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Research Challenges of Cognitive Radio

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Abstract

A cognitive radio is an adaptive, multi-dimensionally aware, autonomous radio system that learns from its experiences to reason, plan, and decide future actions to meet user needs. Due to the technological advancement in last few decades, we have a magnificent communication setup now-a-days. Cognitive radio is considered to be one of the key issues to give such break-through in communication process. In this paper, we are providing a simple yet efficient overview on cognitive radio and the existing research challenges, which will help the researchers around the globe to grab the concept of cognitive radio fast enough and work on it.

1. Introduction

It has been observed that, in some locations or at some time period of the day, 70 percent of the allocated spectrum may be sitting idle. FCC [1] has recommended that significantly greater efficiency could be realized be developing wireless devices that can coexist with the primary users, generating minimal interference while taking advantage of the available resources. A novel class of radio, that is able to reliably sense the spectral environment over a wide bandwidth, detects the presence/absence of primary users and use the spectrum only if the communication does not interfere with primary users is defined by the term cognitive radio. Cognitive radios integrate radio technology and networking technology to provide efficient use of radio spectrum. Cognitive radio network is a complex multiuser wireless communication system capable of emergent behavior [2]. Cognitive radio wireless network is considered as an advanced technology integration environment with focus on building adaptive, spectrum-efficient systems with emerging programmable radio. The idea of cognitive radio extends the concepts of a hardware radio and a software defined radio from a simple, single function device to a radio that senses and reacts to its operating environment. The main feature of cognitive radio is their ability to recognize their communication environment and independently adapt the parameters of their communication scheme to maximize the quality of service for the secondary users [3].

In cognitive radio cycle a cognitive radio monitors spectrum bands, captures their information and then detects the spectrum spaces. The characteristics of the spectrum spaces that are detected through spectrum sensing are estimated. Then, the appropriate spectrum band is chosen according to the characteristics and user requirements. Once the operating spectrum band is determined, the communication can be performed over this spectrum band.

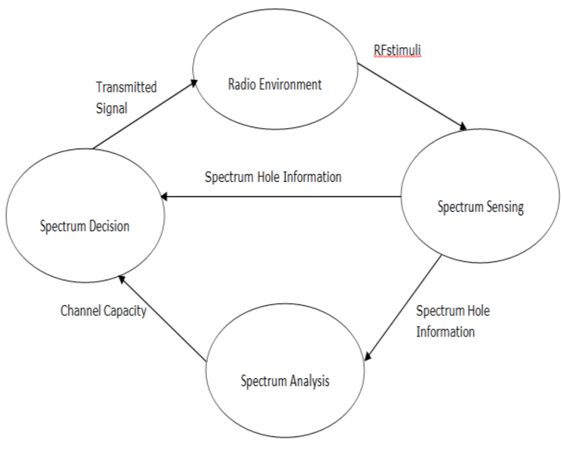

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Figure 1: Cognitive Radio Cycle

2. Cognitive Radio Functions & Primary Objectives

Cognitive radio embodies the following functions:

a) It perceives the radio environment by empowering each user's receiver to sense the environment on a continuous time basis
b) It learns from the environment and adapts the performance of each transceiver to statistical variations in the incoming RFstimuli.
c) Facilitates communication between multiple users through cooperating in a self-organized manner.
d) To control the communication process among competing users through the proper allocation of available resources.
e) To create the experience of intention and self-awareness.

Primary objectives of cognitive radio networks:

I. Facilitate efficient utilization of the radio spectrum in a fair-minded way.
II. To provide highly reliable communication for all users of the network.

3. General Operations

There are three basic areas of radio operation where cognitive radio can make an immediate impact are human-machine interface, radio-centric operations and network-centric operations.

- In HMI area, cognitive radio technology can provide a level of automation that can simplify the user interface to a complex device.
- For radio-centric operations, the adaptive RF signal-in-space formation and adaptive modulation provide adaptation capabilities under cognitive control that could improve system performance based on observed conditions.
- Network-centric applications of cognitive radio could include the autonomous selection of network membership (e.g., 3G/Wi-Fi hotspot/WiMax) where the cognitive device anticipates the need to hand-off based on prior experience rather than simply by following predefined algorithms based solely on signal level. That implies, the device recognizes that it regularly traverses the same path and over time, learns when it is going to enter a "bad spot" and reasons to hand off to a different system before the outage occurs.

