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Preliminary Performance Assessment of TV White Spaces Technology for Broadband Communication in Malawi

Chomora Mikeka[1], Justice Stanley Mlatho[1], Martin Thodi[1], Jonathan Pinifolo[2], Dereck Kondwani[2], Lloyd Momba[2], Marco Zennaro[3], Andrés Arcia-Moret[3], Carlo Fonda[3] and Ermanno Pietrosemoli[3]

[1]*Physics Department, Chancellor College, University of Malawi, Zomba, Malawi*
[2]*Malawi Communications Regulatory Authority (MACRA), Blantyre, Malawi*
[3]*T/ICT4D Lab, ICTP, Trieste, Italy*

Abstract

Recently, the use of TV White Spaces for broadband communication has raised interest. White Spaces refer to regions of radio spectrum that are not used all the time in a specific geographical location. This paper presents the preliminary performance assessment of a TV White Spaces deployment in Malawi. The method used involved coverage simulations at the TV White Spaces frequencies, deployment of the network, monitoring and performance analysis. The preliminary results report usable coverage distance up to 7.5 km which has allowed that remote students access the content of the university library and interact with the university faculty. The results thus show that the TV White Spaces technology can be used for broadband connectivity in rural and undeserved areas even when the WiFi and broadcasting spectrum is already utilized. A typical application that supports remote access of e-library resources from a rural Secondary School was developed using DSpace architecture over the White Spaces infrastructure is discussed.

Selection and peer-review under responsibility of the Organizing Committee of HumTech2014.

Keywords: TV White Spaces, Wireless, ICT4D, Malawi

1. Introduction

The growing demand for wireless data transmission imposes the search for alternatives to the current spectrum exploitation schemes. In the long term, dynamic spectrum access seems to be the only viable 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 [1].

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An evaluation of the performance of well-defined secondary systems in realistic scenarios will eventually help to gauge the usability prospects for TVWS-driven technologies and potentially guide subsequent regulatory rule-making. In Malawi, the partnership team between the regulator (referred to as the Authority in the TVWS regulations) and the University of Malawi-Chancellor College has developed the TVWS rules and regulations, investor side business model and a performance analysis of the network in the mid of December 2013. The deployment of the pilot was completed in September in partnership with the Abdus Salam International Centre for Theoretical Physics (ICTP) from Trieste, Italy. The goals for the Malawi TVWS Pilot are similar to that of the Cambridge Trial [2] that is, to help industry understand the capability of TV white spaces to serve a wide range of applications, through key factors such as the coverage and performance that can be achieved.

The authors herein have previously published on the findings of a TVWS spectrum measurement initiative in Malawi and Zambia. In [3] they introduced 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. An assessment study on TV white spaces in Malawi using affordable tools was presented in [4]. In the current paper however, we focus on the performance of the deployed network since appropriate performance indicators of White Space Devices (WSDs) are badly needed [5].

The rest of this paper is organized as follows. Section II is the description of the deployed TVWS network and the proposed monitoring platform. Network performance results are presented in Section III. A typical application using DSpace over the TVWS infrastructure is presented in Section IV. Conclusions are drawn in Section V.

2. Network Setup and Proposed Monitoring Platform

The Malawi TVWS network topology has a typical star configuration, with the base station as hub and the CPEs as clients. The base station is located in a 40 m tower that was erected by the Chancellor College of the University of Malawi for the installation of an FM broadcasting station, and both the FM broadcasting and WSD antennas are located in the same mast and operate without interference. Both transmitters are housed inside the building adjacent to the tower and are connected to their respective antennas by low loss coaxial cables. The same tower also houses a 5 GHz point to point wireless link to the Internet Service Provider that offers the connectivity to the outside world. A picture of the mast with the FM antennas on top and the TVWS omnidirectional antenna below is shown in Figure 1.

Figure 1: the mast with FM and TVWS antennas.

Station Design and Description

The TVWS network connects three clients in the city of Zomba: the St.Mary's Girls School, the Airwing airport and the Seismological department, as shown in Figure 2. Distances from the base station range from 800 m (Seismological department) to 7.5 km (Airwing). The St.Mary School is about 4 km from the base station.

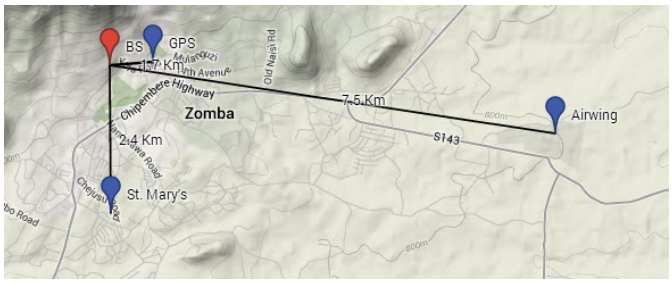

Figure 2: the Malawi TVWS network map.

