# Exigency of Cognitive Radio Networks

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**Abstract**

Cognitive radio is the restorative technology to authorize the efficient usage of restricted natural resource radio frequency spectrum for the wireless devices. The technology empowers the telecommunication industry by renovating the traditional static spectrum access approach to dynamic spectrum access to stimulate the unlicensed users to access underutilized licensed band; without creating any/allowable interference for licensed users. This paper provides the notion of the radio frequency spectrum facet that is required to understand the significance of Cognitive Radio technology in future. Various associated challenges with the realization cognitive radio technology are also highlighted in this paper.

***Keywords:*** *Cognitive radio, FCC, Radio Frequency Spectrum, Spectrum Allocation, Licensed Users, Unlicensed Users, spectrum allocation, radio devices.*

## 1. Introduction

Internet practices has skyrocketed in the last decade; propelled by web and multimedia applications. Massive number of users now demands mobile, universal access whether they are at work, at home or on the move. Mobile, non infrastructure nature of wireless networks poses new design challenges [11]. Recent technologies advances have resulted in the development of wireless ad hoc networks composed of devices that are self-organizing and can be deployed without infrastructure support [14] to establish reliable communications for applications in large scale wireless networking. Now a day spectrum access, efficiency and reliability have become critical public policy issues that spawn the potential of cognitive technologies. This paper is the effort to provide the fundamental preliminary concept required to understand the need of cognitive radio technology in telecommunication industry. The paper bestowed the concepts of Cognitive Radios, Radio frequency spectrum, consequence of radio frequency spectrum to understand cognitive radio technology, cognitive radio devices (licensed & unlicensed radios) and challenges to implement the cognitive technology.

## 2. COGNITIVE RADIO

The transformation of the static spectrum allocation based communication system in a dynamic spectrum allocation to take advantage of the existing wireless spectrum opportunistically to solve the problem in wireless networks ensuing from the restricted available spectrum and the inefficiency in the spectrum usage is the core concept of the cognitive radio and cognitive based networking [2][14]. The term Cognitive Radio technology emerged from the application of advance software techniques to radio processing [3]. J. Mitola identifies the cognitive radio as the point at which wireless Personal Digital Assistants (PDAs) and the related networks are sufficiently computational intelligent about radio resources and related computer to computer communication [1]. A cordless phone in the 43.71-44.49 mhz band is a simple form of cognitive radio [3].

Theoretical transport capacity C; of wireless networks is decided by the available resources [6]:

Spectrum Bandwidth B;
Number of Nodes/Radios N;
$C = O(B \surd N)$ bit meters/sec

B & N can be large in large scale networks with unlicensed bandwidth. Where Spectrum bandwidth B is a scarce resource and number of nodes/Radios N is increasing tremendously. Studies reveals that the growth of N can't be restricted but technology advancement can exploit the possibilities for the usage of B to serve N.

## 3. RADIO FREQUENCY SPECTRUM (RFS)

Radio Frequency Spectrum (RFS) is a restricted natural resource where spectrum represents a collection of various types of electromagnetic radiations with different wavelength. In most of the countries the use of RFS is regulated by government using a spectrum management process known as frequency allocation or spectrum allocation. Radio propagation does not restricted by geographical boundaries. The right of unlimited use of electromagnetic spectrum is share and reserved by all the nations [7][8]. The way radio spectrum is used, it is considered as a merge resource. International Telecommunication Union(ITU), Federal Communication Commission(FCC), Inter-American Telecommunication Commission (CITEL), European conference of postal and Telecommunication Administration (CEPT) etc. are the various standard bodies working on standards for frequency allocation [10].

