RFTrack: a tool for efficient spectrum usage advocacy in Developing Countries

Marco Rainone
Solvitech
Udine, Italy
mrainone@libero.it

Marco Zennaro
ICTP
Trieste, Italy
mzennaro@ictp.it

Ermanno Pietrosemoli
ICTP
Trieste, Italy
ermanno@ictp.it

ABSTRACT

Despite successful pilots in developing countries, TVWS (Television White Spaces, unused portions of television broadcasting spectrum) has not gained the amount of attention that it deserves. One of the reasons is the lack of spectrum measurements that would convince the regulators about the abundance of idle spectrum. Spectrum measurements traditionally require expensive instruments and considerable operator's expertise. This has changed with the emergence of low cost spectrum analyzers and smartphones. In this paper we present RFTrack, a software suite that consists of an Android application and a TVWS analysis server. Together, they measure spectrum using a low-cost spectrum analyzer and geotag the data using the phone's internal GPS. The Android application is very easy to use and campaigns can be carried out by non-technical users. Once an Internet connection is available, the program sends data to the server that performs the required processes to present the results in an easy-to-understand way, also allowing for some user customization. The system has been used in eleven countries. We present the results from a measurement campaign in Costa Rica. We believe that this is a useful tool to demonstrate the existence of underutilized spectrum, especially in rural areas of developing countries.

Keywords

Wireless access networks;Wireless local area networks

1. INTRODUCTION

In telecommunications, TV white spaces (TVWS) refer to frequencies allocated to television broadcasting but not exploited in a given place at a given time. They are quite abundant in areas of low population density, where generally only a few TV channels are actively used since the revenues generated will not sustain many competing broadcasters. This is not going to change in the future since TV broadcasting by satellite (which uses much higher frequencies) is quite cost effective in serving sparsely populated areas, thus further eroding the terrestrial broadcasters business case. Currently TVWS deployments in developing countries [1] are based on temporary licenses.

In the long term, dynamic spectrum access seems to be the best solution, once the technical details for its implementation are solved. In the near term, the use of currently vacant spectrum allocated to TV broadcast is poised to alleviate the spectrum crunch while opening the path for dynamic spectrum access.

ICTD '16 June 03-06, 2016, Ann Arbor, MI, USA

ACM ISBN 978-1-4503-4306-0/16/06.

DOI: http://dx.doi.org/10.1145/2909609.2909617

2. SPECTRUM MEASUREMENTS

Spectrum measurements campaigns have been carried out in several countries, both industrialized as well as developing [2]. The experience from these campaigns shows that large parts of the spectrum are idle, especially in rural and remote areas. Most of the measurements have been performed by skilled operators using expensive equipment. Specialized equipment to measure and visualize spectrum usage cost more than 10 kUSD, making it impossible for engineers, academics and civil society stakeholders in developing countries to advocate for more open spectrum usage.

3. ON LOW COST SPECTRUM MONITORING

Based on our previous experience in low-cost TVWS monitoring, to develop a system suitable for developing countries (where TVWS have the highest potential) some design requirements have to be met. These design challenges include cost, usability, data processing and logging capabilities, availability of source code and privacy considerations. We developed a system based on the following design premises:

- **Low cost.** High-end spectrum analyzers are expensive (in the order of many thousand of dollars), large, heavy and not typically available in developing countries. For our system we chose a low cost spectrum analyzer (available worldwide) and an Android phone.
- **Usability.** After a simple setup, the system should run automatically without any human intervention. The Android GUI should present only the most useful information which can be translated in different languages to accommodate local requirements.
- **Data logging.** Facing the possible lack of reliable Internet connections, the system should be able to store weeks of measurements internally. Once an Internet

connection becomes available, data can be sent for later processing at the remote server. The server will perform all the processes required to extract the most useful information from the data and present it in a user friendly way, while also allowing for some customisation.

- **Open Source.** Publishing the code in an open source manner has two benefits: a community of developers can improve the code and telecom regulators can trust the measurements (and thus the results). The system is easily modifiable thanks to the availability of the source code.

- **Privacy.** While spectrum measurement campaigns are legal in most countries, this activity might be illegal in some places. We want the results of measurement campaigns to be anonymized, so authors maintain their privacy rights. This has the drawback effect of not giving proper credit to campaigners, but privacy has a higher value in our view.

