration for a three year PhD tenure track. The breakdown of the activity time map is as follows:

1. Year one: research training, literature review, to help refine research question. Continue consulting my supervisor.
2. Year two: Piloting of tools to be used, development of research techniques and Main empirical phase.
3. Year three: Analysis, supplementary literature review, simulation, results evaluations and complete write up.

The success of this project will see the setting up of an experimental testbed for direct application along well established oil and gas pipelines in the Niger-delta region of Nigeria

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