Studies on the Use of Television White Spaces in South Africa: Recommendations and Learnings from the Cape Town Television White Spaces Trial

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1. Executive Summary

2. Introduction

There is growing recognition across the globe that dynamic spectrum sharing enabled by geolocation databases has significant potential to increase the availability and ubiquity of broadband access. For example, databases allow providers to deliver wireless broadband over vacant channels (called white spaces) in the television spectrum. Geolocation databases, such as those now being developed to access TV white spaces, indicate via a database query which TV channels are available for data communication based on the geographical location of the radio. The proliferation of trials in Africa exploring television white spaces (TVWS) technology demonstrates that it can broaden the reach of access networks and help bridge the digital divide, particularly in underserved and rural areas.

Developments in database-driven dynamic spectrum sharing also highlight inefficiencies created by the traditional methods of allocating and assigning radio frequency spectrum. As the demand curve for wireless broadband connectivity continues to steepen, new spectrum management tools geared towards introducing greater flexibility in the sharing of spectrum between different users have the potential to realise efficiencies to meet this demand more effectively.

There are currently two TVWS trials in progress in South Africa. A TVWS trial was launched in Cape Town on 25 March 2013, and it is likely to conclude in October 2013[1]. A second trial was announced in the Limpopo Province in the third quarter of 2013 and is set to be launched in the first quarter of 2014.

The Cape Town TVWS trial ("the Trial") provided broadband over TVWS to ten schools. At the beginning of the Trial, partners anticipated that the Trial would:

- Demonstrate that TVWS technology can be used to deliver affordable broadband services without interfering with TV reception;
- Assist the Independent Communications Authority of South Africa (ICASA) in developing a regulatory framework authorizing the use of TVWS in South Africa;
- Provide information to the Minister of Communications and Department of Communications ("DoC") regarding the use of TVWS to meet policy objectives relating to universal service, broadband access and efficient spectrum management; and
- Increase awareness of the potential for TVWS technology in South Africa.

[1] Service provision to the participating schools is to be continued by agreement with ICASA.

It was also hoped that the data gathered and experience gained will be of use to other policymakers and regulatory authorities throughout Africa. A collective learning experience across the various African TVWS trials was encouraged.

More broadly, learnings from the Trial and other efforts to deploy TVWS technology can be applied to many other radio frequency spectrum bands and may underpin future sharing initiatives in these bands.

2.1 Key Findings of the Trial

- The Trial offered reliable and fast broadband services: it produced bit rates of up to 12 mbps[2] at a distance of as far as 6.5km[3]. Graphs showing the results of upload and download throughput tests and latency tests conducted over the Trial network are set out in Annexure A. The graphs also show a trend towards improved performance over time which will continue into the future as the hardware and software is revised. The scope of the trial was to test a configuration with few transmitters and relatively high throughputs, as is common for broadband access. The alternative configuration is multiple transmitters at relatively low throughputs, as is common for telemetry applications.
- A database that calculates channel availability enables TVWS devices with accurate geolocation capability to avoid harmful interference with licensed services. The trial partners did not receive a single interference complaint or detect any measurable interference during the Trial.
- Even in Cape Town — selected as the site of the trial because it has the highest broadcast spectrum use in South Africa and the highest potential for interference — there is significant vacant spectrum for TVWS devices to use. Much more additional spectrum is likely to be available in rural areas where there are fewer broadcasters.

2.2. Recommendations

- Regulators should recognise the contribution that TVWS technology and database-enabled spectrum sharing can make in delivering wireless broadband to end users, especially in hard-to-serve areas, in improving spectrum utilisation, and in addressing increasing demands on spectrum use.
- Regulators should also recognise that TVWS devices can co-exist with established services. A geolocation database (or databases) enabling TVWS spectrum access can also evolve, accommodating changes in technology, market requirements, or regulatory mandates (see section 2.5 for TVWS' relationship to the digital migration process).
- In implementing a regulatory framework enabling the use of TVWS devices, regulators should rely on the following principles:

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[2] 1.5 bits per hertz.

[3] The state-of-the-technology used for the Trial had only been developed to a modulation rate of QAM 16. The current state-of-the-technology is at QAM 64, at the time of this report, which produces a throughput of 22-26 Mbps over an 8 MHz channel. More recent versions of the technology have evolved to deliver even higher data rates.

- Determine protection requirements that are sufficient to avoid harmful interference while allowing maximum usage;
- Consider multiple TVWS device profiles for fixed and mobile devices and for outdoor and indoor use;
- Promote an internationally harmonised approach to TVWS device characteristics and certification to take advantage of economies of scale[4];
- Encourage the development of multiple databases and and promote competition to drive down costs and spur innovation;
- Consider regional coordination when establishing licence-exempt managed access spectrum framework and conformance regimes for the equipment;
- Promote the development of TVWS equipment standards; and
- Recognise the value of spectrum sharing and promote its use as part of a progressive approach to managing spectrum more efficiently.

The Partners wish to express their appreciation to ICASA for its support and assistance in conducting the Trial.

3. An overview of TVWS and License-Exempt Managed Access Spectrum[5] as a Spectrum Management Tool

3.1. What are Television White Spaces?

The term "white space" in the context of radio frequency spectrum management refers to portions of radio spectrum that are allocated for licensed use but are not assigned to a particular licensee or are allocated and assigned for licensed use but are not utilised by the licensees at all times or across all geographical locations.[6] There is growing recognition that the white spaces in bands traditionally allocated to television broadcasting — Television White Spaces (TVWS) — can be used to provide wireless broadband Internet access on a "no-interference no-protection" (NINP) basis[7]. A device that uses these white spaces is referred to as a white spaces device (WSD) or TVWS device.

TVWS were originally established because vacant channels were historically necessary to provide broadcasters protection from harmful interference from other stations. Not all vacant

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[4] Databases can accommodate varying channel use parameters by jurisdiction even if devices are standardised.

[5] In South Africa, ICASA manages the use of spectrum by issuing licences or by allowing certain bands, such as the 2.4 GHz ISM band, to be used on a licence-exempt basis. In the latter case, interference is managed primarily through type approval obligations and transmission power restrictions. In this set of Recommendations, the use of TVWS devices on a licence-exempt basis incorporating control through type approval and a database is referred to as "licence-exempt managed access spectrum" in order to avoid confusion with the existing licence-exempt regulatory framework. South Africa does not have a regulatory framework for "unlicensed use" although this term is often confused with "licence-exempt".

[6] Note that vacant spectrum (also sometimes called white spaces) exists elsewhere in the radio frequency spectrum, and this spectrum could also be shared using a similar approach.

[7] I.e., any device using TVWS does so on the basis that it must not cause interference to licensed users and that users of TVWS will not receive any interference protection from either licensed users or each other.

channels are needed for broadcast-to-broadcast interference protection. In many markets, TVWS also exist because there are few broadcasters -- there are dormant channels in areas of lower demand.

Lower-power devices can operate in these vacant TVWS channels without causing interference to licensed operations. Although the number and precise frequencies of vacant channels varies from location to location, only a fraction of the available UHF channels are being used at any given time in any given location in South Africa. Topography also impacts on the number of transmitters and the associated number of channels required to achieve coverage.

Even after the digital television transition, much of the spectrum in the broadcast bands will remain vacant and available for broadband use. Moreover, advances in technology are facilitating more precision in terrestrial broadcasting planning, which of itself is opening up new white spaces.

Available spectrum in broadcast bands has highly desirable propagation characteristics: signals transmitted over TVWS spectrum can travel long distances and penetrate walls and other barriers[8]. As a result, TVWS technology is particularly suitable for delivering Internet access in rural and under-serviced urban areas. Other applications currently identified using TVWS include:

- Last mile access to augment city-wide or wide-area data networks;
- Data offload from mobile networks;
- Machine-to-machine communications, including smart grid and health care applications;
- In-building media distribution
- Local government and public safety applications; and
- Service to educational and health facilities.

3.2. Benefits of Enabling the License-Exempt Managed Access Use of TVWS[9]

South Africa enjoys a fast-growing Internet economy which contributed up to R59-billion or 2% to South Africa's gross domestic product (GDP) in 2012. This contribution is rising by around 0.1% a year, and is predicted to reach R79-billion by 2016.

Wireless access to the Internet is a key enabler of this growth. In particular, the use of licence-exempt spectrum — including Wi-Fi — has become ubiquitous in many areas of the country and is an important means of accessing the Internet for consumers and businesses.

A number of studies have analysed the potential value to be derived from allowing licence-exempt managed access to broadcast spectrum[10].

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[8] For any given transmission power level, a lower frequency enables greater range for the signal being transmitted.
[9] We use the term license-exempt managed access to refer to license-exempt access that is managed and enabled by a database or other dynamic sharing technique.
[10] See, for example,

According to Richard Thanki, unlicensed or licence-exempt regimes decrease the costs of delivering broadband and increase the quality of the product, but these benefits have, to date, been limited "by the lack of a harmonised globally available broadband-capable band of licence-exempt spectrum in sub-1GHz spectrum"[11]. He concludes that TVWS represents an opportunity to create such a band which will assist in meeting future demand, delivering universal and affordable connectivity to people, facilitating machine-to-machine connections and developing robust and adaptable networks[12].

Thanki quantifies the value of Wi-Fi to fixed broadband and mobile network operators by country[13]. The table below shows economic value generated by Wi-Fi through fixed broadband value enhancement for selected countries:

Country	Population	GNI per capita (USD)	Total fixed broadband connections	Total Wi-Fi connections	Evenly scaled annual economic value (USD million)	GNI scaled annual economic value (USD million)
Brazil	192.4	9 390	13 850 000	11 770 000	2 613.7	517.9
China	1 347.4	4 270	126 650 000	107 650 000	23 899	2 153.4
India	1 210.2	1 330	10 890 000	9 260 000	2 055.3	57.7
Russia	143	9 900	15 730 000	13 379 999	2 968.9	620.2
South Africa	50.6	6 090	760 000	640 000	143.2	18.4
United Kingdom	62.3	38 370	19 560 000	16 630 000	3 691.4	2 988.8
United States	313.2	47 390	82 280 000	70 020 000	15 545	15 545

Table: Economic value generated by Wi-Fi through fixed broadband value enhancement[14]

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(1) "The Economic Significance of Licence-Exempt Spectrum to the Future of the Internet" by Richard Thanki, http://www.wirelessinnovationalliance.org/index.cfm?objectid=DC8708C0-D1D2-11E1-96E9000C296BA163 (accessed August 2013);
(2) "Efficiency gains and consumer benefits of unlicensed access to the public airwaves: The dramatic success of combining market principles and shared access" by Mark Cooper, http://www.markcooperresearch.com/SharedSpectrumAnalysis.pdf (accessed August 2013);
(3) "The Case for Unlicensed Spectrum" by Paul Milgrom, Jonathan Levin and Assaf Eilat, http://www.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf (accessed August 2013) (and sources cited therein);
(4) "The economic value of licence exempt spectrum, A final report to Ofcom from Indepen. Aegis and Ovum", December 2006, http://www.aegis-systems.co.uk/download/1818/value.pdf (accessed September 2013);
(5) "Perspectives on the value of shared spectrum access", Final Report for the European Commission, February 2012, http://ec.europa.eu/digital-agenda/sites/digital-agenda/files/scf_study_shared_spectrum_access_20120210.pdf (accessed September 2013).

[11] See Thanki, *supra* note 10, at ¶ 6.1.

[12] Ibid.

[13] See Thanki, *supra* note 10, at ¶¶ 3.3.2.2, 3.3.2.3, Annex 2, Annex 3.

Thanki presents the value of Wi-Fi to mobile network operators in terms of additional base stations which would have to be built in the absence of the operator off-loading traffic through Wi-Fi. The figures for South Africa are set out below:

Country	**Urban Population (million)**	**Urban Area (1 000 km²)**	**Total mobile broadband connections**	**Urban cell sites needed per operator for data coverage using 900 MHz**			**Urban cell sites needed per operator for data coverage using 2100 MHz**		
				10 MB / user / day	40 MB / user / day	80 MB / user / day	10 MB / user / day	40 MB / user / day	80 MB / user / day
South Africa	31.2	53.53	8 397 000	3 643	3 836	4 351	11 387	11 635	11 838

Table: Value of Wi-Fi to mobile network operators in terms of additional base stations which would have to be built in South Africa in the absence of the operator off-loading traffic through Wi-Fi[15]

Mark Cooper sets out empirical evidence showing that spectrum allocated for unlicensed use has been more effective in encouraging the development of innovative uses. Supporting low-powered uses of unlicensed spectrum allows greater reuse and sharing of the spectrum and encourages third-party innovation while also promoting investment in complementary technologies[16].

Licence-exempt wireless technologies currently contribute significantly to the South African economy by expanding network reach and improving network management[17]. In the future, there will be even greater demand for sub-1-GHz licence-exempt spectrum to address the exponential increase in consumer demand for broadband access, support the expansion of cellular offload, and network the millions of devices that will compose the coming "Internet of Things"[18]. As noted above, the TV broadcast spectrum below 1 GHz has better propagation characteristics than spectrum above 1 GHz, enabling signals to travel further and penetrate walls and irregular terrain. As a result, it is uniquely well-suited for non-line-of-sight broadband communication.

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14 Thanki, *supra* note 10, at Annex 2.

15 Thanki, supra note 10, at Annex 3.

16 Milgrom et al., supra note 10, at ¶ 79.

17 Renaissance Capital quantified the size of the wireless Internet service provider and Wi-Fi hotspot market at revenues of ZAR 250m and ZAR 200m per annum respectively at the end of 2012. "SA telecoms: 2013 outlook. The changing landscape." Renaissance Capital, 25 March 2013.

18 "The Internet of Things" (IoT) is a scenario in which objects, animals or people are embedded with unique identifiers or sensors and the ability to automatically communicate or transfer data over a network without requiring human interaction. The concept was developed by Kevin Ashton in 2009, to describe a system where the Internet is connected to the physical world via ubiquitous sensors. See: "The Internet of Things", McKinsey Quarterly, March 2010 by Michael Chui, Markus Löffler, and Roger Roberts, http://www.mckinsey.com/insights/high_tech_telecoms_internet/the_internet_of_things (accessed October 2013).

3.3. Creating a Regulatory Framework for License-Exempt Managed Access Spectrum

In South Africa, regulators can enable the use of TVWS by designating the 470-694 MHz band as "interleaved" or shared spectrum. Prior to the completion of digital dividend efforts, vacant spectrum between 694-790 MHz should also be made available for shared use. This approach would allow devices to use available channels in this band when doing so will not cause harmful interference to licensed users.

In particular, ICASA should establish the technical parameters for TVWS operation and establish procedures for TVWS devices to access available spectrum.

Most TVWS devices today utilise a white space or geolocation database to determine which channels are available for use. In general terms, TVWS devices are required to register their location with the TVWS database. The database uses this location information and the time of the request to determine and communicate to the TVWS device what channels are available for use in that location at that time.

3.4. Technical Considerations

3.4.1. Coverage and Data Throughput Potential

The coverage/throughput combination for a TVWS device is determined by:

- The transmission power used by a device in a given location;
- The height and gain of the base station and client antennae;
- The specific channels of the UHF band used;
- Varying levels of absorption of the signals between base station and its client or clients, which may be impacted by the presence of foliage or varried terrain; and
- The level of interference and noise that is present in the adjacent protected terrestrial TV channel.

3.4.2. Databases

A white spaces or geolocation database provides TVWS devices with operating parameters for any given location. These include:

- Available white space channels;
- Transmission power limits applicable to the use of these channels, taking into account the location, height, and configuration of the device;
- Duration for which the white spaces channels will be available (if necessary); and
- Timeframe within which the device must re-register in order to receive updated information.

