Piloting White Spaces for DSpaces in Malawi

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Abstract

In this paper, the author describes a potential application that exploits the White Spaces identified in the UHF television band in Malawi to be the channel to connect to University digital repositories based on the DSpace architecture. The Malawi TV White Spaces (TVWS) network was deployed from the 11th September, 2013 in Zomba district (University town), with three stations as pilot in key economic sectors namely; education, security and seismic monitoring and mitigation. St. Mary's Girls Secondary School is one of the pilot stations in the education sector. The ICT-teacher at the school was trained and certified ready to support and sustain the TVWS deployment and the applications running on the TVWS infrastructure. This paper reports on the access that the TVWS network is providing to the senior level students (Form III and Form IV) from the School's Computer Lab to the University of Malawi's DSpace at Chancellor College Campus Library. A parametric study of the link performance between St. Mary's and Chancellor College show data rates up to 700kbps in terms of downstream application data throughput and a per second packet rate of 60, provided that the TVWS base station (BS) is wireless backhauled to a dedicated 2Mbps internet bandwidth stream and that the TVWS link at UHF channel 31 (554 MHz) from the BS to St. Mary's client premise equipment (CPE) measures a Signal-to-Noise Ratio (SNR) of 25.98 dB.

Keywords

White Spaces, DSpace, ICT, Spectral Sensing, Database

1. Introduction

A DSpace is an open source dynamic digital repository. While its benefits are clear from the Submitter (S) through the Collection Curator (CC) to the End-user (E) (data retrieval); the assumption in the DSpace architecture is that there is an infrastructure to connect S-CC-E and by extension provide for 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. The author herein discusses a potential application in the Malawi TVWS project that is aimed at providing broadband connectivity to rural Malawi at affordable cost using the identified gaps (White Spaces) in the television (TV) UHF band thereby filling the gap created by the assumption in above.

White Spaces refer to the identified gaps in a given radio spectrum or band. The gaps are sometimes referred to as idle channels or "blank spaces," existing at the level of the Additive White Gaussian Noise (AWGN) in a given radio or wireless system, with reference to the dBm

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level, mostly below the sensitivity level of the radio. Key to the White Spaces technology is spectral sensing and database look-up capabilities.

1.1 Spectral sensing

Spectral sensing is a cognitive radio technique that monitors transmissions on particular channels and reports when the channels are busy. A spectral sensing device monitors while using the spectrum itself. With this capability it is possible to develop an autonomous, self-contained device that is simpler and less costly to build and may be used anywhere. The device must be able to sense signals that are hundreds of times weaker than a TV station.
Through the Malawi TVWS project, rigorous spectral sensing exercise was carried out from November 2012 to April, 2013 where results showed abundant potential to use the TVWS technology in Malawi (Zennaro *et al*., 2013)

1.2 Database look-up

Database look-up is the capability in which a device determines its location through GPS or other means and consults a dynamically updated database with information on which channels are free in a given site or region. The device then knows which channel to use. Motivated by this opportunity, (Murty, R. et al.,) presented SenseLess, a database-driven white spaces network. As suggested by its very name, in SenseLess, WSDs rely on a database service to determine white spaces availability as opposed to spectrum sensing. The database service uses a combination of an up-to-date database of incumbents, sophisticated signal propagation modelling, and an efficient content dissemination mechanism to ensure efficient, scalable, and safe white space network operation.

The rest of this paper is organised as follows. Section 2 is the description of the Malawi TVWS network. Section 3, is the description of the Chancellor College DSpace in terms of implementation and the access links. Section 4 presents the results in terms of a typical access scenario, performance metrics and comments from the beneficiaries. Finally, conclusions are made in Section 5.

2. Description of the Malawi TVWS Network

The Malawi TVWS network topology assumes a star configuration. It has a single base station and three client stations as shown in Table 1.

