NEW COGNITIVE RADIO TECHNOLOGIES, WHITE SPACES AND THE DIGITAL DIVIDEND IN THE BRAZILIAN CONTEXT

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In the recurring debate in Brazil (a country with nearly 200 million people, 8.5 million km², and 5,565 municipalities), on the approaches to broadly democratize quality access to the Internet, there is an outcry of mobile phone operators who try to convince the public that mobile connectivity will be the "definitive" solution to this democratization. Brazil's telecommunications have been privatized in 1998, and the mobile market is now dominated by four transnational corporations (Vivo/Telefónica, TIM, Oi/Portugal Telecom, and Claro). A fifth European company (GVT/Vivendi) does not offer mobile services. These five transnationals also own the major fiber backbones and satellites.

To reinforce this perception, they promote, through their corporate association, statistics conglomerating cell phone (prepaid and postpaid) contracts and fixed broadband contracts, without any distinction regarding prices, quality, and availability. The four major cell phone operators are systematically in the consumers' lists as paradigms for bad service, breached contracts and very high prices (still among the highest in the world). Numbers are concentrated in the most developed cities, while service in poorer regions is of even lower quality or even non-existent. In fact, most of the Brazilian population considered by these operators as "connected to the Internet" still uses prepaid phones and very rarely browse the Internet.

Depending on the will of these companies, access will follow a caste

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structure - the ones who can pay hefty prices and live in more developed areas will have the best mobile service in their smartphones. They usually are the ones who also have a good fixed broadband connection at home. Prices in these cities are driven a bit down because these are the markets where all five companies try to compete for broadband service, either fixed or mobile. Most of the others will have to accept a very restricted mobile access to the Internet and, if they are lucky, a low-speed fixed broadband connection at home.

However, wireless services both in urban and rural areas can go well beyond mobile services based on a cellular network. Beyond what is already generally known in domestic and community applications using unlicensed or "light-licensed" bands of the so-called "WiFi" spectrum (in most countries using the 2.4 GHz and the 5.8 GHz bands), new techniques of digital radio communication have emerged which make highly efficient use of the available spectrum either in primary or secondary use modes. In particular, there is a new breed of software radios known as "cognitive radios"

Also, one ought to keep in mind the need for significant investments in fiber backbones through which data to and from millions of cell phones, wireless networks, and fixed connections circulate. Data presented by Cisco[1] estimate that global mobile data traffic will grow 26 times from 2010 to 2015 in mobile networks, when about 230 petabytes per day (or 2.67 terabits per second) will be transported - especially due to the growing demand for mobile video and access to Internet cloud services.

1. Cisco, Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015, February 2011.

Besides expanding on the number of base stations (the mobile network's "cells") to relieve congestion on the existing ones (in Brazil there may be up to ten times more cell phones per base station than in the USA or Europe), it is necessary to invest in backbones which transport calls and data among these stations and from them to the Internet. Optical fiber branches of these backbones ought to reach all municipalities, with abundant, future-proof physical capacity, offering one or more points of presence with the guarantee of isonomic access at reasonable prices to community, research, and municipal networks, as well as to local entrepreneurs who may provide a number of Internet services. These are prerequisites to enable broad use of the new radio technologies in boroughs, cities, sparse urban communities and the rural areas in each municipality.

5.1 WHICH SPECTRUM ARE WE TALKING ABOUT?

Electromagnetic radiation becomes more directional and more vulnerable to physical obstacles and climatic conditions as the frequency increases. While AM radio (frequencies between 535 kHz and 1.65 MHz in the Americas) or traditional tropical or short wave radio may reach thousands of kilometers, FM radio and television in VHF or UHF channels barely go beyond the horizon without the help of repeaters.

Certain frequency bands are designated by the International Telecommunication Union (ITU)[2] as unlicensed, with power and antenna gain limitations that restrict the range. These are used for home wireless phones, remote controls, and "bluetooth" devices. It is up to the regulator in each country to establish the specific requirements for commercial or non profit usage, and different strategies have been adopted in regard to the WiFi devices. In order to operate in these bands with longer range or higher power (for example, in community networks, municipal networks, local wireless access providers) a license is required in many countries.[3]

2. http://itu.int

3. Brazil maintains two types of "light licenses" for wireless services networks, which are required even if unlicensed devices are used if they reach beyond the operator's premises or operate at 400 mW or more. For commercial operation the license is known as SCM and requires a single payment of about US$200. For non profit operation (community or municipal networks) there is the SLP license, at the same cost.

Most bands are licensed and rigorously controlled exclusively for specif use by certain operator in a given geographical area. The allocation of these bands is done through bids, auctions or authorizations of several types, usually at very high prices, accessible only to larger telecommunications and media companies.