The methodology and algorithms employed by the TVWS database take into account the known transmission characteristics — power output, frequency, antenna height, type, location and orientation — of existing TV transmitters[19], as well as the topography of the area, in order to model the radio propagation of every channel transmitted in that area. The database is then able to determine which channels are available for use.

Overall, a TVWS database allows TVWS devices to be used on a licence-exempt managed access basis while mitigating the potential for harmful interference. Allowing licence-exempt managed access use of devices increases the utility of TVWS by effectively lowering the barrier to entry for competition and to the introduction of new technologies and applications.

3.4.3. White Space Radio Technologies

Use of TVWS is technology-neutral: Any applicable technology can be used to provide wireless broadband and other applications over TVWS spectrum so long as the end user device contains hardware that can operate in the relevant bands without causing interference.

Thus far, a variety of different technologies have been either discussed or implemented in TVWS spectrum:

- IEEE 802.11af is an emerging standard in the IEEE 802.11 family of standards, generally referred to as Wi-Fi, for wireless local area networks (WLAN) using TVWS. The task group for the 802.11af standard was formed in 2009 and finalisation will likely occur in November 2013 and no later than June 2014[20].
- IEEE 802.22 is a standard for wireless regional area network (WRAN) using TVWS[21]. It is focused on rural broadband connectivity[22].
- Adaptrum and Carlson Wireless have developed proprietary technologies for use in TVWS spectrum. Adaptrum's technology has been used in a trial in Kenya[23]. The Cape Town trial used Carlson's technology.
- Some trials have used the Time-Division Long-Term Evolution standard in deploying white space devices[24].

Most approaches have relied thus far on the use of a database to determine channel availability and protect incumbent licensees from interference. Spectrum sensing is another dynamic

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[19] Current practice is for the data on existing transmitters to be sourced from the communications regulator in each respective country. The integrity of the data and the range of parameters provided has an impact on the accuracy of the analytical results of the database.

[20] "Official IEEE 802.11 Working Group Project Timelines", http://www.ieee802.org/11/Reports/802.11_Timelines.htm (accessed August 2013).

[21] See "IEEE 802.22 Working Group on Wireless Regional Area Networks", http://www.ieee802.org/22/ (accessed July 2013).

[22] IEEE 802.22.2 — Completed for Installation and Deployment of Wireless Regional Area Networks in TV White Spaces, http://standards.ieee.org/news/2013/802.22.2.html (accessed July 2013).

[23] See "Adaptrum", www.adaptrum.com (accessed September 2013); "Bringing Wireless Broadband to Underserved Kenya", http://research.microsoft.com/en-us/projects/spectrum/wireless-broadband-underserved-kenya.pdf (accessed September 2013).

[24] See "Huawei to Launch TV White Space LTE TDD System Trial", http://www.ict-acropolis.eu/index.php?option=com_content&view=article&id=107:huawei-to-launch-tv-white-space-lte-tdd-system-trial&catid=29:newsflash&Itemid=10 (accessed September 2013).

spectrum management tool that can contribute to use of TVWS. Spectrum-sensing cognitive radios detect available channels and change their transmission or reception parameters to allow use of the channels by TVWS devices. Spectrum sensing cognitive radios, especially when used in conjunction with a database, show potential for improving quality of service on TVWS spectrum. Thus far, regulators have found that sensing-only devices – i.e., those without access to geolocation databases – do not reliably enough protect incumbent licensees from interference, and they are not ready for wide-scale commercial deployment at this time.

3.5. The Relationship between TVWS and the Digital Migration Process

In South Africa, a significant portion of television broadcast spectrum is unused at any one place because analogue TV transmitters require significant physical or spectral separation to avoid interfering with each other or because there simply are not that many broadcast licensees in most markets (i.e., there is more unassigned broadcast spectrum than is needed to prevent broadcasters from interfering with one another). South Africa currently plans to finalise its digital migration process in 2015.

While there will be a reduction in the available white space during and after the migration to Digital Terrestrial Television (DTT) and the subsequent digital-to-digital migration necessary to ensure optimal usage of the assigned Digital Dividends, there will still be a substantial amount of spectrum unused at any given location. Substantial spectrum will be available especially if a Single Frequency Network (SFN) is implemented.

Enabling use of TVWS does not need to be tied to the digital migration process and TVWS technology can be utilised before, during and after digital migration. Further, database technology can direct devices to use whatever TVWS channels are available at the time, even as television broadcast stations are being relocated.

4. Introduction to the Cape Town TVWS Trial

The Trial commenced providing broadband services to ten schools in Cape Town on 25 March 2013. The Trial partners will deliver a final report in the fourth quarter of 2013.

4.1. The Partners in the Trial

The Trial was conceived and run as a broad collaborative effort involving the following partners ("the Partners"):

- Carlson Wireless Technologies
- Comsol Wireless Solutions
- CSIR Meraka Institute
- e-Schools Network
- Google
- Neul

- Open Spectrum Alliance
- Tertiary Education and Research Network (TENET)
- Wireless Access Providers' Association (WAPA)

4.2. Objectives of the Trial

The Trial sought to:

- Demonstrate that TVWS technology can be used to deliver affordable broadband services without interfering with TV reception;
- Provide information to the Minister of Communications and Department of Communications regarding the use of TVWS to meet policy objectives relating to universal service and access and efficient spectrum management;
- Assist ICASA in developing a regulatory framework authorizing the use of TVWS in South Africa by:
  - Demonstrating that effective bidirectional communications can occur in TVWS;
  - Demonstrating that frequencies where there is a very low probability of causing interference to other licensed users of the spectrum can be selected and used;
  - Providing ICASA with an indication as to what interference was experienced by licensed users of the spectrum and unlicensed users (including studio to transmitter links, in premises modulation and audio microphones, etc.) of the spectrum;.
  - Providing information to ICASA about the technology involved, including the data, equipment, database, interference testing methodologies and the like;
  - Providing information to ICASA about the costs involved in the technology;
  - Providing ICASA with a proposal on running a database and an assessment whether this is a method ICASA should be using or whether it should be considering truly cognitive radio rather than the database system or alternatively a combination thereof; and
- Increase awareness of the potential for TVWS technology in South Africa and across the African continent.

4.3. The Trial Network

The Trial's TVWS network had multiple base stations located at Stellenbosch University's Faculty of Medicine and Health Sciences in Tygerberg, Cape Town, which delivered broadband Internet service to ten schools within a 10 kilometre radius using Carlson Wireless' RuralConnect TVWS radios. The ten schools were selected based on proximity to the base station, local IT and network support, and other connectivity requirements. Each school received a dedicated 2.5 Mbps service with back-up ADSL in order to avoid any downtime during school hours.

Photographs showing the Trial High Site, Base Station Location, Antenna Placement, Antenna Direction and Sectors are set out in Annexure B.

The following schools participated in the Trial:

- Bellville High School
- Cravenby Combined Schools
- DF Malan High School
- Elswood Secondary School
- Fairmont High School
- Norwood Primary School
- Parow High School
- President High School
- Range Secondary School and
- Settlers High School.

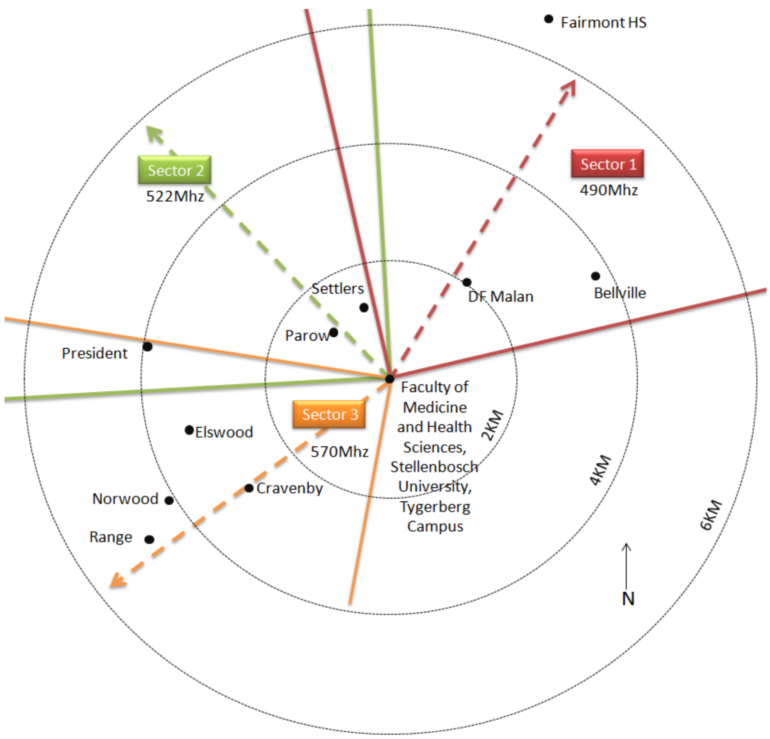

Diagram 1: Trial Network Diagram

Diagrams and photographs of the installation of Local Area Network (LAN) and Customer Premises Equipment (CPE) at the participating schools are set out in Annexure C.

4.4. TVWS Interference Management Protocol

The Trial required that all reported instances of interference be checked and accounted for based on the TVWS Interference Management Protocol. A copy of this Protocol forms Annexure D to these Recommendations.

4.5. Regulatory Basis for the Trial

A Memorandum of Understanding (MOU) between the Meraka Institute and ICASA governed the Trial. The Trial was implemented using the individual electronic communications network service (IECNS) and individual electronic communications service (IECS) licences issued to TENET by ICASA.

The table below traces the timeline of events leading up to the Trial:

Date	Event
October 2011	Government officials, regulators, and industry leaders gather at an event hosted by Association for Progressive Communications (APC), WAPA and Google to discuss the benefits of TVWS technology.
12 September 2012	ICASA issues permission to the CSIR Meraka Institute and its partners to set up a TVWS network in the Western Cape.
25 September 2012	Partners select WAPA member Comsol Wireless Solutions as the network systems integrator.
15 October 2012	After extensive IT audits, partners select ten schools for participation in the trial.
1-7 November 2012	Partners complete pre-installations of network equipment at schools.
25 March 2013	Network is launched with the Department of Communications and ICASA in attendance.
15 October 2013	Interim Report issued to ICASA.
Q4, 2013	Final Report issued to ICASA.

4.6. Purpose of These Recommendations

As a result of their experience with the Trial, the Partners have significant first-hand knowledge and experience regarding deployment of TVWS technology in South Africa. These recommendations and accompanying analysis are a critical outcome of the Trial. They seek to facilitate the drafting and finalisation of a policy and regulatory framework that enables and promotes the use of TVWS technology in the country.

4.7. Other TVWS Research in South Africa

In July 2013, The Department of Science and Technology (DST) announced a pilot project in rural Limpopo, working with partners, to deliver high-speed and affordable broadband to underserved communities using TVWS technology. The pilot aims to show that TVWS technology can be used to meet the South African government's goals of providing low-cost Internet access to a majority of South Africans by 2020.

The pilot is a joint effort between Microsoft, the Meraka Institute, the University of Limpopo and network builder Multisource. It will use TVWS technology to provide low-cost wireless broadband access to five secondary schools in underserved parts of the Limpopo province. The University of Limpopo will serve as a hub that provides nearby schools in local communities with wireless connectivity. The project will also provide each of the five schools with Windows tablets, projectors, teacher laptops and training, education-related content, solar panels for device charging where there is no access to electricity, and other support[25].

There is active communication and collaboration between the two trials, and both sets of trial partners recognize that a bigger and more diverse set of experiences will lead to better implementation and deployment of TVWS technology in South Africa and beyond. The Meraka Institute is a common partner to both trials, further ensuring effective integration of the trial outcomes.

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[25] "Pilots and Demonstrations," http://research.microsoft.com/en-us/projects/spectrum/pilots.aspx (accessed September 2013); "Microsoft Starts TV White Space Pilot in South Africa, http://www.rapidtvnews.com/index.php/2013073029034/microsoft-starts-tv-white-space-pilot-in-south-africa.html, 30 July 2013 (accessed July 2013); "Uncapped broadband for R20/month: Microsoft", http://www.techcentral.co.za/uncapped-broadband-for-r20month-microsoft/42252/, 26 July 2013 (accessed July 2013).

5. Policy and Legislative Context for the Introduction of TVWS Use in South Africa

5.1. Broadband in South Africa

The South African Government has made increasing broadband penetration a central policy objective, recognising that investing in broadband infrastructure is a key driver of job growth. In particular, investments in modern infrastructure will improve South Africa's competitiveness and increase its productivity.

- The National Development Plan (NDP)[26] calls for measures to be taken to ensure that South Africa has an e-literate society by 2030. Extending broadband penetration is key to reaching this goal.
- In setting a target of creating five million jobs by 2020, the Government has adopted the New Growth Path (NGP), which identifies areas where employment creation is possible both within the economic sectors and cross-cutting activities. Investments in broadband are key to job growth both within and outside the communications sector.
- The Presidential Infrastructure Coordinating Commission (PICC) — through its Strategic Infrastructure Project (SIP) 15 — has prioritised broadband and connectivity as part of the national infrastructure programme.
- The latest Consultation on a National Broadband Plan for South Africa[27] ("Draft NBP-13") notes that broadband "is an enabling infrastructure for the building of a knowledge economy and information society and for accelerating growth and development of the South African economy"[28]. The Draft NBP-13 is informed by the need to fast track the deployment of high-speed broadband infrastructure such as fibre-optic backbones, wireless and international connectivity, achieving a holistic and coordinated national approach in the provision of broadband infrastructure and services; and the development of targeted policy interventions to encourage the uptake and usage of broadband services across the country, particularly in rural areas.
- The Draft NBP-13 highlights the role of broadband in improving the competitiveness of the economy and increasing productivity levels through initiatives that support the achievement of the objectives of the National Industrial Policy Framework (NIPF) and ultimately the Industrial Policy Action Plan (IPAP).
- The 2011 Census results indicated that 64.8% of households in the country had no access to the Internet. Of those households that had access to the Internet, 16.3% accessed it via cell phones, 8.6% from home, 4.7% from work, and 5.6% from elsewhere. Adoption of broadband lags for two reasons: (1) in many places, especially in rural

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[26] See National Development Plan 2020, http://www.info.gov.za/issues/national-development-plan/ (accessed July 2013).
[27] "National Broadband Plan for South Africa" (Draft NBP-13), General Notice 350 GG 36332, 3 April 2013.
[28] Id. at ¶1.1.2.

areas, the broadband infrastructure is inadequate, and (2) even where broadband is available, it is often expensive[29].

5.2. International Spectrum Context

South Africa is a signatory to the Constitution and Convention of the ITU. The provisions of the ITU Constitution and the Convention are further complemented by the ITU Radio Regulations, which also have international treaty status[30].

In accordance with the ITU Constitution, South Africa must endeavour to limit the number of frequencies and the spectrum used to the minimum essential to provide the necessary services in a satisfactory manner. To that end, South Africa shall endeavour to apply the latest technical advances as soon as possible[31].

In South Africa, all stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other Member States[32].

