# The Quest for White Spaces in the Democratic Republic of Congo

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**Abstract.** At a time when the opportunistic access to white spaces is a big opportunity for boosting innovation in broadband Internet services, many countries of the developing world are still lagging behind. In the Democratic Republic of Congo (DRC), for example, the TV White Space concept has not yet been tabulated in the operational plan of the national regulator, thus leaving a void in terms of white space discovery and usage. While many studies are still conducted to discover white spaces in several countries of the developing world, most developed countries such as the UK and USA have moved beyond the stage of testing and experimentation to embark on real white space deployments. This paper revisits the issue of spectrum sensing to identify white spaces in the UHF analog broadcast spectrum band ranging from 470 MHz to 862 MHz in the DRC. The experimental results collected from the cities of Lubumbashi and Kinshasa reveal significant white spaces in the frequency band. They provide a proof-of-concept that the national regulator could use as a starting point towards the migration to the digital terrestrial television. The experimental framework can also be used by different telecommunication operators and researchers as a guideline for white spaces identification.

**Keywords:** TVWS · White spaces · Opportunistic access's · Spectrum sensing

## 1 Introduction

Since 2006, many efforts have been made and resources invested in a project that targets the design and implementation of a fiber optic backbone to provide *Internet for all* in the Democratic Republic of Congo (DRC). The expectation is that such an IT infrastructure will benefit rural communities, many public and private institutions of education, the public administration, the health and safety sectors, and many others. However, since 2009, the project has stalled by many administrative, technical and economic issues. Furthermore, due to the country's geographic size, its demographic diversity and the lack of supporting


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infrastructure such as a stable electricity grid, capable of supporting the optical Internet backbone expansion, such a project has a low probability of meeting its goal. Wireless communication is a promising alternative to the battling optical backbone infrastructure of the country and white spaces implementation is a great opportunity for providing a new wireless access model, where the current wireless infrastructure is complemented by additional spectrum.

### 1.1 TV White Spaces Deployment

TV white spaces (TVWSs) are unused channels in the licensed TV spectrum, which either have been allocated but remained unused by the TV operator or can be availed by the spectrum owner for being used by the spectrum borrower on a temporary lease agreement. They fall within the category of unlicensed spectrum. When shared between a primary user (a TV provider) and the secondary user (a Wireless service provider (WSP)), white spaces can become a great opportunity for providing broadband connectivity, especially in the rural and low income areas of the developing world. For different countries of the world, they represent considerable wireless resources that can boost innovation through secondary usage. While the ubiquitous WiFi can not cross walls due to its high operating frequencies, TV white space (TVWS) networks offer the advantages of (i) longer range of more than 10 km; (ii) reaching well beyond certain obstacles (walls, hills, etc.), and; (iii) operating in the unlicensed frequency spectrum, thus enabling to build affordable internet for all networks.

Research in TVWSs identification has revealed significant amount of white spaces in many places worldwide [6,9,13]. The number of white space channels varies by region but the spectrum of exploration in terrestrial network transmission (TNT) lies in the 470–790 MHz range [1,7]. The transition from analog to digital television will enable new wireless architectures to be implemented and services delivered over wireless platforms operating in the white space frequency band. However, while many countries of the developing world are still lagging behind in terms of white space implementation, more developed countries such as the UK and USA have moved beyond the planning and testing stage to embark into real implementation of innovative projects using the TVWSs in view of the advantages they present. Several white space researches and practical experiments have already been conducted in different continents including Africa, Asia, Europe, South America and North America. In most cases, the application targets the provision of additional wireless capacity in rural areas, university campuses, government services support, education and health systems, and public administration systems [6,7]. The USA with Federal Communications Commission (FCC) and the UK with Ofcom [17] can serve as good examples of the use of TVWS. In Africa, Kenya, South Africa, Malawi, Mozambique, and Tanzania are examples of countries that have embarked into TVWS trials. For these countries, the investigation of white space use is a first step towards rational management of the spectrum [16].

### 1.2 Contributions and Outline

According to the International Telecommunication Union (ITU) recommandations of 2006 [16], the period of transition from analog to digital transition television was due to expire on 17 June 2015 for the UHF band ranging from 470–862 MHz to 470–690 MHz, and on June 17th, 2020 for the VHF band of 174–230 MHz for the countries of Region 1 and 3, of which the DRC is part. However, at both the regulation and research levels, white space identification is still a myth in the DRC.

