Cognitive Radio-The New Paradigm in the History Of Wireless Communication

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Abstract: ***Cognitive radio has been considered as the key technology for further wireless technology & mobile computing. In this paper we are focusing that how cognitive radio can form cognitive radio network (CRN) by extending radio link features to the network layer. We also focus how cognitive transceiver is designed to use the best wireless channel vicinity.***

1) Introduction

Cognitive radio is the new paradigm of designing wireless communication systems which aims to enhance the utilization of radio frequency (RF) spectrum. The motivation behind cognitive radio is the scarcity of available frequency spectrum increasing demand cause by the immerging wireless applications for mobile users. A cognitive radio is an intelligent radio that can be programmed and configure dynamically that monitors & senses its radio environment for potential environment opportunities.

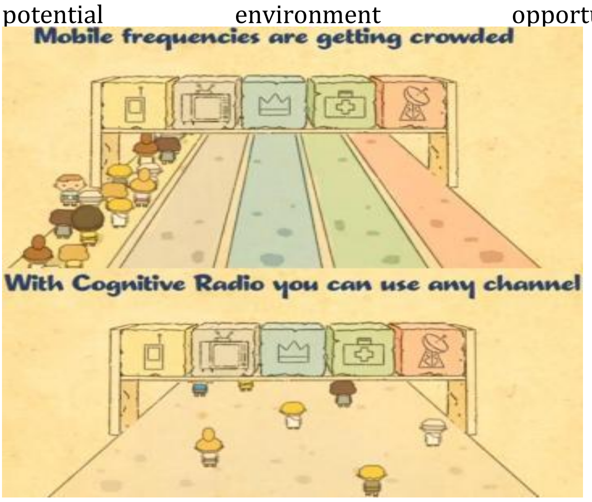

Fig 1-frequency utilization in congnitive radio

2) Implementation

Cognitive radio can be implemented completely on the reconfigurable hardware. Implementation consists of two different parts: Hardware implementation & Software implementation. In following section we are giving brief description of these two types of implementation.

2.1 Hardware Implementation

Depending on the information sensed by the sensors, functionality of the CR can be changed. It can be implemented on the reconfigurable hardware like ASIC and FPGA. Though it can be implemented on ASIC successfully but limitation of such implementation is that such architecture is not flexible because ASIC is a onetime programmable chip. FPGA provides a better solution to this problem. It is flexible enough and can be programmed multiple times. Functionality of the modules as well as of the architecture can be changed even after implementation on the FPGA platform. Using different instructions the same FPGA can be tuned to different applications. Moreover, some FPGA supports partial reconfiguration. Therefore, CR can be implemented on FPGA at running time and its functionality can be changed at a later stage depending on the requirements. Parameters which control the functionality of the components can also be changed at a later stage. It adds flexibility to the implementation techniques.

2.2 Software Implementation

Implementation of CR on the reconfigurable hardware can be done with the help of a set of software instructions. Reconfigurable hardware's can be tuned to a specific application by means of software instructions only. CR can implement complex algorithms. Designers use C++ languages for implementation of such algorithms. For hardware implementation, other programming languages, like VHDL and Verilog can be used. These are hardware programming language used to program the reconfigurable hardware to tune to a specific application. After compilation, VHDL / Verilog programs generate executable codes known as 'software bit stream'. These bit streams are downloaded on the hardware to configure it to a specific application. Once configured, static architecture is sufficient and works fine. Reconfiguration is required only when the CR senses the surrounding environment and decides that accordant changes in the configuration is required to maintain a balance with the outside world. These changes must be made with extreme care and intelligence. To achieve this goal both hardware and software implementations are required.

3) Types of Cognitive Radios

3.1 Full Cognitive Radio (or Mitola radio): In which every possible parameter observable by a wireless node (or network) is considered.

3.2 Spectrum-Sensing Cognitive Radio: In which only the radio frequency spectrum is considered.

Other types are dependent on parts of the spectrum available for cognitive radio

Licensed-Band Cognitive Radio: It is capable of using bands assigned to licensed users such as the UNII band or the ISM band. The IEEE 802.22working group is developing a standard for wireless regional area network (WRAN), which will operate on unused television channel.