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Table 1: Station Identification in the online Operation and Management Center (OMC)

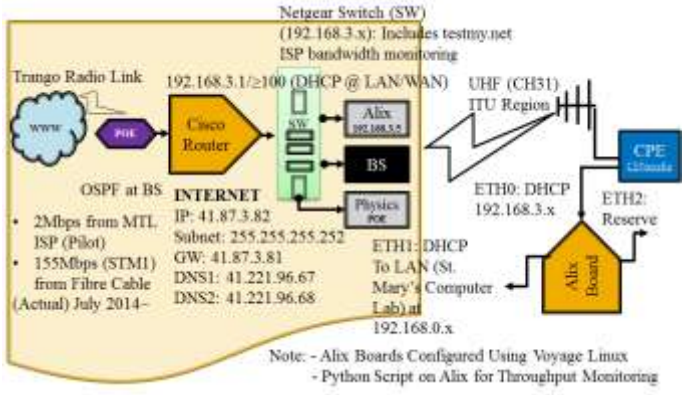
Terminal	Description	Station Name
CST00162	**ICTP CPE 162**	**St. Mary's Girls Sec School**
CST00163	**ICTP CPE 163**	**AirWing**
CST00164	**ICTP CPE 164**	**GPS (Seismology Dept.)**
CSB00490	**ICTP Base 490**	**ZA TVWS Base station**

2.1 Station design and description

Each station comprises client premise equipment (CPE) and a Yagi-Uda type of antenna mounted outdoors and powered by a UTP cable that terminates into an indoor Power-over-Ethernet (PoE) adapter. Additional station devices include a LAN switch and ALIX board (functionality discussed in later sections).

The TVWS base station is an indoor device, ultra-low power consumption compared with cellular base stations. It transmits using a huge monopole antenna (case of Carlson radios) mounted outdoors at a height based on rigorous computations or simulation per design coverage and link quality of the star topology.

Internet provision in the case of the Malawi TVWS pilot network is via a dedicated 2Mbps wireless backhaul as shown in Figure 1 (a).



(a) Malawi TVWS Pilot Network: Showing Only One Client Station (St. Mary's Sec School)

(b) St. Mary's CPE

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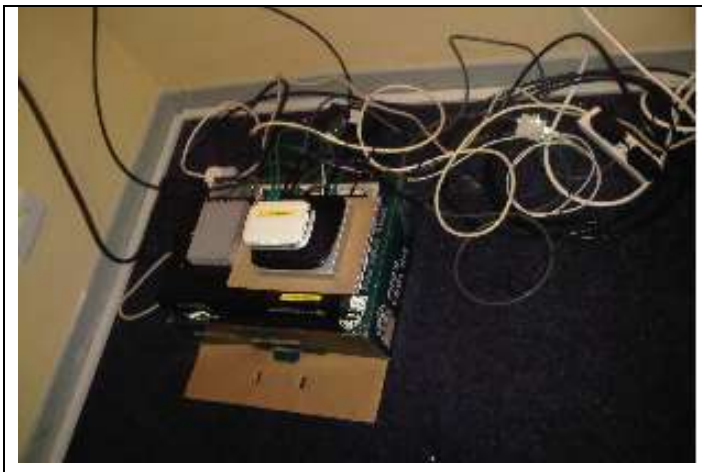

(c) Malawi TVWS Base Station Located at the GPS Coordinates: -15.376415S, 35.318349E

(d) Form IV student writes instructions on how to access the DSpace (DSpace navigation) or simply hit http://dspace.cc.ac.mw:8080/jspui/

Figure 1: Malawi TVWS pilot network diagram and deployment scenario at one station (St. Mary's Sec., School)

1.1.1 Installation of Voyage Linux and configuration of the network interfaces on ALIX Board

Voyage Linux was installed on the ALIX board using the procedure described at the subsequently given site http://linux.voyage.hk/content/getting-started-v08x (sections 1 and 2 should be enough).

After successful installation, Voyage Linux was mounted (with the compact flash (CF) card still connected to the Linux machine used for the installation) on /mnt/cf (the mounting point set in the installation configuration). Then, one network interface (eth0) was enabled and given an IP address (192.168.3.9) so it could be possible to SSH into the ALIX when it is booted. This is the private network where all the other boards one the TVWS pilot network diagram are configured to be on. The configuration was saved, un-mounted the CF card and slotted it into the ALIX board and booted. Finally, it was possible to log on to the ALIX board using SSH.