5.3. National Radio Frequency Spectrum Policy[33]

The National Radio Frequency Spectrum Policy 2010 (NRFSP-10) holds that:

- Radio frequency spectrum is a resource limited by technology and management capability[34].
- The Minister of Communications acts as the custodian of the spectrum on behalf of the people of South Africa[35].
- Management of the radio-frequency spectrum is subject to government authority and spectrum must be managed efficiently so as to be of greatest benefit to the entire population[36].
- To ensure efficient use of the radio frequency spectrum in South Africa, the government will issue policies and policy directions to ICASA in order to ensure that this resource is used "to promote the rational, economical, efficient and effective usage of the radio frequency spectrum in a manner which keeps pace with the rapid evolution of wireless technologies and services within the framework of the Government strategic objectives"[37].

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[29] Id. at ¶1.2.6.
[30] South Africa also participates in the African Telecommunications Union (ATU) and the Communications Regulators' Associations of Southern Africa (CRASA), both of which have a role in developing recommended spectrum policies for the region.
[31] National Radio Frequency Policy for South Africa (NRFSP-10), General Notice 306 GG 33119, 16 April 2010, ¶ 2.3.
[32] Id. ¶ 2.3.4.
[33] Id.
[34] Id. ¶ 2.1.1.
[35] Id. ¶ 2.1.3.
[36] Id. ¶ 2.1.2.
[37] Id. ¶ 2.1.10.

- In allocating the Radio Frequency Spectrum, the South Africa must take into account the outcomes of the International Telecommunication Union ("ITU") World Radiocommunication Conferences ("WRC")[38].

In addition, the NRFSP-10 aims to "contribute to the promotion of national interests, development and diversity, including increasing the amount of spectrum available for assignment, improving sharing conditions among different radio communication services and increasing the number of licences dedicated to community radio and television broadcasting services"[39].

5.4. Draft Policy Direction on Exploitation of the Digital Dividend[40]

On 14 December 2011, the Minister of Communications issued a draft policy direction on Exploitation of the Digital Dividend and requested public comment on the draft document. The draft direction considers the scope of the action to be taken at the national level to promote the efficient use of the Digital Dividend spectrum in the frequency bands 174 - 230 MHz and 470 - 790 MHz.

The draft policy direction required ICASA to undertake an inquiry into the rational and efficient exploitation of the remaining Very-High Frequency (VHF) and Ultra-High Frequency (UHF) spectrum for future Digital Dividends, and report to the Minister on, *inter alia*, the possible use of "white space" technologies[41].

5.5. Electronic Communications Act 36 of 2005

In South Africa, Chapter 5 of the Electronic Communications Act 36 of 2005 as amended ("the ECA") governs radio frequency spectrum usage. The objects of the ECA include:

- Encouraging investment and innovation in the communications sector; and
- Ensuring efficient use of the radio frequency spectrum[42].

Section 30 of the ECA states that ICASA controls, plans, administers and manages the use and licensing of the radio frequency spectrum, except with respect to international matters and the finalisation of the National Radio Frequency Plan. In performing these functions, ICASA must, *inter alia*:

- Take into account modes of transmission and efficient utilisation of the radio frequency spectrum, including allowing shared use of radio frequency spectrum when interference can be eliminated or reduced to acceptable levels as determined by ICASA[43].

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[38] Id. ¶ 2.1.5.
[39] Id. ¶ 2.1.12.
[40] Draft Policy Directions on Exploiting the Digital Dividend, General Notice 898 GG 34848, 14 December 2011.
[41] Id. ¶ 2.2.3.
[42] ECA s2(e).
[43] ECA s30(2)(b).

- Give high priority to applications for radio frequency spectrum where the applicant proposes to utilise digital electronic communications facilities for the provision of broadcasting services, electronic communications services, electronic communications network services, and other services licensed in terms of this Act or provided in terms of a licence exemption[44].
- Plan for the conversion of analogue uses of the radio frequency spectrum to digital, including the migration to digital broadcasting in the Authority's preparation and modification of the radio frequency spectrum plan[45].
- Ensure that in the use of the radio frequency spectrum, harmful interference to authorised or licensed users of the radio frequency spectrum is eliminated or reduced to the extent reasonably possible[46].
- Investigate and resolve all instances of harmful interference to licensed services that are reported to it[47].

In general, the ECA prohibits the transmission of any radio signal or use of radio apparatus to receive any radio signal except under and in accordance with a radio frequency spectrum licence issued by ICASA[48].

Under section 31(6) of the ECA, however, ICASA may allow the use of certain types of radio apparatus that do not require a radio frequency spectrum licence to use or possess[49].

5.6. National Radio Frequency Plan 2013[50]

Recent revisions to the table of frequency applications in South Africa are incorporated in the National Radio Frequency Plan 2013 (NRFP-13), published on 28 June 2013. All frequency assignments made by ICASA must be in accordance with the NRFP-13.

The NRFP-13 has been revised to incorporate the decisions taken by World Radiocommunications Conferences (WRC) up to WRC 2012. The revision reflects the subsequent 2012 version of the ITU Radio Regulations, including the frequency allocations relevant to Region 1 and associated footnotes. It also includes updates on the Table of Frequency Allocations extending up to 3000 GHz and reflects agreements taken at regional level including that of the African Telecommunication Union (ATU) and the Southern African Development Community (SADC).

The NRFP-13 makes provision for the possible use of TVWS as set out in the excerpt below:

[44] ECA s30(2)(c).
[45] ECA s30(2)(d).
[46] ECA s30(3).
[47] ECA s30(4).
[48] ECA s31(1).
[49] Exemptions under section 31(6) are generally set out in Annexure B to the Radio Regulations 2010.
[50] National Radio Frequency Plan ("NRFP-13"), General Notice 354 GG 36336, 28 June 2013.

ITU Region 1 allocations and footnotes	South African allocations and footnotes	Typical Applications	Comments
470-790 MHz (694-790 MHz) BROADCASTING	470-790 MHz BROADCASTING	Television Broadcasting (470 - 854 MHz)	Broadcasting Allotments in accordance with GE89 plan in the process of conversion to GE06. Broadcast assignments in accordance with the latest version of the Terrestrial Broadcasting Frequency Plan. The use of 'White Spaces' in this band is under consideration (subject to NINP[51] basis to users under a primary allocation).

5.7. Radio Regulations 2010[52]

The purpose of the Radio Regulations 2010 is to, *inter alia*:

- Establish the general framework through which ICASA may allocate and assign radio frequency spectrum under the South African Table of Frequency Allocations.
- Allow for greater flexibility such that special conditions and procedures for specific frequency bands can be applied.
- Provide for circumstances in which the use or possession of radio apparatus does not require a radio frequency spectrum licence.
- Set out the principles and procedures for frequency coordination where spectrum is assigned on a shared basis.

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[51] NINP means "no interference, no protection".

[52] Radio Frequency Spectrum Regulations ("Radio Regulations 2010"), General Notice 184 GG 34172, 31 March 2011.

Part II of the Radio Regulations 2010 sets out the procedure to be followed by ICASA in planning for radio frequency spectrum assignments. A Radio Frequency Spectrum Assignment Plan may specify:

- the types of services to be provided;
- specific terms and conditions for the use of the frequency bands;
- specific qualification criteria to be met by applicants;
- the procedures and timetable to be followed for assignment and licensing, if applicable;
- the apportionment of the relevant frequency bands in the Radio Frequency Plan for exclusive or shared assignments;
- detailed frequency channelling arrangements; and
- any other matter as ICASA may deem necessary.

A Radio Frequency Spectrum Assignment Plan must indicate whether it is intended that licences for the assignments will be issued on a first-come-first-served basis or on a competitive basis where there is deemed to be insufficient spectrum to accommodate demand[53].

Part III of the Radio Regulations 2010 notes that the radio apparatus and related radio frequency spectrum for which a radio frequency spectrum licence is not required under the ECA are set out in Annexure B to the Regulations and that users of licence-exempt radio apparatus and related radio frequency spectrum must comply with the applicable operational rules.

5.8. Radio Frequency Migration Regulations & Migration Plan 2013[54]

The Radio Frequency Migration Regulations make it clear that a "change in the use of a radio frequency band(s) must be initiated through a Radio Frequency Spectrum Assignment Plan for the radio frequency spectrum bands in the manner specified in the latest Radio Frequency Spectrum Regulations"[55].

5.9. Type Approval

Use of TVWS devices in South Africa would be subject to existing requirements relating to the type approval and labelling of electronic communications equipment and facilities. However, in order to take advantage of economies of scale and bring devices to market quickly, ICASA should consider a harmonized and streamlined approach for type approval.

[53] Id. at Part II.
[54] Frequency Migration Regulation and Frequency Migration Plan, General Notice 352 GG 36334, 3 April 2013.
[55] Id. Regulation 5(1).

6. Comparative Analysis

6.1. Introduction

It is likely that establishing a regulatory framework for the use of TVWS in South Africa will require, at a minimum, the following steps:

- Drafting and publication of a Discussion Document addressing the possible introduction of TVWS in South Africa. This Discussion Document would request information and encourage debate regarding the following questions:
  - Does the use of TVWS further ICASA's objectives of encouraging investment and innovation in the communications sector and ensuring efficient use of radio frequency spectrum?
  - If so, should devices be subject to a licence-exempt managed access spectrum regime or should they be licensed?
  - What technical standards and rules should be adopted?
  - If a licence-exempt managed access spectrum approach is adopted, how should TVWS databases and TVWS database service providers be managed?
- Public hearings pursuant to written submissions received in response to the Discussion Document.
- Publication of a Position Paper setting out ICASA's decisions regarding the possible introduction of TVWS in South Africa, including draft regulations incorporating technical rules and provisions relating to the accreditation or authorisation of TVWS databases.

6.2. United States Federal Communications Commission (FCC)

The FCC issued its final rules for the use of TVWS in September 2010[56].

The rules were modified in April 2012. A copy of the rules as modified is included in these Recommendations as Annexure E.

The final rules provide for the following:

- Both fixed and personal/portable devices may operate in the white spaces in the TV bands on an unlicensed basis.
- The primary method of avoiding harmful interference is reliance on the geo-location capability of TVWS devices combined with database access to identify vacant TV channels at specific locations. Databases must be certified by the Commission, but they can be managed by private entities.

On 26 January 2011, the FCC designated nine companies to provide the database services required for use by TVWS devices[57] and further designations have followed. Three databases

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[56] Unlicensed Operation in the TV Broadcast Bands: Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, Second Memorandum Opinion and Order, http://fjallfoss.fcc.gov/edocs_public/attachmatch/FCC-10-174A1.pdf (accessed July 2013).

have been certified for use by the Commission[58]. The detailed rules for use of TVWS devices in the United States are contained in Part 15 of Title 47 of the U.S. Code of Federal Regulations.

Useful links:

- FCC TV Band Device Rules: Title 47 C.F.R. Subpart H
  http://www.ecfr.gov/
- White Space Database Administration:
  http://www.fcc.gov/encyclopedia/white-space-database-administration
- White Space Database Administrators Guide:
  http://www.fcc.gov/encyclopedia/white-space-database-administrators-guide
- White Space Database Administration Q & A Page:
  http://www.fcc.gov/encyclopedia/white-space-database-administration-q-page

6.3. Ofcom in the United Kingdom

Ofcom initiated a consultation titled "Implementing Geolocation: Ofcom proposals on how to successfully launch White Space Technology and how new devices will be made available to consumers without the need for a licence" on 9 November 2010[59]. Ofcom initiated a further consultation – "TV white spaces - A consultation on white space device requirements" on 22 November 2012[60]. The November 2012 consultation includes proposed rules for the use of TVWS.

Ofcom's proposed rules for TVWS devices allow devices to operate on a licence-exempt managed access basis, using databases to protect other spectrum users from harmful interference. The proposed rules differ from the FCC's final rules in that Ofcom has provided for flexibility in the manner in which devices meet the technical standards for the protection of television broadcast receivers from interference. Ofcom has proposed that devices must dynamically adjust their transmitter power levels based on information received from the database to ensure that television broadcasting interference protection requirements are met.

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[57] Unlicensed Operation in the TV Broadcast Bands: Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, Order, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-131A1.pdf (accessed July 2013).
[58] Letter from Julius Knapp, Chief, Office of Engineering and Technology, FCC, to Rodney Dir, CEO, Spectrum Bridge, December 20, 2011, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-11-2044A1.pdf;
Office of Engineering and Technology Announces the Approval of Telcordia Technologies, Inc.'s TV Bands Database System for Operation, March 26, 2012, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-12-466A1.pdf; Office of Engineering and Technology Announces the Approval of Google Inc.'s TV Bands Database System for Operation, June 28, 2013, http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0628/DA-13-1472A1.pdf (all accessed July 2013).
[59] Implementing Geolocation: Ofcom proposals on how to successfully launch White Space Technology and how new devices will be made available to consumers without the need for a licence, November 11, 2010, http://stakeholders.ofcom.org.uk/consultations/geolocation/?a=0 (accessed July 2013).
[60] TV white spaces - A consultation on white space device requirements, November 22, 2012, http://stakeholders.ofcom.org.uk/consultations/whitespaces/, (accessed July 2013).

This approach could increase the amount of spectrum available to TVWS devices without increasing the risk of harmful interference.

Ofcom has indicated that it will conduct a pilot of TVWS technology in the UK to be launched in Quarter 4 2013. This pilot will provide an opportunity for database, service, and equipment providers to conduct further trials using the proposed framework, and aims to demonstrate a proof of concept of Ofcom's proposed framework while gathering further evidence prior to publishing final rules[61].

Companies wishing to participate in the Ofcom pilot must comply with the ETSI Harmonised European Standard for White Spaces devices published in July 2013[62].

If the pilot is successful, Ofcom intends to move to implement final rules in the third quarter of 2014[63].

A further consultation – "TV white spaces: approach to coexistence" – was published by Ofcom on 4 September 2013[64]. This document proposes a set of parameters and algorithms designed to ensure a low probability of harmful interference from TVWS devices.

6.4. Industry Canada

In August 2011, Industry Canada[65] launched a "Consultation on a Policy and Technical Framework for the Use of Non-Broadcasting Applications in the Television Broadcasting Bands Below 698 MHz"[66].

The consultation considered:

> whether to introduce a new wireless telecommunications application into the television (TV) broadcasting bands using TV white spaces. TV white space refers to portions of the TV broadcast spectrum that are unassigned so as to prevent interference between broadcast stations or remain unassigned due to limited demand (usually for TV stations in smaller markets).

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[61] For further detail on the proposed pilot, see "Ofcom TV White Spaces Pilot", 25 July 2013, http://stakeholders.ofcom.org.uk/binaries/spectrum/whitespaces/1124340/25july2013.pdf (accessed August 2013).

[62] "White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive", Draft ETSI EN 301 598 V1.0.0 (2013-07), http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.00.00_20/en_301598v010000a.pdf, (accessed September 2013).

[63] See Presentation at the Dynamic Spectrum Forum Africa "White spaces: TV band and beyond" delivered by Professor H. Sama Nwana, Group Director, Spectrum Policy Group, Ofcom, 30 May 2013, https://sites.google.com/site/tvwsafrica2013/presentations (accessed July 2013).

[64] http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/summary/white-spaces.pdf (accessed July 2013).

[65] Industry Canada is the Canadian equivalent of the South African Department of Trade and Industry.

[66] Consultation on a Policy and Technical Framework for the Use of Non-Broadcasting Applications in the Television Broadcasting Bands Below 698 MHz, August 2011, http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10058.html (accessed July 2013).

This portion of the spectrum is also used by other devices and, as such, creates a complex sharing situation where new approaches are required, including the use of databases that ensure that TV white space devices use frequencies in a manner that does not cause interference to nearby broadcast stations.

Comments [were] sought on all aspects of the policy and technical framework, including the:

1. possible introduction of licence-exempt TV band white space devices;
2. possible changes to the policy and regulatory framework for licensed remote rural broadband systems (RRBS); and
3. possible changes to the policy and regulatory framework for licensed low-power apparatus (LPA), such as wireless microphones.

