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# Quantities Study of Cognitive Radio Networks Broadband Wireless Access

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**Abstract**: **In this paper, we discuss the scenario of cognitive radio networks and have given a overview of the emerging IEEE 802.22 standard, based on dynamic spectrum access model, providing opportunities for broadband access in rural area and remote communities. In urban areas, cognitive radios are constrained to short ranges and many broadband alternatives already exist. We discuss the main design challenges and have also highlighted the new spectrum model adopted in 802.22 standard.**

**Keywords: Cognitive radio, spectrum, 802.22.**

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## I. INTRODUCTION

Many wireless technologies are currently available like WiMAX, WiFi, and cellular systems (e.g. 3G networks). All of these have their own advantages and disadvantages. But none of these can be considered as a ideal solution for rural broadband access. There we come with Cognitive radios (CR) having the potential for providing Broadband wireless access (BWA). In particular, the IEEE 802.22 Wireless Regional Area Networks (WRANs) standard [2][3] is being currently developed to specifically address the rural wireless broadband market. The 802.22 WRANs will operate in the TV spectrum band, as secondary users, under regulatory rules to avoid interference with the primary users, i.e., TV broadcasting services.

In this paper a general purpose BWA spectrum requirements and economic tool has been developed. We will also study the regulatory scenario for Cognitive radio networks. We will also get to the design challenges and features of 802.22 standards. We would also understand the new 802.22 spectrum management model that provides the flexibility to operate under a range of different regulatory domains.

## II. REGULATORY SCENARIO

Measurements have shown that some parts of the spectrum allocated are virtually unused and are known as spectrum white spaces. These white spaces bring opportunities for enabling new BWA. CRs can be seen as the technology to solve the spectrum utilization problem. CRNs enable flexible, efficient and reliable spectrum by adapting real time conditions of the environment [1]. As CRNs have limited applicability [5], in which spectrum are assigned to a specific service. In order to exploit the full capabilities of CRNs new models are needed.

### 1. Dynamic Spectrum Access Models

Two types of models are proposed [5]:

**Shared-use of primary licensed spectrum:** As the name indicates, in this model secondary users share the spectrum with primary users on a non interfering basis. This model can moreover can be classified in two ways: spectrum underlay and spectrum overlay. The underlay approach requires the secondary users to limit their transmit power so that their signal do not in interfere with primary users. This model is the basis of Ultra Wide Band technology [6], as it is useful only for short range applications. On the other hand spectrum overlay model enables devices to operate in the spectrum while spaces provided implement reliable incumbent detection and frequency agility mechanisms to adapt their operation when a primary user is detected.

**Spectrum Commons:** This model allows all devices to share the spectrum on an unlicensed basis. There are two modalities of commons [5], open access (uncontrolled) commons and managed commons. The open access model is adopted in the ISM (2.4 GHz) and I-NII (5 GHz) bands used in Wi-Fi and Bluetooth. But due to overcrowding, this technology is facing interference problems. The managed commons model tries to give solution to this problem by enforcing common rules and management protocols for all devices.

Although the spectrum common models provides more efficient spectrum utilization but the associated technical challenges as well as regulatory issues are not fully understood [7]. On the other hand, the shared use with primary users on a non interfering basis is more efficient dynamic spectrum access. For instance, FCC in the US has adopted such a model for regulating the access to the TV bands by secondary users on an unlicensed basis [4]. The IEEE 802.22 standard [2] is being developed to exploit these spectrum white spaces so as to provide cost-effective option to bring wireless broadband access to rural areas.