The SSH configurations are as follows:

IP: 192.168.3.9
User: root
Password: voyage (this is the default, so remember to change as soon as possible using passwd)

The other interfaces (eth1 and eth2) were also configured. The interface eth0 connects to the client radio (the CPE) and interface eth1 was configured to be providing dynamic IP addresses in the range 192.168.0.5/ to /240 to computers on the client side using DHCP. The DHCP server used was dnsmasq whose configuration file is /etc/dnsmasq.conf. The interface itself has IP address 192.168.0.1. The last interface (eth2) was left with a static IP address which can also be used to SSH into the ALIX board with the above credentials.

Note:

i. eth2 can also be configured to provide DHCP.

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ii. dnsmasq uses the TVWS base station wireless backhaul nameserver for resolution.

A typical usage scenario at St. Mary's is captured in Figure 2 below.

(a) Station gear comprising a PoE, ALIX board, and Netgear LAN switch

(b) Sandra Khasu, 13 years old Form 4 connects a TVWS UTP cable to the PC Ethernet card

(c) Shereen Manjombe, Form IV fixes a faulty PC memory card

(d) Martin Thodi, Malawi TVWS researcher, assists the girls to access the DSpace and create emails using the White Spaces Internet

Figure 2: TVWS station at St. Mary's Girls Secondary School deployed in the computer laboratory

3. Of the Need for Digital Repositories at Chancellor College

Chancellor College is a constituent College of the University of Malawi (http://www.cc.ac.mw/). It's library management has recently been responding to the pressure of access as described in Matto, G. & Bwabo M. (2012).

The study by Matto G. & Bwabo, M. (op.cit.) revealed that despite the fact that each Higher Learning Institution (HLI) had a library, but the seating capacity did not keep pace with the increasing number of students enrolled each year. There are also numerous challenges such as

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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 digital library (Matto, G. & Bwabo, M., op cit.). However, digital library implementation fall into doldrums because of the following identified factors; shortage of funds, low technology, 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 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.

3.1 Chancellor College DSpace

An interaction with the Malawi Libraries Consortia (MALICO) at its 10 years celebration revealed that DSpaces were tested in some 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, out-of-the-box and supports large community, all institution types and any digital content. The Chancellor College DSpace is accessible at http://dspace.cc.ac.mw:8080/jspui/.

4. Results

With the network setup as per design and all configurations running alright, it was necessary to carry out some measurements on and off-peak hours with and without traffic on the network in order to determine the performance of the network. The performance results are discussed in two subsections namely; performance metrics and comments from beneficiaries.

4.1 Performance metrics

The basic performance metrics included SNR for the link which correlated with the level of the received signal strength (RSSI) shown by LEDs at the CPE. In simple terms, an SNR equal to 25 dB or more implied a maximum of four LED count on the CPE and an SNR < 10 dB was equivalent to one or no LED count on the CPE. This indicated the link quality. In terms of throughput and packet rate, two independent approaches were used. The first approach was to use the integrated algorithm/solver in the OMC of the TVWS base station. It plots performance graphs accessible via a web interface just like many wireless access points or clients do. These graphs are good for viewing but to manipulate them for scholarly purposes is often difficult and the accuracy of its captured data requires verification. As such, it was necessary to develop a custom script that would be loaded on ALIX boards at each station, to do, precisely one task i.e. measure throughput and packet rate (with the capability to sniff each packet and isolate desired packets for further analysis). Such a script (we named it netmon.py) was written using the Python programming language. Results show that using netmon.py script, downstream data rates around 200kbps were measured as shown in Figure 3 (a) whereas observations in the OMC, downstream data rates up to 700kbps were achieved as shown in Figure 3 (b). The time stamp on both graphs coincide with GMT but the data was taken on different dates (31st Oct for OMC and 1st Nov for 2013 for netmon.py script). Future work will attempt to compare (with controlled parameters), the data measured by the netmon.py script to that of the OMC.

