A Review on Spectrum Sensing and Management under Wireless Cognitive Radio Networks

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Abstract: ***With the rapid deployment of new wireless devices and applications, the last decade has witnessed a growing demand for wireless radio spectrum. However, the fixed spectrum assignment policy becomes a bottleneck for more efficient spectrum utilization, under which a great portion of the licensed spectrum is severely under-utilized. The inefficient usage of the limited spectrum resources urges the spectrum regulatory bodies to review their policy and start to seek for innovative communication technology that can exploit the wireless spectrum in a more intelligent and flexible way. The concept of cognitive radio is proposed to address the issue of spectrum efficiency and has been receiving an increasing attention in recent years, since it equips wireless users the capability to optimally adapt their operating parameters according to the interactions with the surrounding radio environment. There have been many significant developments in the past few years on cognitive radios. This paper surveys recent advances in research related to cognitive radios. The fundamentals of cognitive radio technology, architecture of a cognitive radio network and its applications are first introduced. The existing works in spectrum sensing are reviewed, and important issues in dynamic spectrum allocation and sharing are investigated in detail***

Keywords: Cognitive radio (CR), platforms and standards,radio spectrum management, software radio, spectrum sensing,wireless communication

1. Introduction

Current wireless networks are characterized by a static spectrum allocation policy, where govern mental agencies assign wireless spectrum to license holders on a long-term basis for large geographical regions. Recently, because of the increase in spectrum demand, this policy faces spectrum scarcity in particular spectrum bands. In contrast, a large portion of the assigned spectrum is used sporadically, leading to underutilization of a significant amount of spectrum [1].Hence, dynamic spectrum access techniqueswere recently proposed to solve these spectrum inefficiency problems.

The key enabling technology of dynamic spectrum access techniques is cognitive radio (CR) technology, which provides the capability to share the wireless channel with licensed users in an opportunistic manner. CR networks are envisioned to provide high bandwidth to mobile users via heterogeneous wireless architectures and dynamic spectrum access techniques. This goal can be realized only through dynamic and efficient spectrum management techniques. CR networks, however, impose unique challenges due to the high fluctuation in the available spectrum, as well as the diverse quality of service(QoS) requirements of various applications.In order to address these challenges, each CRuser in the CR network must:

Determine which portions of the spectrum are available
• Select the best available channel
• Coordinate access to this channel with other users Vacate the channel when a licensed user is detected [2]

These capabilities can be realized through spectrum management functions that address four main challenges spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility

This article presents a definition, the functions, and the current research challenges of spectrum management in CR networks. More specifically, we focus our discussion on the development of CR networks that require no modification in existing networks. An overview of CR technology is provided, and the CR network architecture is presented. We explain the concept of spectrum management and the required functionalities. Then we describe spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility concepts.

2. Cognitive Radio Technology

The key enabling technologies of CR networks are the cognitive radio techniques that provide the capability to share the spectrum in an opportunistic manner. Formally, a CR is defined as a radio that can change its transmitter parameters based on interaction with its environment[1]. From this definition, two main characteristics of cognitive radio can be defined [3]:

Cognitive capability: Through real-time interaction with the radio environment, the portions of the spectrum that are unused at a specific time or location can be identified. As shown in Fig. 1a, CR enables the usage of temporally unused spectrum, referred to as **spectrum** hole or white space Consequently, the best spectrum can be selected, shared with other users, and exploited without interference with the licensed user.

Cognitive radios have many advantages where the no.of users is high:
- More efficient use of the spectrum
- Ensures connectivity

- They are aware of their surroundings and bandwidth availability and are able to dynamically tune the spectrum usage based on location, nearby radios, time of day
- Reduced power consumption
- Enabling high priority communications to take prece dence if needed
- Unlimited internet access.