A Framework for the Use of Certain Non-broadcasting Applications in the Television Broadcasting Bands below 698 MHz[67] was published on 30 October 2012, setting out responses received to the Consultation and the decisions taken, including the decision to allow TVWS devices to operate in Canada. No detailed technical rules have yet been developed, but it appears from the Framework that the Canadian approach will largely mirror that adopted in the United States in order to promote regional harmonisation and capture device economies of scale.

[67] Framework for the Use of Certain Non-broadcasting Applications in the Television Broadcasting Bands Below 698 MHz, http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10494.html, (accessed July 2013).

7. Overview of Trials in Africa and elsewhere

This section provides an overview of TVWS trials elsewhere in Africa and across the globe.

7.1. Kenya

Trial Overview: A trial network in Kenya uses TVWS technology and solar-powered base stations to deliver broadband access and create new opportunities for commerce, education, healthcare and delivery of government services. This trial focuses particularly on the commercial feasibility of TVWS technology in delivering low-cost broadband in communities currently lacking access to both broadband and reliable electricity[68].

Partners: Partners include Microsoft, Indigo Telecom (dba Mawingu Networks) and Kenya's Ministry of Information and Communications. Radio partners include Adaptrum and 6Harmonics.

Geography/Scope: The trial serves Kenya's rural Laikipia County, with Nanyuki as its seat[69]. The network currently covers approximately 108 km2 and has a population of about 20,000 under coverage. The network currently provides broadband access and ICT labs to three schools (Gakawa Secondary School, Male Primary School, and Male Secondary School), as well as broadband access to two healthcare clinics (the Burguret Health Dispensary and the Red Cross Office in Nanyuki), the Laikipia County Government Headquarters in Nanyuki, two local businesses, and the first Mawingu bandwidth and charging test agent. In the next four months, project partners intend to significantly expand coverage and quadruple the number of end user locations.

7.2. Tanzania

Trial Overview: A pilot in Tanzania focuses on deploying broadband in an urban setting and delivering an integrated device, service and connectivity solution to university students[70]. It was announced at the World Economic Forum on Africa in May 2013[71].

Partners: Partners include Microsoft, local ISP UhuruOne, and the Tanzania Commission for Science and Technology (COSTECH).

Geography/Scope: The pilot's initial deployment will target four universities in Dar es Salaam with a combined student population of about 74,000.

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68 "Pilots and Demonstrations", http://research.microsoft.com/en-us/projects/spectrum/pilots.aspx, (accessed September 2013).

69 These parties have entered into a memorandum of understanding that presents a framework of cooperation between them.

70 "Pilots and Demonstrations", *supra* note 68.

71 See "Microsoft Partners with COSTECH", May 8, 2013, http://www.costech.or.tz/?s=white+space (accessed July 2013).

7.3. Malawi

Trial Overview: A TVWS trial connecting hospitals and schools in the south of the country is currently active. The trial is testing the use of white space devices in ISM bands[72].

Partners: University of Malawi in conjunction with the Malawi Communications Regulatory Authority (MACRA) and the Marconi Wireless Lab (T/ICT4D) at the International Center for Theoretical Physics (ICTP) [73]. The trial uses Carlson Wireless' RuralConnect TVWS radios.

Geography/Scope: The trial targets hospitals and schools in rural areas.

7.4. Finland

Trial Overview: The Finnish Communications Regulatory Authority (Ficora) issued a test radio license for cognitive radio devices on the TV White Space frequencies for Turku University of Applied Sciences on 27 August 2012. The licence covers the 470-790 MHz frequency.

Partners: Partners are members of the WISE consortium and include Nokia, Digita, Fairspectrum, Ficora, Turku University of Applied Sciences, University of Turku and Aalto University.

Geography/Scope: The test licence is valid for one year and covers a 40km^2 area around Turku.

7.5. The Philippines

Trial Overview: This trial targets fishing communities and other remote areas in the Philippines. If successful, the trial may be expanded in 2014.

Partners: Partners include the Philippines Department of Science and Technology's Information and Communication Technology Office (DOST-ICT Office), its Department of Agriculture's Bureau of Fisheries and Aquatic Resources (DA-BFAR), Microsoft, and the United States Agency for International Development (USAID) [74].

Geography/Scope: The trial targets five municipal areas: Talibon, Trinidad, Bien Unido, Ubay and Carlos P Garcia).

7.6. Singapore

Trial Overview: In Singapore, there are eight projects demonstrating a variety of commercial services that could be deployed using TVWS technology.

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72 "eCRG Research Report on the Preliminary Findings on White Spaces in Malawi", 28 May 2013, https://docs.google.com/a/google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0dndzYWZyaWNhMjAxM3xneDoxODBhOTY5N2ZlZTFlMGM5 (accessed September 2013).
73 "The Role of White Spaces in Universal Access"
, https://sites.google.com/site/tvwsafrica2013/presentations (accessed September 2013).
74 "Pilots and Demonstrations", *supra* note 68.

Partners: The Singapore White Spaces Pilot Group (SWSPG)[75] was established in April 2012 with 18 participating members and has supported a number of diverse trials[76].

Geography/Scope: Applications being tested include machine-to-machine communications, security networks and WLANs.

7.7. United States

There have been a number of successful trials of TVWS in the United States[77]. The FCC conducted extensive laboratory and field tests of prototype devices in 2007 and 2008. These trials were used to inform the FCC's final rules as amended. A number of commercial deployments are in the works including a city wide network in Willmington, NC [78].

7.8. United Kingdom

A consortium of partners launched a TWVS trial in Cambridge, England, in June 2011[79]. The trial was designed to evaluate both the technical capabilities of the technology as well as potential end user applications and scenarios.

The trial tested several different applications of TVWS:

- City centre coverage: Base stations were established in four pubs and a theatre, providing widespread coverage including "pop-up" Wi-Fi hotspots. The tests showed that TVWS can extend broadband access and offload mobile broadband data traffic. These hotspots enabled users to enjoy data-intensive services such as online video during peak usage times. The tests also demonstrated that TVWS technology delivered improved range and experienced less interference than conventional 2.4 GHz Wi-Fi.

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[75] The pilot group members are: Adaptrum, Eurokars, Grid Communications, HDB, iconectiv, Institute for Infocomm Research, Neul, NexWave, National Institute of Information and Communications Technology (NICT), Power Automation, the Singapore Island Country Club, Sentosa Development Corporation, Spectrum Bridge, StarHub, ST Electronics, Terrabit Networks, ZDW Systems, and Microsoft.

[76] "Pilots and Demonstrations", *supra* note 68.

[77] See, for example, "Nation's First Campus 'Super Wi-Fi' Network Launches at West Virginia University", 10 July 2013, http://www.fiercebroadbandwireless.com/press-releases/nations-first-campus-super-wi-fi-network-launches-west-virginia-university (education); "Google and Spectrum Bridge Deliver Enhanced Broadband Access and Telemedicine Applications to Healthcare Providers", http://spectrumbridge.com/Libraries/White_Spaces_Case_Studies/Logan_Telemedicine_-_Success_Story.sflb.ashx (health); "The Future Is Now – Nation's First "Smart Grid" TV White Space Network Trial", http://spectrumbridge.com/Libraries/White_Spaces_Case_Studies/Plumas-Sierra_County_Success_Story.sflb.ashx (Machine-to-machine) (all accessed September 2013).

[78] http://www.engadget.com/2012/01/30/north-carolina-launches-fcc-approved-tv-white-space-network-in-w/

[79] See "Cambridge White Spaces Consortium: Recommendations for Implementing the Use of White Spaces: Conclusions from the Cambridge TV White Spaces Trial", http://research.microsoft.com/en-us/projects/spectrum/cambridge-tv-white-spaces-trial-recomms.pdf; "Cambridge White Spaces Consortium:
Cambridge TV White Spaces Trial: A Summary of the Technical Findings", http://www.cambridgewireless.co.uk/docs/Cambridge%20White%20Spaces%20Trial%20-%20technical%20findings-with%20higher%20res%20pics.pdf (both accessed August 2013).

- Rural connectivity: Residents experienced radical improvements in their broadband service. Broadband speeds reached 8Mbps over 5.5km links using a modified, prototype version of the Neul Weightless technology. Results suggest that further optimization could result in speeds greater than 20Mbps.
- Machine-to-machine communications: A waste management application sent automated messages when city waste bins required emptying.

The trial partners were:

- Adaptrum
- Alcatel-Lucent
- Arqiva
- BBC
- BskyB
- BT
- Cambridge Consultants
- CSR
- Digital TV Group
- Microsoft
- Neul
- Nokia
- Samsung
- Spectrum Bridge
- TTP
- Virgin Media

The trial ended in April 2012 and verified that Cambridge has significant TVWS capacity — upwards of 20 white spaces channels corresponding to 160 MHz in total. Based on the results, the consortium recommended that Ofcom adopt a regulatory framework to enable the commercial operation of TVWS technology.

8. Discussion Points

This section highlights key issues and questions for resolution as South Africa considers opening up vacant spectrum in the broadcast bands for license-exempt managed access use.

8.1. The Benefits of TVWS

The potential benefits of introducing TVWS technology and spectrum sharing in South Africa are well-documented. If successfully deployed, these technologies will foster broadband adoption and economic growth. They will also assist the regulator in meeting its mandate to ensure efficient use of radio frequency spectrum.

In addition, allowing TVWS devices to operate on a licence-exempt managed access spectrum basis will — based on experiences in the ISM bands and in other jurisdictions — spur innovation and new applications flowing from the development of associated technologies[80]. Jurisdictions at the forefront of enabling TVWS use will also become competitive contributors to the global TVWS industry and participate in a global market for these services.

TVWS is close to spectrum used by commercial wireless services, creating potential synergies. The use of white space devices, moreover, need not be restricted to the television broadcasting bands.

The potential benefits to consumers include:

- availability of consumer devices with significantly improved range;
- availability of lower cost wireless broadband equipment; and
- potential future availability of innovative new products and services.

Potential consumer applications include:

- last-mile Internet service to individual homes by a wireless Internet service provider; and
- local area networking within a home or office using consumer-owned equipment.

Key Questions

What are the benefits that could be expected from making TVWS available in South Africa? Are there any potential negative consequences?

Does allowing the use of TVWS further ICASA's *mandate to ensure that spectrum is efficiently used?*

Does it support ICASA's overall goals regarding the deployment and adoption of broadband?

Is there a role for licence-exempt managed access spectrum in meeting future demand for spectrum in South Africa?

[80] See ¶ 2.2, *supra*, and sources cited there.

Could TVWS provide increased consumer value and/or improved social and economic inclusion?

8.2. On What basis Should TVWS Usage Be Allowed?

A regulatory framework must address whether to allow devices to operate in TV broadcast spectrum at locations and times when spectrum is not being used, and what technical requirements are sufficient to protect licensed services in the television broadcast bands from harmful interference.

The Trial Partners believe that adopting a licence-exempt managed access approach (i.e., license-exempt access managed by a database that provides information on which channels are a available in a given location) could have significant benefits to the economy, businesses and consumers by allowing the development of new and innovative types of unlicensed devices in much the same way as Wi-Fi has done. WAPA has also expressed interest in exploring a light-licensing approach in addition to pursuing a license-exempt managed access approach.

Key Questions

On what basis should white space use in the 470 – 790 MHz band be authorised?

Do the benefits of adopting a licence-exempt managed access approach apply in South Africa?

If a license-exempt managed access approach is adopted, what -- if any -- registration requirements might apply?

Could a licensed approach, a light-licensing/coordination approach, or a combination of approaches to TVWS bring similar or other benefits?

Could these approaches to dynamic sharing be used in other bands?

8.3. White Space Databases and Spectrum Sensing

Introducing TVWS in South Africa requires that ICASA develop appropriate technical standards and specify appropriate operating parameters to mitigate the potential for harmful interference.

The licence-exempt model currently used in South Africa[81] relies primarily on type approval certification when equipment is registered with ICASA. But ICASA's experience indicates that this is not always an adequate means of preventing harmful interference being caused by such equipment. As a result, ICASA has tended to impose conservative transmission power restrictions on licence-exempt devices, recognising the difficulties of correcting technical standards that are too permissive.

White space databases require registration of TVWS devices before such devices will be able to access available channels. The database provides real-time interference management and the ability to impose centrally varying parameters across the devices in their area of operation.

[81] See ECA section 31(6), Annexure B to the Radio Regulations 2010, and NFRP-13.

Non-functioning or interference-causing devices can quickly be located and isolated, allowing speedy resolution of interference complaints.

This implies that – under a licence-exempt managed access spectrum approach - regulators need not be as conservative when establishing power restrictions, and can allow considerably more flexibility when developing technical rules applicable to TVWS devices.

As noted above[82], dynamic spectrum sensing is another dynamic spectrum management tool that may enable more efficient use of TVWS – these techniques use sensing to determine whether or not a channel is vacant and available for use. These tools are in development stages for the television bands and have not yet been commercially deployed.

Key Questions

Should the white spaces database approach be adopted?

Is "license-exempt managed access spectrum" an appropriate term to describe this form of spectrum management in South Africa?

Should ICASA allow sensing as an option at this time?

8.4. Provision of Information Regarding Incumbent Operations

In other jurisdictions, in order to protect incumbent operations, database providers have relied, in part or in whole, on a repository of information collected by the regulator regarding those operations' locations and characteristics. The success of databases will necessarily depend on receiving sufficient and accurate information regarding the entities to be protected.

How will database providers obtain information required to protect incumbent operations (e.g., location of TV transmitters)?

How should ICASA ensure that this information remains current? How should ICASA work with broadcasters to ensure that databases obtain updated information?

8.5. Management of White Spaces Databases

The Trial Partners support the development of multiple TVWS databases with open standards in South Africa in order to facilitate competition and innovation. Competition among databases will encourage innovation and improvement in this sector, helping to develop the expertise and the infrastructure necessary to offer a managed access service. In particular, allowing multiple databases will allow South Africans to take advantage of expertise in developing and maintaining resilient infrastructure, managing device queries, providing customer service, and developing value-added services.

[82] See ¶ 2.4.3, *supra*.

ICASA must, however, retain ultimate regulatory responsibility for the operation of TVWS databases in order to discharge its mandate under the ECA of protecting licensed users against harmful interference. ICASA should develop and implement a set of criteria for officially recognising a white spaces database, including the circumstances under which such recognition may be suspended or withdrawn.

The regulatory framework should permit (and perhaps even encourage) multiple databases to operate simultaneously, and ICASA should consider imposing a regulatory obligation for white space databases to share information or otherwise co-operate with each other.

Management options for white space databases include:

- Certifying a TVWS device in conjunction the database or databases it will operate in rather than certifying the device in isolation.
- Requiring that the database restrict the operation of a device causing harmful interference.
- Requiring data retention to allow auditing of interference complaints.

The FCC originally conditionally designated 10 entities to serve as TVWS database administrators. The Commission held workshops with the designated database administrators to discuss implementation issues, and most of the database administrators then met separately to agree on algorithms for calculating TV contours and develop a standard for information sharing. Databases are evaluated by the FCC and then put out for a 45 day public trial. If a trial is successful, the FCC issues a Public Notice approving the database administrator to provide services.

Industry Canada has proposed the following process for the recognition of third party white space database administrators (WSDBAs):

- Call for Applications
- Review of Applications
- Sign WSDBA Agreement
- Evaluation and Testing of WSDB
- Publish List of Designated WSDBA
- First-come, First Served (Future) WSDBA Approvals.

