Sensing TVWS with open source technology in Ecuador

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RESUMEN

La identificación de TVWS es fundamental para concientizar sobre la existencia de espectro radio eléctrico subutilizado y que podría ser utilizado para aliviar la falta de espectro existente. Estándares recientes que aplican Radio Cognitiva tales como WRAN o White-Fi pueden ser utilizados para explotar estas frecuencias. Las herramientas tradicionales utilizadas para detectar TVWS son caras difíciles de aprender. La utilización de hardware y software libre, así como un método basado en detección de energía para desarrollar una herramienta que ayude a detectar estos TVWS, es presentada para evaluar el espectro radio eléctrico en la banda UHF desde 500 MHz hasta 686 MHz en la provincia de Pichincha del Ecuador, Sudamérica.

Palabras clave: TVWS, espectro, detección de energía, código abierto, Raspberry PI.

ABSTRACT

The identification of TVWS is fundamental to raise awareness about the existence of spectrum that is currently underutilized and that could be used to alleviate the current spectrum crunch. Recent standards that employ Cognitive Radio such as WRAN or White-Fi can then be employed for the exploitation of these frequencies. The traditional tools used to detect TVWS are expensive and difficult to master. The utilization of open hardware, software and an energy based detection method that helps detect these TVWS is developed and presented to assess the radio electric spectrum in the UHF band from 500 MHz to 686 MHz in the Pichincha province of Ecuador, South America.

Keywords: TVWS, spectrum, energy detection, open source, Raspberry PI.

1. INTRODUCTION

The idea of allocating frequencies for different applications was developed at the beginning of the XX century to facilitate the use of the spectrum by many services and applications in different countries. The International Telecommunications Union (ITU) is the oldest United Nation institution and is tasked with the international harmonization of the spectrum usage. Its recommendations are the basis for the actual spectrum regulations in every country.

Frequency allocation has traditionally been done by considering the technical requirements of different services. New technologies have rendered this approach obsolete, since most operator nowadays strive to offer triple play, in which, over the same frequency band, services like TV broadcasting, telephony, and Internet access are made available to their coveted clients (Motorola, 2012; USWITCH, 2014; Barrows, 2004). So, what is relevant is the availability of portions of spectrum over which to offer services, and the propagation characteristics of different frequency bands that will ultimately determine the business case for the operators in face of their competitors.

Sharing the radio electric spectrum can be accomplished by classifying the transmitters as primary and secondary, where secondary users could use the frequency as long as they would not interfere with the primary user. Such technologies are currently being leveraged by the use Cognitive Radio.

A good amount of research have been made in this area, to the point that now there are technologies that work with Cognitive Radio as a main tool. The most relevant example of this is the IEEE 802.22 standard (WRAN) that allows shared spectrum in the analog television bands, using the Television White Space (TVWS) to transmit data where and when possible (Stevenson *et al*., 2009).

The equipment currently used to determine spectrum occupancy, full-fledged spectrum analyzers, is expensive, complex and requires a steep learning curve for its operation.

2. SPECTRUM ALLOCATION IN ECUADOR

In Ecuador the radio electric spectrum is considered to be a strategic not renewable resource that eases the deployment or distribution of services and development in the country (CONATEL, 2012). The National Telecommunications Council (CONATEL) is the entity responsible for allocating the different frequency bands in Ecuador. The television services are classified as it is shown in Table 1.

Table 1. VHF and UHF TV bands.

Band	Frequency
One (I)	54 to 72MHz and 76 to 88MHZ
Three (III)	174 to 216MHz
Four (IV)	500 to 608MHz and 614 to 644MHz
Five (V)	644 to 868MHz

TV channels are distributed by regions according to geographic localizations to avoid interference between stations. The frequencies in the bands four and five go from 500 to 686MHz are divided in channels of 6MHz as shown in Table 2.

Table 2. Channel according to group.