The aim of the paper is to present a TVWS identification model using spectrum sensing as a first experimental study of white spaces in the DRC. Measurement experiments targeting the dynamic acquisition of TVWS data in the 470–862 MHz broadcast spectrum were conducted in two cities of the DRC: Lubumbashi, the economic capital, and Kinshasa, the political capital of the country. The objective was to acquire an overall view of the existence of the TVWSs in the country by building upon the experimental work conducted in the two cities. Base on the results of the experiments, the channels, which were found actually occupied from the measurements were mapped to the list of TV stations actually registered with the regulatory authority to discover their activity. The results collected from the experiments revealed significant TVWSs in the frequency band. The experimental setting presented in this paper is a proof-of-concept that the national regulator could use as a starting point towards white space quantification during its migration to the digital terrestrial television (DTT). As a contribution to research and practice in the emerging white space research field, the experimental framework proposed in this work can be adapted to be used by different national telecommunication operators and researchers as a guideline for white space identification and quantification. This work also contributes to bridging the gap that exists in many African countries in terms of experimental research leading to the discovery of TVWSs and also scientific literature targeting TVWS identification in these countries.

This paper comprises five sections. The first section introduces the research work while Sect. 2 presents a TVWS Identification Model. Section 3 shows the TVWS identification methodology used. Section 4 describes the experimental settings and results collected from two experiments carried out in the two cities. Section 5 presents conclusions and directions for future work.

## 2 TVWSs Identification Model

TVWSs can be identified and used based on their temporal, spatial and dynamic characteristics. As such, they provide access to dynamic spectrum (DSA) as described in [17], hence the importance of knowing their spatio-temporal availability and geo-localization in addition to their electromagnetic characteristics. The accurate identification of TVWSs in a given area depends on the way and method applied for its identification. Spectrum detection and geo-location database [8] are two of the methods, which are traditionally used to identify the TVWSs. A third method referred to as beacon transmission has also been investigated by different researchers [17].

Spectrum detection is based on the detection of the signal energy (amplitude) to determine the number of TVWS channels and occupied channels. This method was used for this research because of its flexibility and the possibility of using low cost off-the-shelf equipment that was available. The technique consists of measuring the lowest signal strength of a TV station (the lowest power received from the lowest TV signal also called Low Power Television (LPTV)) and comparing this signal strength to a threshold that is considered normal for a White Spaces Device (WSD). The FCC sets the lower limit of the threshold to −114 dBm [15], while the European Communications Commission (ECC) spectrum threshold ranges between −91 dBm and −155 dBm. There is a great debate on the spectrum detection method with regards to the admissible threshold it uses to detect the presence of white spaces. It should be understood that such a level of sensitivity, according to FCC, corresponds to a noise whose power corresponds to almost −100 dBm and to a signal-to-noice ratio (SNR) of −15 dB. The identification of the TVWSs will be found based on the measured direct values on one hand, and on the other hand, on the basis of a statistical analysis made. The mathematical identification scheme can be represented as follows:

Consider a frequency band, where it is possible to measure the probability of the existence of TVWSs at a given time, on a given channel and for a given place. Let us denote a TVWS by $ws$:

$$ws = \begin{cases} 1, & \text{one of the spectrum channels is occupied and busy} \\ 0, & \text{one of the spectrum channels is white space.} \end{cases} \tag{1}$$

The TVWS is determined by the average value of the signal strength of the channel in question with respect to a fixed threshold. This leads to the following series of equations.

$$ws = \begin{cases} 1 & \Longleftrightarrow \forall \frac{1}{n} \sum_{k=1}^{n} p_k - p_{th} \leq 0 \\ 0 & \Longleftrightarrow \forall \frac{1}{n} \sum_{k=1}^{n} p_k - p_{th} > 0 \end{cases} \tag{2}$$

where:

- $n$: the number of measurements performed per channel for a given period of time;
- $p_k$: discrete powers taken and recorded during the measurement;
- $p_{th}$: threshold set.

