TV White Spaces, I presume?

The quest for TVWS in Malawi and Zambia

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ABSTRACT

TV White Spaces (TVWS) technology and regulation has the potential to make connectivity both technically and economically feasible in rural Africa where affordable access remains a challenge. The superior propagation characteristics of TVWS technology make it particularly well suited to connecting remote communities. Evidence collected from our measurements in Malawi and Zambia suggest that most UHF spectrum is already available both in urban as well as in rural areas and could be used to provide Internet connectivity. In this paper we present the findings of a TVWS spectrum measurement initiative in Malawi and Zambia. We introduce an open hardware device that geo-tags spectrum measurements and saves the results on a micro SD card. The device can also be used to record the use of spectrum over long periods of time.

Categories and Subject Descriptors

C.2 [**Computer-Communication Networks**]: Network Architecture and Design,Wireless communication

General Terms

ICT4D, Wireless, White Spaces, Africa

1. INTRODUCTION TO TVWS

Because of their range and affordability, wireless technologies offer the most hope for effectively bridging the digital divide. Mobile phones have become more or less synonymous with access in the South. However, much has changed since mobile networks began rolling out in the early-to-mid nineties. When the first generation of mobile operators were granted licenses to use wireless spectrum to build their networks, they were simply given the spectrum at no charge. The availability of spectrum exceeded demand. Today, popular frequency bands are auctioned for large amounts of money, often running into the billions of dollars [1].

Because so much money is now at stake concerning spectrum, the process of making new spectrum available has become complex. It is increasingly hard to ensure that spectrum is made available in a timely manner and to the entities that are most likely to serve a country's strategic interest. As ICTs become increasingly valuable to government, industries and citizens alike, demand for spectrum has steadily increased. Yet the process of making spectrum available and managing it as a resource still fails to feature in ICT4D initiatives and strategies.

In poor countries, regulators and governments are caught between the growing market demand for more spectrum and the need for more human and financial resources to manage the increasingly complex web of issues including spectrum auctions, technological advances, regional harmonisation, not to mention vested interests. This is compounded by the fact that decisions about spectrum can have consequences that can last a generation or more. The interplay of investment, evolving technical standards, and administrative complexity tends to make this a very slow-moving decision-making environment. This means that not only does it take a long time to introduce new spectrum regulation but also that strategic errors in regulation can take many years to undo.

It is instructive to contrast traditional licensed spectrum approaches with the rapid uptake of technologies based on unlicensed spectrum. Unlicensed spectrum is regulated but instead of being managed through a licensing process, it is regulated through the technical specifications imposed on

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devices operating within the designated unlicensed band. Typically this means that the power output of these devices is required to be lower than in licensed environments. The dominant example of this is WiFi, a technology whose growth rivals that of mobile technologies. In excess of 2.14 billion WiFi chipsets will ship in 2013, a 20% increase over 2012.

Recently, a new opportunity for unlicensed spectrum use has emerged in the form of TV White Spaces spectrum. Originally conceived of as a technology that could take advantage of the guard bands or ”white spaces” that were left between television channels to prevent interference, TV White Spaces (TVWS) spectrum is a secondary spectrum exploiting technology that can take advantage of unused television spectrum in a dynamic manner. In the US and the UK, communication regulators have endorsed TVWS regulation and the commercial scale-up of TVWS technology has begun [2].

In 2013, two notable TVWS trials have begun in Africa. A Google-sponsored trial of TV White Spaces in the Western Cape of South Africa began officially in March 2013 with the goal of providing ten primary and secondary schools with Internet access [3]. In Kenya Indigo Telecoms, a local Internet Service Provider (ISP), has partnered with Microsoft and the Government of Kenya to build a TVWS pilot in the Nanyuki region [4]. The pilot connects a health care clinic, a library and three local schools.

2. SPECTRUM MEASUREMENTS

Spectrum occupancy has become topical as the quest for efficient access to the spectrum continues. This is evidenced by empirical measurements of the radio environment in a bid to ascertain the spectrum usage by different wireless services.

The majority of researches reach a common conclusion on the necessity for further occupancy measurements at different locations over varied times. This thus motivates the need for more occupancy measurement. On concluding their investigations, some authors affirm that, to obtain local spectral pattern usage in multiple locations, the challenges for measurement-campaigns are not only costly (in equipment) but also time-consuming (for deployment) [5].

3. ASCII-32

ASCII-32, shown in Figure 1, is a low-cost device to identify and geo-tag RF spectrum in the sub 1-GHz band. The name ASCII-32 is derived from the ASCII character set, where the number 32 corresponds to a white space. Selling for $110, ASCII-32 is affordable for Universities and civil society organizations in Developing Countries.

