ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

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International Journal of Advanced Research in Computer and Communication Engineering

SITES

Smart And Innovative Technologies In Engineering And Sciences

Gyan Ganga College of Technology

Vol. 5, Special Issue 3, November 2016

Intelligent Wireless Communication System Using Cognitive Radio

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Abstract: The increasing demand for wireless communication introduces efficient spectrum utilization challenge. To address this challenge, cognitive radio (CR) is emerged as the key technology; which enables opportunistic access to the spectrum. CR is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. In this paper, we present a state of the art on the use of Multi Agent Systems (MAS) for spectrum access using cooperation and competition to solve the problem of spectrum allocation and ensure better management. Then we are discussing an approach which uses the CR for improving wireless communication for a single cognitive radio mobile terminal (CRMT).

Keywords: Cognitive Radio, wireless communications, mobility, Artificial Intelligence, Multi Agent Systems.

I. INTRODUCTION

Wireless communication 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 specifically TV spectrum and cellular spectrum are underutilized. 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 [1].
The Cognitive Radio (CR) was presented officially by Joseph Mitola in 1999, and since, this concept has been very popular with researchers in several fields such as telecommunications, artificial intelligence, and even philosophy. Joseph Mitola has defined the CR as "a radio that employs model-based reasoning to achieve a specified level of competence in radio-related domains" [2].

II. DESIGN OF COGNITIVE RADIO

Artificial intelligence (AI) techniques for learning and decision making can be applied to design efficient cognitive radio systems. Different learning algorithms can be used in CR networks (Hidden Markov Model, neural networks, genetic algorithms, decision trees, and fuzzy logic or classification algorithms) [3].

CRs need to have the ability to learn and adapt their wireless transmission according to the ambient radio environment. Intelligent algorithms such as those based on machine learning, genetic algorithms, and fuzzy control are therefore key to the implementation of CR technology. In general, these algorithms are used to observe the state of the wireless environment and build knowledge about the environment. This knowledge is used by a cognitive radio to adapt its decision on spectrum access. For example, a secondary user can observe the transmission activity of primary users on different channels. This enables the CR to build knowledge about the primary users' activity on each channel.

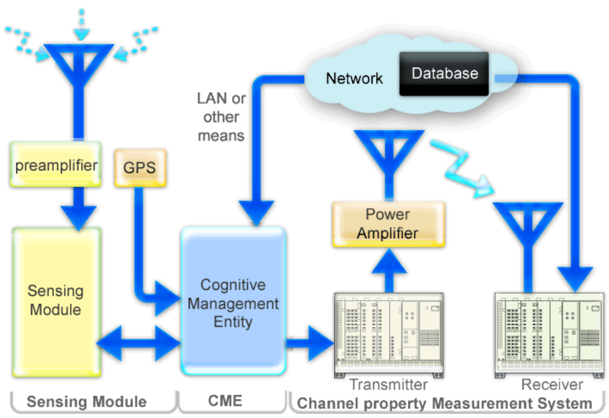

Fig.1 Concept of Cognitive Radio

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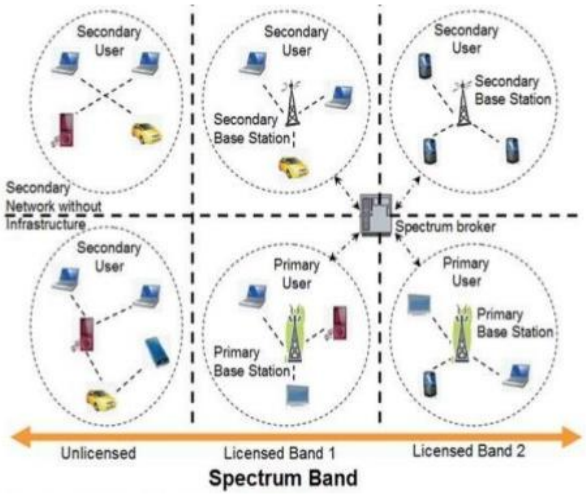

Fig.2 Cognitive Radio Network Architecture

III. FUZZY LOGIC AND NEURAL NETWORK

• Neural Network

The neural network provides a black-box model for the non-linear relationship between the inputs and the outputs. This neural network model can learn from training data which can be obtained in an on-line manner when the real-time measurement data are available. Therefore, this model is suitable for a cognitive radio network for which a prompt response to the changing radio environment is required from an unlicensed user [4].