The number of white space channels are given by

$$n_{ws} = \sum_{i=1}^{j} n_{ws}(i) \tag{3}$$

For the DTT, the channel bandwidth is 8 MHz. Therefore, the number of channels located between channels $i$ and $j$ are given by

$$n_c = \frac{f_i - f_j}{\Delta f} \tag{4}$$

where, $f_i$ is the starting frequency of channel $i$, $f_j$ is the starting frequency of channel $j$ and $\Delta f = 8\,\text{MHz}$.

## 3 TVWS Identification Methodology

This section describes both the system and software architectures behind the TVWS identification methodology proposed in this paper. These architectures are expressed in terms of a TVWS identification system that describes the main hardware components used by the system and a TVWS identification process showing the different software components used.

### 3.1 TVWS Identification System

The device configuration for the TVWS identification used in this experiment is shown in shown in Fig. 1. It shows how the different elements were integrated into a white space identification system called RTfTrack. RfTrack is composed of the following key elements [14]:

- RF-Explorer, a low cost spectrum analyzer.
- An Android device (tablet or smart phone) equipped with GPS and running RfTracker [14], an application for logging management.
- Analysis server, accessible via the Web: receives data from measurement campaigns and generates spectrum measurements reports.

During the TVWSs tracking campaign, the RF-Explorer makes measurements and records TVWSs data continuously using the RFtracker [14]. Connected to mobile cellular Internet and equipped with an integrated Global Positioning System (GPS), the smart phone registers the GPS coordinates of the

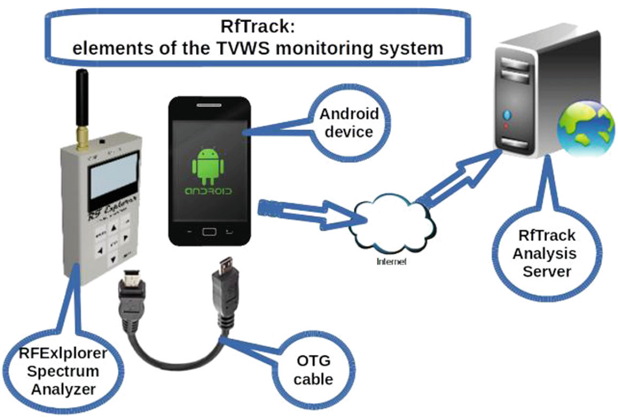


**Fig. 1.** White spaces tracking infrastructure

location of interest as well as the amplitude of the measured signal automatically. After acquisition, the data is stored either locally or uploaded by mail on the International Centre for Theoretical Physics (ICTP) (Trieste, Italy) platform located at the url http://wireless.ictp.it/tvws/ from where it can be accessed using various tools that the platform offers. During a measurement campaign, the battery life of the phone is an important parameter that determines the volume of data recorded.

In our experiments, the RFTracker was installed on a Galaxy A3 smart phone connected to the RF-Explorer. During the measurements, On the smart phone, an Orange 3G mobile Internet connection was used for the whole duration of the measurement campaign.

For each measurement campaign, we proceeded in the same manner by: (i) connecting the devices as shown in the diagram 1, (ii) having the mobile Internet connection on our smart phone set up, and (iii) then performing a dynamic acquisition of data while moving aboard a vehicle on the streets and avenues in most densely populated and urbanized areas of the two cities. According to satellite reports collected from the platform at the url http://wireless.ictp.it/ platform, we have travelled 53 km in Lubumbashi and 56.6 km in Kinshasa.

### 3.2 TVWS Identification Process

TVWS Identification methodology is summarized in Fig. 2, which shows the whole process from measurement to analysis of the results. The process include three main steps:

1. **Parameters setting.** This is done by setting the parameters to be used during a TVWS identification campain. These include parameters of the RFtracker software and RFexplorer spectrum sensing device and as well as activation parameters for the mobile phone to be used.
2. **Data acquisition and uploading.** This is done by using the RFexplorer to collect the energy in different channels along the route planned using Google Map.
3. **White space identification.** This step include the analysis of the data collected using a given threshold for differentiation between free and occupied channels and the analytical model expressed by the equations in Sect. 2.

