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A Review of Cognitive Radio (CR) Technology Application, Prospect and Challenges

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ABSTRACT

Cognitive Radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not. It instantly moves into vacant channels while avoiding occupied ones. It does not cause any interference to the licensed user. Thus, CR is widely regarded as one of the most promising technologies for future wireless communications. Cognitive radio (CR) technology has great potential to alleviate spectrum scarcity in wireless communications. It allows secondary users (SUs) to opportunistically access spectrum licensed by primary users (PUs) while protecting PU activity. Spectrum sensing is one of the most important functionalities of Cognitive Radios cycle discussed in this paper. This paper presents a review of cognitive radio technology applications, prospects, and challenges with focus on radio frequency (RF) section. We summarize the status of the related regulation and standardization activities which are very important for the success of any emerging technology. We point out some key research challenges, especially implementation challenges of cognitive radio (CR), Advantages and Disadvantages. A particular focus is on RF front-end, transceiver, and analog-to-digital and digital-to-analog interfaces which are still a key bottleneck in CRS development.

Key words: Dynamic spectrum access; software-defined radio; intelligent wireless communication system; radio frequency

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1. INTRODUCTION

Cognitive Radios (CR)

The term "Cognitive Radio" (CR) was coined by JoeMitola in 1999-2000, in a number of publications and in his PhD thesis. The term was intended to describe intelligent radios that can autonomously make decisions using gathered information about the RF environment through model-based reasoning, and can also learn and plan according to their past experience. Clearly, such a level of intelligence requires the radio to be self-aware, as well as content and context-aware [1]. Moreover, Haykin defines CR as a radio capable of being aware of its surroundings, learning, and adaptively changing its operating parameters in real-time with the objective of providing reliable anytime, anywhere, and spectrally efficient communication [2].

The term CR is defined in as follows: “Cognitive radio is an intelligent wireless communication system that is aware of its ambient environment. A cognitive radio transmitter will learn from the environment and adapt its internal states to statistical variations in the existing RF stimuli by adjusting the transmission parameters (e.g., frequency band, modulation mode, and transmission power) in real- time and on-line manner.” This definition essentially captures the fundamental concept behind CR. A cognitive radio network (CRN) enables us to establish communications among CR nodes/users. The communication parameters can be adjusted according to the change in the radio environment, topology, operating conditions, or user requirements. Two main objectives of the CR are to improve the utilization of the frequency spectrum and to achieve the highly reliable and highly efficient wireless communications.

The concept of Cognitive Radio (CR) appeared as a new paradigm in 1999 as an extension of Software Defined Radio (SDR). It describes the situation where intelligent radio devices and associated network entities communicate in such a manner that they are able to adjust their operating parameters according to the needs of the user/network, and learning from experience since then, there has been a significant amount of effort in the research community on CR-related topics.Cognitive radio networks can be designed to manage the radio spectrum more efficiently by utilizing the spectrum holes in primary users licensed frequency bands. In this way, spectrum utilization efficiency is dramatically enhanced.Cognitive Radio (CR) is a paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users.Interference management can be described as a technique or process employed for the control and mitigation of interference. It can be further described as a scheme for interference cancellation, avoidance or reduction in a system. Several mitigation techniques are available to address interference issue in the broadcast industry. Based on recent contributions in both academia and industry, the various interference mitigation techniques may be categorized into the family of active and passive approaches. Interference cancellation and suppression are referred to as the Passive Approach while interference avoidance and the usage of Smart antennas (CR Technology) are regarded as Active approach [3].

The cognitive radio is, therefore, an accelerating trend of the current wireless technology research.CR is built on SDR technology. It represents an SDR with not only the ability to adapt to spectrum availability, protocols, and waveforms but the capability to learn waveforms and protocols, to adapt to local spectrum activity, and to learn the current needs of its user. CR can be defined as “An intelligent wireless communication system that is aware of its surrounding environment” (i.e., outside world). One of the most important components of the cognitive radio concept is the ability to measure, sense, learn, and be aware of the parameters related to the radio channel characteristics as depicted in Fig. 1. Cognitive radio technique is the next step toward efficient wireless bandwidth utilization.

Fig. 1 Basic function of a Cognitive Radio

We postulate that cognitive radio offers the ability to manage interference situation more effectively by utilizing the ability to sense the actual propagation conditions that occur, and to adjust the radio dynamically to best fit these conditions. To do this, we distinguish between two radio operating objectives. In the first, the radio attempts to minimize its own spectral “footprint,” consistent with the environment and needs of the networks it supports. In the second, it adapts itself to fit within whatever spectrum is available, based on local spectral analysis.