The main component of the design is the SI4313 low cost wideband receiver IC. It covers a frequency range from 240 to 960 MHz which adequately spans the spectrum of TVWS. Although this IC has the circuitry to decode multiple wireless signaling protocols, in this application, the main function used is the energy detection. After tuning to a certain frequency, one function of the IC is to check that frequency to see how much energy is there, recording the value in the RSSI (Received Signal Strength Indicator) register. It measures the RF energy from the antenna at that particular frequency and gives a dBm output. This is the same function as a standard spectrum analyzer, however at a vastly different cost scale.

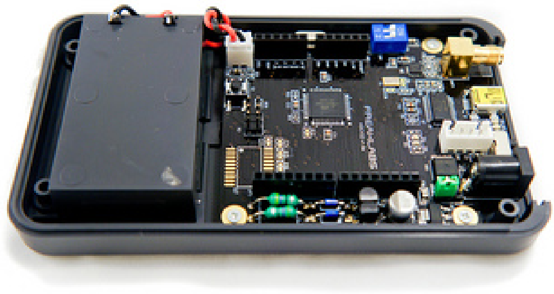

Figure 1: Low-cost ASCII-32 device.

The essential part of the design is to use a microcontroller to tune the IC to each frequency in pre-determined bandwidth intervals and measure the amount of energy at each frequency. By doing this quickly enough, it’s possible to build up a plot of the occupied spectrum within the 240 to 960 MHz frequency range. This implements the spectrum analyzer functionality of the device.

Besides the spectrum analyzer functions, there are other requirements specific to white space identification. Two of those are GPS location and local storage. By adding a GPS to the device, it is possible to tag the occupied spectrum for a specific location. Bulk local storage, in the form of inexpensive micro SD cards, allows vast amounts of data to be stored for later processing and visualization. This combination allows the geographic variance of spectrum occupation to be measured, recorded, and visualized and automates the task of doing wide area site surveys for white space identification.

Finally, small details were added on to the design in the form of battery and power management and a ruggedized enclosure. This improves the portability of the device and allows it to be taken around easily and unintrusively. Conventional spectrum analyzers are often subject to import duties (even for temporary usage) in many countries significantly encumbering the logistic of measurement campaigns.

3.1 Calibration

To make sure that the device provides reliable measurements, we compared ASCII-32 against a professional Agilent N9344C recently calibrated spectrum analyzer. A calibrated Agilent 8648C signal generator provided signals at 5 different power levels, i.e., -50, -60, -70, -80 and -90 dBm, for each of the central frequencies of UHF TV channels, between 482 MHz and 554 MHz in steps of 8 MHz (the bandwidth of a UHF analogue channel). Figure 2 shows the results, the Y axis shows the reference calibrated power from the signal generator (also measured with the reference Agilent spectrum analyzer) as dotted horizontal lines, while the corresponding readings from the ASCII-32 device are represented by different symbols (upward triangle for -50 dBm, circle for -60 dBm, and so on). From the figure, we can infer that in the frequency range of interest, from 482 MHz to 554 MHz, the device is providing accurate results with a maximum difference of ± 2 dB from the calibrated value.

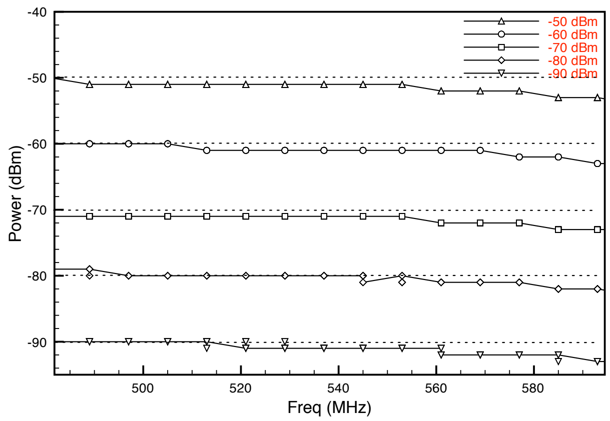

Figure 2: Measured power by ASCII-32 when input with pre-calibrated values.

4. TRIAL IN MALAWI

From June 10 to 14, 2013, we traveled extensively across Malawi by car gathering spectrum data using the ASCII-32 device. We present a measurement campaign of a semi-urban area.