### 2. Protection of Incumbents

Although wireless microphones are secondary users (licensed) and are allowed to share spectrum on non interfacing basis with TV broadcasting services according to the part 74 of FCC rules [8], but are considered as incumbents for new unlicensed secondary users, such as 802.22 WRANs. CR capability is the ability to reliably detect usable incumbents in different domains. The 802.22 group has proposed an Incumbent Detection Thresholds (IDT) through which incumbent signal with probability more than the Probability of Detection (PD) parameter and lower than the PFA parameter can be detected. Secondary devices must detect incumbent signal within the Channel Detection Time (CDT). If an incumbent signal above IDT is detected, the system must react appropriately to avoid interference.
Minimizing the PFA is a key design issue for spectrum sensing algorithms [9], but for efficient sensing algorithms it is important to design MAC layer carefully to avoid interference and for coordination in the sensing process.

**TABLE I.: 802.22 INCUMBENT PROTECTION PARAMETERS**

| Parameter | Wireless Microphones | TV Services |
|---|---|---|
| Incumbent Detection Threshold (IDT) | -107 dBm (over 200 KHz) | -116 dBm (over 6MHz) |
| Probability of Detetcion (PD) | 90% | 90% |
| Probability of False Alarm (FPA) | 10% | 10% |
| Channel Detection Time (CDT) | <= 2sec | <= 2sec |
| Channel Move Time (CMT) | 2 sec | 2 sec |
| Channel Closing Transmission Time (CCTT) | 100 msec | 100 msec |

The incumbent detection and protection parameters adopted by 802.22 standards are given in TABLE I.

## III. OVERVIEW OF 802.22 STANDARD

The IEEE 802.22 WRAN standard defines PHY and MAC layer specifications for operation and avoidance of harmful interference to incumbents in TV frequency bands ranging between 54 MHz and 862 MHz. The standard includes new cognitive radio features and s currently under development.

### A. Spectrum Sensing

Although the algorithm used is implementation dependent, 802.22 standards describes several sensing techniques that can be used as reference for implementation. Detection based on DVT pilot locations and high order statistics are the algorithms that achieve best performance results.

### B. 802.22 PHY

It supports data rates of 1.5 Mbit/s in the downstream and 384 Kbit/s in upstream direction. It is based on OFDMA scheme and the system parameters are summarized in TABLE II. . Overall 14 PHY modulation/ coding rata modes are specified providing different spectrum efficiency and data rates. The first version of 802.22 standards supports only Time Division Duplex (TDD) mode, while Frequency Division Duplex (FDD) mode may be considered in future versions.

**TABLE II.: SYSTEM PARAMETERS**

| Parameters | Specification |
|---|---|
| Frequency range | 54~862 MHz |
| Bandwidth | 6 and/or 7, and/or 8 MHz |
| Data rate | 1.51~22.69 Mb/s |
| Spectral Efficiency | 0.25~3.78 b/s/Hz |
| Payload Modulation | QPSK, 16-QAM, 64-QAM |
| Transmit EIRP | Default 4W for CPEs |
| FFT Mode | 2048 |
| Cyclic Prefix Modes | ¼, 1/8, 1/16, 1/32 |
| Duplex | TDD |
| FEC codes | LDPC, Turbo Code, and STBC |

### C. 802.22 MAC

Some of the basic concepts of 802.22 MAC are borrowed from the IEEE 802.16 standards [10], and includes cognitive radio features for reliable incumbent detection, frequency agility and self coexistence. The BS controls the access to wireless medium within its cells and grants bandwidth resources in the US direction to the CPEs on an on-demand basis while the BS uses TDM (Time Division Multiplexing) to communicate with the CPEs.

#### i. Super frame and frame structures:

A new super frame structure (Figure I.) has been introduced by 802.22 MAC in order to facilitate incumbent protection, synchronisation and self coexistence. It consists of 16 frames starting with super frame preamble followed by frame preamble and Super frame Control Header (SCH). SCH is followed by Frame Control Header (FCH) of the first frame. The frame structure is divided into DS and US sub-frames. Broadcasting messages are transmitted following the FCH as part of the DS sub-frame. The two dimensional MAC frame structure is depicted in Figure II. . In US sub-frame, the BS can allocate some resources for contention based access; these can be used for ranging, bandwidth request and Urgent Coexistence Situation (UCS) notification. In addition, it BS may also reserve up to 5 symbols at the end of the US at the end of sub-frame, known as Self-Coexistence Window (SCW). The UCS and SCW allocations are the new cognitive radio features introduced in 802.22 MAC. The UCS notifications enable CPEs to transmit measurements report to indicate the presence of incumbents while SCW allows coordination among neighbouring 802.22 cells to facilitate incumbent protection and spectrum sharing.

