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# A Novel Approach to Enhance the Spectrum Usage and Regulatory Certification for Cognitive Radio

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***Abstract*** *– 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. Applications of Spectrum Sensing Cognitive Radio include emergency networks and WLAN higher throughput and transmission distance extensions. Engineers are now working to bring that kind of flexible operating intelligence to future radios, cell phones and other wireless communications devices. During the coming decade, cognitive radio technology should enable nearly any wireless system to locate and link to any locally available unused radio spectrum to best serve the consumer. It is proposed to investigate and develop cognitive radio algorithms to enable co-existence between IEEE 802.11b and 802.16a networks in the same unlicensed band. In particular, a system model would be developed in which the two wireless systems share radio resources in frequency, space and time, and coordination methods will be used to reduce the mutual interference and improve link throughput. The cognitive radio schemes will utilize the available degrees of freedom in frequency, power and time, and react to observations in these dimensions to avoid interference.*

***Keywords****: MILTON, SDR, PDA, WiMAX.*

## I. Introduction

We are observing recently a huge interest in the Cognitive Radio-related wireless communications, both from the research and policy and regulation community. From the moment of publishing seminal paper by Mitola on Cognitive Radio [1], 19 books and 15 special issues of various journals have been published, together with 33 organized conferences and workshops dedicated to Cognitive Radio [2].

In this Paper it is proposed to develop a system model in which the two wireless systems share radio resources in frequency, space and time, and coordination methods will be used to reduce the mutual interference and improve link throughput. This Paper will also describe what is meant by cognitive radio and the technical challenges associated with this concept. The cognitive radio schemes will utilize the available degrees of freedom in frequency, power and time, and react to observations in these dimensions to avoid interference.

## II. Literature Review

At WRC-03 the regulatory community agreed on a method for 5 GHz spectrum sharing of radar and wireless access systems. The basis for the sharing was agreement on the use of Dynamic Frequency Selection in 5230-5350 MHz and 5470-5725 MHz.

One of the projects at Canada's Communications Research Centre (CRC) is Microwave-Light Organized Network (MILTON); a system to economically and effectively distribute fiber bandwidth using license-exempt spectrum. It is primarily designed to use 5 GHz license-exempt spectrum. By using so many panels and aggressive frequency reuse, it's expected that a MILTON can effectively distribute approximately 1 GBps of bandwidth from a fiber connection- a reasonable, effective use of fiber bandwidth. MILTON implements cognitive radio techniques to deal with the interference that can be expected when using 5 GHz on specific pedals and channels. The demonstrations will exercise

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prototypes in spectrum bands between 30 MHz and 2 GHz. Internet in remote areas began propagation studies of the possible use of the 5 GHz unlicensed spectrum for cognitive radio. More Unlicensed Spectrum Allocations Unlicensed spectrum is ideal for cognitive radio.' A further look at the regulations and monitoring of unlicensed spectrum may be needed.

The latest WRC-2003 allocation for wireless access systems use in the 5250-5350 MHz and 5470-5725MHz is under consideration in Canada for unlicensed 'last mile' solutions in rural and remote areas for Internet access. Applications may include real time transfer of video files, CD files, digitized voice and high data content information.

## III. Radio Frequency Spectrum and WiMax

The radio spectrum--the segment of the electromagnetic continuum containing waves in the radio-frequency range--accommodates countless communications devices today. The tremendous growth in the wireless based systems and the evolution of the radio communication technologies at a much faster rate have put a great pressure on radio frequency spectrum management in order that the spectrum is used in an efficient, economical, rational and equitable manner. Many new technologies are emerging like Broadband, Wi-Fi / Wi-Max etc., which require spectrum for faster growth. There are growing, conflicting and competing demand on the spectrum by all sectors -government, private and telecom service providers. The requirement of spectrum by all sectors has increased manifold for variety of applications. The problem is not a dearth of radio spectrum; it's the way that spectrum is used. The radio spectrum managers allocate the radio spectrum in swaths of frequency of varying widths. One band covers AM radio, another VHF television, still others cell phones, citizen's-band radio, pagers, and so on; now, just as wireless devices have begun proliferating, there's little left over to dole out. But as anyone who has twirled a radio dial knows, not every channel in every band is always in use. In fact, in some locations or at some times of day, 70 percent of the allocated spectrum may be sitting idle, even though it's officially spoken for. Jens Zander, an authority on radio systems at the Royal Institute of Technology, argues that there is no shortage of radio spectrum, only a dearth of affordable communications infrastructure. The solution lies with cognitive radios, devices that figure out which frequencies are quiet and pick one or more over which to transmit and receive data. This can be compared with the scheme to a driver's reacting to what one sees other drivers doing. In a traffic lane that is heavy, maybe it's time for me to shift to another lane that is not so busy. When shifting lanes, however, a driver needs to follow rules that prevent her from bumping into others.