Key Questions

What parameters should ICASA set forth for TVWS databases?

What criteria should be used to certify, recognize, or authorize TVWS databases?

How should interference management be tested?

How should ICASA approach issues such as non-discrimination, security, and quality of service?

Would TVWS databases qualify as "critical databases" as that term is defined in the Electronic Communications and Transactions Act 25 of 2002?

8.6. Technical Issues

8.6.1. Types of White Space Devices

Under the FCC and Industry Canada approach, white space devices (WSDs) may be classified as fixed or mobile:

- Fixed: the WSD transmits and receives communications at a specified fixed location and obtains information on available white space channels from a white space database.
- Mobile[83]: the WSD transmits and receives communications while moving or from different unspecified fixed points. Mobile WSDs in turn can be categorised as:
    - Mode I mobile WSDs ("slave WSDs") which do not use an internal geo-location capability and do not directly access a white space database to obtain a list of available white space channels. Rather they obtain this information from a Mode II device. A Mode I WSD does not initiate a network of white space devices or provide a list of available white space channels to another Mode I device.
    - Mode II mobile WSDs ("master WSDs") use an internal geo-location capability to access a white space database either directly or through another Mode II WSD.

Ofcom's proposed rules[84] contain the following categorisation:

- Type A: a device whose antennas are permanently mounted on a non-moving outdoor platform.
- Type B: a device whose antennas are not permanently mounted on a non-moving outdoor platform. A type B WSD must have an integral antenna.

Ofcom noted that the purpose of the distinction was to allow a TVWS database to generate different parameters for the different device types. The lower risk of harmful interference from Type A devices means that less restrictive operating constraints can be imposed, allowing more spectrum to be used)[85].

Key Questions

How should the regulatory framework differentiate between fixed and mobile devices or among mobile devices?

What rules should attach to each type of device? Should operating parameters differ by device type or technology?

What type of type approval should be required?

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[83] Mobile devices can be nomadic or transportable.
[84] See Annexure F.
[85] Id. at ¶¶ 5.16, 5.17.

Should ICASA require the registration of some or all devices? If only some, which devices?

Should all White Space Devices require a self determined location or is there a role for professional installation?

8.6.2. Operational Parameters

Detailed technical parameters for TVWS devices have not yet been developed in South Africa. The Trial Partners expect that the data generated by Cape Town trial will be used for this purpose. Results from other trials and practical deployments, both in South Africa and abroad, will also feed into this process.

8.6.2.1 Power Output

The FCC's approach mandates specific power levels for fixed and mobile devices. The power limits for mobile devices vary. Operations on channels adjacent to protected operations must be limited to a lower power than operations on non-adjacent channels. By contrast, the proposed Ofcom approach allows for a continuous range of TVWS device transmitter power levels and uses the database to limit the locations and frequencies the TVWS device can use to ensure that television broadcasting interference protection requirements are met. This approach could increase the amount of spectrum available to TVWS devices without increasing the risk of harmful interference.

The Partners believe that output power requirements for the base station and the terminals should provide greater flexibility than the FCC's static approach. Specifically, to increase the potential range and utility of devices, ICASA should allow a power output greater than the FCC's 4W requirement when there are no TV broadcasters in adjacent channels.

Key Questions

Should fixed and mobile devices have different power levels?

Should ICASA consider a variable power limit, which could increase the utility of spectrum for devices?

8.6.2.2 Channels Available for Use

For fixed operations, the FCC requires at least one channel of guard band between television transmitters and TVWS devices. The FCC allows adjacent channel operation of mobile devices, but only at very low power.

Allowing the database to select unused channels — even if those channels are adjacent broadcast transmitters — increases the amount of allowed spectrum and does not result in interference. The Cape Town Trial operated in channels adjacent to channels used by TV broadcasters, and in some cases, between two channels used by TV transmitters (adjacent on either side to the TVWS channel). No interference was detected. The Trial Partners believe that this evidence demonstrates that the FCC approach is very conservative and does not maximize spectrum utilization.

Key Questions

Recognizing that allowing adjacent channel use would significantly improve spectrum utilisation and increase the amount of spectrum available for use by TVWS devices, should ICASA permit 4W fixed TVWS devices to operate in channels adjacent to incumbent operations?

Are there any substantiated concerns regarding harmful interference associated with adjacent channel operation?

8.6.2.3 Out-of-Band Emissions

The FCC's requirements governing out-of-band emissions for TVWS are extremely stringent. The devices used in the Cape Town Trial were developed to meet FCC rules and have been tested in the lab by the Meraka Institute. In operation, they operate very tightly within the band. Use of devices that conform to these standards reduces chance for interference and increases channel availability.

Key Questions

What out-of-band emissions rules will best improve spectral efficiency and protect incumbent operations?

8.6.2.4 Propagation model for interference calculations

In practice, a number of different methods have been used to model TV signal propagation for the purpose of protecting incumbent operations. The FCC's white spaces rules rely on the F(50,50) curves propagation model to protect incumbents. This model calculates a circular contour around each incumbent installation, regardless of the terrain in and around the transmitter location. This approach can lead to both over-protection and under-protection. Over-protection typically occurs because the F(50,50) curves approach does not take into account the fact that broadcast signals cannot pass over mountainous territory.

By contrast, to calculate broadcaster to broadcaster inteference protection, the FCC relies on the Longley-Rice propagation model. The Longley-Rice propagation model is more accurate than the F(50,50) curves model because it takes into account terrain effects. As such, it does not over- or under-protect in the way that a rigid, circle-shaped contour does.

To compare and contrast the two models (see also Diagram 2):

- Longley-Rice takes detailed terrain into account.
- FCurves is mildly affected by terrain, but misses most of the terrain details.
- Longley-Rice calculates spectrum power being occupied at any point in 3D space.
- FCurves uses a very simple on/off (inside/outside) 2D logic to determine whether spectrum is occupied.

- When computing power levels for white space devices, Longley-Rice computes exact non-interfering power levels, whereas FCurves provides a few static "approximated" (40 mW, 100 mW, or 4 W) power levels.
- FCurves will under- and over- protect actual signal use in many areas, and this leads to less efficient use of spectrum.

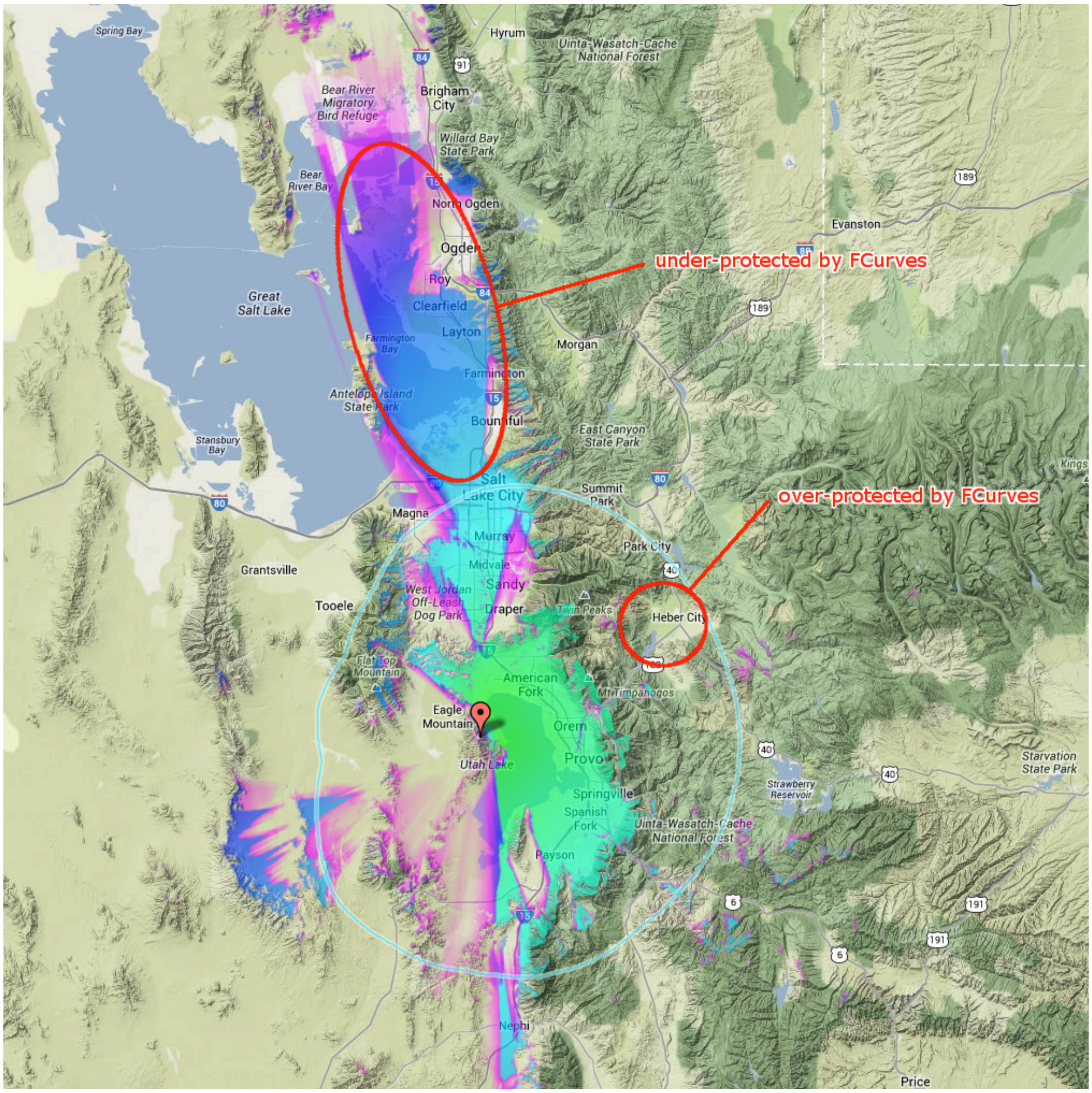
Given the goal of minimizing interference, the trial minimized coupling loss based on Longley-Rice propogation calculations. The Trial has caused no interference.

Key questions

Should ICASA mandate a particular propagation model for database providers to use when calculating protection contours?

Which propagation model or models are most accurate? Which model or models maximize spectral efficiency? Which models best protect incumbent operations? Are there models that are superior to Longley-Rice or other terrain-based models?

Overall, what is the appropriate method of determining the required separation from authorized users in the TV bands?



8.6.2. Diagram 2: Longley-Rice vs. FCurves. FCurve protection defined by blue circle, Longley-Rice defined by heatmap.

8.6.3. Impact on Radio Astronomy

Allowing access to TVWS in South Africa will need to be carefully considered against the award of the majority of the Square Kilometre Array (SKA) to South Africa. The SKA is a $2 billion radio telescope to be constructed in the Northern Cape Province of South Africa. The telescope will operate in the 70 MHz to 10 GHz range[86].

Key Questions

Are there specific protections which should be implemented to ensure that no harmful interference is caused to radio astronomy uses of the 470-790MHz band and the SKA?

[86] For further information, see "Square Kilometre Array," www.ska.ac.za (accessed September 2013)

8.7. International Rules Applicable to TVWS Devices

At the time of drafting these Recommendations, the FCC is the only regulator to have finalised a set of rules applicable to the use of TVWS devices in conjunction with a database. These rules are provided as Annexure E.

The Ofcom proposed rules, while not finalised, nevertheless provide an alternative rule set for consideration. These proposed rules are provided as Annexure F.

The Trial Partners have – based on the conduct and outcomes of the Trial – prepared a suggested set of rules. These suggested rules are provided as Annexure G.

Key Questions

Comments are solicited on the strengths and weaknesses of the different rule sets.

What can be gained from international experience with TVWS access?

8.8. General

On balance, do the potential benefits of permitting licence-exempt managed access TVWS devices to operate in South Africa outweigh any potential risks?

Do the techniques discussed above adequately mitigate any interference potential?

9. List of Useful Resources on TVWS

- Cape Town TVWS Trial
  http://www.tenet.ac.za/tvws
  http://www.engadget.com/2013/08/19/connecting-cape-town-inside-south-africa-tv-white-spaces/

- Federal Communications Commission (US) TVWS page:
  http://www.fcc.gov/topic/white-space

- Ofcom (UK) TVWS page:
  http://stakeholders.ofcom.org.uk/spectrum/tv-white-spaces/

- TV White Spaces Africa Forum 2013 presentations page:
  https://sites.google.com/site/tvwsafrica2013/presentations

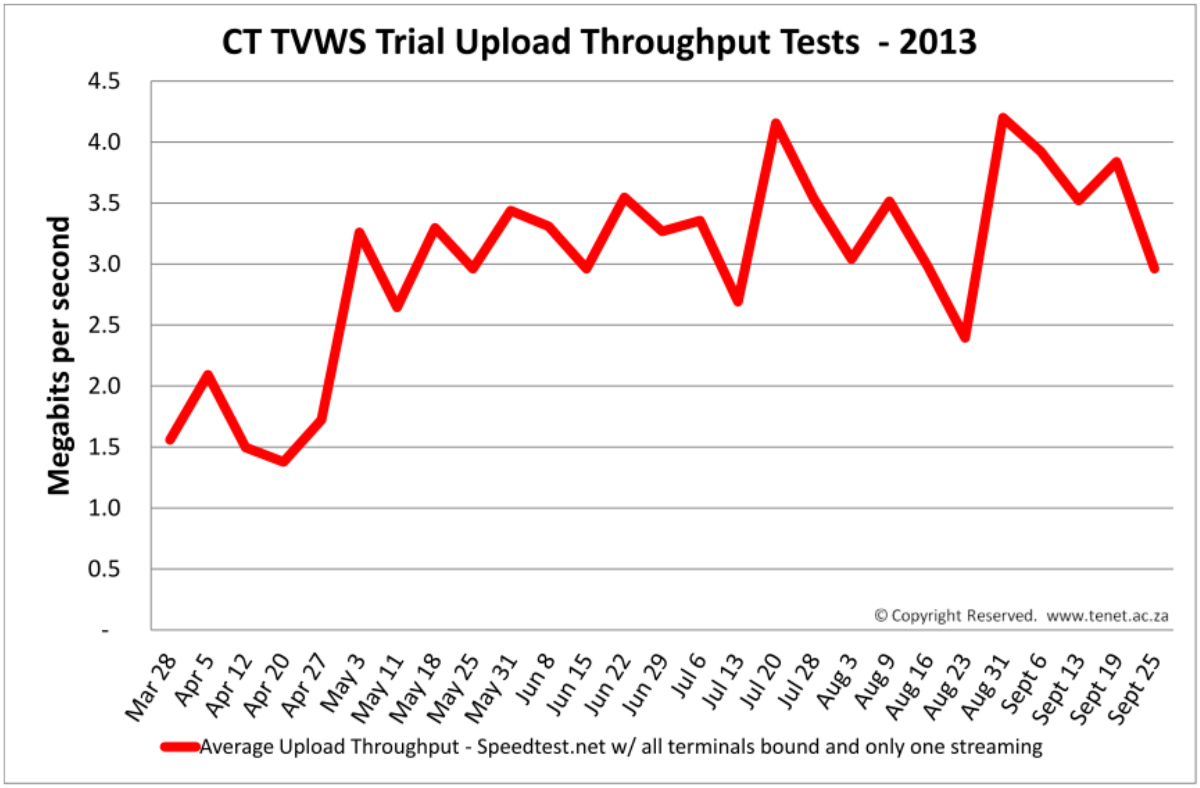
- Google Spectrum Database
  http://www.google.org/spectrum/whitespace/

