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Cognitive Radio, Its Applications and Architecture

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ABSTRACT---The main problem of wireless system is to fine the suitable spectrum band, and to solve this here we propose the concept of cognitive radio. This paper provides an overview of cognitive radio for spectrum access and related research topics. Cognitive radio is used to solve the problem of overcrowded spectrum. In this article we discuss about the application and architecture of cognitive communication. In this there is Channel selection techniques for opportunistic access such as frequency hopping, frequency tracking, and frequency coding are presented. In this we discuss the Spectrum hole which is used by unlicensed users, that is a basic resource for cognitive radio (CR) systems. It provides us high spectrum efficiency.

***Index Terms*—Cognition Cycle, Reconfigurability, Regulation, Sectrum Hole, DSSS.**

I. INTRODUCTION

A. Definition of cognitive radio

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 free, and quickly move into free channels while avoiding occupied ones. This reduces the interference to other user and optimizes the use of radio frequency spectrum. The Cognitive Radio is a hybrid technology that involve software defined radio (SDR) as applied to spread spectrum communication. The cognitive radio has the ability of encrypt and decrypt the signals, to fine and authorize its user, transceiver to identify its geographic location, and adjust output power and modulation characteristics. A ''Cognitive Radio'' is a radio that can replace its transmitter parameters according to interaction with the environment in which it operates. After the selection of the best available channel the next task of the cognitive radio is to make the network protocols adaptive to the available spectrum. In which the new functionalities are required in an xG network to support its adaptivity. [2] The functions of cognitive radios in xG networks are as follows:

- **Spectrum management:** Identify the best spectrum which provides the best communication advantage to the user.
- **Spectrum sensing**: Detect the unused frequency spectrum and use that spectrum by sharing with other without harmful interference with another user.
- **Spectrum mobility:** Maintaining the seamless communication requirements during the transition to best spectrum.
- **Spectrum sharing:** Giving the good spectrum scheduling method between coexisting xG users. [3]

B. Characteristics of cognitive radio

Cognitive capability: Cognitive capability is the ability of the radio technology to sense the information from its radio environment. In this there are some sophisticated techniques are required to capture the temporal and spatial variation in the radio environment instead of simply be realized by monitoring the power and avoid interference to other users. By this capability, the unused spectrum can be identified at a specific time and location. Whereas, the best spectrum and appropriate operating parameters can be selected. The cognitive capability enables real time interaction with its atmosphere to determine suitable communication parameters and adjust to the dynamic radio environment.[5] The three steps of cognitive cycle under this category are:

- **Spectrum sensing:** A cognitive radio detects the available spectrum bands, take their information, and then detects the spectrum holes.
- **Spectrum analysis:** The spectrum holes that are detected by the spectrum sensing are estimated.
- **Spectrum decision:** A cognitive radio analyze the data rate, the bandwidth of the transmission mode. Then the suitable spectrum band is select according to the spectrum characteristics and user requirements. Once the spectrum band is detected, the communication can be begun by this band.[4]

Reconfigurability: spectrum awareness is selected by the cognitive capability, on the other hand reconfigurability tells the radio that how to program the radio environment dynamically. The cognitive radio has the ability to transmit and receive on a number of frequencies and to Use different transmission access technologies supported by its hardware design. Reconfigurability is the capability of adjusting operating parameters for the transmission on the fly without any modifications on the hardware components.

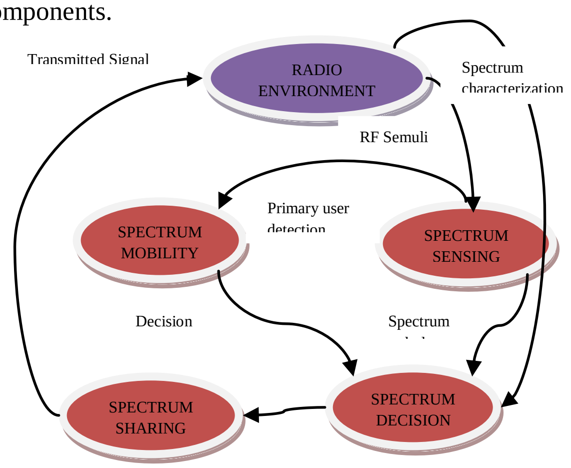

Fig 1. Cognitive cycle

There are several reconfigurable parameters:

Operating frequency: Operating frequency can be changed by the cognitive radio. The most suitable operating frequency can be determined and the communication can be dynamically performed on the

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appropriate operating frequency based on the information about the radio environment.