The original WiMax system was designed to operate at 10-66 GHz and it had to change to offer broadband wireless access (BWA) in the 2-11 GHz frequency range. To do this, the WiMax standard includes variants (profiles) that use different combinations of radio channel types (single carrier –vs- multicarrier), modulation types, channel coding types to provide fixed, nomadic or portable services. WiMax can provide multiple types of services to the same user with different QoS levels. WiMAX has the potential applications in Connecting Wi-Fi hotspots with each other and to other parts of the Internet, Providing a wireless alternative to cable for last mile broadband access, providing high-speed mobile data and telecommunications services (4G), providing a diverse source of Internet connectivity as part of a business continuity plan and providing Nomadic connectivity. WiMax can use radio channel bandwidths that can vary from 1.25 MHz to 28 MHz and data transmission rates can exceed 155 Mbps. The types of data connections on WiMax radio channels include basic (physical connection), primary (device control), and secondary (configuration) and transport (user data). There are two main applications of WiMAX today: fixed WiMAX applications are point-to-multipoint enabling broadband access to homes and businesses, whereas mobile WiMAX offers the full mobility of cellular networks at true broadband speeds. Both fixed and mobile applications of WiMAX are engineered to help deliver ubiquitous, high-throughput broadband wireless services at a low cost. Mobile WiMAX is based on OFDMA (Orthogonal Frequency Division Multiple Access) technology which has inherent advantages in throughput, latency, spectral efficiency, and advanced antennae support; ultimately enabling it to provide higher performance than today's wide area wireless technologies. Furthermore, many next generation 4G wireless technologies may evolve towards OFDMA and all IP-based networks as an ideal for delivering cost-effective wireless data services.

## IV. Cognitive Radio

The idea of Cognitive radio was first presented officially in an article by Joseph Mitola III and Gerald Q. Maguire, Jr. It was a novel approach in wireless communications that Mitola later described as the point in which wireless personal digital assistant (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to detect user communications needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs.. It was thought of as an ideal goal towards which a software defined radio (SDR) platform should evolve: a fully reconfigurable wireless black box that automatically changes its communication variables in response to network and user demands. Regulatory bodies in various countries found that most of the Radio frequency spectrum was inefficiently utilized, for example, cellular network bands are overloaded in most parts of the world, but amateur radio and paging frequencies are not. The studies demonstrate that spectrum utilization depends strongly on time and place. Moreover, fixed spectrum allocation prevents rarely used frequencies from being used by unlicensed users, even when their transmissions would not interfere at all with the assigned service. Depending on the set of parameters taken into account in deciding on transmission and reception changes, certain types of cognitive radio can be distinguished as:

*IV.1. Full Cognitive Radio*

In which every possible parameter observable by a wireless node or network is taken into account.

*IV.2. Spectrum Sensing Cognitive Radio*

In which only the radio frequency spectrum is considered. Depending on the parts of the spectrum available for cognitive radio, it can be distinguished:

*IV.3. Licensed Band Cognitive Radio*

In which cognitive radio is capable of using bands assigned to licensed users, apart from unlicensed bands, such as ISM band. One such system is described in the IEEE 802.15 Task group 2 specification.

*IV.4. Unlicensed Band Cognitive Radio*

Which can only utilize unlicensed parts of radio frequency spectrum. An example of Unlicensed Band Cognitive Radio is IEEE 802.19.

The 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. No specific Radio Regulation has defined cognitive radio. Working Part 8A of the ITU-R in a Draft New Report on Software Defined Radio (SDR) tentatively defines cognitive radio as ‘A radio or system that senses, and is aware of its operational environment and can be trained to dynamically and autonomously adjust its operating parameters accordingly’.