## 4 Experimental Evaluation

Our experiments consisted of two main activities: (i) identification of white spaces channels in the UHF analog TV broadcasting band in Lubumbashi and Kinshasa in the DRC and (ii) association of the identified TVWS channels to the spectrum owners in order to find out how the spectrum is being used in the two cities.

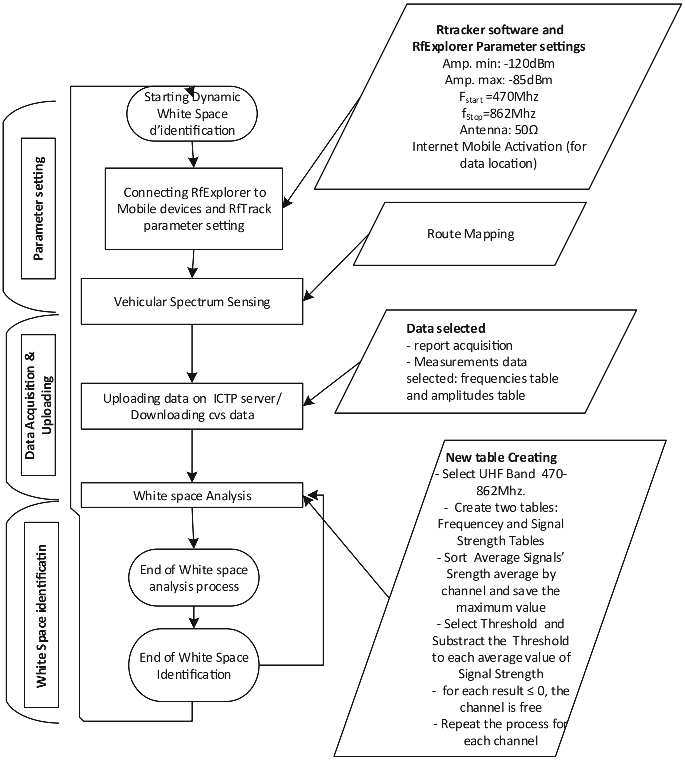


**Fig. 2.** The white spaces identification process.

### 4.1 City Wide TVWS Identification

Lubumbashi and Kinshasa are among the most developed and urbanized cities of the DRC but with prospect of migrating to DTT is still unknown. Kinshasa has about fifty TV stations whereas Lubumbashi has about twenty. The two cities are about 2000 km apart.

A statistical analysis was applied to the collected data based on the Eqs. 1, 2 and 3 to calculate the approximate number of TVWSs in the UHF TV band for each of the two cities. Taking into account the lower limit set by the FCC, the threshold values were chosen in the range −114 dBm to −85 dBm. The data was accessed from the ICTP Web site using SQLite Database. The database was consulted to extract the data to a Microsoft Excel spreadsheet using the SqlStudio tool. For the purposes of this paper, two tables from the whole SQLite Database were selected: a frequency measurement and the measurement of amplitude.

Eleven threshold values were used in the analysis from the range −114 to −85 dBm. Table 1 shows the total number of occupied channels and the corresponding number of total TVWSs detected by each of the thresholds used. The plots in Fig. 3 tell us more about the availability of whites spaces in the two cities at the moment. The spectral measurement results between the two cities

**Table 1.** Occupied and TVWSs channels detected by 11 threshold values

| Threshold (dBm) | Kinshasa | | Lubumbashi | | *Total* |
|---|---|---|---|---|---|
| | *Occupied* | *TVWSs* | *Occupied* | *TVWSs* | |
| *−85* | 2 | 47 | 3 | 46 | 49 |
| *−90* | 3 | 46 | 5 | 44 | 49 |
| *−95* | 8 | 41 | 8 | 45 | 49 |
| *−100* | 19 | 30 | 24 | 25 | 49 |
| *−105* | 40 | 9 | 43 | 6 | 49 |
| *−106* | 47 | 2 | 49 | 0 | 49 |
| *−107* | 49 | 0 | 49 | 0 | 49 |
| *−108* | 49 | 0 | 49 | 0 | 49 |
| *−109* | 49 | 0 | 49 | 0 | 49 |
| *−110* | 49 | 0 | 49 | 0 | 49 |
| *−114* | 49 | 0 | 49 | 0 | 49 |