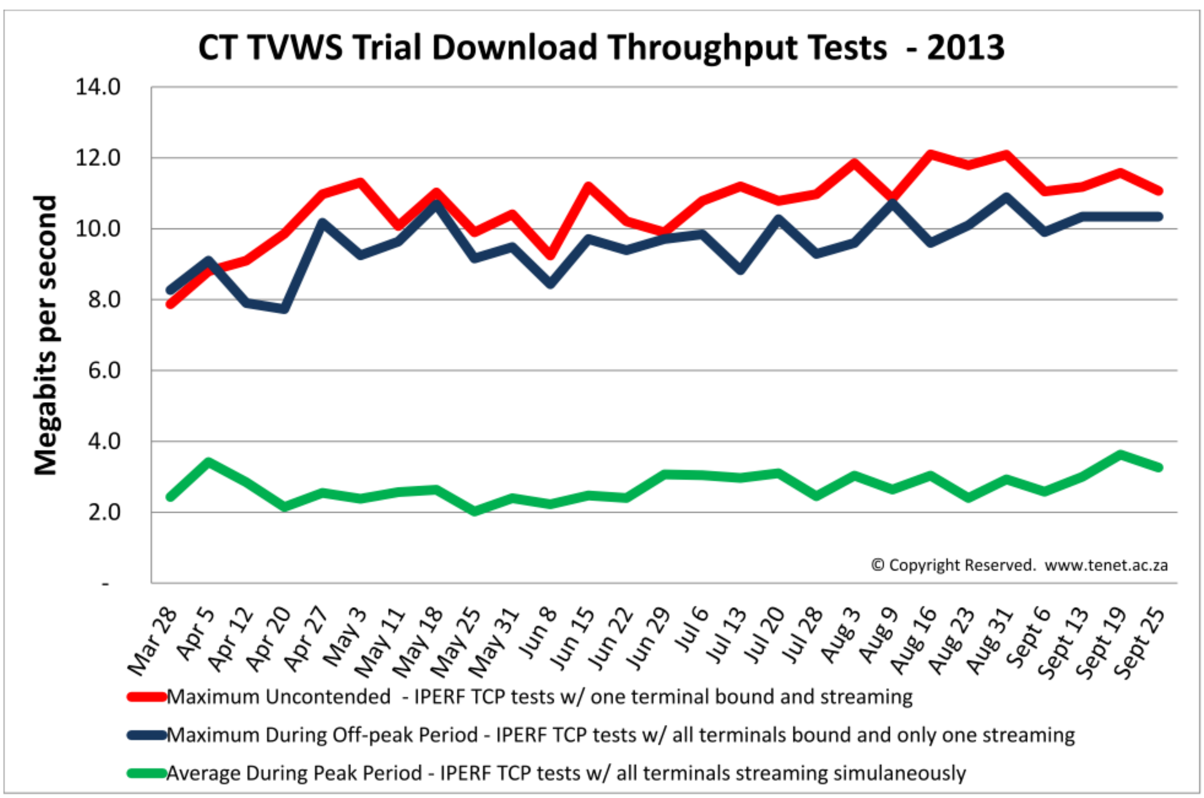
- Wireless Innovation Alliance
  http://www.wirelessinnovationalliance.org/index.cfm

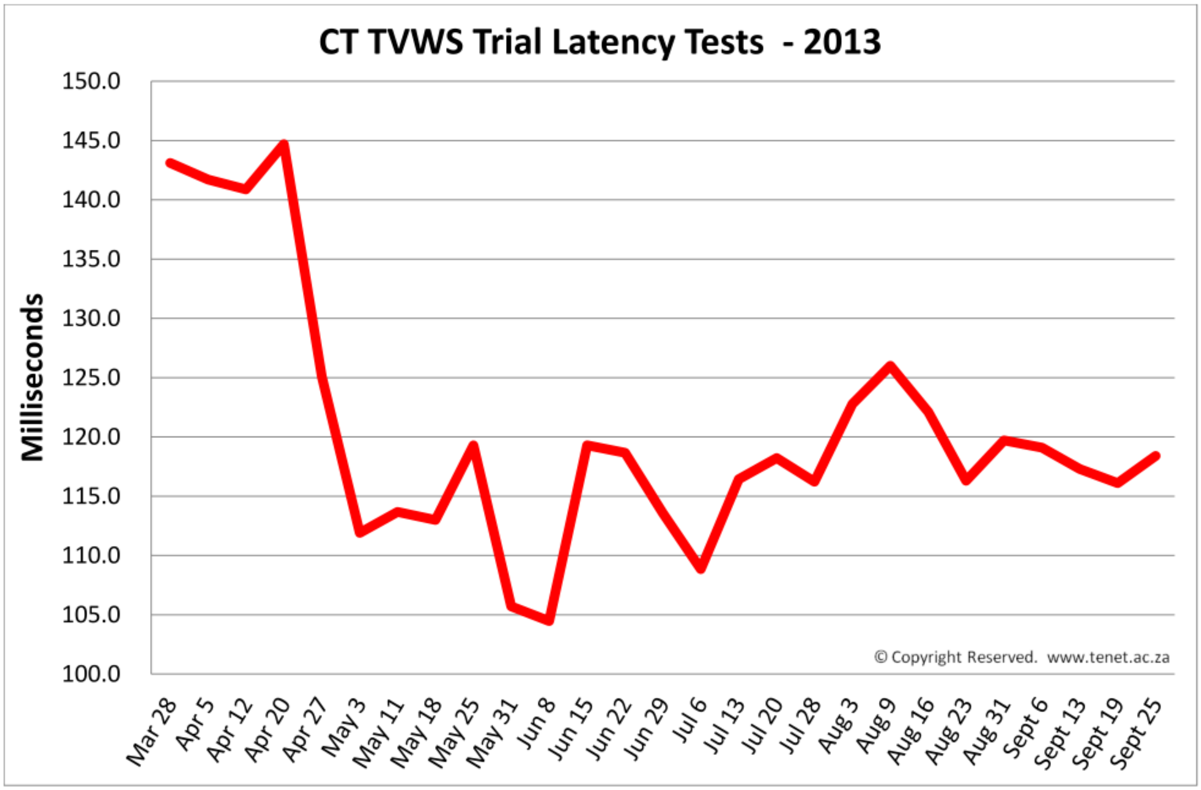
- Microsoft Spectrum Policy Website
  http://research.microsoft.com/en-us/projects/spectrum/default.aspx

- IEEE 802 LAN/MAN Standards Committee
  http://www.ieee802.org/

Annexure A: Upload & Download Throughput and Latency Test Graphs







CT TVWS Trial Latency Tests - 2013
Milliseconds
150.0
145.0
140.0
135.0
130.0
125.0
120.0
115.0
110.0
105.0
100.0
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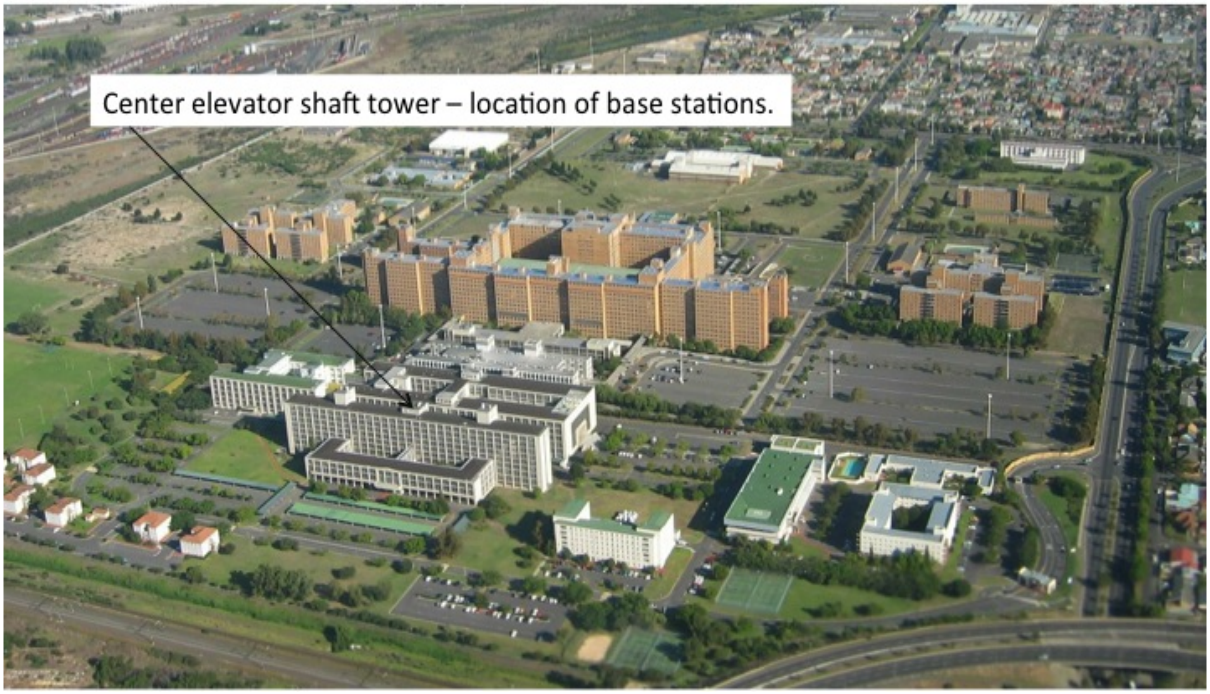
Mar 28
Apr 5
Apr 12
Apr 20
Apr 27
May 3
May 11
May 18
May 25
May 31
Jun 8
Jun 15
Jun 22
Jun 29
Jul 6
Jul 13
Jul 20
Jul 28
Aug 3
Aug 9
Aug 16
Aug 23
Aug 31
Sept 6
Sept 13
Sept 19
Sept 25

Annexure B: High Site, Base Station, Antenna Location, Antenna Direction and Sectors