4. THE RFTRACK SYSTEM

RFTrack [3] is composed of a hardware system that measures spectrum while being carried around, and a software suite consisting of an Android application coupled with Linux scripts running in a remote server. Spectrum measurements are geo-tagged. Once a measurement campaign is over, data is sent to a server that generates a web page with the results. This section describes the system both from the hardware and software perspectives.

4.1 RFTrack hardware

The hardware is made out of four components:

1. **Spectrum Analyzer** We tested several low cost spectrum analyzers, and chose the RFExplorer due to its accurate calibration and affordability. There are several RF Explorer models, covering the most used bands below 6.1 GHz. In our system we use the Sub 1 GHz model, fitted with the Silicon Labs Si4431 receiver chip (covering 240 MHz to 960 MHz). The device is powered by a high capacity battery, rechargeable through USB port, which allows for 16 hours of continuous run. It has an SMA antenna connector (50 ohms) and a dynamic range of -115 dBm to 0 dBm. We compared the RFExplorer against a professional and recently calibrated Agilent N9344C spectrum analyzer. A calibrated Agilent 8648C signal generator provided signals at 10 different power levels, from -95 dBm to -50 dBm, for the set of measured frequencies. From the results we can conclude that in the frequency range from 300 MHz to 900 MHz, the RFExplorer measured value is consistently slightly less than the power applied to its input, with a maximum discrepancy of 4.5 dB. In the UHF TV spectrum range that lays below 806 MHz the under estimation is bounded to 2.8 dB. With a cost of around a hundred dollars, the RFExplorer can be easily acquired by Universities and civil society organizations worldwide.

2. **Android phone** Our system uses an Android phone to store measurements and to geo-tag them. Android phones are very popular in Developing Counties, commanding 80% of the market. With the open Android SDK, it is possible to develop software and install it without the need for any authorization.

3. **OTG Cable** To connect the RFExplorer to the phone we need a cable that has a mini USB-A connector on one side and a micro USB-B connector on the other side. This arrangement is called OTG (On The Go) and can also be implemented by coupling two different cables with the proper terminations.

4. **Antenna** To capture signals from every directions in the plane, we need to use an omnidirectional antenna suited for TVWS frequencies. Although the antenna gain has a very significant effect in the measurement, in this case we are looking for relative readings of signal level, specifically at the difference in spectrum usage as related with the population density, so that measurements taken in cities constitute a sort of baseline, thus compensating for variations in antenna gain. Any suitable omnidirectional antenna can be used, although for more precise results the actual gain of the antenna in the different frequency intervals should be accounted for. Likewise, the height of the antenna above the surrounding terrain has also a significant effect.

Figure 1 shows the complete RFTrack hardware system. The system is portable enough to fit in a backpack and it can easily be hand held.

Figure 1: The RFTrack system portability

4.2 RFTrack software: the Android app

RFTrack is an Android application that reads data from the RFExplorer (via the adapter cable), geo-tags the measurements and saves them in the internal phone memory using an sqlite database. Once an Internet connection is available, data can be sent via email.

- **Setup** Once the spectrum analyzer is connected, the RFTrack application launches automatically. The user can specify the frequency range or leave the default value (300 MHz to 900 MHz). The default antenna type is omnidirectional, but the user can choose a directional antenna as well. The measurement campaign starts immediately.

- **Measurements** Every ten measurements a beep is produced as a reminder that the phone is correctly acquiring data. Once the campaign is over, users can send the data to an email address of their choice to analyze them independently or to a predefined address configured for the automatic processing and subsequent visualization. We decided to use email to minimize the transfer time (email servers are generally closer to the user than other type of servers).
- **Database** The latest version of RFTrack uses an sqlite database to store data. This has improved the data sampling frequency considerably. In the database we store name and info of the measurements campaign, the type of antenna used (omni or directional), latitude, longitude, altitude (meters above the see level), speed (in m/s), estimated measurement accuracy and time as provided by the GPS. If it is not possible to detect the position neither through the network connection nor the GPS signal, the user can manually enter longitude, latitude and altitude.
- **User Interface** Figure 2 shows the basic UI of RFTrack. The user can start a new measurement campaign, or open an existing campaign to add measurements to one already initiated (this is useful in case of an interruption such as that experienced when crossing a tunnel). The program then sends the measurements via email and performs some hardware tests. Data can be published openly (sent to a default address), published privately (the measurement campaign is not visualized on the main site) or they can be sent to a specific address to be later analyzed.