BASIC COGNITIVE RADIO CYCLE

Analog-to-Digital Converters

The rate of technology improvement versus time has not been as profound for A/D converters as for digital logic. The digital receiver industry is always looking for wider bandwidth and greater dynamic range. Successive approximation ADCs were replaced by flash converters in the early 1990s, and now are generally replaced with sigma-delta ADCs. Today’s ADC can provide up to 105 Msps at 14-bit resolution. Special-purpose ADCs have been reported to provide sample rates over 5 Giga samples per second (Gsps) at 8-bit resolution. State-of-the-art research continues to push the boundaries of analog-to-digital (A/D) performance with a wide variety of clever techniques that shift the boundaries between DSP and ADC. The CR is a “smarter radio” inthe sense that it can sense channels that contain signalsfrom a large class of heterogeneous devices, networks, and services. On the basis of this sensing, the radio willimplement sophisticated algorithms to share the limited bandwidth channel with other users in order to achieveefficient wireless communication as shown in figure 2.

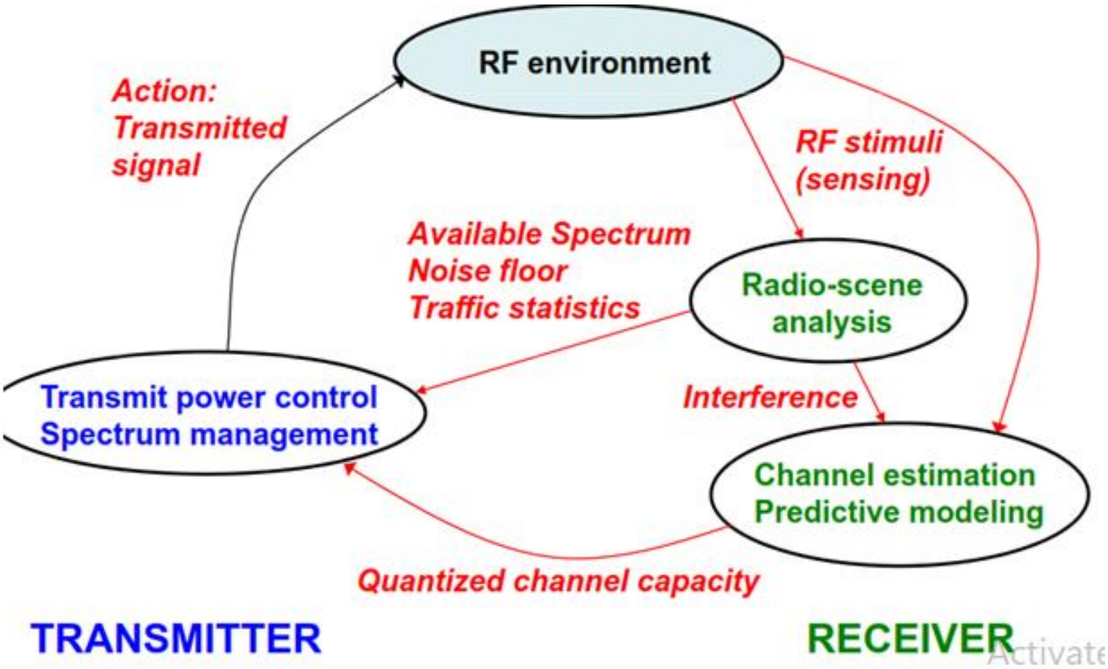

Fig. 2 Basic Cognitive Radio Cycle

The major tasks of the cognitive radio can be characterized with the cognitive cycle. This cycle implements the capabilities required of CR in a reactive sequence. Stimuli enter the CR as sensory interrupts, dispatched to the cognitive cycle for a response. Such a CR continually observes (senses and perceives) the environment, orients itself, creates plans, decides, and then acts. The CR observes its environment by passing incoming information streams.

Techniques used include:- Observe (Sense and Perceive);- Orient;- Plan;- Decide;- Act; and – Learning as demonstrated in figure 2.

The CRconcept generalizes the idea of multiple access involvingdevices in a single homogeneous system to multiple accessamong devices in different radio spectrums using differentradio transmission techniques and hence different systems (i.e., inter-system multiple access as opposed to the moretraditional intra-system multiple access), which havedifferent priorities in accessing the spectrum.

Cognitive RadioClassification

Depending on transmission and reception parameters, thereare two main types of cognitive radio:

- Full Cognitive Radio (or Mitola radio): In which everypossible parameter observable by a wireless node (ornetwork) is considered.
- Spectrum-Sensing Cognitive Radio: In which only theradio-frequency spectrum is considered.