• Fuzzy Logic

A fuzzy logic control system can be used to obtain the solution to a problem given imprecise, noisy, and incomplete input information. In short, instead of using complicated mathematical formulations, fuzzy logic uses human- understandable fuzzy sets and inference rules to obtain the solution that satisfies the desired system objectives. The main advantage of fuzzy logic is its low complexity. Therefore, fuzzy logic is suitable for real-time cognitive radio applications in which the response time is critical to system performance [4].

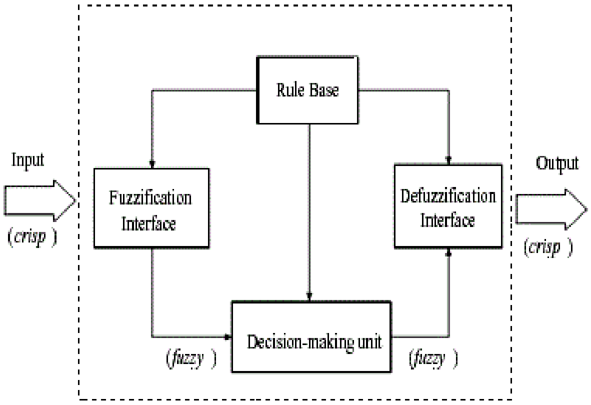

Fig.3 Basic configuration of a fuzzy logic system

In general, there are three major components in a fuzzy logic control system: fuzzifier, fuzzy logic processor, and defuzzifier. While the fuzzifier is used to map the crisp inputs into fuzzy sets, the fuzzy logic processor implements an inference engine to obtain the solution based on predefined sets of rules. Then, the defuzzifier is applied to transform the solution to the crisp output [4].

IV. METHOD TO ACHIEVE COGNITIVE RADIO GOAL

• Multi Agent System (MAS)

The association of MAS and the CR can provide a great future for the optimal management of frequencies (in comparison with the rigid control techniques proposed by the telecommunications operators). In the case of use of unlicensed bands, the CR terminals have to coordinate and cooperate to best use the spectrum without causing interference.

In [8], the authors propose architecture based on agents where each CR terminal is equipped with an intelligent agent, there are modules to collect information about the radio environment and of course the information collected

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ISSN (Print) 2319-5940

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will be stored in a shared knowledge base that will be accessed by all agents.

Agents are deployed on the user's terminals to cooperate and result in contracts governing spectrum allocation. SU agents coexist and cooperate with the PU agents in an Ad hoc CR environment using messages and mechanisms for decision making. Since the internal behaviors of agents are cooperative and selfless, it enables them to maximize the utility function of other agents without adding costs result in terms of exchanged messages.

However, the allocation of resources is an important issue in CR systems. It can be done by making the negotiation among SUs [5] [7]. In [5] the authors propose a model based on agents for the spectrum trading in a CR network. But instead of negotiating spectrum directly with the PU and SU, a broker agent is included. This means that the equipment of PU or SU does not require much intelligence as it does not need to perform the spectrum sensing. The objective of this trading is to maximize the benefits and profits of agents to satisfy the SU. The authors proposed two situations, the first uses a single agent who will exploit and dominate the network, in either case there will be several competing agents.

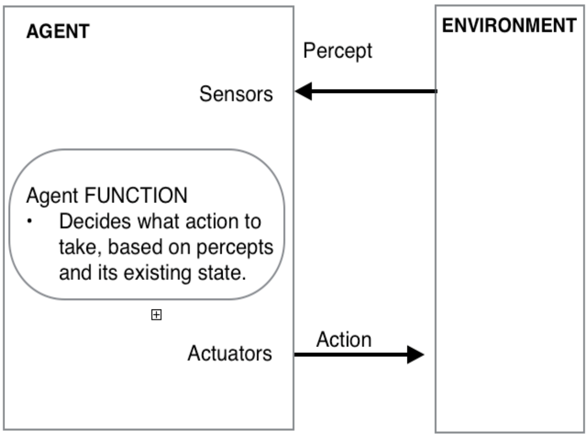

Fig. 4 Function of MAS in Cognitive Radio

The authors of [14] and [15] used the MAS to design a new cognition cycle with complex interaction between PU, SU and wireless environments and they used the hidden Markov chains to model the interactions between users and the environment. The results of this approach have shown that the algorithm can guarantee fairness among users.