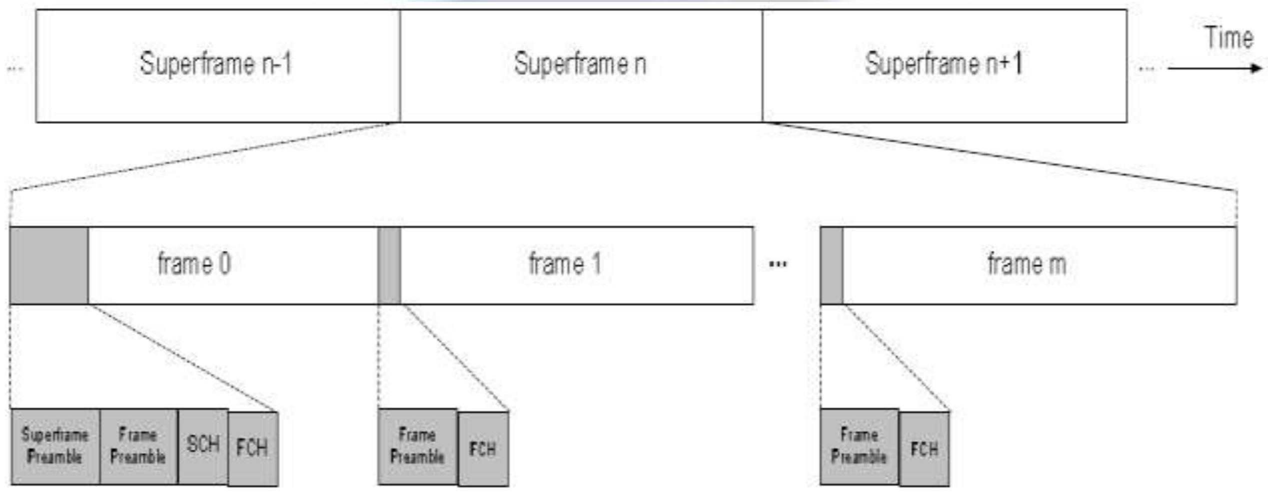


Figure I. MAC Super frame structure.

Figure II. Illustrates that how the MAC packets are mapped into the time-frequency model at the PHY layer. In the DS sub frame, MAC information is layered vertically to sub channels and then stepped horizontally in time domain while in the US sub frame, information is mapped horizontally in same sub channel, increasing the sub channel order once to its maximum capacity. Another mode is to lay the information to fill one column of OFDM symbols at a time.

