A Study of IEEE 802.22 as an Alternative to the Brazilian Digital Television Return Channel

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***Abstract*— The IEEE 802.22 work group is developing the first cognitive radio Wireless Regional Area Network (WRAN), which will allow the non-interfering opportunistic use of the spectrum reserved to broadcasting television service. The Brazilian digital television (DTV) standard ISDB-Tb (Integrated Services Digital Broadcasting – Terrestrial) was published in 2006, when the IEEE 802.22 standard was still under development, and it was not considered as an alternative to the return channel. This paper presents some aspects of the IEEE 802.22 standard, discusses the broadcasting television frequency distribution characteristics in Brazil and discusses the feasibility of use the IEEE 802.22 as a solution to implement the return channel.**

I. Introduction

Terrestrial television broadcast is popular in Brazil, reaching at least 95% of the Brazilian homes [1]. One of the ISDB-Tb objectives is to take advantage of broadcasting television popularity to promote the digital inclusion by using the DTV return channel.

Digital inclusion means the provision of services as: e-commerce, e-government and broadband Internet access. This process of inclusion is necessary in Brazil, where the digital divide is high, and only 23% of the homes have access to the Internet [1].

This paper considers the localities with small economic feasibility as those with low population density, or those located in remote and hard to access areas. The investment necessary to install and operate an Internet provider in those areas, outweighs the financial return expectation.

The DTV deployment substitutes the current analog television system. In the near future, DTV will operate the return channel, and that is an opportunity to reduce the digital divide by using the return channel. However, there are some questions that must be answered before the return channel becomes operational. Which technology will be used to provide de access, is one of them.

Several technologies were studied for the return channel, including Wi-Fi, WiMAX, DVB-Return Channel Terrestrial, Power Line Communications, among other [2]. Currently, an acceptable solution for the return channel is WiMAX-700, which is an WiMAX profile that covers the 400 MHz to 960 MHz band, including all UHF TV channels [3].

The Brazilian General Telecommunications Law (LGT) (Law 9472, 1997) defines the electromagnetic radio-frequency (RF) spectrum as a public and limited resource. Anatel (National Telecommunications Agency) is responsible for the allocation of frequencies to each service. Since the RF is a limited resource, an essential factor to decide on which return channel solution to use, is its RF bandwidth requirement.

One of the major obstacles for the creation of a new service, as the return channel, is to find a free RF spectrum band that may be reserved to the service, once almost all frequencies are already reserved to other services. To restructure the RF spectrum allocation is a laborious task which involves not only technical, but also political and economic factors.

The adoption of a regulatory policy that deals with dynamic spectrum access may be a solution to facilitate the deployment of new services. The Federal Communication Commission (FCC) has already allowed the use of TV channels in VHF and UHF band for fixed broadband access systems [4].

The current Brazilian policy does not permit the use of frequencies by unlicensed users. One objective of this paper is to show that an update in the RF spectrum access policy has the potential to reduce the digital divide. The update would permit the use of Cognitive Radio (CR) systems in frequency bands without the need for a license [5].

The CR can change its transmitting characteristics based on its interaction with the environment [6]. One of the major steps towards a worldwide policy of opportunistic access using CR systems is the definition of the IEEE 802.22 standard [7].

The IEEE 802.22 premise is the use of unused RF spectrum band reserved to broadcasting television services. Spectral holes are RF spectrum bands in which momentarily there are no services been provided [8], [9].

One of the main advantages of the IEEE 802.22 as a solution for the return channel instead of the WiMAX-700, lies in the fact that the IEEE 802.22 based systems is capable to sense the environment and react by adapting its characteristics. This reduces the possibility that the IEEE 802.22 systems interfere in the broadcasting television services provided in the area.

This paper discusses the advantages and drawbacks of using the IEEE 802.22 standard as a solution for the ISDB-Tb return channel implementation. The discussion starts with the description of some IEEE 802.22 technical features, such as coverage, capacity and some physical characteristics. Following the Brazilian scenario particularities as the basic RF distribution, and cities population density are discussed. To finish the paper one analyzes the possible digital inclusion effects of this solution for the people who lives in areas with small economic feasibility.

II. IEEE 802.22

The IEEE 802.22 working group was formed in 2004 as an answer to the FCC NPRM 04-113 resolution which proposed ”to allow unlicensed radio transmitters to operate in the broadcast television spectrum at locations where that spectrum is not being used” [10]. However, to access those bands, the unlicensed devices needs to avoid interference with the incumbent operation and low power licensed devices. It is mandatory that those devices be able to detect if there are licensed users operating in the area before provision of any service [11].

The IEEE 802.22 standard defines the characteristics of a CR based Wireless Regional Area Network (WRAN), whose focus is to use cognitive radio techniques to allow that unused RF spectrum bands, reserved to broadcast television services (from 54 to 862 MHz), be used to provide broadband access in regions with low population density [12].