Brazil considers the spectrum to be an asset of the commons - it cannot be bought or sold. For licensed portions of the spectrum, licenses are issued (through bidding, auctions or other granting forms) for primary use in certain regions for a limited time, subject to renovation under certain conditions. No one can "own" spectrum in Brazil - or at least this is what the law says. Also, even in the case of unlicensed spectrum bands, equipment must be certified by the telecommunications regulator.

WiFi radios are well known as software-driven radios which use spread spectrum techniques to share the unlicensed bands with many other radios in a given area. These are frequently used in community and municipal networks, as well as for local commercial services. A typical application in a community network is the use of dual-band radios which operate simultaneously in the 2.4 and 5.8 GHz bands - where the higher frequency is used to interconnect the radios, thus extending the network range, and the lower is employed to distribute the signal in each small area.

Recent advances which combine computing power, information logistics and advanced digital radio techniques have lead to what is known today as cognitive radios. These are software radios specially conceived to operate in several frequencies in programmable automatic mode, either by accessing data in a remote database to obtain available frequencies in its operating area (information logistics), or through sophisticated sensing algorithms to detect available frequencies (computing power), thus even allowing for secondary use (i.e., coexisting with the primary use allocated by the regulator) of frequencies without affecting their primary use. As an example, an operator might hold a primary use license in the 700 MHz band, but uses only certain portions of it in each region - a cognitive radio can identify which portions are not in use every fraction of a second and operate in these frequencies, thus providing other services.

Cognitive radios are already capable of operating in several portions of the spectrum, expanding its data transmission capacity. One example is a radio capable of operating in any frequency between 100 MHz and 7.5 GHz delivering up to 400 Mbps.[4]

4. "Frequency-Hopping Radio Wastes Less Spectrum", Technology Review, June 13, 2012, http://www.technologyreview.com/news/428182/frequency-hopping-radio-wastes-less-spectrum

5.2 THE DIGITAL DIVIDEND AND WHITE SPACES

Each country has its own spectrum attribution table (which defines which services should be run on which chunk of spectrum), generally compatible with the attribution proposals agreed upon at the ITU. The "beach front property" of the spectrum is currently between 50 MHz and 6 GHz. This includes all FM and TV (analog and digital) bands, as well as the numerous frequency bands for mobile telephony and point-to-point/multipoint data links, among several others.

Television channels in the Americas are in the ranges 54-88 MHz and 174-216 MHz for VHF (channels 2 to 13) and 470-890 MHz for UHF (channels 14 to 83). The range 88-174 MHz is allocated to FM radio, aeronautical radio services, and ham radio. Analog TV channels in Brazil broadcast with the PAL-M standard - a variation USA's NTSC using the European PAL color standard. As with NTSC, each channel bandwidth is 6 MHz. Channel 37 is reserved for radioastronomy, and channels 53 to 83 (698-890 MHz) are reserved for mobile terrestrial services to be granted to operators of 4G/LTE services.

Since digital TV uses less spectrum than the analog one, the transition to digital has produced what the ITU calls "digital dividend". Also, in analog broadcasting a blank (non used) channel is required between two contiguous channels to avoid interference - these empty channels are called "white spaces". Thus, channels 2 and 4 can coexist in a given area, but channel 3 must remain empty. With digital broadcasting this separation is no longer required, as the technology enables the use of adjacent channels without mutual interference.

The new opportunities for efficient use of the spectrum in community networks, particularly with cognitive radios, are significantly enhanced with the availability of channels from white spaces and gains from the digital dividend. These frequencies propagate to far longer distances than the ones currently used for WiFi. This offers an exceptional opportunity to connect sparse communities in rural areas, especially because there are no plans to extend fiber to these communities.

Digital TV is regulated in Brazil by decrees 4901/2003 and 5820/2006, with the creation of the Brazilian digital TV system (Sistema Brasileiro para Televisão Digital, SBTVD[5]). The regulator has defined 45 channels (UHF channels 14 to 69, in the range 470-806 MHz)[6]. The current holders of analog channels have been automatically assigned digital

5. http://en.wikipedia.org/wiki/SBTVD

6. The complete list of channel distribtuion in Brazilian cities is on Wikipedia: http://pt.wikipedia.org/wiki/Anexo:Lista_de_canais_da_televis%C3%A3o_digital_brasileira

channels. The bandwidth for each channel continues to be 6 MHz, and commercial channels are not allowed to operate with multiprogramming - this is only allowed for public services.[7]

SBTVD is a modified version of the Japanese platform ISDB-T, and is known internationally as ISDB-Tb. This modified version has also been adopted by Argentina, Chile, Peru, Venezuela, Ecuador, Paraguay and Costa Rica. Several other contries in Latin America and in Africa have also adopted or are considering adoption of the Brazilian system. ISDB-Tb uses H.264 (MPEG-4 AVC) for video compression and a middleware developed in Brazil - the Ginga system. In April of 2009 the ITU certified the Ginga-NCL module and its programming language NCL/LUA as the first international recommendation for interactive digital multimedia environments for digital TV and IP-TV (ITU recommendation H.761).