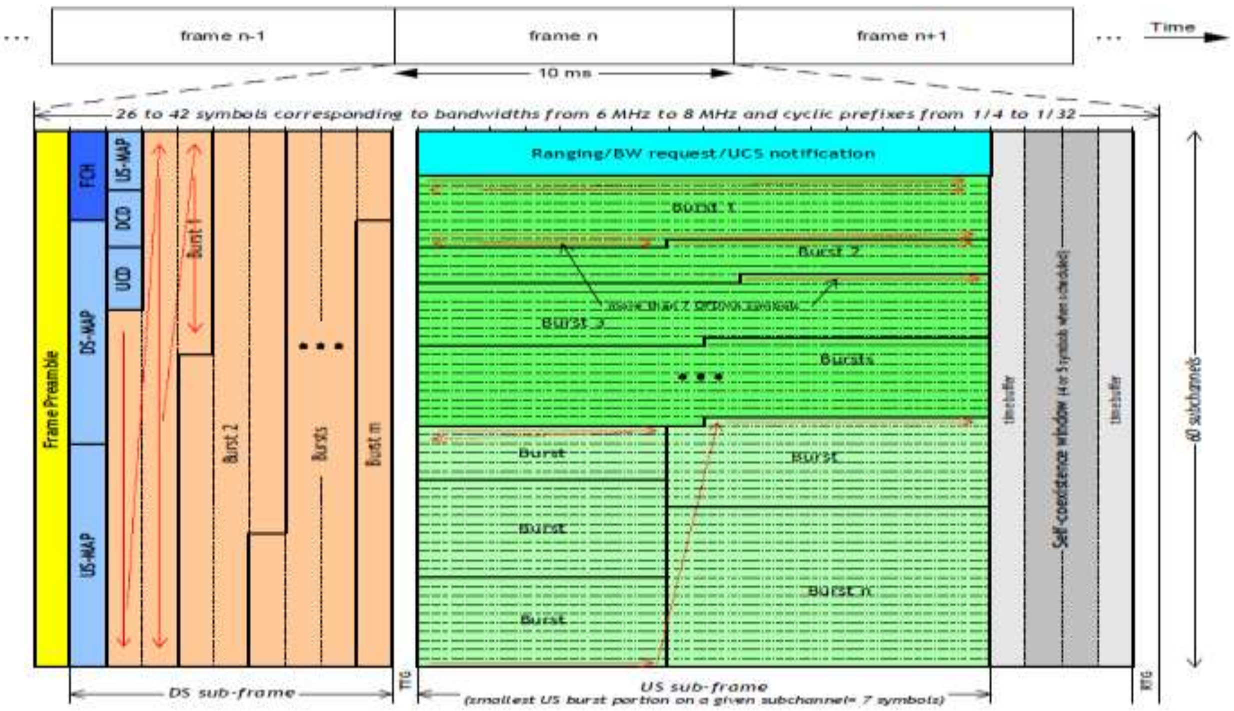


Figure II. Time Frequency MAC frame structure [2].

### ii. Incumbent Detection Support:

It can be done by: i) scheduling of network quiet periods; and ii) channel measurement management. Overlapping of data transmissions and sensing on the same channel affects the sensing performance, resulting in a high rate of false alarms. In order to avoid such problems, the BS can schedule network wide quiet periods (QPs) for sensing, while all the traffic in the cell is suspended so that the CPEs can sample the channel for detecting the presence of incumbents. Figure III. Illustrates concepts of intra and inter-frame quiet periods. The 802.22 MAC provides required features for BS to implement a two-stage sensing approach. According to which BS first schedules short (or intra-frames) QPs and may also schedule a longer (or inter-frame) QP as required in order to perform more detailed measurements. Thus BS can reduce the impact of QPs on the user's QOS. To achieve the required sensing reliability in terms of PD and PFA parameters, it is necessary to schedule a minimum number of QPs.

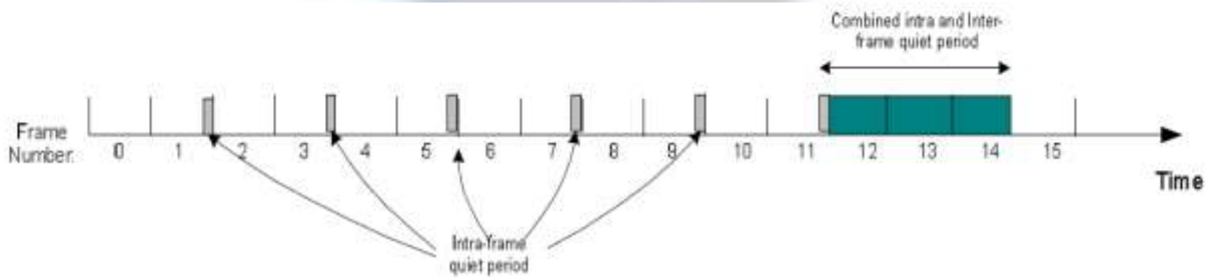


Figure III. Intra-frame and inter-frame quiet periods.