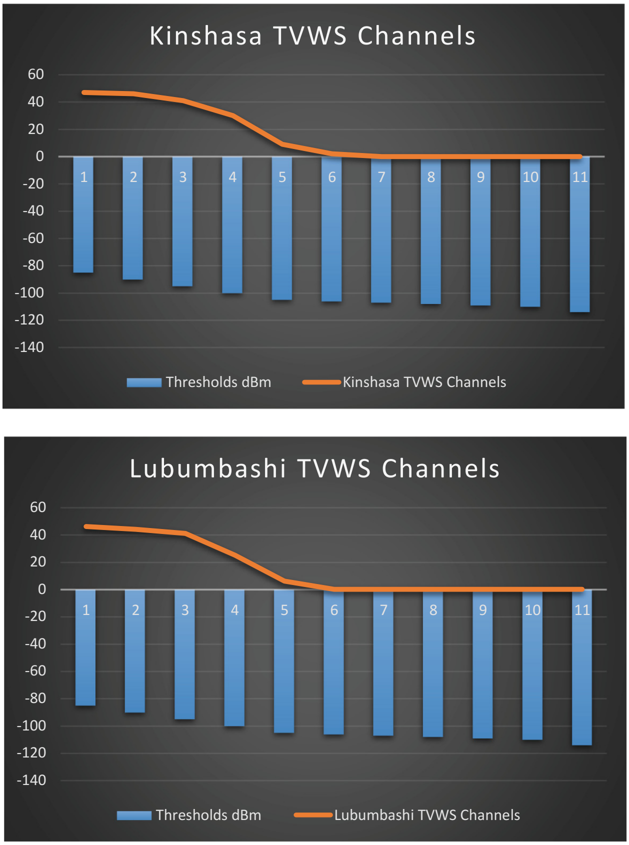


**Fig. 3.** Trend graphs of TVWS channels

reveal a certain similarity based on the results depicted in Table 1 and Fig. 3. At thresholds below −100 dBm, detection becomes rare and almost impossible.

### 4.2 White Spaces/Channel Owners Association

In order to discover how the television broadcasters of the two cities use their allocated channels and associate the TVWSs found with a detection threshold of −100 dBm to the TV broadcast owners as allocated by the regulator, the spectral measurements results were compared with the TV channel allocation to the TV broadcasters by the DRC telecommunications regulator. The results of the comparison between the TVWSs discovered and the TV channel allocation to the broadcasters are reported in Table 2. They reveal that: (i) many of the allocated channels are unused by their owners, (ii) Lubumbashi has a small number of TV providers owning to several consecutive channel allocation to same broadcaster and Kinshasa has many TV broadcasters.