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. Applications of Spectrum Sensing Cognitive Radio include emergency networks and WLAN higher throughput and transmission distance extensions. Engineers are now working to bring that kind of flexible operating intelligence to future radios, cell phones and other wireless communications devices. During the coming decade, cognitive radio technology should enable nearly any wireless system to locate and link to any locally available unused radio spectrum to best serve the consumer. Employing adaptive software, these smart devices could reconfigure their communications functions to meet the demands of the transmission network or the user. The design of cognitive radio would depend on the measurement of the propagation characteristics, signal strength and transmission quality of the different bands. The next-generation wireless technology in Cognitive, uses both embedded signal-processing algorithms to sift out weak radio signals and reconfigurable code structures to receive and transmit new radio protocols. Experts anticipate that in the relatively near term this software-driven advance will produce a seismic shift in radio design. A cognitive radio will be able to autonomously sense how its RF environment varies with position and time in terms of the power that it and other transmitters in the vicinity radiate. These data structures and related software will enable a cognitive radio device to discover and use surrounding networks to the best advantage while avoiding interference from other radios. In the not too distant future, cognitive radio technology will share the available spectrum optimally without instructions from a controlling network.

## V. Significance of Cognitive Radio

The potential for cognitive radio technology to redefine existing wireless services becomes clear when one considers their economics. A monthly cell-phone service bill, for instance, contains charges for leasing radio spectrum, renting cell towers and purchasing the handset, as well as the amortization of the hardware at the cell base site, the cost of interconnections among cell sites, billing expenses and network operator profit. These fees pay for the investments that cellular service providers make to create and operate dedicated RF networks.

Such costs could drop dramatically, and service quality could improve greatly, when cognitive radio is finally unleashed in the marketplace. Think about the best advanced-technology cell phone now being sold. More than one gigahertz (GHz) of useful but underutilized radio spectrum is available to that handset. At any instant, however, the device employs at most 10 MHz--a hundredth of what there is--and even that is selected from only about 100 MHz of fixed spectrum allocations that the phone's circuits can access. The cognitive radio technology is recommended for use in low-power ad hoc networks in unused TV bands. An RF cognitive radio card can therefore turn a cell phone into a WLAN, a laptop into a cell phone or a cordless telephone into a picocell "tower." From such a picocell, a home computer fitted with a cognitive radio control system could rent airtime to passersby, billing for secure wireless voice or data through the associated Internet service provider. The growth of cognitive radio will take some time to occur, but the effect on all our lives will be significant. A cognitive radio unit requires to know how radiated RF power at its location varies with distance along the ground, among obstructions and up in the air. Cognitive radios instead sense the entire local RF environment of low, medium and high bands, mapping its features as a function of space, time and frequency propagation. The development of spectrum-sensing cognitive radio will require the design of high-quality sensor devices and practical algorithms for exchanging spectrum-monitoring data between cooperating communications nodes. Systems that feature multiple-input/multiple-output capabilities will direct transmissions along complex multipath components--thereby accounting for reflections of signals from objects such as buildings and vehicles--and away from other potentially interfering radios. A fully functional cognitive radio system will be smart enough to sense the local RF "scene," to choose the radio band, mode and service it needs to upload connections to the selected band and mode. It will then direct its transmission energy toward the intended receiver while minimizing interference with other radios, including cognitive ones. Thus, it will display a high level of spectrum etiquette and connect the user securely and privately. The accuracy of such operations could be improved by the development of three-dimensional computer representations of the full local cityscape stored on gigabyte hard drives, which would be accessed wirelessly as needed. Predictions of received signal strength based on these models would allow cognitive radios to avoid most interference.

Utilizing cognitive dynamic spectrum access in adhoc networks can increase the amount of spectrum available to these networks thereby improving communications performance and spectrum efficiency. Researchers hope that by using underutilized spectrum cognitive radio will provide a 10 times spectrum capacity improvement. Potential users of cognitive adhoc wireless LAN technologies include public safety, military, homeland defense, and commercial wireless organizations.

## VI. Proposed Methodology

It is proposed to investigate and develop cognitive radio algorithms to enable co-existence between IEEE 802.11b and 802.16a networks in the same unlicensed band. In particular, a system model would be developed in which the two wireless systems share radio resources in frequency, space and time, and coordination methods will be used to reduce the mutual interference and improve link throughput. The cognitive radio schemes will utilize the available degrees of freedom in frequency, power and time, and react to observations in these dimensions to avoid interference.

The effect of interference produced by the environment, which includes that created by natural electrical noise (from lightning), electrical power generators, electric motors, automobile ignition systems and other radio transmitters on cognitive radio.

Cognitive radios instead sense the entire local RF environment of low, medium and high bands, mapping of these features will be done as a function of space, time and frequency propagation.

## VII. Conclusion

This Paper has introduced a system model for overcoming a number of principal challenges associated with the network coordination in cognitive radio.

It has been shown that cognitive radio can be used to enhance the spectrum usage, by using a highly flexible cognitive radio platform the implementations can be done and system performance is examined using experimental results.

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