Incumbent detection can be done both in-band (i.e. in the operating channel and first adjacent channels) out-band (other channels that may be used as backup). It is important to note that if out-band to be sensed is occupied by another 802.22 system, the sensing CPEs should use the QPs scheduled by 802.22 BS in order to avoid interference.

Next to the incumbent detection is the notification phase. The 802.22 MAC provides a set of management and control frames that allows BS to take full control of both these steps. The measurements are reported back to the BS after sensing is completed. The BS must allocate sufficient US bandwidth for CPEs to report their measurements, if not allocated than the CPEs can use UCS notification slots, In such case the notification is transmitted using CDMA-based approach [2]. By combining the UCS notification with sensing results, the BS can react efficiently in a timely manner.

**iii. Frequency Agility:**

Once an incumbent is detected, the BS is responsible for triggering a switch to a backup channel, which should be clear of incumbents (see TABLE I.). A common priority list of backup channels is transmitted periodically or as needed be BS.

**iv. Self-coexistence:**

It plays a very important role in protecting incumbents. The Coexistence Beacon Protocol (CBP) allows CPEs to exchange coexistence beacons that carry information about QP schedule and about CPEs allocated bandwidth. The CBP packets are transmitted periodically as scheduled. As soon as a CBP packet is received from neighbouring cells, the CPE forward the received information to its BS. The second role of coexistence is to achieve efficient spectrum sharing.

## IV. SPECTRUM REQUIREMENTS

There are many factors that determine the required spectrum. We have come across three approaches in this paper to determine the required spectrum. The first approach is based on service data rate, denoted as minimum service rate spectrum requirements (MSR). The second approach is based on minimizing the number of APs, denoted as minimum system cost spectrum requirement (MSC). The third approach is based on analyzing the total capacity required by system to carry each user’s average traffic load. Thus there is a trade-off between available spectrum and cost of providing the service. Based on value placed on spectrum used, we determine a spectrum minimizing the cost of BWA deployment and spectrum, denoted as minimum total cost specification requirements (MTC).

## V. SPECTRUM MANAGEMENT MODEL AND ARCHITECTURE

The 802.22 standard has adopted a spectrum management in order to achieve efficient spectrum utilization and protection of incumbents. It is all dependent on a central entity collocated with the WRAN BS, called Spectrum Manager (SM) as it is only responsible for taking the key decisions and triggering the proper events/actions. SM is the central intelligence of the system and is shown in figure IV. . At CPE side, standard defines the Spectrum Automation (SA), acting as a slave to SM at BS. The SA controls the Spectrum Sensing Function (SSF) and can also use SSF to perform sensing autonomously during CPEs idle time.

Main functions of SM’s are listed below:

a. Maintain spectrum availability information.
b. Channel classification and selection.
c. Trigger frequency agility related actions.
d. Manage mechanisms for self-coexistence.
e. Association control.