4. Research Challenges

In this section, there will be an extensive discussion on the research challenges of cognitive radio. To simplify this concept, we point out the core challenges of cognitive radio.

4.1 Spectrum Sensing

Spectrum sensing has been identified as a key enabling cognitive radio to not interfere with primary users, by reliability detecting primary user signals. So, sensing requirements are based on primary user modulation type, power, frequency and temporal parameters. It is often considered as a detection problem. Many techniques were developed in order to detect the holes in the spectrum band. Focusing on each narrow band, existing spectrum sensing techniques are widely categorized into energy detection[4] and feature detection[5]. However, the performance of the energy detector is susceptible to unknown or changing noise levels and interference. In addition, the energy detector does not differentiate between modulated signals, noise and interference but can only determine the presence of the signal. It does not work if the signal is direct-sequence or frequency hopping signal, or any time varying signal. On the other hand cyclostationary models have been shown in recent years to offer many advantages over stationary models. Thus, cyclostationary feature detection performs better than energy detector. But, it is computationally complex and requires significantly long observation time[6]. The biggest challenge regarding sensing is in developing sensing techniques which hare able to detect every weak primary signal while being sufficiently fast and low cost to implement.

4.2 Advance Spectrum Management

Cognitive radios have a great potential to improve spectrum utilization by enabling users to access the spectrum dynamically without disturbing licensed primary radios. A key challenge in operating these radios as a network is how to implement an efficient medium access control mechanism that can adaptively and efficiently allocate transmission powers and spectrum among Cognitive radios according to the surrounding environment. Most existing works address this issue via suboptimal heuristic approaches or centralized solutions [7].

4.3 Unlicensed Spectrum Usage

It is this discrepancy between FCC allocations and actual usage, which indicates that a new approach to spectrum licensing is needed [8].What is clearly needed is an approach, which provides the incentives and efficiency of unlicensed usage to other spectral bands, while accommodating the present users who have higher priority (primary users) and enabling future systems a more flexible spectrum access.

4.4 Spectrum sharing strategies

Spectrum sharing is allocation of an unprecedented amount of spectrum that could be used for unlicensed or shared services. Opportunistic communication with interference avoidance faces a multitude of challenges in the detection of sharing in multi-user cognitive radio systems. Because of the presence of user priority (primary and secondary), they pose unique design challenges that are not faced in conventional wireless systems. A major issue in a multiple secondary user environment is sharing, a topic that has generated a lot of research interest in the recent past [9] [10]

4.5 Hidden node and sharing issues

Cognitive radio sensitivity should outperform primary user receivers by a large margin in order to prevent what is essentially a hidden node problem of Secondary User Primary User Unused band cognitive radios to ensure cognitive radios do not interfere with each other [11].

4.6 Trusted access and security

With increased focus over the past few years on system security and survivability, it is important to note that distributed intelligent systems, such as cognitive radio, offer benefit in the event of attacks. Intelligence and military application require application-specific secure wireless systems [12] [13].

4.7 Cross-layer design

The flexibility of cognitive radios has significant implications for the design cross layer algorithms which adapt to changes in physical link quality, radio interference, radio node density, network topology or traffic demand may be expected to require an advanced control and management framework with support for cross-layer information [14][15]. Spectrum handoff and mobility management will face some new challenges which are required to do a cross-layer design, especially when required providing the necessary capabilities in terms of quality of service at the same time.

4.8 Hardware and Software architecture

The potential for Cognitive radio is a novel efficient methodology, extension of software-defined radio, to transmit and receive information over various wireless communication devices [16]. According to the existing operators in the environment, Cognitive radio chooses the best available option based on performance for each application. The different performance measuring parameters include frequency, power, antenna, transmitter bandwidth, modulation and coding schemes etc. This means that the radio has to deal with different radio frequencies spectrum and baseband varieties at the same time, thus requiring a more robust, efficient and reconfigurable hardware and software architecture.

5. Conclusion

Cognitive radio is already being considered as the candidate for the 5th generation of wireless communications. The study of the cognitive radio will be one of the most influential scientific endeavors in the 21st century. This paper presents some of the cognitive radio research challenges which are crucial while applying the cognitive radios in order to determine the effectiveness and reliability of wireless networks. Existing methods in a wide ranging wireless environment are not considered to be the most reliable methods and so more research is needed to overcome the challenges specified in this paper.

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