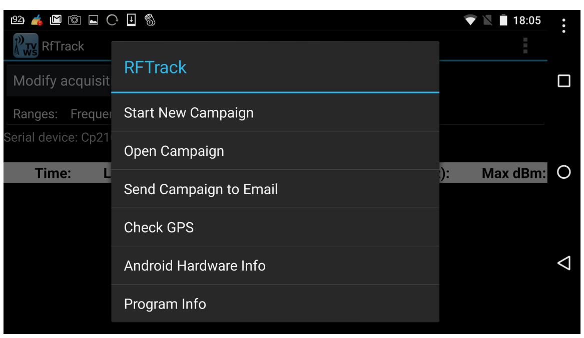

Figure 2: RFTrack basic UI

4.3 RFTrack software: TVWS analyzer

The TVWS analyzer comprises a series of scripts running on a Linux server. Once the server receives the measurements as an email attachment, it starts analyzing the data. It generates eight graphs: a map showing where the measurements have been carried out, a graph showing the measurements as a heatmap, statistics on the number of measurements below a certain threshold, the noise level of the different measurements, etc. These graphs are produced in about thirty seconds and are then inserted in a web page that is automatically published. The server starts then to produce a video showing the spectrum measurements on one side and the map on the other side. Figure 3 shows a frame of the video. Green bands in the spectrum part shows 10 MHz channels and the pink band shows 20 MHz channels. Producing the video takes some minutes and the result is then added to the web page. Finally, a point is added to the map that accumulates the worldwide measurements made.

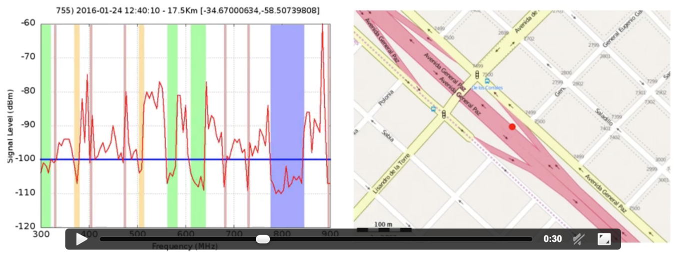

Figure 3: Video with spectrum measurements

5. MEASUREMENT CAMPAIGNS

As of January 2016, measurements with this setup were carried out in eleven different countries [4]: Argentina, Canada, Comoros, Costa Rica, Ecuador, Italy, Liberia, Mauritius, Morocco, Mozambique and Spain. Figure 4 shows the measurement campaigns.

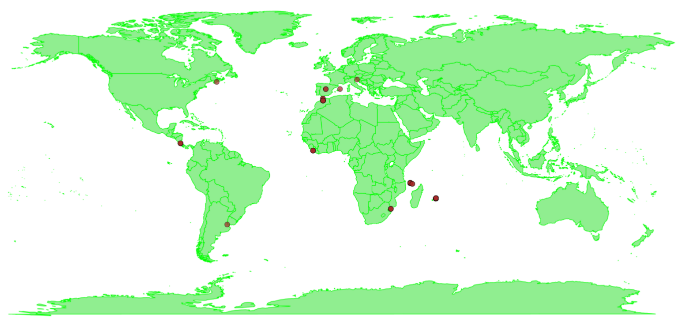

Figure 4: Measurement campaigns worldwide

We present some of the results from Costa Rica. The complete reports are available online. We emphasize the fact that the measurements were automatically carried out by placing the RFTrack system in a car, with no human intervention.

Being in Costa Rica for a workshop, we carried out a measurement campaign while driving from Alajuela to Boca Arenal, in the San Carlos Province. Table 1 is automatically produced by the server, reporting the main information about the campaign.

Info	*Value*
Date	22/11/2015
Duration	2:17:14
Route length	99.2 km
N. Points	10419
Country	Costa Rica
Country Code	CR

Table 1: Measurement campaign in Costa Rica

Figure 5 shows the route that was driven in Costa Rica, with a color code to represent the maximum value measured in that point (the worst situation in terms on TVWS).