Unlicensed-Band Cognitive Radio: This can only utilize unlicensed parts of the radio frequency (RF) spectrum. One such system is described in the IEEE 802.15 Task Group 2 specifications, which focus on the coexistence of IEEE 802.11 and Bluetooth.

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4) Spectrum Utilization in Cognitive Radio

Some of the most common spectrum sensing techniques in the cognitive radio is:

Energy Detector Based Sensing: Energy detector based approach which is also known as radiometry or periodogram, is the most common way of spectrum sensing because of its low computational and implementation complexities. It is more generic method as receivers do not need any knowledge on the primary users' signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor.

Waveform-Based Sensing: Patterns known are usually utilized in wireless systems to assist synchronization or for other purposes. A preamble is a known sequence transmitted before each burst and a midamble is transmitted in the middle of a burst or slot. In the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself. This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing or coherent sensing.

Cyclostationarity-Based Sensing: Cyclostationarity feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of the received signals. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing.

. **Matched-Filtering Technique:** Matched-filtering is known as the optimum method for detection of primary users when the transmitted signal is known. The main advantage of matched filtering is the short time to achieve a certain probability of false alarm or probability of misdetection as compared to other methods. Matched-filtering requires cognitive radio to demodulate received signals. Hence, it requires perfect knowledge of the primary users signaling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame form.

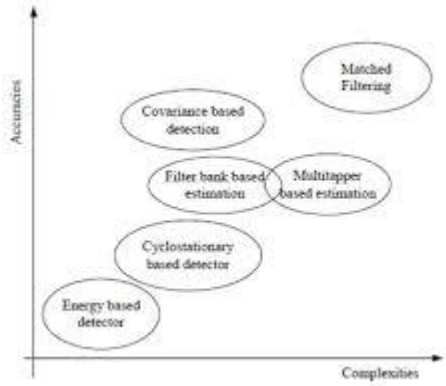

Fig 2:Spectral sensing methods for cognitive radio

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5) Spectrum sensing

Spectrum Sensing A major challenge in cognitive radio is that the secondary users need to detect the presence of primary users in a licensed spectrum and quit the frequency band as quickly as possible if the corresponding primary radio emerges in order to avoid interference to primary users. This technique is called spectrum sensing. Spectrum sensing and estimation is the first step to implement Cognitive Radio system. We can categorize spectrum sensing techniques into direct method, which is considered as frequency domain approach, where the estimation is carried out directly from signal and indirect method, which is known as time domain approach, where the estimation is performed using autocorrelation of the signal. Another way of categorizing the spectrum sensing and estimation methods is by making group into model based parametric method and periodogram based non parametric method.

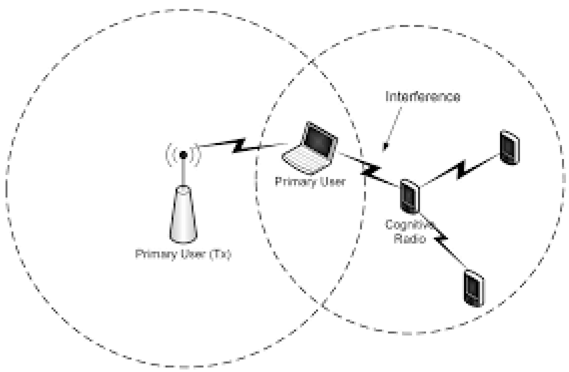

Fig 3: Spectrum sensing in cognitive radio

5.1 Spectrum sensing for spectrum opportunities:-

a. Primary transmitter detection: In this case, the detection of primary users is performed based on the received signal at CR users. This approach includes matched filter (MF) based detection, energy based detection, covariance based detection, waveform based detection, cyclostationary based detection, radio identification based detection and random Hough Transform based detection.

b. Cooperative and collaborative detection: In this approach, the primary signals for spectrum opportunities are detected reliably by interacting or cooperating with other users, and the method can be implemented as either centralized access to spectrum coordinated by a spectrum server or distributed approach implied by the spectrum load smoothing algorithm or external detection.