- **Transmission power: W**ithin the power constraints Transmission power can be reconfigured. Power control enables the dynamic transmission power configuration within the permissible power limit. There is no need of high power operation, at lower level the cognitive radio allow more users to share the spectrum and to decrease the interference.
- **Modulation:** The modulation scheme adaptive to the user requirements and channel conditions should reconfigure by the cognitive radio. For example, in the case of delay sensitive applications, data rate is more important than error rate. In which the modulation scheme that enables the higher spectral efficiency should be selected.

C. Cognition Cycle

A cognition cycle is that which interact with the environment. as interrupts Stimuli enter the cognitive radio; and then get dispatched to the cognition cycle for a response. This cognitive radio continually examine the atmosphere, orients itself, creates plans, decides, and then acts.

- In this, machine learning is used into these phases. Since the compiling of knowledge by machine language can be computationally intensive, cognitive radio has sleep and period that support machine learning. A sleep period is a relatively long period of time, during this time the radio will not be in use, but has enough electrical power for processing. During the sleep period, the radio uses the machine learning algorithms and satisfies user needs.

During the wake period, a new primary cognition cycle is initiated, when a new stimulus is received on any of its sensors, The cognitive radio feel its environment by testing the incoming information streams. There is also include the monitoring of radio broadcasts, e.g. stock ticker tapes the weather channel, etc. In the observation phase, it also reads location, temperature, and light level sensors, etc. to infer the user's communications context. The cognitive radio orients itself by determining the priority associated with the stimuli. A power failure might directly invoke an "Immediate" path as shown in the figure. A non-recoverable loss of signal on a network might invoke reallocation of resources, e.g. from examining input to searching for alternative RF channels. This is achieved via the path labeled "Urgent" in the figure. However, an incoming network message would normally be dealt with by Generating a plan ("Normal" path). Planning includes plan generation. The "Decide" phase selects among the candidate plans. The radio might have the choice to alert the user to an incoming message (e.g. behaving like a pager) or to delay the interruption until later (e.g. behaving like a secretary who is screening calls during an important meeting). "Acting" initiates the selected processes using effect or modules. Learning is a function of observations and decisions.

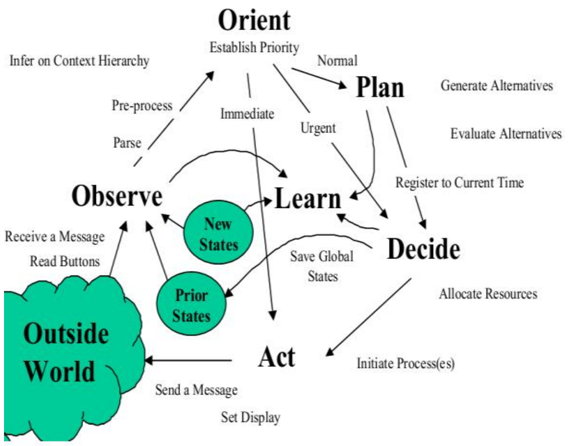


Fig 2. Cognition Cycle

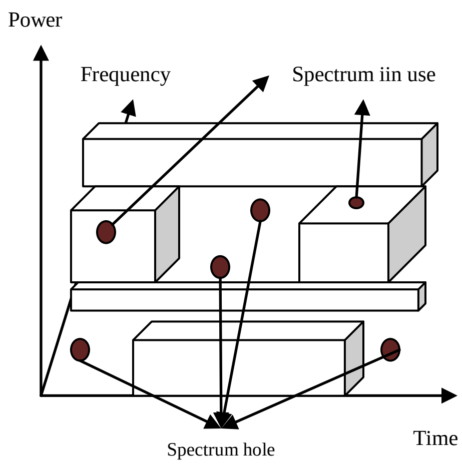
D. Communication technology

A cognitive radio can also be used to provide interoperability among different communication systems. The transmission parameters of a cognitive radio can be reconfigured not only at the beginning of a transmission but also during the transmission. According to the spectrum characteristics, these parameters can be reconfigured such that the cognitive radio is switched to a different spectrum band, the transmitter and receiver parameters are reconfigured and the appropriate communication protocol parameters and modulation schemes are used.

E. Need of cognitive radio

In many bands, spectrum access is a big problem than physical scarcity of spectrum. Due to legacy command-and-control regulation the ability of potential spectrum users to obtain such access is limited. By scaning the portions of the radio spectrum we find that:

1) Some frequency bands in the spectrum are highly unoccupied most of the time.
2) Some other bands of frequency are partially occupied.
3) The remaining bands of frequency are largely used.