4.1 Zomba

The data recording was from Zomba to the outskirts of Lake Malombe. The Zomba District has a total population of about 600000 resulting in a population density of 230 persons per km^2, more than half of whom are 18 years or younger. It represents a semi-urban environment. While traveling to Lake Malombe we passed through rural areas, with few small villages and no infrastructure.

Figure 4 shows the road we drove, in direction of Lake Malombe. This is a path of 130 km approximately, where we gathered some 25000 sample points. Figure 3 shows the whole spectrum measured along the way, with the Y axis showing the maximum value recorded in the 25000 samples for the frequency in the X axis.

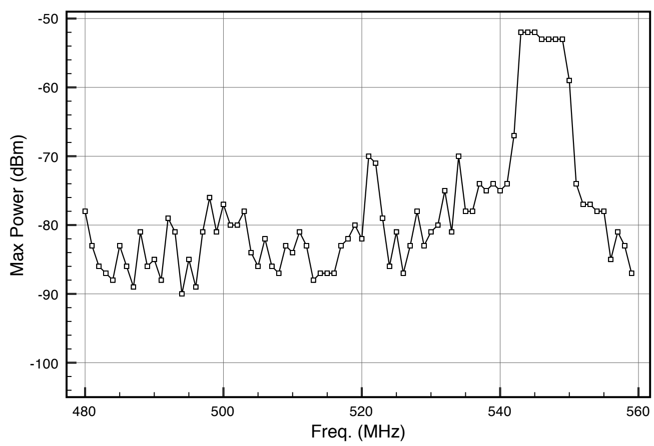

Figure 3: Spectrum measured in Malawi, maximum value in 25000 samples.

We observed that different frequencies had different behaviors. For example, 546 MHz has a noticeable activity when compared to other frequencies. By visualizing the results in a heatmap, it is easier to analyze where the activity is happening. Figure 4 shows the heatmap for 546 MHz, with points evenly separated by 1km. Each point contains the average of the activity within that 1km (linear distance). Lighter colors indicate low or now occupancy of the spectrum and darker colors indicate that the spectrum is used.

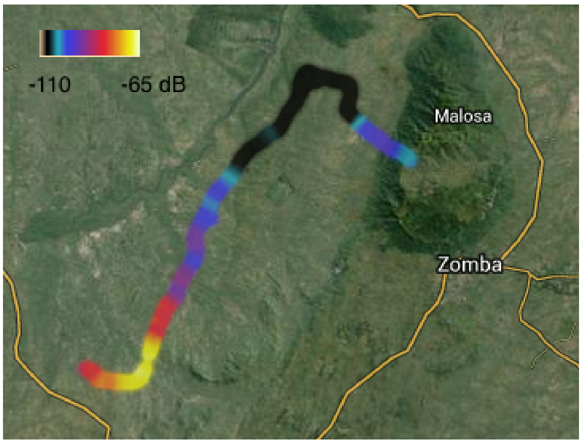

Figure 4: Heatmap for 546 MHz in Malawi.

The frequency of 498 MHz, on the other hand, is scarcely used along our path. Figure 5 shows the heatmap for this frequency.

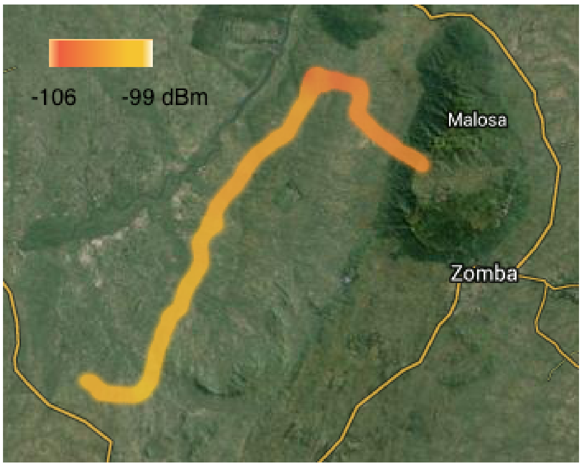

Figure 5: Heatmap for 498 MHz in Malawi.

5. TRIAL IN ZAMBIA

Another campaign was carried out in Zambia where we traveled 352 km from Lusaka to the city of Kitwe, in the North. More than 20000 measurements were taken during the car travel.

Figure 6 shows the whole spectrum measured along the way, with the Y axis showing the maximum value recorded in the 20000 samples for the frequency in the X axis. The whole spectrum is scarcely used.