Systems based in IEEE 802.22 operate as Secondary User (SU), in other words, it should not exceed the interference threshold of the Primary Users (PU) operation [13]. To avoid interference it is important to establish the interference limits of IEEE 802.22 in television channels [13]. The identification of spectrum holes by spectrum sensing techniques [14], and the use of an appropriate channel allocation technique [11] also reduces the interference probability.

A SU also does not have warranties that will not suffer interference from other SU, in this way the IEEE 802.22 systems need to sense other SU operating in the neighborhood [14]. Besides the sensing, the IEEE 802.22 systems apply techniques, such as Dynamic Frequency Hopping, to avoid the interference due to WRAN coexistence problems [15].

The IEEE 802.22 standard uses the Orthogonal Frequency-Division Multiple Access (OFDMA) technique for the air interface, which is based on the IEEE 802.16e standard, with single channel operation bandwidths of 6, 7 or 8 MHz [13]. Systems based on IEEE 802.22 can use three modulation schemes, Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (16-QAM) and 64-QAM. There are also four convolutional coding rates available (1/2, 2/3, 3/4 e 5/6). The IEEE 802.22 defines 14 operation modes, chosen according to the channel characteristics. For a 6 MHz channel, the spectral efficiency of those operation modes varies from 0.76 to 3.78 bit/s/Hz [12].

The IEEE 802.22 operation frequency band, small industrial noises and low ionospheric reflections in those frequencies, increases the coverage area [16]. According to the IEEE 802.22 system requirements, the coverage radius is typically between 17 and 30 km (in special cases the radius can reach a 100 km) [12], [8].

Due to the large coverage reached, the IEEE 802.22 needs to support long time delay spreads. The Physical (PHY) layer tolerates time delay spreads up to 37 μs, inserting cyclic prefixes in the Orthogonal Frequency-Division Multiplexing (OFDM) symbols.

If the radius exceeds 30 km, the time delay spread will exceed 37 μs and the PHY layer will not be able to fix it. In this case the Media Access Control (MAC) layer deals with the delay [12].

Because the IEEE 802.22 handle with long cyclic prefixes, the number of OFDM carriers is fixed in 2048 to avoid the overhead caused by reducing the number of carriers [17].

Another important characteristic is the system capacity. The IEEE 802.22 standard guarantees a minimum bit rate of 1.5 Mbit/s for downstream and 384 kbit/s for upstream. To verify the system feasibility as a solution to implement the return channel, one needs to verify the capacity of the system to provide access.

Based on the upstream and downstream rates, it is possible to calculate the minimal data rate of 1.884 Mbit/s to each user in the coverage area. Assuming an spectral efficiency of 2 bit/s/Hz, a single 6 MHz channel, and an over subscription rate of 40:1, one can calculate that the system is able to handle 255 users [8].

The system can allow 255 users, providing a connexion of 1.5 Mbit/s in downstream and 384 kbit/s in upstream for each 6 MHz channel available in the region. The Figure 1 illustrates the service provision scenario.

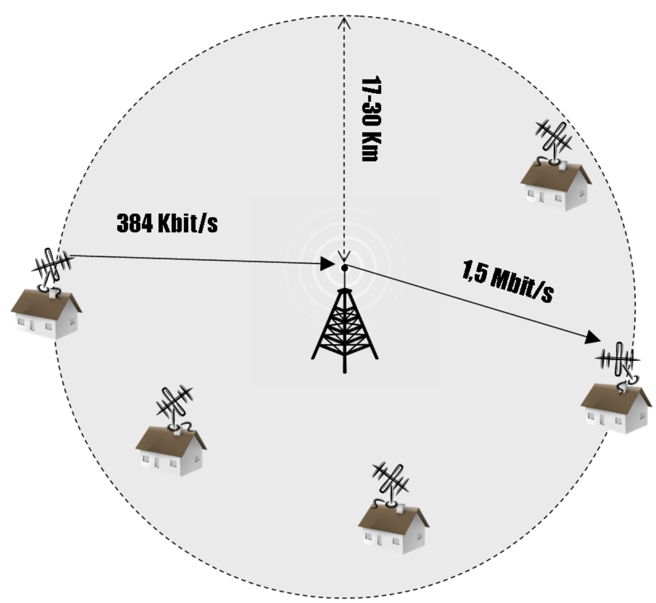

Fig. 1. Physical limits of IEEE 802.22.

III. BRAZILIAN CHARACTERISTICS

In order to analyze the standard feasibility as the return channel, one needs to verify the frequency occupation in the VHF and UHF bands. Anatel is responsible to distribute the television channels over the Country. The Basic Channel Allocation Plan (BCAP) is the document that determines which channels are available and in which region each channel can be used.

By analyzing the BCAP, one verified that currently Brazil has 14,949 channels authorized for television related services [18]. According to the LGT, each authorized channel can only be used by licensed users to provide service in the region of authorization, and operate as primary.

The number of cities in Brazil, in 2008, was 5507 [1]. The population density of those cities varies, and reflects in the economic feasibility of the location.