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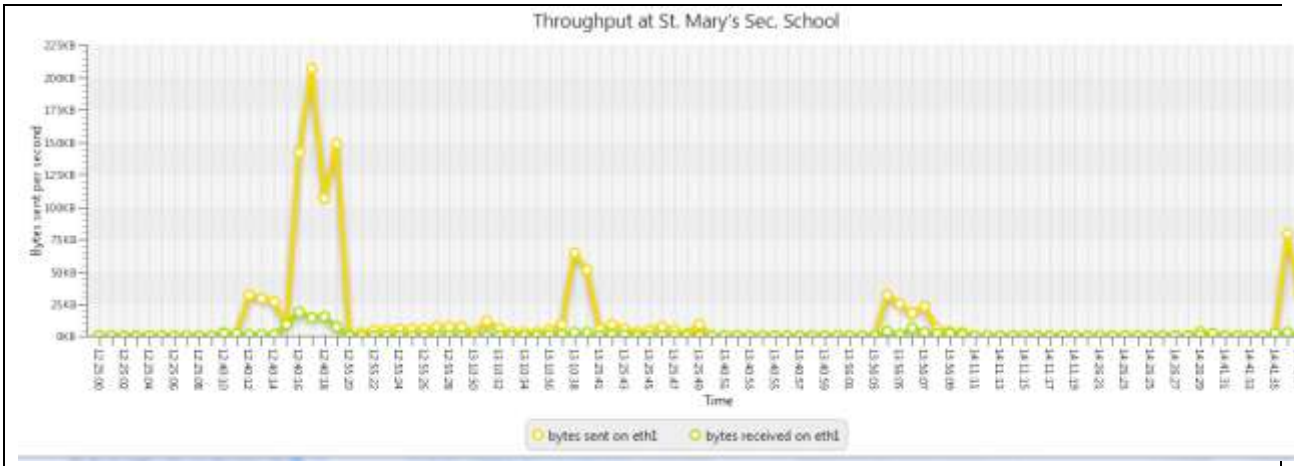
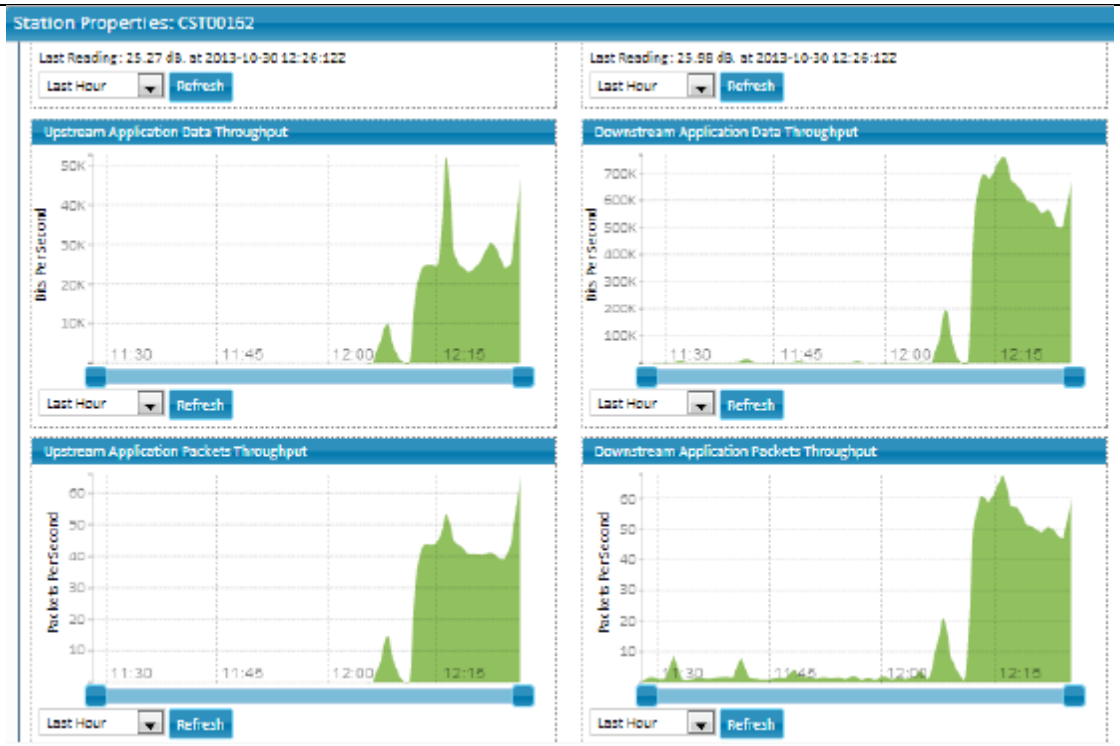