.Fig 3. Spectrum hole

The under processing of the electromagnetic spectrum known as spectrum holes, that can be defined as-A

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spectrum hole is that in which a particular bands of frequencies are assigned to a particular user at some specific geographical region for some specific time, and this band is not used by the another user at that time. The cognitive radio enables the usage of unused spectrum, which is known as white space or spectrum hole.

When one user is not using the specific band, at that time the another user can use that band and improve the spectrum utilization Cognitive radio can be used to make efficient use of spectrum.

II. APPLICATIONS OF COGNITIVE RADIO

Cognitive radio can observe its environment and, without interrupt throw user. Some useful applications of cognitive radio are:

A. REGULATION

- **National Broadband Plan**

The National Broadband Plan (NBP) is a policy document in which there is that how to use the spectrum to facilitate the broadband for the next upcoming years. The main recommendations of the NBP is to free up 500 MHz of spectrum for broadband use in the next 10 years with 300 MHz being made available for mobile use in the next 5 years. This goal is achieved by number of ways: repacking spectrum, incentive auctions, The Plan urges the FCC to initiate further proceedings on opportunistic spectrum access beyond the already completed TV White Spaces.

B. PUBLIC SAFETY NETWORKS

Wireless communications are mostly used by emergency responders, such as police, fire and emergency medical services, to prevent the incidents, and by people to fast provide emergency services. Public safety workers are mostly use wireless laptops, handheld computers, and mobile video cameras to improve their efficiency, visibility, and ability to instantly collaborate with central command, coworkers and other agencies. The desired wireless services for public safety is now extend from voice to messaging, email, Web browsing, database access, picture transfer, video streaming, and other wideband services. Video cameras and sensors are now important devices to extend the eyes and ears of public safety agencies. Data rates, reliability and delay requirements vary from service to service.

In urban area, the radio frequency allocation for public safety is more. The US Department of Homeland Security (DHS) released its first National Emergency Communications Plan (NECP) in July 2008. In both the NECP report and the National Broadband Plan the cognitive radio is the best technology to increase the effectiveness and to increase the efficiency of radio spectrum. In cognitive radio, the additional spectrum is used by the user for the public safety like license-exempt TVWS for daily operation from location to location and time to time.

C. CELLULAR NETWORKS

There is a big change in the communication by using the cellular network through which any one can communicate with other, any time and any where. The introduction of smart phones, the popularity of social networks, growing media sites such as Youtube, Hulu, flickr, introduction of new devices such as e-readers, have all added to the already high and growing use of cellular networks for conventional data services such as email and web-browsing. This trend is also identified in the FCC's visionary National Broadband Plan. This presents both an opportunity and a challenge for cellular operators. The opportunity is due to the increased average revenue per user due to added data services. At the same time, the challenge is that in certain geographical areas, cellular networks are overloaded, due partly to limited spectrum resources owned by the cellular operator. Recent analysis suggests that the broadband spectrum deficit is likely to approach 300 MHz by 2014, and that making available additional spectrum for mobile broadband would create value in excess of $100B in the next five years through avoidance of unnecessary costs. With the FCC's TVWS ruling, new spectrum becomes available to cellular operators. In the long term, television band spectrum that is currently not described as white spaces may also become available to cellular operators, as discussed in the National Broadband Plan. Specifically, the plan discusses the possibility for current license holders of television spectrum to voluntarily auction their licenses, in return for part of the proceeds from the auction. The plan envisions that this newly freed spectrum could be used for cellular broadband applications (hence the name of the plan). For access network applications, two use cases can be envisioned. The first is hotspots, such as game stadiums and airports, where a large number of users congregate at the same time. Take the example of a stadium: users increasingly have phones equipped with cameras that can capture pictures or videos of events at the game and upload them to media sites or send them to their friends. Such picture and video data puts enormous strain on the cellular network. In Cisco's study 60% of growth is expected from such picture and video data. Today, some of this data can be offloaded to ISM band WiFi networks. However, due to the large amount of data generated in a small area ("hotspot"), both cellular networks and ISM band WiFi networks, are likely to be overloaded. If this data can be offloaded to additional spectrum, such as TVWS, the cellular network can then be used for voice applications in a more reliable fashion, thus benefiting both the user and cellular operator. The second access network application is similar to a femtocell. Today several of the cellular operators sell a mini-cell tower (looks like a WiFi access point) that consumers may buy and install in their homes. Typical users of femtocell are those that have bad coverage in certain parts of their homes, such as basements. These femtocell devices operate on the same frequencies as