Although cognitive radio was initially thought of as a software-defined radio extension (Full Cognitive Radio), most of the research work is currently focusing on Spectrum Sensing Cognitive Radio, particularly in the TV bands. The essential problem of Spectrum Sensing Cognitive Radio is in designing high quality spectrum sensing devices and algorithms for exchanging spectrum sensing data between nodes. It has been shown that a simple energy detector cannot guarantee the accurate detection ofsignal presence, calling for more sophisticated spectrum sensing techniques and requiring information about spectrum sensing to be exchanged between nodes regularly. Increasing the number of cooperating sensing nodes decreases the probability of false detection [7]. Filling free radio frequency bands adaptively usingOFDMA is a possible approach. Timo A. Weiss and Friedrich K. Jondral of the University ofKarlsruhe proposed a Spectrum Pooling system in which free bands sensed by nodes were immediately filled by OFDMA subbands. Applications of Spectrum Sensing Cognitive Radio include emergency networks and WLAN higher throughput and transmission distance extensions.

3. Research Challenges

Developments of cognitive radio are related to many research challenges like:

- Detecting interference at primary receiver - primary goal of cognitive radio is to protect primary system from interference, up to now there is not feasible method of detecting influence of cognitive radio at primary receiver due to its passive nature,
- Speed and reliability of detection - complete cognitive cycle of cognitive radio is happening in real time, therefore it is essential to develop reliable and fast methods of spectrum awareness,
- Spread spectrum detection - primary users using spread spectrum are difficult to detect as the power of the primary user is distributed over a wide frequency range, possibly hidden in the noise,
- Hidden node problem - there is danger of not detecting working primary system due to possible shadowing effect or multipath fading in propagation between primary transmitter and sensing receiver,
- Learning and intelligence - appropriate models of artificial intelligence, bio inspired intelligence and machine learning methods have to be embedded in cognitive radio in order to fulfil its demanding tasks,
- Multi-multi environment - most of cognitive radio will have to autonomously work in multi-service, multi-technology and multi-user environment, it remain to be seen how cognitive radio can work and adapt in this challenging environment without causing chaos,disorder and anarchy,
- Vertical and horizontal sharing of radio spectrum - cognitive radio has to protect the operation of primary licensed radio services (vertical sharing) and also to overcome the problem of co-existence with other secondary use devices (cognitive devices and others),
- Spectrum space opportunities - cognitive radio is primarily focusing on frequency efficiency, but to achieve efficient usage of natural resources, all dimensions of radio spectrum space as a theoretical hyperspace have to be used efficiently,
- Spectrum mobility - cognitive radio have to vacate spectrum when primary user begins to transmit, therefore cognitive radio have to switch its operating frequency from one spectrum hole to another while preferably not interrupting data transmission,
- Transmission power control - have to find right balance between cognitive radio self-goal of achieving maximum data rate and altruistic network or community goal leaving enough opportunities for other secondary devices,
- Hardware requirements - cognitive radio must be capable of spectrum sensing and operating over wide radio spectrum range, emulate many radio technologies and different modulation schemes, which causes various hardware challenges.

4. Discussion

Radio system founded on cognitive radio technology is challenging and promising concept, leading to new directions in developments of wireless communications and leap progress in radio spectrum usage efficiency. It is seen as a groundbreaking and founding technology of future wireless systems. Nevertheless, cognitive radio is not a magic wand which will instantly solve radio spectrum scarcity problems, liberate all the frequency bandsand abrogate radio spectrum regulation. As we look in the future, we see that cognitive radio has the potential for making a significant difference in the way how the radio spectrum can be accessed and used by wireless systems However, cognitive radio is still in its infancy. Development of cognitive radio systems are cross related and dependent to developments in many different technical and non-technical areas like: software defined radio, digital signal processing, artificial intelligence and machine learning, but also bioinspired intelligence, social group behaviour, economical studies, etc. Emergence of full cognitive radio capable radio system is still years, even decades far away from practical realization. What we currently see is: many research advances in the area and gradual implementation of various cognitive radio related technological concepts in modern communication systems. Even if only thirty percent of predicted cognitive radio system functionalities will be realized in radio devices in the forthcoming years, this would bring significant advances to future wireless communications systems

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