Group	Channel	Frequency (MHz)
G1	19,21,23,25,27,29,31,33,35	500 - 602
G2	20,22,24,26,28,30,32,34,36	506 - 608
G3	39,41,43,45,47,49	620 - 686
G4	38,40,42,44,46,48	614 - 680

In the province of Pichincha, groups of channels that can be leased are G1 and G3 (CONATEL, 2012). It is necessary to consider that in Ecuador the analog TV is still being used, although a complete transition to Digital TV should be done in 2018. The technology used for analog television transmissions in Ecuador is the same as the one proposed by the National Television Standard Committee (NTSC). This technology requires a signal power above -94dBm for proper detection (Cordeiro *et al*., 2006; Rao *et al*., 2010). This is signal power threshold that will classify the state of a channel, deciding whether is occupied or available.

3. SPECTRUM SENSING MODULE DEVELPOMENT

3.1. Selection of the sensing method

There are several types of algorithm that accomplish the task of detecting TVWS in a given frequency range. The three most popular algorithms are energy detector, characteristic detector, and matching filtering and coherent detector.

Energy detector decides by measuring the energy in the received signal. It is easy to implement, and doesn't require any prior information about the primary transmitter. It also has a high probability of false alarm, it's not accurate in low SNR environments, and cannot make any inference about the type of signal being detected (Babu, 2006).

Characteristic detector bases its statistical tests in a cyclical density function applied to the received signal, or comparing different characteristic of the received signal with those of a stored one. It has a higher tolerance against noise and it behaves better in low SNR environments. It can also differentiate one user from another.

Matching filtering and coherent detection bases its statistical test in the waveform pattern. It also has a higher tolerance to low SNR environments and it can also distinguish between different types of signals in the air. To do this, it requires precise information about the primary signal patterns. Its implementation also requires significant complexity (Ko, 2010; Ray Liu & Wang, 2011).

Table 3 was made to select a detection technique based on criteria like easiness of software implementation, hardware resources required and implementation challenges (Tandra *et al*., 2009), where 1 is very low or not so helpful and 5 is very high or helpful.

Table 3. Detection method technique features.

Requirement	Energy detector	Characteristic detector	Matching filtering and coherent detection
Speed of detection	5	2	4
Energy detection efficiency	5	2	3
Processing requirements	5	2	2
False alarms detection accuracy	2	5	5
Total	17	11	14

Speed of detection is inversely proportional to the time needed to determine the presence of the signal in the given channel. Energy detection efficiency is the measure of the energy required to determine the presence of a signal in the channel, the higher the number the most efficient the method.

Processing requirements refers to the complexity of the algorithm needed to detect the signal; energy detection can be done with a simple process whereas characteristic detector implies a more sophisticated one.

False alarm detection accuracy is a measure of the probability of missing the occupation of the channel. Energy detection is particularly sensitive to erratic energy peaks that can be misunderstood as a primary users' signal. To avoid this, several samples were taken on the same channel and averaged to determine the signal presence.

From Table 3, the total score for each algorithm was selected. Since the Energy Detector had the highest score, it was decided that it would be the technique to be implemented. Previous work (Ray Liu & Wang, 2011) has also chosen this method as the most cost effective (Matamoros, 2014).

3.2. Implementation

The hardware and software selected to implement the prototype is completely based on open technology, both in hardware and software. The use of affordable equipment and free software constitutes a new solution to an existing problem (Zennaro *et al*., 2012). The list of hardware and software used for implementation is described in Table 4. The coding was done in Python following a module organization scheme. This code enables all the devices to work together to acquire data in a mobile environment, avoiding communication and sampling problems.

Although it had its advantages to develop in a lighter software environment, there was also a processing and memory allocation issue due to the raspberry PI´s random access memory allocation characteristics. This was solved, importing only the necessary functions from the libraries therefore reducing RAM memory space, and leaving it for data acquisition and variable storage, programming development guidance with error logs, and a complete data acquisition system.

Table 4. Hardware and software of the prototype.

Hardware/Software	Description
Raspberry PI	Revision B; CPU 777 MHz; 512 RAM; 16 GB HDD.
RF Explorer WSUB 1G	Spectrum analyzer from 240 MHz to 960 MHz, open hardware.
Global Sat BU-353-S4	USB low consumption GPS.
Monitor	7 inch TFT monitor.
Python	Open software for development.
MySQL, Javascript, PHP	Open source data base and Software for web development.