The systems based on IEEE 802.22 are able to provide access in areas with population density less than 60 persons/km^2 [12]. It reflects the density of 82% of the Brazilian cities [1]. Those systems are a feasible solution for data communication specially in emerging countries, which have a large territorial extension (e.g. Brazil, China, India, etc.) [19].

Based on city densities data and BCAP, one verified that most of those cities with low population density, also have few reserved channels in the BCAP.

According to the analysis, 27.4 % of the cities, with low density profile, do not have one channel reserved to provide television related services. The graphic presented in Figure 2 illustrates the scenario.

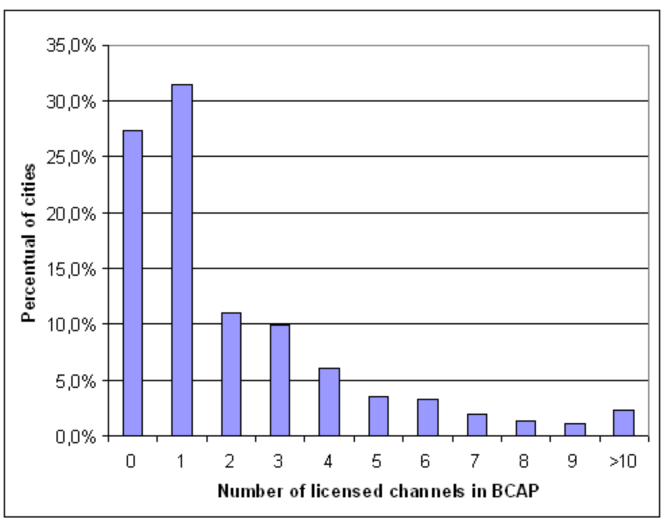

Fig. 2. Channels allocation in cities with population density lower than 60 inhabitants/km^2.

The mean area of the cities with low density profile is 1836 km^2, considering the density of 60 persons/km^2, and 3.55 inhabitants per home [1], one calculates that there are approximately 31,000 homes in the area.

Considering that one station can provide service to 255 users for a 6 MHz channel, 121 channels would be necessary to provide service to all inhabitants of the city.

There are 67 channels reserved for television related services VHF(2-13) and UHF (14-69), which means that a city without allocated channels can have a maximum of 17,000 users.

The solution to the problem is to reduce the base station coverage area, and allocate more base stations in the region to create a cellular structure in the coverage area.

It is possible to distribute all unused frequencies over different cells. One can plan the channel distribution to the cells, and apply a reuse factor to avoid the interference between cells.

Each cell can use a certain group of available channels, which cannot be used by the adjacent cells. The idea is illustrated in Figure 3.

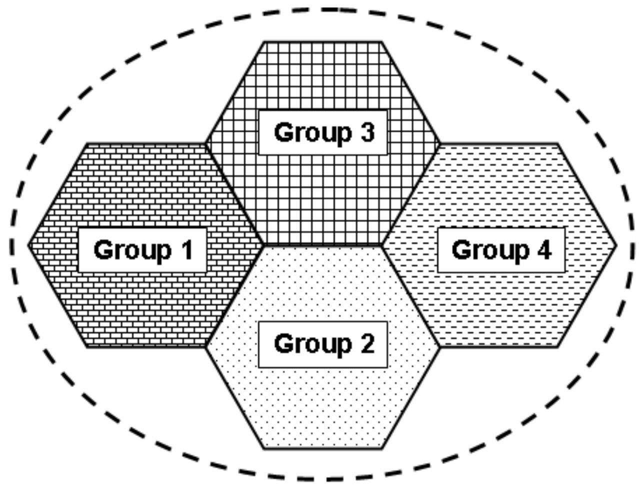

Fig. 3. Cellular based allocation of frequencies.

One possible scenario illustrated by the figure 3 would be a city with 40 unused channels divided in four groups of 10 channels each. The channels are allocated according to their availability in the cell region. It means that the channel allocation to each cell it is dynamic.

In the Brazilian scenario, the mean density of the cities with low population density profile is 21 persons/km^2. It means that for a city with 1836 km^2 area, there are approximately 11,000 homes.

To provide service to 11,000 users with only one base station, the system would require 43 channels. According to the analysis 99.9 % of the cities with low population density profile have at least 43 unused channels.

IV. Conclusion

By analyzing the Brazilian scenario, one concludes that is necessary to update the spectrum allocation policy to allow an efficient dynamic spectrum, usage to avoid the current underutilization. The IEEE 802.22 based systems is a possible solution to deploy the return channel, and consequently reduce the digital divide.

The use of a cognitive radio based system makes the IEEE 802.22 more practical solution than the WiMAX-700, but both solutions will need to coexist (without interfering) with the primary television systems. The use of a cellular structure can increase the bit rate and the number of system users. It is necessary to define the dynamic spectrum allocation in Brazil, and one start point is the deployment of a cognitive radio based digital television return channel.

Acknowledgments

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