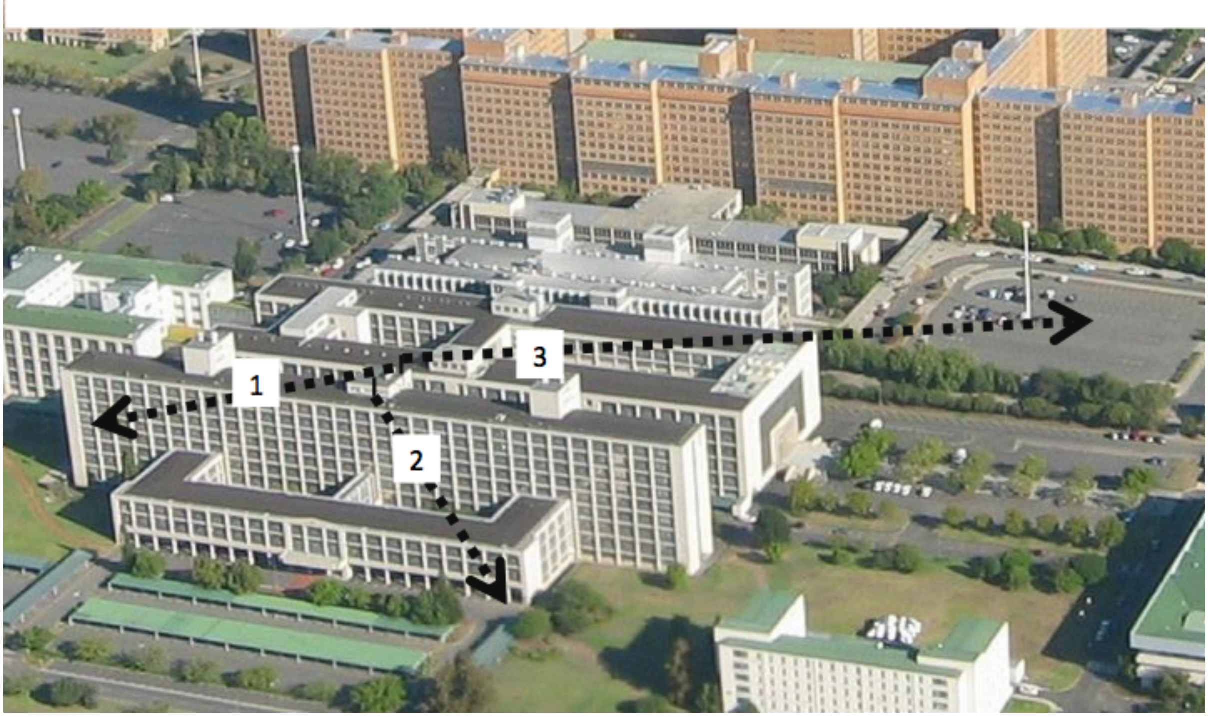
The High Site

The BTS Location



Antenna Placement

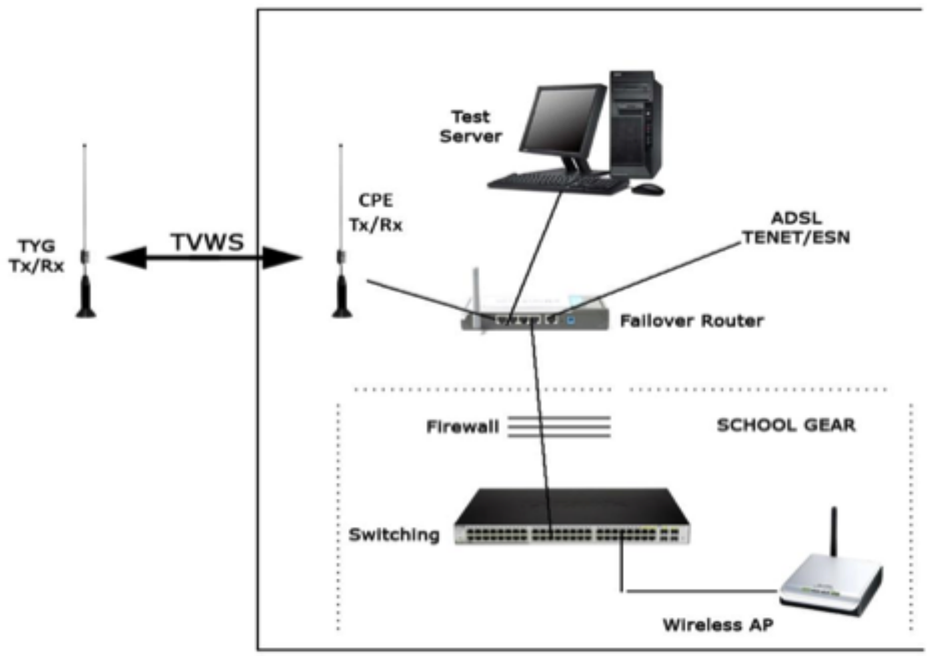
Antenna Direction

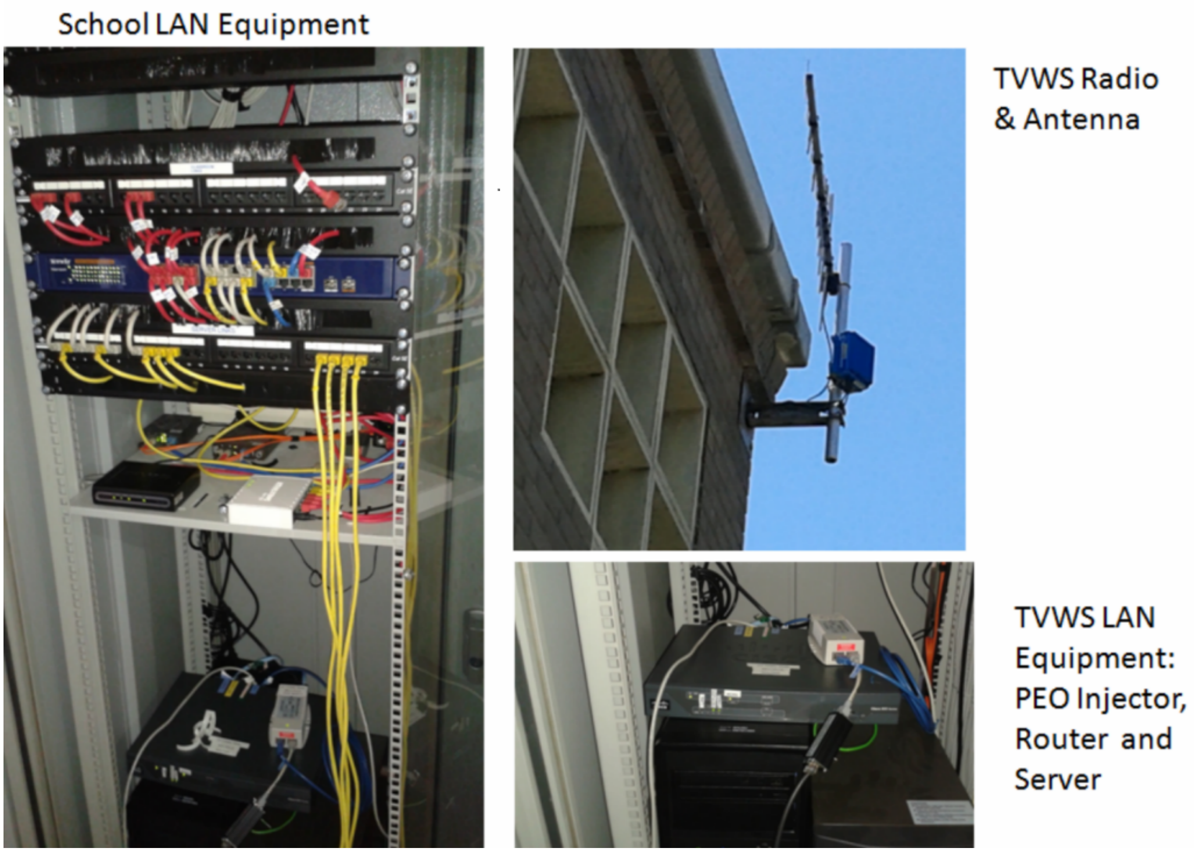


Sectors

Annexure C: School LAN and CPE Installation

School LAN design




School LAN Equipment
TVWS Radio & Antenna
TVWS LAN Equipment: PEO Injector, Router and Server

Annexure D: Cape Town TVWS Trial Interference Management Protocol

The CSIR Meraka is making all efforts to mitigate any harmful interference to the primary users (TV viewers) of the TV spectrum during the period of the TVWS trials in Cape Town. This includes initial field measurements (to identify free channels), equipment testing in the lab, using the RF predictions and making sure that only the available TV channels are accessed or utilized for trial purposes. However, due to uncertainties in the wireless environment and the different causes of interference, it is possible for the TV viewers to experience some interference due to secondary access of the adjacent channels or the same channels (co-channel). If such interferences are experienced by the primary users, the following protocol should be followed to mitigate interference caused by the TVWS trial network. The TVWS trial network consists of three Base Stations (BS) and ten Radio Terminals (RT). Both the BS and RT are referred to as white space devices (WSD).

Interference Management Protocol

Steps	Procedures to be followed	ICASA Online reporting
Step 1	A normal poor TV quality reception problem (such as interference) reporting procedure will be followed by the TV Viewer (subscribers).	N/A
Step 2	The broadcaster will follow its internal processes to investigate whether the problem is due to interference or not. If it is interference problem, the broadcaster should determine whether the area where interference is reported is in the vicinity of the TVWS trial network.	N/A
Step 3	If interference is in the vicinity of the TVWS trial network, then the broadcaster will notify CSIR about the possible interference by the TVWS trial network.	Broadcaster to log an online report.
Step 4	CSIR and the broadcaster will cooperate to perform the following tests to determine whether or not the WSDs are causing interference.	CSIR to log an online report.

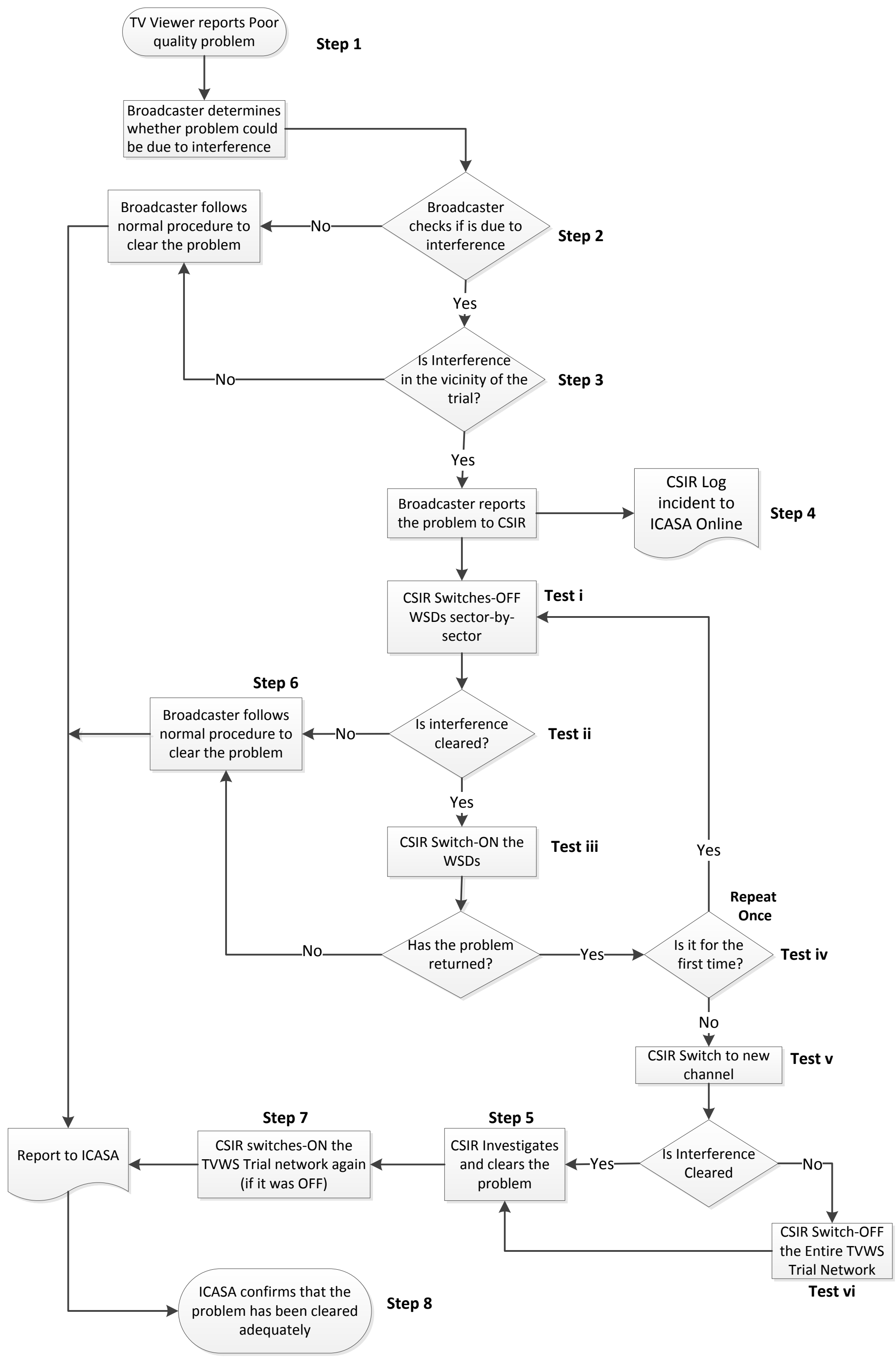
Test i	CSIR will switch-OFF the WSDs sector by sector and inform the broadcaster	N/A
Test ii	The broadcaster will check with the TV Viewer whether the interference has been cleared.	N/A
Test iii	If the interference is cleared (while the WSDs are switched-OFF), the CSIR will switch-ON the WSD again (on the same channel) and check with the broadcaster whether the TV Viewer still experience interference or not. If the TV Viewer no longer experiences interference (i.e. interference is cleared), Go to Step 6.	N/A
Test iv	If the TV viewer still experiences interference, repeat Tests i, ii and iii (Repeat only once).	N/A
Test v	If the TV Viewer still experiences interference, CSIR will switch/change the TVWS trial network channel and transmit on the new/different channel.	N/A
Test vi	If the interference continues (not cleared) on the new channel (after Test v), CSIR will switch-OFF the entire TVWS trial network and go to Step 5. If the TV Viewer no longer experience the interference, Go to Step 5	N/A

Step 5	If the procedure/testing in Step 4 reveal that TVWS trial network may have caused the problem, CSIR will conduct the investigation and report the problem to ICASA, clearly indicating the source of the problem and how it was resolved.	CSIR to log an online report to ICASA
Step 6	If the interference is not caused by TVWS trial network, broadcaster will report the problem to ICASA using the normal procedure to deal with such problems.	Broadcaster to log an online report to ICASA
Step 7	Once interference is cleared, the CSIR will switch-ON the entire TVWS trial network if it was switched-OFF (and report to ICASA)	CSIR to log an online report to ICASA
Step 8	ICASA will also use their existing internal investigations to study the cause of the interference and confirm whether CSIR has cleared the problem.	ICASA to report back to Broadcaster and CSIR

D.2 depicts a flow diagram for the interference management protocol discussed above.

The above protocol shall be in place for the duration of the TVWS trial (i.e. the TVWS trial network is still active). In addition to the protocol, the process in Annexure A shall be in place to fast track interference mitigation.

Interference Management Protocol Flowchart



Lines of support

In support of the above protocol, the following processes (which form part of the Agreement between TENET and CSIR Meraka) will also be in place to fast track interference mitigation.

TENET will engage with communities such as the Cape Town Wireless User Group and the Cape Town Amateur Radio Centre who operate in the coverage area and ask for their assistance in systematically monitoring television broadcasts to ensure non-interference.

TENET will keep CSIR well informed on the feedback from the communities and user. The feedback on possible interference will be provided within a reasonably short time, preferably as soon as feasible, and CSIR shall not be responsible where such feedback is for whatever reason delayed.

CSIR will, as the Licence holder, have the full authority to control the TVWS transmissions (including switching it on and off), as per the needs of spectrum measurements, or in case of interference to primary users.

TENET undertakes, as the operator of the Trial Network, to act speedily to bring down any TVWS transmissions about which it has become aware, whether by instruction from the CSIR or otherwise, that are causing interference to primary licensed spectrum users.

The interference monitoring and management protocol doesn't attempt to monitor interference and manage secondary co-users of the TV spectrum, such as RF Cable interference and wireless microphones.

Annexure E: FCC Final Rules as Amended

Annexure F: Ofcom Proposed Rules

Annexture G: Suggested Technical Rules and Regulations for the Use of TVWS and Managed Access Spectrum

Annexure H: Network Continuation Report

Introduction

Build on the Trial's Success

The Trial was successful, specifically demonstrating that broadband services can be delivered over unused TV channels without causing interference to incumbent TV transmissions in adjacent channels. Based on the success, there is a consensus to continue providing broadband services over the Trial network.

The Regulator Approves Continuation of the Trial Network

On August 28, 2013, ICASA accepted a set of recommendations by Meraka Institute, specifically to allow the Trial network to remain operational, as well as for the network footprint to expand[1]. This will be enabled as a continuation of the MoU between ICASA and Meraka to "explore and develop the potential of new converging communication, media and information technologies and associated platforms". The Trial network will not be the only ongoing TVWS Trial. A Microsoft funded Trial is slated for early 2014, and Meraka has plans for other Trials[2]. These Trial activities are intended to serve as a basis for continued inputs into ICASA's TVWS regulatory process.

Continue the Partnership

e-Schools' Network (eSN) and TENET, with the support of the other Trial partners, have agreed to continue the operation of the Trial network. Google has agreed to continue supporting the white space database, on an interim basis, and WAPA supports the continuation.

Continue on Non-Commercial Trial Basis

The Trial network will continue to operate on a non-commercial basis. TENET will work with eSN to develop a cost recovery pricing scheme, which will be trialled with the schools. Both TENET and eSN are well established not-for-profit entities providing internet services to the research and education community on a cost recovery basis.

Phased Approach

The continuance will be phased, whereby the next six months will be spent working with eSN staff on capacity building to be able to assume full responsibility of operating the Trial network. At the end of the 6 months, a determination will be made as to how to proceed, in consultation with Meraka Institute and ICASA.

Network Design and Operation

The Base Station

The Trial's TVWS network high site is located at Stellenbosch University's Faculty of Medicine and Health Sciences in Tygerberg, Cape Town, and operates three base stations. The three base station radio operate at a power output of 500mW, each of which cover specific sectors using an

[1] Reflected in meeting minutes and presentation materials provided by Meraka to TENET.
[2] Ibid.

antenna with reflectors arranged to create a 90 degree coverage area on the E plane. The antenna have a 25 dBi front-to-back ratio allowing for a high degree of directionality with a gain of 10 dBi at 0 degrees. The total EIRP (effective isotropic radiated power) for each sector is estimated at 4 Watts, assuming a 1dBi loss from cables and connectors[3]. More detailed information about the Trial High Site, Base Station Location, Antenna Placement, Antenna Direction and Sectors are set out in Annexure B above.

Customer Sites

The following schools serve as the customer sites served by the Trial network:

- Sector 1
  - Bellville High School
  - DF Malan High School
  - Fairmont High School
- Sector 2
  - Settlers High School
  - Parow High School
  - President High School
- Sector 3
  - Elswood Secondary School
  - Norwood Primary School
  - Range Secondary School
  - Cravenby Combined Schools

Diagrams and photographs of the installation of Local Area Network (LAN) and Customer Premises Equipment (CPE) at the participating schools are set out in Annexure C above. Each customer radio operates at a power output of 500mW and are attached to Yagi directional antenna with a gain of 10 dBi at 0 degrees. The total EIRP for each client is estimated at 4 Watts, assuming a 1dBi loss from cables and connectors[4].

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[3] EIRP = 27dBm (500mW) + 10dBi – 1dBi = 36dB (3.98W).

[4] Ibid.