The measurements were taken at a height of 1.5m, with the Nagoya 773 antenna, which has a gain of 2.5dBi, and is the recommended one from the manufacturer of the spectrum analyzer used.

4. RESULTS

The system is completely energized from a USB through a 12VDC outlet of a car. It was all mounted in drawing board to ease the transportation of the module. To ensure most of the province was covered, we took in consideration the different cantons of the province. These can be observed in the Fig. 1, where PTO QUITO stands for Puerto Quito, PVM stands for Pedro Vicente Maldonado, PM stands for Pedro Moncayo, and R stands for Rumiñahui. For the acquisition of spectrum samples the tracks that covered most of the area in the different cantons were selected. They were also chosen due to the fact that rural populations normally settle aside the main roads, to facilitate terrestrial communication. The roads where the samples were taken can be appreciated in Fig. 1.

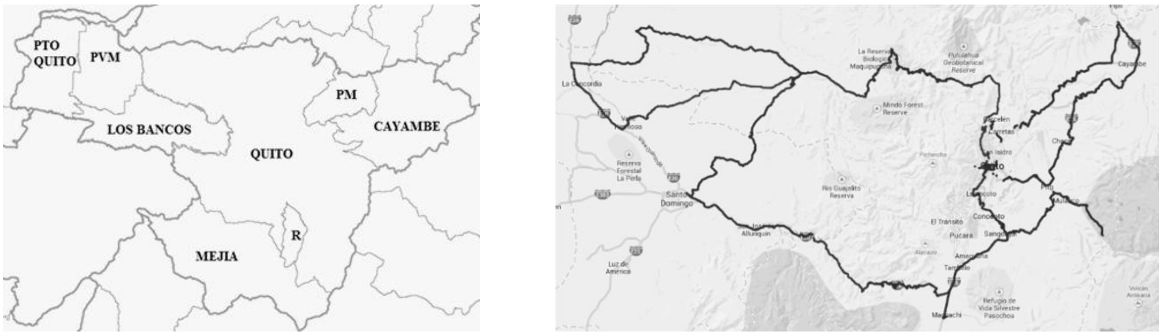

Figure 1. Cantons of Pichincha province and traveled roads.

Traveled roads were divided in four routes; each route was divided in different sections for a better appreciation of the final results. A channel is considered empty when the received power was below -94 dBm (Stevenson *et al.,* 2009).

The four routes were:

1) ESPE to Papallacta town.
2) Quito - Cayambe - limit of the province - Tabacundo - Guayllabamba - Quito
3) Sangolquí - Machachi
4) Quito - Calacalí - Los Bancos - Pedro Vicente Maldonado - Puerto Quito - limit of the province - Aloag - Quito.

Organizing all the data collected, and doing the same analysis for every canton it was possible to obtain the mean number of free channels in the Pichincha province. These results are listed in the Table 5.

Table 5. Free channel percent per canton.

Canton	Percent of TVWS
Cayambe	49,44%
Mejía	85,47%
Pedro Moncayo	72,55%
Pedro Vicente Maldonado; Puerto Quito	74,19%
Quito	29,03% (Center); 69,35% (North - East); 67,74% (North - West)
Rumiñahui	54,83%
San Miguel de los Bancos	85,48%

5. CONCLUSIÓN

It is possible to assemble a device based on open source technology that is accessible from a monetary and equipment aspect to work as a different solution to measure the spectrum occupancy in the province of Pichincha. An application was developed using open source tools such as a Raspberry PI as a mini PC, an RF explorer as a spectrum analyzer, Python and PHP/Javascript as software, MySQL and GoogleMaps® API as tools for data management and representation. All of these tools were acquired at a very low cost and assembled with the intention of creating a system capable of identifying TVWS. This measurement campaign can be easily replicated in other places (Tandra *et al*., 2009), hopefully aiding to overcome the entrance barrier to other communication service providers, be it public, commercial or through wireless community networks.

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