Each client station or customer premise equipment (CPE) comprises an outdoors wireless router connected to a Yagi-Uda type antenna and powered by a UTP cable that terminates into an indoor Power-over-Ethernet (PoE) adapter. Additional station devices include a LAN switch and an ALIX board, included for measurement purposes.

The TVWS base station is an indoor device, and has low power consumption compared with cellular base stations. It transmits using a wide band omnidirectional antenna with a gain of 6 dBi over the UHF band of interest located at a height of 21 m above the surrounding terrain, thus providing a good coverage of the intended clients.

Internet connectivity in the Malawi TVWS pilot network is provisioned through a dedicated 2 Mbps wireless backhaul operating at 5 GHz. The actual network setup is shown in Figure 3.

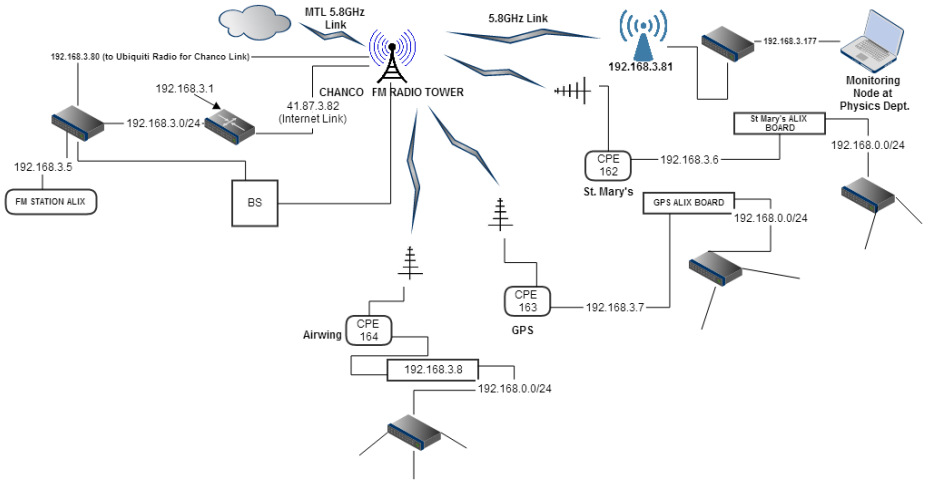

Figure 3: the Malawi TVWS network topology.

The TVWS network was deployed by a team composed by staff of University of Malawi and of the Abdus Salam International Centre for Theoretical Physics in September 2013. A group of MACRA experts followed the installation process and measured the frequencies used with a calibrated spectrum analyzer, as shown in Figure 4.

Figure 4: MACRA experts measuring spectrum usage.

Following the measurements of the MACRA experts and the previous TVWS measurements campaigns carried out by University of Malawi, we decided to use the 554 MHz frequency, with an 8 MHz channel width. This frequency was not in use in the city of Zomba and surrounding area.

2.1. Low Cost Monitoring Platform

The network was deployed using Broadband Rural-Connect equipment from Carlson Wireless Technologies. The Carlson equipment uses a cloud based Operation and Management Center (OMC) that provides a cloud level view of all the devices comprising a given cell. This online tool is used for the initial configuration as well as to monitor the network, since it provides information like SNR (Signal to Noise Ratio), modulation type, throughput and amount of packets per second delivered to each of the clients connected.

The data presented in OMC has one major shortfall in that it cannot be saved or exported in any format for later viewing or analysis. Therefore the performance data in the OMC is only useful when one only wants to see the current performance and the past over a period of time of 24 hours. This prompted the authors to identify some low cost tools of capturing and saving performance data using Python and Perl.

To enable the collection of performance data, ALIX boards were fitted at each client station. A version of Linux for embedded boards (Voyage Linux) was installed on the ALIX boards using the procedure described in [6]. On each ALIX board, one Ethernet port was connected to the CPE while another Ethernet port was used to distribute the network locally using a DHCP server.

Given the limitations of the cloud based operations and management center (OMC), a need arose to have custom scripts that would capture and save network throughput data in real-time. For this purpose, Python programming language was chosen because it can leverage existing open source libraries and modules that can be used as-is as well as modified to suit different needs.

The developed scripts were used to collect network performance and packet throughput data. The data was collected for each day at a one second interval. The collected data was then saved using comma separated values (CSV) files, chosen mainly for their portability. The files used the date stamp for the name for easy sorting and identification during analysis.

In addition to the scripts that capture throughput data, Python scripts were also used to plot the data obtained into graphs. This was achieved by exploiting the plotting functionalities of the matplotlib module. The Python scripts that

were developed did not capture network latency data. For this purpose, other scripts were developed in the Perl programming language to capture and save network latency from the base station to every client site.

3. Results

In this paper we present the preliminary measurements of throughput and latency at St. Mary's Secondary School.

The downstream throughput (orange) and upstream throughput (green) from the school to the base station are shown in Figure 5 below for a period of 2 hours. As can be seen, a maximum throughput of 2 Mb/s has been reached.