These relevant authorities are intent to ensure interference free operations in the telecommunication field by means of applying Radar Regulation (RR) and regional agreement in the whole world. Radio waves are defined as electromagnetic waves of frequency arbitrary frequency (3khz -3000Ghz) propagated in space without artificial guide. To regulate the radio waves fixed frequency band are allocated in the Table of Frequency Allocation[9] which is used by one or more terrestrial or space radio communication services under specified conditions. In India the Nation Frequency Allocation Plan (NFAP) forms the basis for development and manufacturing of wireless equipment and spectrum utilization [7]. The RFS allocation for wireless communication Systems; like Radio Navigation, Mobile, Broadcasting, Mobile Satellite, Radio Location etc.; are generally based on the fixed radio resource allocation[9]. Studies reveal; the traditional approach for RFS allocation avoids the harmful interference in an allocated RF band but lead into significant under utilization of the RFS due to intermittent usage across different geographical and time zone. Spectrum access, efficiency and reliability have become critical public issue [3]. Necessity to explore the potential of radio systems gives way to novel Dynamic spectrum access approach that is cognitive radios [10].

## 4. WHY FOCUS ON SPECTRUM

### 4.1 Radio Frequency Device

To understand the importance of spectrum allocation for Cognitive Radio technology it is necessary to know the concept of radio frequency devices. A radiofrequency device is any device which in its operation is capable of emitting radiofrequency energy by radiation, conduction, or other means. The radio frequency device for which a license from the FCC or a frequency assignment from the National Telecommunications and Information Administration is not required known as unlicensed device [16]. Product such as baby monitor, cordless phone, Remote access of home devices, toy wireless microphones, wireless computer network etc are consider into this category. Unlicensed wireless devices are permitted to emit radio frequency energy, without specific authorization, registration, or grant of a license.

A multi-billion dollar industry is specific for unlicensed wireless communications devices and market is experiencing exceptional growth in it. Advances in technology and policy liberalization make unlicensed devices popular within industry, scientific, medicine, government, defense and home [19].

This growth and public interest towards unlicensed devices necessitate the effective policy reform includes enabling more unlicensed spectrum and promulgating rules to encourage technological and market-based solutions to optimize efficient use and sharing of spectrum [19].

The rules and technical specifications that apply to non-federal use of unlicensed devices are in Title 47 of the Code of Federal Regulations Part 15 (47 CFR 15) [18]. Unlicensed devices with limitation can tender great opportunities to system designers and program managers because of their low cost and minimal administrative overhead. Three types of unlicensed devices are defined and regulated under the Part 15 rules [16]: 1) Intentional radiators 2) Unintentional radiators 3) Incidental radiators The basic principle of unlicensed devices is noninterference to licensed operations and they are not protected from any received interference. Unlicensed devices are hassle free from licensing process and use the spectrum free of cost.

### 4.2 RFS and Cognitive Radio Network

During 1920s radio communication was free from any policy and radio devices were allowed to broadcast over the air. This arrangement resultant in immense interference due to many transmitters operated in proximities. This high probability of working radio device in proximities and at a time leads to chaos. To overcome the telecommunication market failure due to this chaos; was fate towards today's regulatory environment during early 1930's. FCC was created as result of communication act in 1934. FCC is responsible for the controlled access to radio spectrum by allocating specific frequency bands for use by licensed service provide[19].

In 1938 FCC first time allowed unlicensed devices to operate in the medium frequency (0.3-3MHz) and high frequency (3-30MHz) frequency band; without causing any harmful interference. These unlicensed equipments were mainly record players and control devices.

With technology advancement and demand for more useful operations; it was very difficult for manufacturer to design devices within the constraints imposed by FCC. During 1960s to 1970s FCC make expansions and amendment in Part-15 rule to allow operations of numerous new devices. These devices include TV interface devices, auditory assistant devices, door openers, telemetry systems, cordless microphones, security apparatus, cordless telephones and many more. In 1985 FCC expanded Part 15 Rule for the maneuver of low power, unlicensed spread spectrum system in the frequency band 900-928MHz, 2400-2483.5MHz and 5725-5850MHz. The low potential for causing interference leads spread spectrum system striking technology for consumer use. To regularize these spread spectrum unlicensed devices the FCC established a number of general usage frequency bands placing limits on peak emissions to standardized the emission limits in various bands[19].