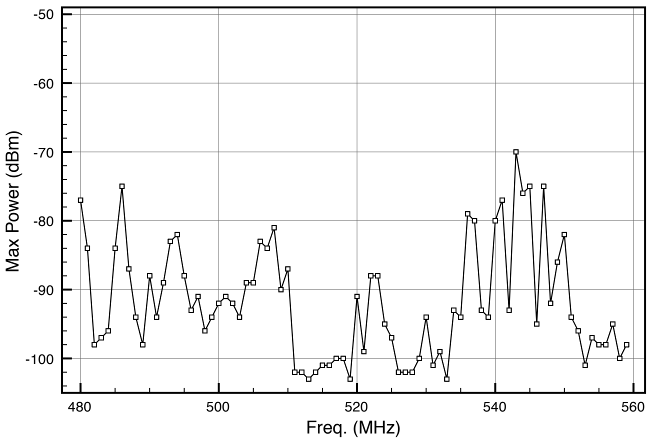

Figure 6: Spectrum measured in Zambia, maximum value in 20000 samples.

As an example of an available frequency, Figure 7 shows the heatmap of channel 546 MHz in Zambia, with the same color scheme as the one in Malawi.

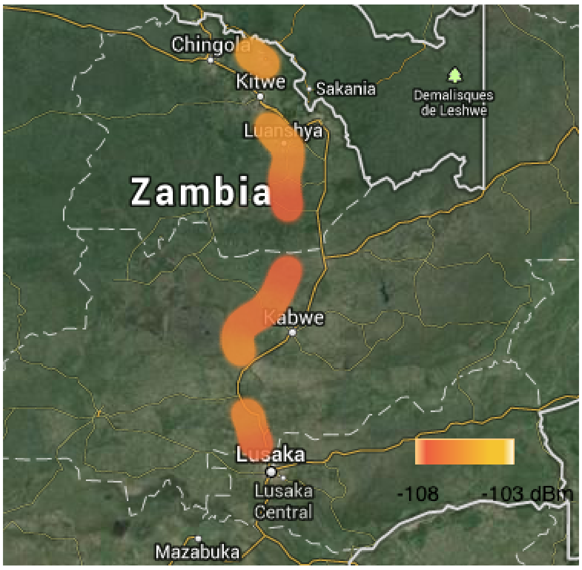

Figure 7: Heatmap for 546 MHz in Zambia.

6. FUTURE WORK

The ASCII-32 device was first used in Malawi and Zambia in June 2013. Based on these experience , the original design was modified and two variants were created. The first variant does away with the mobility aspects by removing the GPS and battery/power management, and instead adding a network IC and a TCP/IP stack. This allows the RF spectrum to be measured in one location and automatically sent to a server for continuous monitoring. Essentially, it facilitates measuring the change of spectrum occupancy over time. The second variant is a low cost version without the GPS and the network IC. It will record the occupied spectrum in one location and store it locally on the SD card for offline processing. This variant is targeted at places where the location is known and somebody is willing to maintain and upload the data, but cannot afford or do not need the other features. The main additional component in this variant is a real-time clock which replaces the GPS or network IC for accurate timekeeping and timestamping of the data. It is noteworthy that all versions of the ASCII-32 are very user friendly and can be operated by people with limited training, as opposed to traditional spectrum analyzers that require a very steep learning curve.

7. CONCLUSIONS

Our intention with this work was to show that the use of low cost spectrum analyzers can raise awareness about the vast swaths of underutilized spectrum available in Developing Countries. Spectrum occupancy measurements are routinely performed by the spectrum regulator agencies. In Developing Countries there is a lack of trained personnel capable of managing the nuances of a full fledged spectrum analyzer, and the cost of the equipment can be daunting for a typical University. The development of low cost alternatives for spectrum occupancy measurements presented here fills this void. Having real measurements of the actual spectrum occupancy can pave the way to a more efficient use of the spectrum.

The first version of the instrument was field tested during measurements campaigns in Malawi and in Zambia, where it showed that most of the UHF TV spectrum is not currently being used and there is room for deployment of two way data communications networks using these frequencies. We are planning to do a trial installation of such a network in Malawi using commercial TV white spaces devices for Internet access in a joint collaboration venture among the Malawi Communications Regulatory Authority (MACRA), the Chancellor College of the University of Malawi and the International Centre for Theoretical Physics (ICTP). On the other hand, the heatmap and the graphs of maximum measured power versus frequencies also identified certain frequencies, like the ones centered in the TV channel at 546 MHz that warrant further investigation to find out if they correspond to spectrum usage without the local regulator approval or just random noise peaks. This investigation should be carried out using the ASCII-32 version with the micro SD card to gather information over a period of time long enough to draw definite conclusions.

8. REFERENCES

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