Each channel allows broadcasting of one program in full high definition (1080p) or simultaneous broadcasting of a high definition channel (720p) and a standard channel (480p) - this latter form is the one being adopted by the main broadcasters already operating digital TV services.

While full transition to digital TV in Brazil is not expected to complete before 2020, the use of white spaces with cognitive radios is possible right now, depending only on regulatory decisions.

7. "TV Digital: Minicom permite compartilhamento de multiprogramação," SINRAD-DF, 13/março/2012, http://www.radialistasdf.com.br/noticia2.php?id=758

5.3 ADVANCES IN DEVELOPED COUNTRIES

The first commercial network using white spaces was deployed in Wilmington, North Carolina, culminating a regulatory process initiated by the Federal Communications Commission (FCC) in May, 2004, when a public consultation on the use of unlicensed devices on unused TV channels was issued [8]. As a result, in September 2006, the Engineering and Technology Office of the FCC announced a "projected schedule for proceeding on unlicensed operation in the TV broadcast bands" [9].

Given its propagation characteristics, the Wilmington network enables a far easier positioning of certain connected devices and services, like the municipal network of monitoring cameras, public vehicles communication, and the activation of local WiFi access points. Interference with the existing TV channels is avoided because the radio must consult a database of occupied broadcasting channels before transmission is allowed.

The USA has been pondering the destination of analog TV channels for digital applications since 2002. At the end of 2008 the FCC agreed to open the white spaces for unlicensed or light-licensed use. In September 2010, the FCC approved rules to operate radios in white spaces, as well as in free channels left by the transition to digital TV. To enable automatic channel selection by the cognitive radios a central geolocation database providing information on free channels has been activated.

8. http://www.forbes.com/sites/elizabethwoyke/2012/01/26/worlds-first-commercial-white-spaces-network-launching-today-in-north-carolina/

9. US Federal Communications Commission, "Office of Engineering and Technology Announces Projected Schedule for Proceeding on Unlicensed Operation in the TV Broadcast Bands", DA 06-1813, ET Docket Nr. 04-186, Sept.11, 2006.

Radios thus check this database to obtain a list of available channels in its area of operation, in order to protect the primary user of the spectrum from interference. A total of 48 analog TV channels, spanning 288 MHz of bandwidth, can be accessed for unlicensed or light-licensed use. Meanwhile, a new standard for cognitive radio for these applications was developed by the IEEE (802.22) [10] and published in 2011.

10. http://www.ieee802.org/22

The FCC has been supporting since 2009 (through regulatory measures and concrete experiments), the use of cognitive radio technologies in municipal and community networks. This has stimulated manufacturers to launch commercially available cognitive radios for these applications. With these advances, network architectures can be optimized for the coverage of large areas with the adequate combination of cognitive radios in the TV bands with WiFi radios in the 2.4 GHz and 5.8 GHz bands, as well as underlying fiber, thus significantly increasing the options at hand for the design of optimal municipal networks.

In August, 2011, Industry Canada carried out a public consultation for the possible use of unlicensed cognitive devices using white spaces or free channels below 698 MHz. Since September 2010, Canada follows a policy of light licensing for these bands, similar to the USA's. For applications in rural areas, also under light licensing, Canada reserved the ranges 512-608 MHz and 614-698 MHz. Other countries which have progressed with similar rules are Finland, the United Kingdom [11] and Japan. The European Union is working to define similar common rules.

11. In the United Kingdom the following bands are available for unlicensed or light-licensed use: 566-590 MHz (current UHF channels 33 to 35) and 806-854 MHz (VHF channels 63 to 68). The ranges 470-550 MHz, 790-806 MHz and 630-790 MHz are reserved for digital TV, totalling 259 MHz of spectrum, or 34 8 MHz channels. Some minor variations might happen with the relocation of bands currently being used for radar and radioastronomy.

The advance of cognitive radio technologies enables numerous applications for secondary use of the spectrum. With the use of advanced modulation technologies (like the ones currently deployed with 4G/LTE networks) data densities of 15 bit/Hz or more can be reached. On a white space 6 MHz channel, with this density data transmission can theoretically reach 90 Mbps (compared to 20 Mbps of digital TV broadcasting). As already mentioned, a radio can combine several channels to increase throughput.