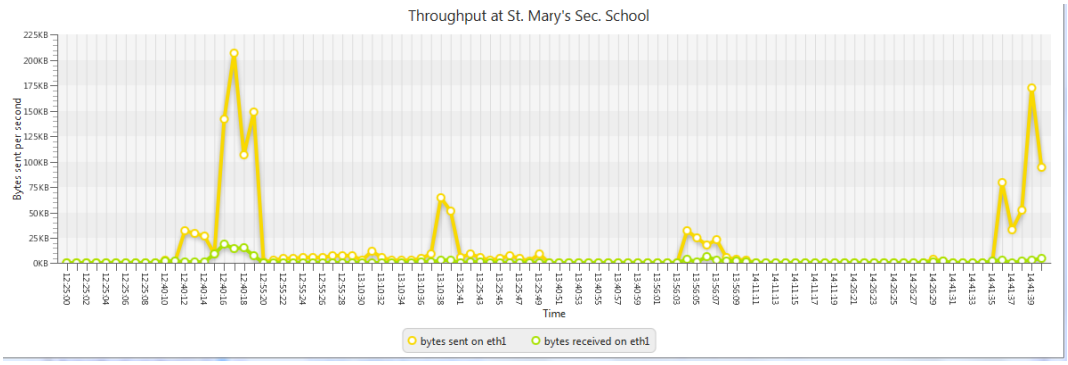

Figure 5: throughput at St.Mary's School.

The average latency in milliseconds (ms) for a given hour study is shown in Figure 6.

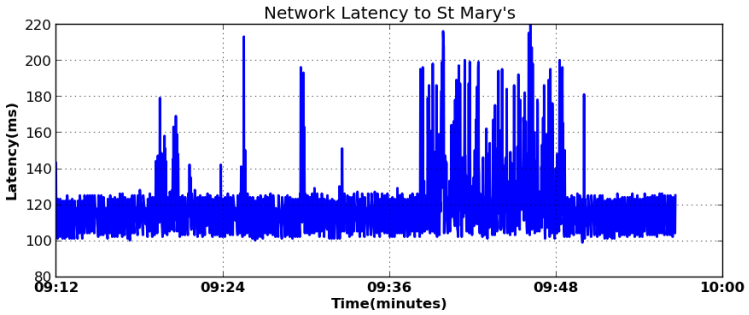

Figure 6: latency at St. Mary's School.

The low latency allows for audio and video conferencing in the network.

4. DSpace at University of Malawi

A DSpace is an open source dynamic digital repository. While its benefits are clear spanning from the submitter through the collection curator and to the end-user; the assumption in the DSpace architecture is that there is an infrastructure to connect the submitter, curator and the end-user provided by the fabric of a typical DSpace

community. A community is the highest level of the DSpace content hierarchy and corresponds to parts of the organization such as faculties, departments, labs, research centres or schools.

4.1. Of the Need for Digital Repositories at Chancellor College

Chancellor College is a constituent College of the University of Malawi [7]. Its library management has recently been responding to the pressure of access as described in [8].

The study in [8] revealed that despite the fact that each Higher Learning Institution (HLI) had a library, the seating capacity did not keep pace with the increasing number of students enrolled each year. There are also numerous challenges such as limited opening and closing hours, lack of variety and updated books in various study disciplines, and involvement of a lot of manual search for books. The turning point for the above mentioned challenges is to establish a digital library. However, digital library implementation often fall into doldrums because of the following factors: shortage of funds, limited technology skills, power rationing, inadequate Information and Communication Technology (ICT) tools in the libraries, shortage of skilled personnel who can start and run digital library, unstable network infrastructures, and high cost for Internet bandwidth. The aforementioned study calls for deliberate action to implement digital libraries especially in HLIs in order to harvest the prospects of digital libraries in enhancing access to learning materials and consequently improving students' academic performance.

4.2. Chancellor College DSpace

An interaction with the Malawi Libraries Consortia (MALICO) at its 10 years' celebration revealed that DSpaces were tested in some Malawian Colleges and Universities as solutions for digital repository implementation and access. At Chancellor College, a server was configured and mounted with DSpace software appropriately configured to host various digital data from all possible communities. DSpace is an open source repository application that is free, customizable, and out-of-the-box supports large community, several institution types and most digital content. The Chancellor College DSpace is accessible at http://dspace.cc.ac.mw:8080/jspui/.

4.3. DSpace and St. Mary's School

Given the broadband connection, students at St. Mary's Secondary School are able to access content from the University of Malawi digital library over the TV white spaces network infrastructure. Additionally, the teenage students are able to ask questions via email to University of Malawi Professors for career guidance.

5. Conclusions

This paper has presented the implementation of the Malawi TVWS network and discussed its operation, monitoring and performance. The deployment in Malawi has demonstrated how unused TV channels could be leveraged to provide broadband connectivity to rural schools with emphasis on increasing access to learning material and career guidance using the DSpace architecture. This, according to the authors, is a positive outcome with significant impact in the context of a developing country. Further study on the network performance is ongoing in order to compare the network resilience both in dry (September to December) and rainy seasons (January to June).

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