6) Functions

The main functions of cognitive radio (CR) are:-

a. **Power Control:** Power Control is usually used for spectrum sharing CR systems to maximize the capacity of secondary users.
b. **Spectrum Sensing:** Detecting unused spectrum & sharing it without harmful interface to other user; an important requirement to cognitive radio network. Detecting primary user is the most efficient way to detect empty spectrum.
c. **Transmitter Detection:** Cognitive radio must have the capability to determine if a signal from primary transmitter is locally present in a certain spectrum.
d. **Wide Band Spectrum Sensing:** Refers to spectrum sensing over large spectral bandwidth typically 100 of MHz or even several GHz.
e. **Spectrum Management:** Capturing the best available spectrum to meet user communication requirements while not creating undue interface to other users.

7) Cognitive Radio(CR) v/s Intelligent antenna(IA):

POINT	Cognitive Radio(CR)	Intelligent Antenna(IA)
Principal goal	Open spectrum sharing	Ambient spectral reuse
Key cost	Spectral sensing &multi band rf	Multi or cooperative-antenna arrays
Applied technique	Cognitive software radio	Generalized dirty paper coding
Basement approach	Orthogonal modulation	Cellular based smaller cells

8) Applications:

- A cognitive radio intelligently detect whether any portion of spectrum is in use,& can temporarily use it without interfering with the transmission of other users.
- Cognitive radio senses its environment & without the intervention of the user can adapt the user communication need while confirming the fcc rules.
- It provides wireless spectrum users with the ability to adapt the real time spectrum conditions.

9) Future planes:

The success of the unlicensed band in accommodating a range of wireless devices and services has led the FCC to consider opening further bands for unlicensed use. In contrast, the licensed bands are underutilized due to static frequency allocation. Realizing that CR technology has the potential to exploit the inefficiently utilized licensed bands without causing interference to incumbent users; the FCC released a Notice of Proposed Rule Making which would allow unlicensed radios to operate in the TV-broadcast bands.

Technical challenges in cognitive radio:

Research Challenges:

CRS covers multidisciplinary areas attracting a large number of research works with many interesting obtained results. The challenges remain numerous, namely, intelligence distribution and implementation, delay/protocol overhead, cross-layer design, security, sensing algorithms, and flexible hardware design. Due to the huge amount of published papers and the interdisciplinary nature of the topic, it is very difficult to provide an exhaustive analysis of all research works available on CRS. The purpose of this section is therefore to briefly describe challenges which are yet open and current under debate in the framework of research on CRS.

- **Decision Making:**

As CRS is driven by a decision making, the first relevant research challenge is where and how the decision (e.g., the decision on spectrum availability, strategy for selecting channel for sensing or access, or how to optimize radio performance) should be taken. The first issue is directly related to whether the cognitive process should be implemented in a centralized or distributed fashion. This aspect is more critical not only for cognitive networks, where intelligence is more likely to be distributed, but also for cognitive radios, as decision making could be influenced by collaboration between them and also with other devices. The second issue is the choice of the decision algorithms.

Security:

The challenges of employing CRS include that of ensuring secure devices operations. Security in this context includes enforcement of rules. Enforcement for static systems is already a challenge due to the amount of resources necessary to authorize equipment, the requirement of obtaining proof that violations have occurred, and the determination of the violator' identities. As the systems become more dynamic, there is an increase in the number of potential interaction that can lead to a violation. Additionally, this leads to a decrease of the time and special scales of these interactions. Both of these changes will amplify the enforcement challenges.

The first issue is on equipment authorization, especially on evaluation criteria and security certification. It becomes even more problematic with the employment of self-learning mechanisms. Software and hardware certification will not provide sufficient assurances that the device conforms to the operational envelopes.

Software certification and the security of the software are also challenging area, especially when software provides the control of dynamic systems. The security of that software is critical to ensure that rogue behaviour is not programmed into the devices.

The number of combination of interactions is high and the mobility and the agility of CRS is great, so the monitoring mechanisms are challenging tasks.

9) Conclusion:

This paper presented an overview of basic cognitive radio & its standards. In order to fully utilize the scarce spectrum resources, with a development of cognitive radio (CR) technologies, dynamic spectrum sharing becomes a promising approach to increase the efficiency of spectrum usage. Cognitive radio, which is one of the efforts to utilize the available spectrum more efficiently through spectrum usage has become an exciting & promising concept. herby we increase the efficiency of spectrum utilization. This method is called as dynamic spectrum access(DSA).

Fig 4 cognitive radio interaction with other frequencies.

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