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those of cellular operators. However, these femtocell devices have several issues. First, due to the fact that femtocell devices and cellular networks operate on the same frequency, the quality of the network suffers when these two networks interfere with each other. Secondly, the coverage of these devices is limited. TV white space radio coverage is significantly improved due to the better propagation characteristics and in addition, there is no interference between the femtocell and main cell. A somewhat different issue than the data overload or spotty coverage discussed above also can be noted with cellular networks. Rural areas (to be more precise, areas with low population density distribution) are known to have poor coverage. Cellular operators have rights to use their spectrum nationwide, however, choose not to deploy their networks in rural areas. The reason for this is that a significant part of the costs of a cellular operator is infrastructure costs. These costs cannot be recovered in rural areas due to lack of sufficient number of subscribers in a given area. With white space spectrum, for example, being made available for unlicensed use, cellular operators can use them for backhaul, to connect their cell towers to their backbone networks, thus reducing labor intensive backhaul cables installation, and thus provide coverage to more customers in unserved and underserved areas. TV white space radio coverage is significantly improved due to the better propagation characteristics and in addition, there is no interference between the femtocell and main cell.

III. COGNITIVE RADIO ARCHITECTURE

There is a cognitive architecture for high performance, which has many adaptive wireless network protocols ranging from simple to complex combination of ad-hoc. The design provides fast RF scanning capability, an agile RF transceiver working over a range of frequency bands, a software-defined radio modem capable of supporting a variety of waveforms including OFDM and DSSS/QPSK, a packet processing engine for protocol and routing functionality, and a general purpose processor for implementation of spectrum etiquette policies and algorithms.[1] The proposed architecture is shown in the diagram: In it, we assume that there is a need for baseband and network processor board which would interface to the RF front-end and allow dynamically reconfigurable software and hardware implementations of multiple wireless links supporting individual data rates of 50Mb/s and a maximum aggregate data rate of 100 Mb/s.

There is some combination of DSP and FPGA blocks together with their required memories. By using DSP's there is a difficulty with programming these devices. So we decided to use a combination of FPGA for hardware software implementation. Two channels are also support by the analog Front-End, one is used for measurement and another is used for data, which has bandwidths selectable in 1 Mhz increments.

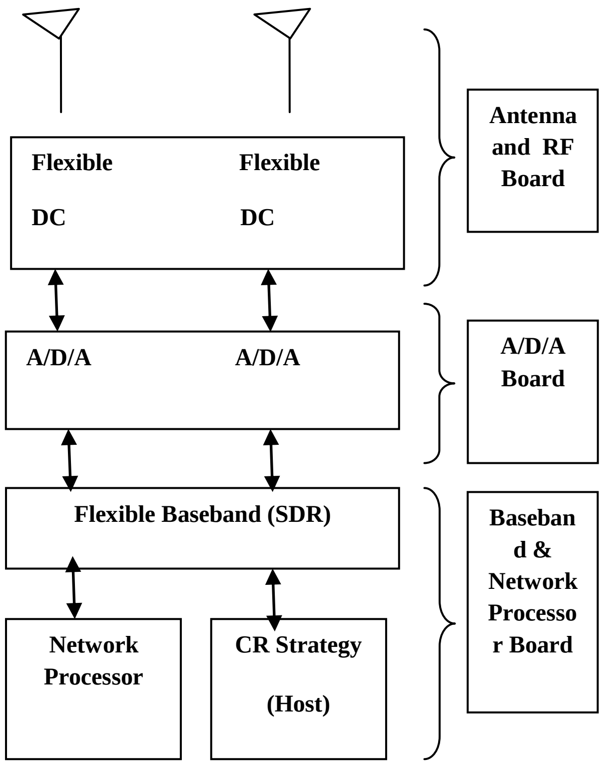

Fig 4. Architecture of Cognitive Radio

IV. CONCLUSION

In this paper, we discuss about the architecture of cognitive radio network (CRN) to enhance the efficiency of the networking from cognitive radios' spectral efficiency. Cognitive radio technology plays a vital role in making the better use of spectrum to fulfill the large demand for wireless applications, ranging from intelligent grid, safety for public, broadband cellular, for medical applications. Standard Development Organizations (SDOs) have begun to develop standards to take advantage of the opportunities. However, challenges still remain since CR-enabled networks have to coexist with primary as well as secondary users and need to ignore interference in such a way that they can better support such applications from end to end.

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