Other types are dependent on parts of the spectrumavailable for cognitive radio:

- Licensed-Band Cognitive Radio: It is capable of usingbands assigned to licensed users such as the UNIIband or the ISM band. The IEEE 802.22workinggroup is developing a standard for wireless regionalarea network (WRAN), which will operate on unusedtelevision channels.
- Unlicensed-Band Cognitive Radio: Which can onlyutilize unlicensed parts of the radio frequency (RF) spectrum. One such system is described in the IEEE802.15 Task Group 2 specifications, which focus onthe coexistence of IEEE 802.11 and Bluetooth.

Cognitive Radio Features

The increased availability of SDR platforms is spurring developments in CR. The necessary characteristics of a SDR required to implement a practical CR are excess computing resources, controllability of the system operating parameters, affordability, and usable software development environments including standardized Application Programming Interfaces (APIs) [4]. The CR features are as follows:

- ✓ Frequency Agility
- ✓ Dynamic Frequency Selection (DFS)
- ✓ Location Awareness
- ✓ Negotiated Use
- ✓ Adaptive Modulation
- ✓ Transmit Power Control (TPC)

Implementation Challenges

Although the theoretical research for CRS is blooming, with many interesting results, hardware implementation and system development are progressing at a slower pace, because of the complexities involved in designing and developing CRS. In this section, we present the implementation challenges of CR in the system on chip (SoC) integration's perspective. The first SDR architecture was proposed by Mitola and Maguire, in which the RF and analog processing are reduced to only a pair of data converters, thus providing the maximum flexibility and programmability through the digital processing block [1]. This idealistic approach, however, suffers from the poor tolerance of to the interferers. In many wireless applications, a small desired signal could be accompanied by several large in-band signals created by nearby transmitters of the same communication standard or out-of-band blockers caused by any transmitter. RF Front-Ends Transceiver Challenges, ADC and DAC Challenges, Baseband Challenges and Spectrum sensing.

Technical challenges

• Programmable multirate baseband architectures
• Wide, multiple and flexible RF front-ends
• High-performance and flexible ADC/DAC
• Dynamic signal processing
Spectrum sensing, channel estimation, MIMO, modulation and coding, spectrum shaping, transmitpower control, interference avoidance
• Cognitive wireless network etiquette: Sense, discover, negotiate, transfer,

PROSPECTS OR BENEFITS OF COGNITIVE RADIO

Following are the benefits or advantages of Cognitive Radio:

- ❖ It offers better spectrum utilization and efficiency.
- ❖ It improves link reliability.
- ❖ It is lower in cost.
- ❖ It uses advanced network topologies.
- ❖ It has simple network architecture.
- ❖ It is easy in configuration and easy to upgrade.
- ❖ It is less in complexity.
- ❖ Overcome radio spectrum scarcity.
- ❖ Avoid intentional Radio jamming scenarios.
- ❖ Switch to power saving protocol.
- ❖ Improve satellite communications.
- ❖ Improves quality of Service (QoS).

DRAWBACKS OR DISADVANTAGES OF COGNITIVE RADIO

Following are the disadvantages of Cognitive Radio:

- ✓ There is no complete automation and it requires user intervention for any changes to be implemented.
- ✓ It always requires multi band antenna.
- ✓ Security concern: There are more chances open for attackers in cognitive radio technology compare to traditional wireless networks. The data may be eavesdropped or altered without notice. The channel might be jammed or overused by the adversaries.
- ✓ Quality of Service (QoS) in Cognitive radio is affected due to its adverse effects.
- ✓ Translation of observations into actions is a big challenge in cognitive radio.
- ✓

CONCLUSION

Cognitive Radios are intelligent devices with ability to sense environmental conditions and can change its parameters according to the requirements to get the optimized performance at the individual nodes or at network level. Thus, CR is widely regarded as one of the most promising technologies for future wireless communications. Cognitive radio (CR) technology has great potential to alleviate spectrum scarcity in wireless communications. It allows secondary users (SUs) to opportunistically access spectrum licensed by primary users (PUs) while protecting PU activity. Spectrum sensing is one of the most important functionalities of Cognitive Radios cycle discussed in this paper. We pointed out some key research challenges, especially implementation and Technical challenges of cognitive radio (CR), Advantages and Disadvantages. A particular focus is on RF front-end, transceiver, and analog-to-digital and digital-to-analog interfaces which are still a key bottleneck in CRS development.

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