What could make the use of MAS in the CR interesting and more concrete is the existence of a simulation framework to test the proposed works and approaches. This is precisely what the authors propose in [16]. Their platform allows studying the emerging aspect, the behaviors of heterogeneous CR networks.

V. PROBLEMS AND PROPOSED SOLUTION

When a mobile subscriber switches to an area where the signal quality drops to an unacceptable level due to a gap in coverage, we assume that the client uses video conferencing over the route.

• Proposed Solution

After several incidents, the CR should be aware of the problem. Then, through some geolocations or the ability to learn the time of the day when this happens, the radio can anticipate the difference in coverage and know the necessary signal to the base station to change characteristics of the signals when the user approaches the deficient coverage.

VI. APPLICATION

- Quality of Service in video conferencing

With the emergence of new services such as video conferencing and video streaming, the need to treat the frames one by one and to know how differentiate services becomes primordial.

An interactive video conferencing cannot tolerate long delays because there is not enough time to retransmit lost packets. Lost packets or very late ones are simply ignored which will cause deterioration of images and sound. With a network that provides an acceptable throughput, we should control the delay between the transmission and reception of a packet.

However, we think that CR nodes possess the necessary qualities to ensure the connection continuity of video conferencing and thus ensure a good quality of service.

In the literature, we found that to have a good QoS in video conferencing, it is necessary that:

• Throughput must be > 384 Kb/s.
• Delay must be < 200 ms.
• Packet loss must be < 1%.

However, as we don't have real data used in the CR and it is the case of the whole community, we had to play the role of the expert to assign the needed data for our simulation.

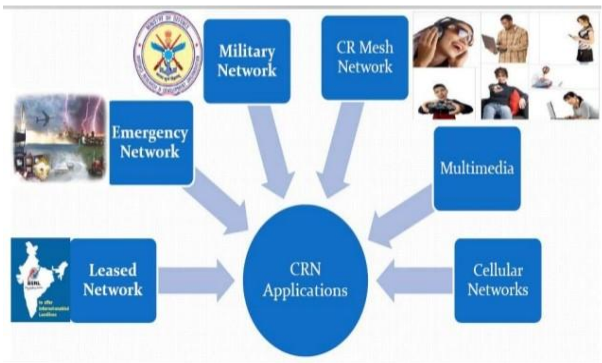

Fig. 5 Cognitive Radio Applications

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As mentioned above, we will use video conferencing in the case of a mobile user who needs to take a path where the signal quality drops to an unacceptable level due to a gap in coverage, giving a very low QoS. This can be remedied by using the CR.

VII. CONCLUSION

We presented in this paper a new approach that uses Cognitive Radio to improve wireless communication for a cognitive radio mobile terminal by enhancing the QoS of video conferencing application. Our contribution is positioned in learning from events (machine learning). Our expert role has allowed us to choose the throughput parameter to perform a classification that allows the terminal used to gain experience for future events that means that it will know when and where it will activate the cognitive radio. The usefulness of cognitive radio is a hypothesis that has been proved based on the required time for a connection to a new frequency band, and this, whatever of the number of frequency bands that a terminal used to remedy a failed connection. Different approaches using the MAS in the CR are studied, those offering cooperation between SUs only, others offer a cooperation between primary and SUs and those proposing to include a broker agent to negotiate the spectrum , knowing that the most works studied are using reinforcement learning.

In our future work, we think we can improve the wireless links reliability and ensure good quality of service to CR mobile terminals [9] [10] [11] by integrating MAS. We will seek also to reduce the impact of mobility on cognitive radio communications by building predictive models of mobility [12][13].

ACKNOWLEDGMENT

The author wish to thank their guide, parents and god for supporting and motivating for this work because without their blessing this was not possible.

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Vol. 5, Special Issue 3, November 2016

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