To predict future needs, the FCC has underway a proceeding in which it seeks to promote the commercial development of spectrum in the 71-76 GHz, 81-86 GHz and 92-95 GHz bands. To exploit the utilization of these three high frequency bands FCC established a Spectrum Policy Task Force (SPTF) in June 2002. The SPTF report identified three distinctive approaches to spectrum policy based on the establishment of a set of legal rights: 1) an exclusive use approach; 2) a commons approach; and 3) a command-and-control approach.

The task force provides four key recommendations to achieve the policy reorganization: 1) Migrate toward more flexible, consumer-oriented policies 2) Adopt quantitative standards to provide interference protection: interference temperature 3) Improve access through the time dimension 4) Shift from “command and control” model to exclusive and commons models [19].

These recommendations motivate the use of unlicensed device by providing the concept of minimum allowed interference in shared spectrum.

Researcher observed that allotted radio frequency spectrum; discussed in Radio Frequency Spectrum section; utilization is based on communication systems, services, geographical location and timing day/night. It has been observed that radio spectrum utilization is deprived in rural areas and Industrial, Scientific and Medical (ISM) systems whereas radio spectrum dedicated to mobile networks are occupied in excess that results in deprived efficiency [10]. It is observed that ad hoc network operations are mostly limited in the 900 MHz and 2.4 GHz bands. These bands are getting congested due to enormous and ubiquitous demand of wireless devices. At the same time, there are several under-utilized frequency bands licensed to operators, such as in the 400-700 MHz range; for transmission [14].

Researcher found that a huge segment of the assigned spectrum is used intermittently and geographical disparity in the utilization of assigned spectrum ranges from 15% to 85% with a high inconsistency in time [17]. The inefficient usage of limited spectrum is the motivation of the introduction of new communication paradigm to exploit the existing wireless spectrum panorama. The evolution of new innovative technology networking paradigm is referred to as Dynamic Spectrum Access (DSA) is also known as self adaptive and self organizing cognitive radio networks.

CR is widely considered as a promising technology to deal with the spectrum shortage problem; caused by the current inflexible spectrum allocation policy [13]. CRAHNs are equipped with the essential capabilities of the cognitive radio to endow with an ultimate spectrum aware communication paradigm in wireless communication.
There are few observations listed below; based on the recent report of Synergy Research Group to symbolize the tremendous growth of wireless LAN Market [16]

Table 1: Synergy Research Group Observations

| SN | OBSERVATIONS |
|---|---|
| 1. | Eight consecutive quarterly reports represent the double digit growth in the wireless LAN market |
| 2. | Total growth in the wireless LAN market from 200o has been over 150 percent |
| 3. | It was estimated that over 5 million unlicensed wireless LAN device were shipped in 2001 |
| 4. | It was predicted that 21 million American would be using wireless devices by 2007 |
| 5. | As per the prediction of Gartner Research that $5.6 billion per year approximately would be spent on Bluetooth technology by 2006 and businessman and consumers would purchase more than 560 million Bluetooth-enabled devices |
| 6. | It was estimated that by 2004 over 45 million business laptop computers will use the Wi-Fi standard |
| 7. | By 2007 over 90 million; Wi-Fi enabled devices worldwide and over 40 million people roaming in Wi-Fi hotspots were projected by analyst |

The FCC recently approved the usage of licensed band by unlicensed devices. According to a report in May 2014; depending upon how much spectrum is voluntarily

relinquished by broadcasters in a reverse auction and repacked for the forward auction, a total of 14 to 28 MHz of guard band spectrum should be available for unlicensed use in a given area. The commission's Report and Order lays out a 600 MHz band plan consisting of 5 MHz, paired uplink and downlink bands, with the uplink portion starting at channel 51 (698 MHz) and expanding downward [15]. By aiming to maximize the utilization of inefficient usage of licensed spectrum by unlicensed devices cognitive radio techniques are proposed by the researchers.