(a) Using python net-monitoring (netmon) script (netmon.py) running at the station ALIX board



(b) Using the Operation and Management Centre (OMC) for Neul and now migrated to Carlson

Figure 3: Performance metrics (SNR, Throughput and Packet Rate) using python and OMC

4.2 Comments from the beneficiaries (Form IV Students)

On 31st October, 2013, the author of this paper and his research expert assisted three Form IV girls to create email addresses using the internet facility provided by the TVWS. The students were selected due to their active idea, fearless engagement with professionals and curiosity to know more about their own fields of study, the usefulness of TVWS and a possible exploration

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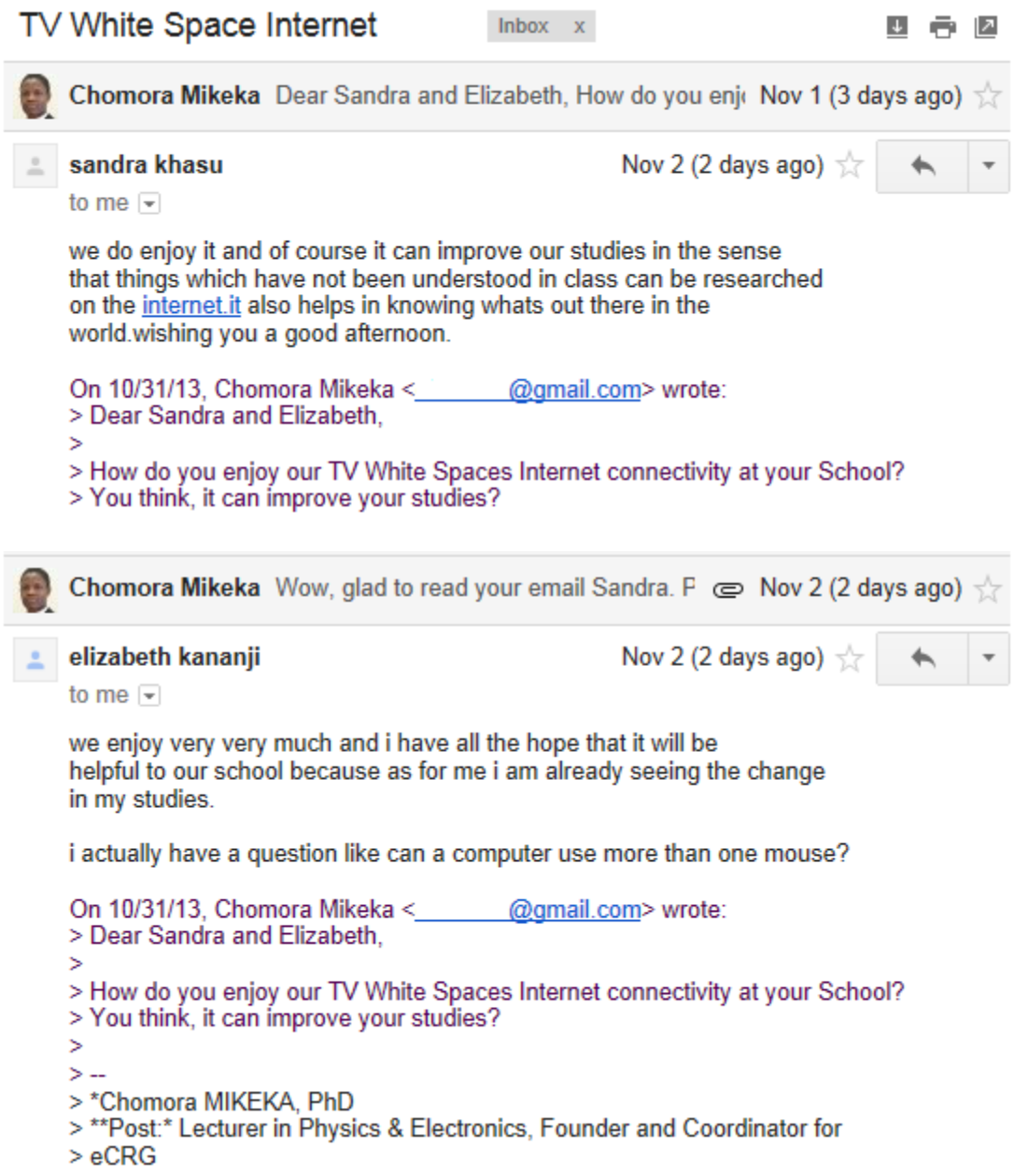
on their future University study programmes of their interest (Law for Sandra and Engineering for Elizabeth). A simple email was sent to them by the author to prompt responses that would give an indication on the usefulness of the TVWS internet access at the school. Below are some few selected responses and interactions which point to benefits this technology is likely to achieve now and into the future generations.