**Table 2.** Channels/Broadcasters Association: Lubumbashi- and Kinshasa

| Channel | Lubumbashi | | Kinshasa | | Channel | Lubumbashi | | Kinshasa | |
|---|---|---|---|---|---|---|---|---|---|
| | *Owner* | *Status* | Owner | *Status* | | *Owner* | *Status* | Owner | *Status* |
| *1* | La V. Berger | Free | Ant. A | Free | *26* | La V. Kat. | Occ | CEBS | Free |
| *2* | - | Free | CMB | Occ | *27* | Mapendo | Free | Fond. P. E. | Free |
| *3* | - | Occ. | Retalki | Occ. | *28* | - | Free | CCTV | Free |
| *4* | - | Free | TV5 | Occ. | *29* | TV5 | Occ. | B-One | Free |
| *5* | - | Free | RTMV | Free | *30* | heritage | Occ. | Hope TV | Occ. |
| *6* | - | Free | tropicana | Free | *31* | - | Occ. | Africa TV | Occ. |
| *7* | RTIV. | Free | Mirador TV | Free | *32* | - | Occ. | Global TV | Free |
| *8* | Malaika | Free | Raga TV | Free | *33* | - | Occ. | Digital | Occ. |
| *9* | - | Free | C. Num. TV | Free | *34* | - | Occ. | Ant. V | Free |
| *10* | - | Free | Amen TV | Free | *35* | - | Occ. | RTDV | Occ. |
| *11* | Kyondo | Free | Canal5 | Free | *36* | - | Free | RTACK | Occ. |
| *12* | - | Occ. | KTM | Free | *37* | - | Free | RTVA | Free |
| *13* | - | Free | Horiz.33 | Free | *38* | - | Occ. | RTC | Free |
| *14* | Nyota | Free | Euro News | Occ. | *39* | Tele50 | Occ. | DRTV | Occ. |
| *15* | Wantanshi | Occ. | Nzondo | Occ. | *40* | - | Free | Alpha-Om. | Occ. |
| *16* | Jua | Occ. | CMC | Occ. | *41* | - | Free | Numerica | Free |
| *17* | Tam Tam | Occ. | RTNC2 | Occ. | *42* | - | Free | 2 AS TV | Occ. |
| *18* | - | Occ. | RTK | Free | *43* | Molière | Occ. | RTVS1 | Free |
| *19* | - | Free | CVV | Free | *44* | - | Occ. | RLTV | Free |
| *20* | - | Free | DRTV | Free | *45* | - | Free | - | Occ. |
| *21* | Canal de V. | Occ. | Congo Web | Free | *46* | - | Occ. | - | Free |
| *22* | Digital | Occ. | Canal Futur | Free | *48* | - | Occ. | Brazzaville | Occ. |
| *23* | - | Free | SSM TV | Free | *48* | - | Occ. | Brazzaville | Occ. |
| *24* | - | Free | RTAE | Free | *49* | - | Occ. | RTC Elikya | Occ. |
| *25* | - | Occ. | RTGA | Free | | | | | |

From the experimental results presented Table 1 and the association results in Table 2, it looks like a threshold of −100 dBm is a good fit for the white space identification as it gives results close to reality. Note that the number of TVWSs identified through spectrum sensing and the numbers of channels identified as unused through the TV channel owner association as allocated by the DRC telecommunication regulator are similar as revealed by Table 3. It is important to point out that in both cities, there are channels that are theoretically occupied but are no longer functional or active, as the television broadcasting service in those channels was closed by government.

**Table 3.** Correlation between spectrum sensing and channel association

| City | Spectrum sensing | Channel association |
|---|---|---|
| Lubumbashi | 25 | 33 |
| Kinshasa | 30 | 2 |

Following the current regulator plan, Kinshasa has a total of 392 MHz spread along about 49 analog TV registered channels in the UHF band without counting those reaching the city from the neighbouring country of Congo/Brazaville. Lubumbashi has 176 MHz, totalling 22 channels registered in the UHF band, making half of the quantify found in Kinshasa.

## 5 Conclusion and Future Work

This paper has addressed the issue of TVWS with the objective of finding if there are TVWSs in the DRC. To address this issue, spectrum sensing measurements were carried out using three parameters: location, frequency, and time. The experiments were conducted with the aim of not only assessing the availability but also discovering the quantity of TVWSs at various locations and at different times of the day. Overall, our experimental goal was to demonstrate the possibilities of reusing licensed frequency channels by detecting unused licensed channels in the UHF analog TV frequency band from 470 MHz to 862 MHz in DRC. The experimental results revealed the existence of TVWSs in both DRC cities, even though the TV broadcasting technology in DRC is still analog. Licensed spectrum encourages investment and guarantees interference avoidance among the users. However, freeing unused spectrum is open to innovation. Studies in [10] have shown that 95% of the licensed spectrum, only 20% is used in general. Innovations are therefore possible in white spaces and we believe that the DRC should invest in these frequencies to boost innovations.

The availability of white space in the DRC is a great opportunity for complementing the capacity of the existing mobile networks with wireless mesh networks used to expand broadband availability. For a country like the DRC, routing and route identification models such as proposed in [2,4] can be redesigned to implement time-of-the-day traffic engineering depending on the temporal variations of white spaces. It is also expected that the findings presented in this paper will lead to broadband access boost and create an opportunity for the design of novel data dissemination techniques in rural applications such as proposed in [11,12] and urban applications such as presented in [3,10] to provide additional spectrum for specific applications. The identification and quantification of white spaces could also be piggy-backed on the techniques and architectures proposed in [5] by mounting the RF devices on UAV/Drones. The design of such novel white space identification and quantification techniques is an avenue for future work.

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