In the 450 MHz band there are already commercial devices and concrete examples of deployment of cognitive radio for interconnecting offices in companies which traditionally use this band for its internal networks [12]. In this case there should be flexibility in the regulation to allow for secondary use, especially in rural areas and to connect sparse communities.

12. See the example of Petrobras in Brazil at http://convergenciadigital.uol.com.br/cgi/cgilua.exe/sys/start.htm?infoid=27950

5.4 PERSPECTIVES IN BRAZIL AND ITS REGION

While in the USA and other developed countries there has been a significant advance in regulatory strategies associated with cognitive radio technologies to enable its broad deployment to optimize spectrum usage at the edge, in Brazil and other countries of the region these initiatives have been timid at the best. Communities and local governments, without qualified information, are unable to demand proper regulations to facilitate licensing in the available chunks of the TV bands, and the regulatory agents are basically concentrated in responding to the commercial demands of the large media and telecommunications companies.

The digital dividend is a specially delicate case, since the current holders of analog TV channels (large media networks) have plans to occupy these channels for their own future digital services - and they of course also eye the white spaces. On the other hand, under the argument of "spectrum crunch", mobile phone companies are also disputing these bands. A report for AHCIET and GSMA [13] argues that coverage of mobile broadband could be from 75% to 95% in Argentina and Brasil, from 53% to 90% in Colombia, from 39% to 94% in Mexico, and from 65% to 89% in Peru [14]. But the outcome of these disputes is not clear. Just as the telecommunications companies seek to offer multimedia services (IP-TV and others), the current media companies wish to provide digital wireless services in these bands.

13. http://www.ahciet.net

14. Study by Telecom Advisory Services LLC (TAS) for the GSMA and AHCIET. See http://convergenciadigital.uol.com.br/cgi/cgilua.exe/sys/start.htm?infoid=27781

In this dispute around white spaces and the digital dividend, media companies in Brazil argue that it is too early for the regulator to take decisions on these channels, and that the telecommunications operators already retain a lot of spectrum which they use inefficiently. According to the calculations of one of the corporate media associations (ABERT) [15], the telecommunications companies in the country already hold spectrum equivalent to a total range of 795 MHz, while in the USA, where usage is much more intense, this total is 574 MHz - and in both countries there is evidence of inefficient spectrum usage [16]. ABERT also argues that the claimed need of 1,280 MHz of additional spectrum for a sample of 14 countries is not confirmed in practice.

15. http://www.abert.org.br

16. Luís Osvaldo Grossman, "Teles e radiodifusão afiam disputa pelo 700 MHz", Convergěncia Digital, Nov.25th, 2011, in http://convergenciadigital.uol.com.br/cgi/cgilua.exe/sys/start.htm?infoid=28199

The Ministry of Communications (MiniCom) informs that the reattribution of these channels will only happen when the transition to digital TV is complete. Civil society organizations which monitor spectrum policy in Brazil insist that attribution and distribution of spectrum ought to be decided on the basis of public consultations with society and not just taking into account business models. The Brazilian Constitution foresees a pervasive public TV system, but this has not advanced as it should, partly because of the alleged "lack of spectrum". However, digital TV provides an exceptional opportunity to realize in full the constitutional goal [17].

17. Intervozes is one of these civil society organizations, http://www.intervozes.org.br, and another one is Nupef, http://www.nupef.org.br

While in the USA, Canada and Europe practically the bulk of regulation for community use has already been established or is in its final stages, with actual commercial or community installations already in operation in some municipalities, in Brazil Anatel is concentrated only in the licensing of mobile services in the 4G/LTE modality in the range 698-806 MHz [18]. For ITU's Region 2, Recommendation 224 defined this range for mobile services. This ITU Recommendation was discussed in the Interamerican Telecommunications Commission (CITEL, a commission of the OAS [19]) in 2006, which defined the ranges 698-764 MHz

18. Anatel, Portaria 681, Aug.6th, 2012.

19. http://web.oas.org/citel/en/Pages/default.aspx

and 776-794 MHz for mobile services, and the ranges 764-776 MHz and 794-806 MHz for governmental use - but so far there has been no formal adoption of this recommendation by the member countries.

Local governments and entrepreneurs, as well as community organizations and movements for digital inclusion, ought to proactively support a public policy allowing for unlicensed or light-licensed use of spectrum currently not in use (or that can be used in secondary mode), employing the new radio technologies at the edge of the network. These opportunities also require a policy to ensure isonomic access to backbones through points of presence in each municipality with an affordable cost/benefit ratio, as well as stimulus to deploy local fiber networks. It is hoped that the national broadband strategies supported by the federal government contemplate these prerequisites to stimulate innovation and digital inclusion at the edge.