The availability of spectrum for unlicensed operations has spawned a significant market for unlicensed devices. These devices range from simple consumer devices, such as, cordless telephones; remote control toys; garage door openers; and, baby monitors; to sophisticated business and commercial applications, such as security systems; inventory control systems; manufacturing controls; and, business computing networks [16].

Congested spectrum allocation and inefficient utilization is the notion towards cognitive networks. Cognitive radio (CR) is an enabling technology to allow unlicensed (secondary) users to exploit the spectrum allocated to licensed (primary) users in an opportunistic Manner [13]. Incompetent spectrum allocation and the burgeoning problem of spectrum scarcity have prompted an examination of how the radio frequency spectrum is utilized [12].

## 5 COGNITIVE RADIO NETWORKS AND SPECTRUM ACCESS EFFICIENCY

In cognitive radio networks, the secondary users (SUs) switch the data transmission to another empty spectrum band to give priority to primary users (PUs) [20]. Since last few decades shows the explosive usage of wireless devices. It leads to highly congested frequency bands mainly due to inclusion of tremendous unlicensed user like in ISM band. Unlicensed users contribute towards the problem of poor network performance and interference. Cognitive radios are intelligent radios with ability to sense environmental conditions and configure its parameters dynamically to get the optimized performance at the individual nodes or at network level. These transmitter parameters include “waveform, protocol, operating frequency and networking” [21] can be configure based on interaction with the environment in which these radios operates that involves active negotiation & communication with other spectrum users and/or passive sensing &decision making within the radios [3].

Cognitive radio technologies can be used to improve spectrum access & efficiency in at least four scenarios below [3]:

1) Licensed user can utilize CR technology internally within its own networks to increase efficiency of usage
2) CR can facilitate secondary market in use that can be implemented by voluntary agreements between licensees and third party
3) CR technologies can facilitate automated frequency coordination among licensees of co-primary services
4) It can be used to enable non-voluntary third party access to spectrum

Cognitive radios are aware of their surrounding and bandwidth availability and are able to dynamically tune the spectrum usage based on the location, nearby radios, time of day and other dimensions. CR provides more efficient use of the spectrum as well as reduced power consumption and enabling high priority communications to take precedence when required [5]. Cognitive Radio technologies emphasize on [5]

- Methods for flexible spectrum use
- Innovative ways of sensing the radio environment and location
- Distributed networks that wisely cooperate
- Low power flexible implementation of wireless in mobile devices

The above specified responsibilities of cognitive radios are open challenges among researcher. There are many other issues in CR technologies like how the usage of CR technologies could benefit to determine our regulatory processes for a given application [3].

The current research challenges are the function of the cognitive radio networks like spectrum management, spectrum mobility and spectrum sharing [19]. What are the various innovative ways to achieve the following capabilities of Cognitive Radio Technologies?

1) Ability to achieve frequency agility by a radio by changing its operating frequency dynamically
2) Ability for modification of transmission characteristics & waveforms to exploit opportunity to use spectrum,
3) Ability to control transmission power by allowing transmission at the allowable limits when necessary
4) Ability to determine its location and the location of other transmitters and then select the appropriate operating parameters such as the power and frequency allowed at its location

5) Ability to enable the sharing of spectrum under the terms of an agreement between licensees and third party
6) Ability to incorporate security features to allow only authorized use and averts unauthorized amendment.

## 6. CONCLUSION & FUTURE SCOPE

This paper provides the exigency of cognitive radio network in future considering the fact that our day to day life getting dependent on wireless devices. As these devices provides high data transmission rate with numerous imperative services to facilitate the quality life style. This paper with imparting institutional knowledge about cognitive radio technology also encourage researcher to exploit the cognitive radio technology to meet the future demands in telecommunication industry.Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

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