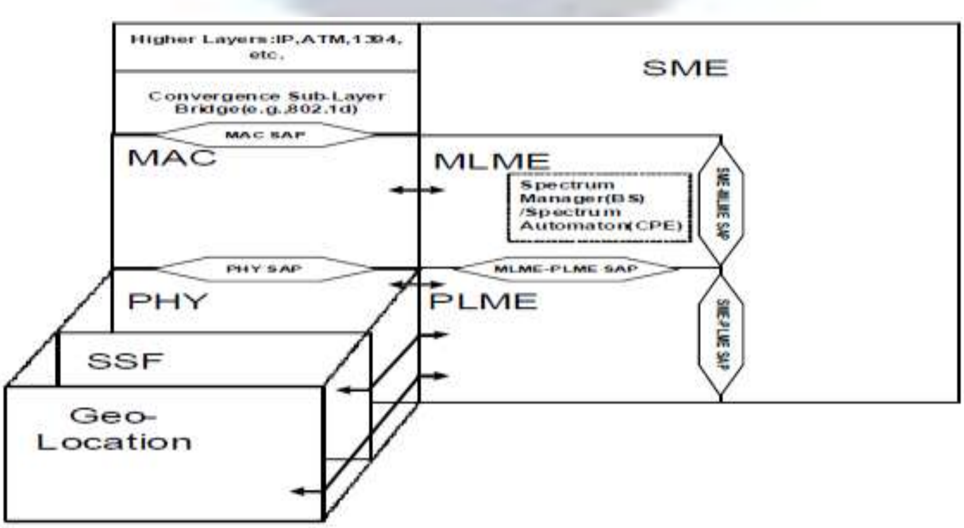


Figure IV. Reference Architecture of 802.22[2]

### a. Communication Architecture:

The purpose of BWA is to provide connectivity between user stations and the internet. It consists of APs that is responsible for communicating with fixed user stations. The AP consists of multiple antennas covering different directions. The APs communicate to users over links having frequencies below 3 GHz. Since TV bands are below 1 GHz and have large tracks of unused spectrum, are especially suitable. The BWA system uses unused spectrum in TV bands for its access spectrum. The BWA system must avoid interfering with the licensed broadcast use of spectrum. Being specific, we consider using combination of geolocation and access to a database.

## VI. CONCLUSIONS

In this paper we have examined that under what conditions cognitive radios could be viable to provide BWA in the licensed TV bands. We came to know that in rural areas an unlicensed model is viable and an additional spectrum would be useful despite existing unlicensed spectrum while in the densest urban areas no model is viable. CRNs utilizes spectrum more efficiently, requiring new regulatory frameworks that enable dynamic spectrum access models. These models provide access to new spectrum with ideal characteristics in order to enable new BWA opportunities. The 802.22 standard is being developed to harness these opportunities. We have come across two fundamental problems: i) to ensure protection of incumbents and ii) to achieve efficient spectrum utilization. The 802.22 standard also defines a SM model that combines centralized intelligence with collaborative spectrum sensing to trigger the required frequency agility actions to protect incumbents as well as guarantee QOS for users. However given cognitive radio features ensures the success of the 802.22 standard including: 1) optimized scheduling algorithms. 2) Channel selection and intelligence scheduling algorithms. 3) Collaborative sensing techniques. 4) System level evaluation.

## REFERENCES

[1]. S. Haykin, “Cognitive Radio: Brain-Empowered Wireless Communications.” in IEEE JSAC, vol. 23, no. 2, Feb 2005.
[2]. IEEE 802.22 draft standard, “IEEE P802.22TM/D0.4.8 Draft Standard for Wireless Regional Area Networks.” http://www.ieee802.org/22/, Draft 0.4.8 March 2008.
[3]. C. Cordeiro, K. Challapali, D. Birru, and S. Shankar, “IEEE 802.22: The First Worldwide Wireless Standard based on Cognitive Radios.” In IEEE DySPAN, Nov. 2005.
[4]. Federal Communications Commission (FCC) “Notice of Proposed Rule Making,”ET Docket no. 04-113, May 24. 2004.
[5]. M. Buddhikot, “Understanding Dynamic Spectrum Access: Models, Taxonomy and Challenges”, DySPAN 2007.
[6]. WiMedia Alliance www.wimedia.org
[7]. W. Lehr, and J. Crowcroft, “Managing Shared Access to a spectrum Commons,” in IEEE DySPAN 2005.
[8]. FCC, “Part 74 – Experimental radio, auxiliary, special broadcast and other program distributional services”.
[9]. C. Corderio, M. Ghosh, D. Cavalcanti and K. Challapali, “Spectrum sensing for dynamic spectrum access of TV bands” CROWNCOM 2007, Aug. 2007 (Invited).
[10]. IEEE 802.16 Working Group on Broadband Wireless Standards. http://wirelessman.org/.