TV White Space Internet Inbox x

Chomora Mikeka Dear Sandra and Elizabeth, How do you enj Nov 1 (3 days ago)

sandra khasu Nov 2 (2 days ago)

to me

we do enjoy it and of course it can improve our studies in the sense that things which have not been understood in class can be researched on the internet.it also helps in knowing whats out there in the world.wishing you a good afternoon.

On 10/31/13, Chomora Mikeka <_____@gmail.com> wrote:
> Dear Sandra and Elizabeth,
>
> How do you enjoy our TV White Spaces Internet connectivity at your School?
> You think, it can improve your studies?

Chomora Mikeka Wow, glad to read your email Sandra. F Nov 2 (2 days ago)

elizabeth kananji Nov 2 (2 days ago)

to me

we enjoy very very much and i have all the hope that it will be helpful to our school because as for me i am already seeing the change in my studies.

i actually have a question like can a computer use more than one mouse?

On 10/31/13, Chomora Mikeka <_____@gmail.com> wrote:
> Dear Sandra and Elizabeth,
>
> How do you enjoy our TV White Spaces Internet connectivity at your School?
> You think, it can improve your studies?
>
> --
> *Chomora MIKEKA, PhD
> **Post:* Lecturer in Physics & Electronics, Founder and Coordinator for
> eCRG