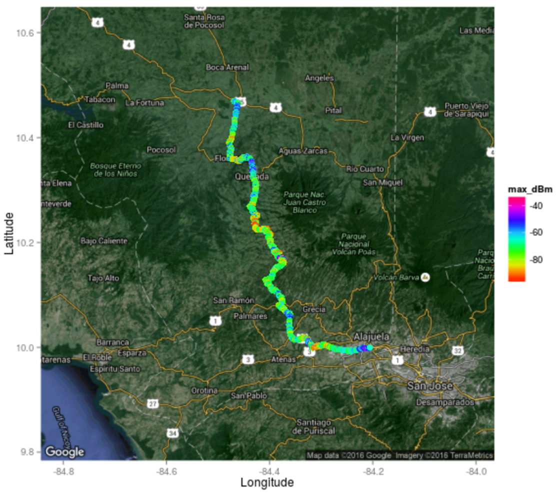

Figure 5: Route driven in Costa Rica

Figure 6 is a heatmap where the X axis shows the measurement number, the Y axis shows the frequencies and the color represents the measured signal level. From this figure we immediately recognize the signal from the cellular network (slightly below 900 MHz). It is also clear that the measurements carried out when approaching the city (we were going from a rural area to the capital of the province) show more RF activity. In the rural area, there is plenty of idle spectrum.

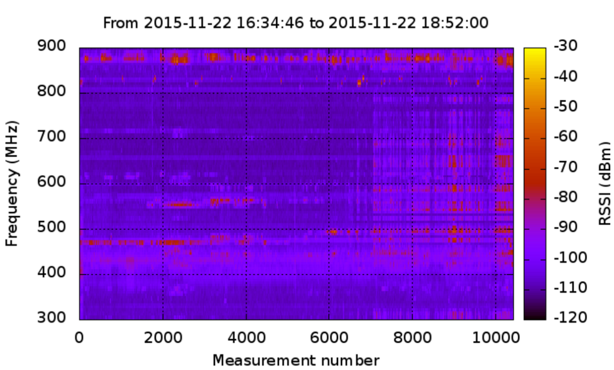

Figure 6: Heatmap of the Costa Rica campaign

Figure 7 highlights the percentage of measurements at a specific frequency that are under a certain threshold. This is particularly useful as the choice of the threshold is quite significant in deciding if a particular channel is being used or not. The -100 dBm threshold value is a conservative one and yet many frequencies are below this value for most of the time, despite that we have over ten thousand measurements.

6. CONCLUSIONS

We have presented a low cost system based entirely on open source software and an open hardware device that is easy to operate and automatically process the measurement to display the spectrum usage from different view-

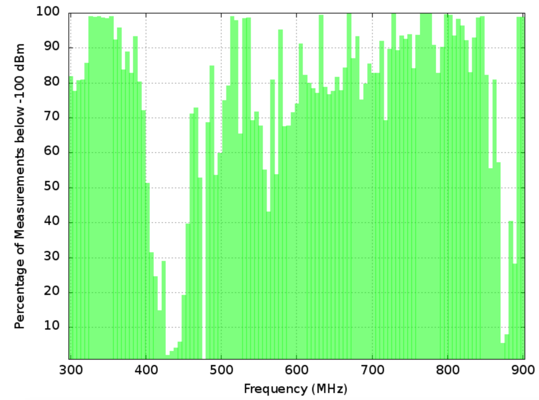

Figure 7: Percentage of measurements in Costa Rica below the -100 dB threshold

points. The determination of spectrum occupancy is highly dependent on several factors like the antenna gain and its height above the terrain. Nevertheless, by letting the user of the data to choose the threshold for spectrum occupancy, these issues can be somewhat factored in. Furthermore, the difference in spectrum usage in rural areas as compared with cities, obtained from measurements performed in eleven countries, confirms the usefulness of the system in identifying occupancy and its adequacy as an advocacy tool for more efficient spectrum usage. We believe that simplicity of usage and affordability are the most important issues for the intended application.

We hope that this tool will empower many stakeholders from developing countries to convince their respective spectrum regulators about the need to tap the underutilized spectrum in rural areas to provide much needed Internet connectivity precisely where it is more lacking due to the increased cost of traditional connectivity solutions when applied to sparsely populated areas.

Acknowledgments

The authors would like to thank the Shuttleworth Foundation for supporting the development of RFTrack and the user community for contributing with their measurement campaigns.

7. REFERENCES

[1] K. Ronoh, et al. "TV white spaces in Africa: Trials and role in improving broadband access in Africa." AFRICON, 2015. IEEE, 2015.

[2] T.Brown, et al. "A Survey of TV White Space Measurements", in proceeding of Africomm2014, Kampala, Uganda, 24-25 November 2014

[3] http://wireless.ictp.it/tvws/rftrack/

[4] http://wireless.ictp.it/tvws/