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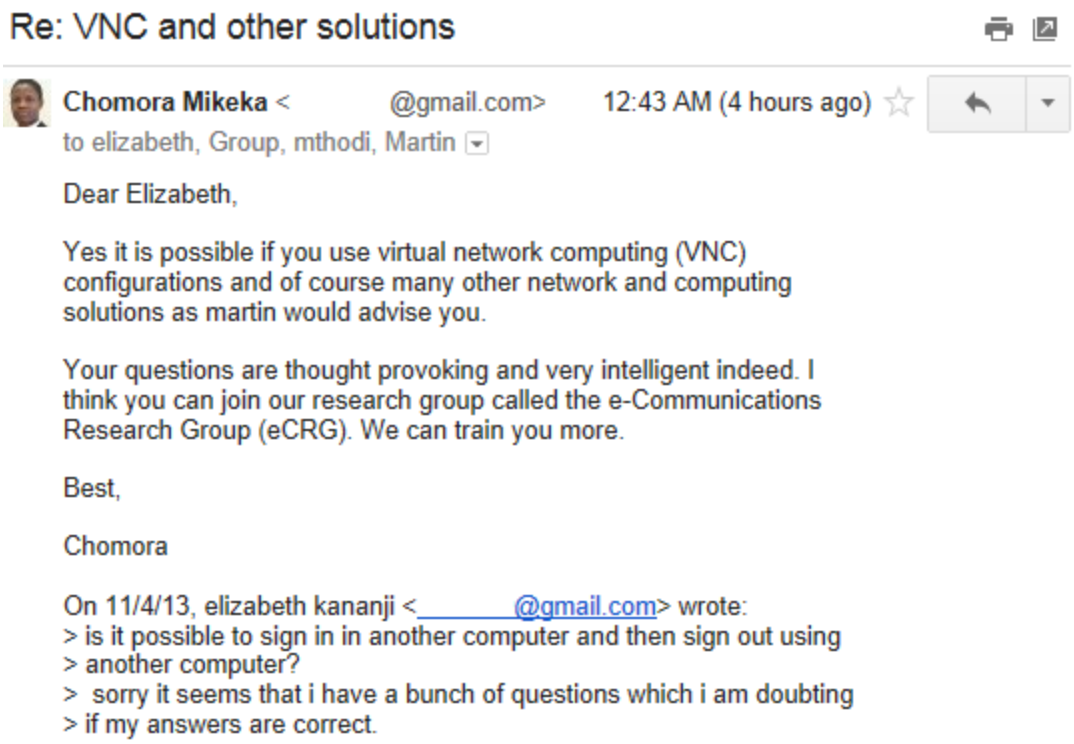

Re: VNC and other solutions

Chomora Mikeka < @gmail.com> 12:43 AM (4 hours ago)

to elizabeth, Group, mthodi, Martin

Dear Elizabeth,

Yes it is possible if you use virtual network computing (VNC) configurations and of course many other network and computing solutions as martin would advise you.

Your questions are thought provoking and very intelligent indeed. I think you can join our research group called the e-Communications Research Group (eCRG). We can train you more.

Best,

Chomora

On 11/4/13, elizabeth kananji <_____@gmail.com> wrote:
> is it possible to sign in in another computer and then sign out using
> another computer?
> sorry it seems that i have a bunch of questions which i am doubting
> if my answers are correct.

5. Conclusion

In this paper, TV White Spaces has been described as a potential technology to support education, particularly in the improvement of access to study and research materials in DSpaces. The performance of the TVWS network that was designed and deployed in Malawi has been discussed to provide future benchmarking platform for other countries or institutions that desire to exploit the technology for low cost broadband connectivity. Internet provision and DSpace application access at St. Mary's Girls Secondary School proves to be pivotal to the academic success for the students at this school. Future work aims at increasing the number of applications and examining the network performance in handling balanced and unbalanced traffic loads over the network.

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Biography

The author was born on 6th January, 1978 and is a Senior Lecturer in the Physics Department at Chancellor College Campus of the University of Malawi in Zomba. He is also the Director for the Malawi White Spaces Project in partnership with the Malawi Communications Regulatory Authority (MACRA) and Marconi Wireless T/ICT4D Laboratory in Trieste, Italy. Chomora Mikeka holds a PhD from the Division of Physics, Electrical and Computer Engineering at Yokohama National University, Japan. His PhD research was about power autonomous sensor radio based on cellular and digital TV RF energy harvesting.

As a visiting researcher at the Communications Subsystems Lab, CTTC in Barcelona (Spain), he collaborated in the design, simulations and fabrication of an ultra-low power DC-DC buck boost converter with regulated output for less than a milli watt RF energy harvesting. He has held a Lecturer position at the Graduate School of Information Technology (Kobe Institute of Computing), training 30 African participants on Problem Resolution for Development Issues by Information and Communication Technology (ICT) *(J11-30012)* (a JICA funded project).

Apart from being a lecturer, Dr. Chomora Mikeka coordinates the e-Communications Research Group (eCRG) on several research topics and projects, one such being on TV White Spaces Technology for Broadband Rural-Connect in Malawi.