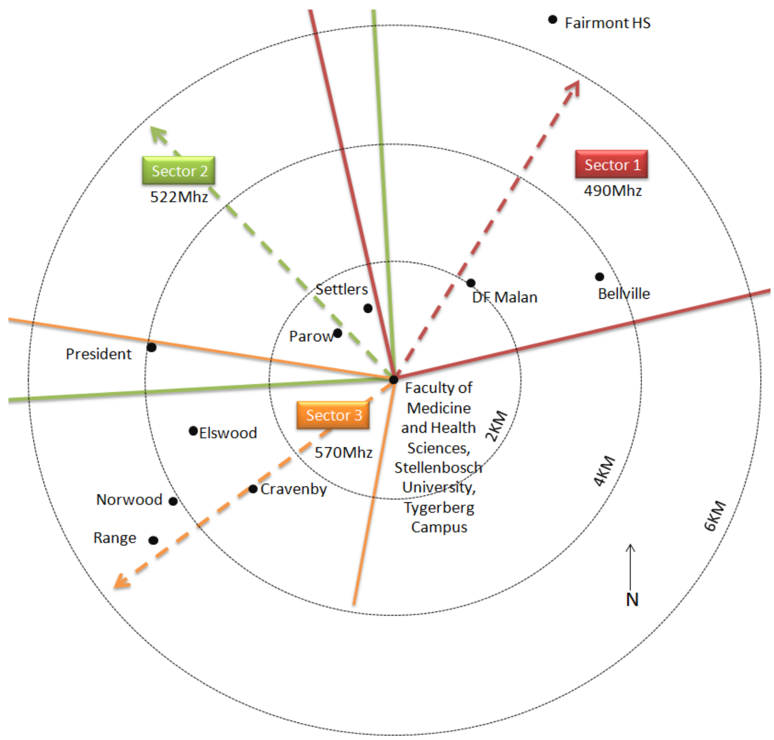

Diagram 1: Trial Network Diagram

Channels Allocations

The Trial network has been allocated channels 23, 25, 27, 29, 31 and 33 to operate in. This is based on detailed white space spectrum analysis performed by Google with data provided by ICASA, spectrum field tests conducted by Meraka Institute, and subsequent consultation with ICASA and the Joint Spectrum Advisory Group (JSAG).

The specific odd-number pattern is no accident and is a function of the practice of using at least one empty adjacent channel as a guard band to avoid interference among TV transmitters. It is also as a result of the Trial network operating in one of the busiest TV markets in Africa. Cape Town is essentially surrounded on three sides by water, and a series of mountains. As a result, there are multiple TV broadcast transmitters serving the local communities, broadcasting the same combination of networks from each transmitter. In order to avoid interfering with each others, different sets channels are used at each transmitter.

The Backhaul

A contribution to the Trial's success is the high capacity and reliable backhaul infrastructure used. The base station high site is located at a Point of Presence (PoP) of the South African Research and Education Network (SANReN) which TENET operates under an exclusive arrangement with Meraka Institute. The backhaul down from the rooftop is a 1 Gigabit optical fibre link, which connects with the 10 Gigabit SANReN Bellville Grey Ring in the basement of the building. The Trial network is provided a specific pool of un-contended internet bandwidth through nationally and internationally based internet exchanges.

Network Performance and User Experience

Data Throughput Speeds

The Trial network produced data throughput speeds that are on par with existing fixed line offerings. The peak downlink speed attainable on the Trial network is 12 megabits per second (Mbps). The peak uplink speed is 5Mbps. Latency between the base station and the terminal is approximately 120 milliseconds, the reason related to the radio being largely software designed in its current state and not due to the over the air TVWS link itself[5].

Graphs showing Upload & Download Throughput and Latency test results are included as Annexure A above.

Schools Experienced Broadband

The Trial schools experienced the real promise of TV White Spaces. Some even temporarily replaced their existing dial up and ADSL service with TVWS. For the first time, students at some schools could research rich-media educational materials and teachers collaborated with other schools over Skype[6]. The hope is that all schools in South Africa may experience this quality of service if TVWS is made available throughout the country.

Base-Line Conditions

Prior to the Trial, all of the schools served by the Trial were ADSL customers, and continue to be. The Sector 1 and Sector 2 schools have up to three ADSL lines, ranging from 2Mbps to 4Mbps each ("premium" ADSL users). The Sector 3 schools all are served by 1Mbps lines ("basic" ADSL users). The premium group of schools use a mix of business and residential services offering low contention, while the basic group side with low-cost, highly contended, residential services. As a result, prior to the Trial, the consumption of internet services between the premium ADSL user group and the basic ADSL user group varied considerably. The premium ADSL schools were already well established users of the internet. Students are able to access the internet as part of regular lessons, and teachers use the internet as a teaching aid. The basic group is not considerable user of the internet; Internet use is intermittent and primarily limited to lab activities and admin. Teacher access is afforded to those who teach the lab lessons and to administration; regular teachers have to go to the lab between lessons or after schools. The premium user group outsourced their networking and internet services to private vendors. Teacher and administrator attitudes toward connectivity can be classified as "make sure that admin, students and teachers always have fast and reliable access". The basic user group receive network support from the Provincial government, and a large portion of their internet costs are subsidized by the Province (as are the premium user group, but at an effectively smaller share of total costs). Teacher and administrator attitudes toward connectivity can be classified as "we can't afford to let everyone freely access the internet".

[5] Latency in the lab is the same as latency in the field. This is expected to be largely eliminated once the system becomes more chip based, and less software dependent.

[6] http://www.engadget.com/2013/08/19/connecting-cape-town-inside-south-africa-tv-white-spaces/

TVWS as a Primary Source of Internet

The implementation plan leading into the Trial was to use TVWS as the primary source of Internet for the basic user group, with ADSL as failover. This approach worked well, especially for one school whose copper phone/ADSL cables were stolen a week before the Trial commenced, and remained inactive for several months thereafter. TVWS will continue to be the primary source of internet for this group. For the premium user group, it was generally accepted that TVWS would play a secondary role for connectivity. These schools opted to continue using their premium ADSL services for students, teachers and essential administration services. TVWS was allocated to non-essential sectors of these schools – portions of the network accessed by students. However, once the Trial got underway, and these schools were able to gauge the speeds and reliability of the Trial service, they shifted more of the network onto TVWS, with some choosing to use entirely TVWS with ADSL as failover. The reasons for this are explained below.

Increased Access to Rich Media Content

The higher throughput speeds from TVWS allowed teachers to increasingly rely more on rich media content to aid teaching. Earlier practices of downloading and saving videos at home at night, and carrying the content to work no longer became the practice.

Improved Symmetry

Symmetry is a very important benefit for the internet user. A key factor siding with the improved TVWS user experience is the higher relative upload speed capability. Internet over ADSL, which is the predominant last mile technology used by schools in South Africa, has a distinctly asymmetrical ratio between the downlink speed and the uplink speed. Whereas, the TVWS link yields a 2:1 downlink to uplink ratio, ADSL is typically at 10:1 for up to 10Mbps and generally 5:1 for 20Mpbs and 40Mbps lines. Effectively, in order for a school to get a 4Mbps uplink from ADSL, it would need to purchase a premium 20Mbps service, compared to only needing an 8 to 9Mbps TVWS link for the same uplink speed. This greatly affects the user experience.

Able to Make Reliable Voice Calls

Higher upload speeds allow for improved voice calls, particularly over Skype. For example, schools which pay for premium ADSL lines, stated that they were not able to make regular Skype calls. Since participating in the Trial, they were able to make calls to schools around the world and collaborate during lessons, greatly enriching the teaching and learning experience.

Reliable TCP/IP Management

Limited uplink speeds also result in an overall degradation of TCP/IP link stability and uptime, especially if uplink congestion results in delaying important management packets which are critical to maintaining link stability and continuous uptime.

Send More Outgoing E-Mails and Frequently Update School Website

Schools with lower tiered ADSL links, like a 1Mbps line with 100Kbps up, stated that they were unable to send regular email updates and reports with attachments to parents. Simply updating the school website was a difficult, slow and cumbersome process. This changed for the better since participating in the Trial.

Uptake of Internet Services

The uptake of internet services varied considerably between the premium user group of schools and basic user group. The traffic volumes over the TVWS links serving the premium schools grew over the course of the Trial, while they remained constant and low for the basic user group.

The largely variant uptake levels, as it turns out, are completely logical. That is, schools which are enabled to respond to increased bandwidth – that have a low computer to pupil ratios, with computers all over school, which are effectively networked, are easily accessible by students and staff, are not bogged down by strict firewall rules - did so. Those schools which were not enabled to the same degree – high pupil to computer ratio, limited to labs that are generally locked up, running early generation operating systems, on early model PCs, which are not easily accessible by students and staff, with limited LAN/WLAN coverage, and stringent firewall rules – did not show a high uptake due to improved internet services.

Wireless Access Point Case Study

As part of the Trial, the schools were donated with one wireless access point (A/P). The purpose was not TVWS related, but to provide additional opportunity for accessing the internet, and greater uptake. These were provided on the basis that they would be supported to get the A/Ps up and running, and thereafter were the respective school's asset and responsibility to mange. All of the schools in the premium user group had existing A/Ps so the installation and utilization was almost immediate. Little support from the Trial support team was needed. The A/Ps at these schools are generally accessible by staff and students, with some exceptions when installed in the staff room. On the other hand, it took several weeks to complete installation at the basic user group schools. The TVWS support team provided onsite support installing the devices, as well as liaising with the Provincial networking and IT staff supporting these schools. While accessing the school LAN through the A/P was quickly achievable, the Province required proxy login credentials to browse the internet through the A/P, required further support from the TVWS support team. Access to the A/Ps at these schools is generally limited to teachers, and in one case, not all teachers.

Lesson to Build On

The real reason for driving increased uptake is not the increased traffic statistics *per se*, but the real and tangible benefits to the users. The most significant lesson going forward is that the very schools that stand to benefit most from the versatility offered by TVWS – high performance connectivity for underserved markets – also need significant capacity building support to ensure uptake of the service. Providing the underserved schools with TVWS connectivity, coupled with capacity building, is critical to achieving increased traffic at these schools. And the real benefits are what lie behind the traffic graphs.

Ongoing Trial Network Support Plan

Zero Instances of Interference

The Trial's proudest accomplishment is that there was no interference to TV transmissions occurred throughout the entire course of the Trial. For that reason, the support plan to be utilized for the continuation of the Trial network will resemble the very successful plan used during the Trial. Another reason for using the previous support plan is that it helped deliver significantly improved broadband throughputs and reliability for the Trial schools.

First Line of Support

eSN will provide the first line of support, using its existing call centre and technical support team. This was the same arrangement for the Cape Town Trial and it worked well. TENET will continue to provide support, but through capacity building, and not direct resolution. This is to support a strategy to increasingly shift more network support responsibilities to eSN.

Systems Integrator

Comsol, the Trial systems integrator, will provide the second line of support, including replacing equipment as needed. Their experience installing the Trial network, and supporting it throughout the Trial will prove valuable for the continuation of operations.

Interference Compliance

An Interference Protocol was developed by Meraka Institute for the Cape Town Trial, and approved by ICASA and the Joint Spectrum Advisory Group (JSAG). This Protocol will be adhered to for the continued operations. A copy of the Interference Protocol is included as Annexure D above.

Whitespace Database Support

Google has agreed to continue supporting the whitespace database developed for the Trial network. We know it is accurate, that it is operational, and that the base stations are able to continuously interact with it. TENET will notify Google if there are plans to move equipment outside the geography of the database, or if ICASA and/or Meraka Institute informs TENET of a channel allocation change.

Operational Perspectives to Build On

Line-of-Sight is Important

The network is made up of fixed devices which are installed on top of building structure and rooftops. All of the links on the Trial network were installed as line-of-sight (LOS), this despite the non-line-of-sight (NLOS) qualities offered by TVWS. As a result, all links operate at the highest signal to noise ratios (SNR) allowing for optimal possible throughputs, at the currently available modulation rates. Prioritizing LOS is an important practice in optimizing network performance, despite the very tangible NLOS benefits TVWS has to offer.

A great deal of trial and error went into the installation of the Trial network, testing the two key advantages TVWS offers over other wireless technologies:

Propagation
Radio waves in the TV bands have greater propagation qualities and are able to reach further distances. The ability to reach further at nominal power levels makes TVWS an attractive technology for rural broadband. The furthest link on the Trial network was 6.5 kilometres.

Multipath
Multipath propagation is when signals reach a receiver by two or more paths. The specific radios[7] deployed for the Trial network had built-in hardware and equalizer software that could overcome and even capitalize on multipath propagation.

Given this information, the Trial network was initially installed with a mix of LOS and NLOS links, without a preference one way or the other. During implementation, the goal was to achieve a minimal SNR of 25dB. However, early throughput (speed) tests showed that LOS links with SNRs of over 30dB yielded substantially greater throughputs than NLOS links with SNRs of around 25dB. LOS links produced 8Mbps to 10Mbps[8] compared to 4Mbps and 5Mbps for NLOS links[9]. Based on this information, the Trial implementation team set a SNR target of 30dB or greater for all links, where possible. The antennae at several sites were relocated to LOS positions to meet this operational goal. In addition, a new 5 metre tower was installed at the high site to overcome obstructions on the building roof (elevator shaft).

It is worth sharing at least one anecdote demonstrating how multipath can play an advantage:

Fairmont High School Case Study
At Fairmont High School, the initial installation was NLOS and produced an average SNR of 5dB. After relocating to a LOS position on the roof of the school, the SNR jumped to 20dB. This was initially accepted as a function of distance. However, upon further trial, it was found that pointing the antenna toward Bellville CBD (tall buildings), the SNR increased to 29dB. This position, pointed approximately 20 degrees away from the high site, achieves greater SNR than a direct LOS. It was determined that the steep terrain directly under the LOS path caused significant attenuation, and that on the other hand, the buildings in the CBD provide signal "bounce".

Versatility of TVWS
As a result of the aforementioned experimentation, the Trail network has proven that TVWS is a versatile technology.

Enables Extended Reach
TVWS signals are able to deliver broadband services over long distances, while maintaining competitive performance levels. Bit error rates over the air remain low even at long distances. As a result, the Trial network's furthest link is able to operate at the highest modulation rate available at this time. This feature will prove useful for rural networks.

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[7] Carlson Wireless' RuralConnect TVWS radios.
[8] Subsequent firmware upgrades have resulted in top-end download throughputs of 12Mbps.
[9] Note that a NLOS link that yields a throughput of 5Mbps is considered excellent. However, for this Trial, the implementation team adjusted strategy to install LOS link at all sites.

Benefits from Multipath Propagation

Wireless Internet Service Providers (WISPs) view TVWS multipath capabilities as an opportunity to offer connectivity to the un-served NLOS customer. Based on anecdotal experiences shared by WISP over the course of the Trial[10], between twenty and thirty percent of all new customer calls cannot be serviced due to NLOS issues. With current unlicensed options, adding NLOS customers would require adding a new base station to achieve LOS. Building a base station to serve one customer is an infeasible option.

Offers High Performance

TVWS spectrum is also a competitive application over higher performance short distance links. The Trial network LOS links operate at spectral efficiency rates of 1.5 bits per second per hertz of spectrum, limited only by the current Quadrature Amplitude Modulation (QAM) rate of 16 available on the development version hardware used for the Trial. Next generation hardware are capable of processing data at QAM64, with a spectral efficiency rate of between 2 and 2.5 bits per second per hertz of spectrum.

Best Practices for Non-Interference

Non-interference to primary spectrum holders is the core TVWS prerogative. The following are best practices which came out of the Trial:

Radio Design

Radio technology, specifically the amplifier design requirements are, key to ensure zero interference. The use of a band pass filter that ensures an extremely tight spectral mask which keeps the out of band signal spread to extremely low levels is what makes the radio technology used for the Trial so successful. It was developed to meet the FCC's strict requirement for fixed TVWS devices. These requirements, and those of Ofcom, are outlined in the main recommendations document (see Sections 6.2 and 6.3)

Adherence to Communications Protocols

Ensuring that the firmware installed on the radios adhere to strict communications protocols. For example, the client radios used for this Trial network do not go into transmit mode until assigned a channel and a master base station to attach to. Upon boot-up, they go into "listen" mode while scanning the UHF range. Once a base station beacon is detected, the client will transmit a response in the respective channel, and await instructions from the base station. Base station radios are programmed to authenticate with the white space database at boot-up, at which time they are assigned a channel and power limit. They transmit beacons from the assigned channel so at to identify client radios. Following the "handshake" between the client and the base station, the line of communication is open to data flow. These protocols prevent radios from transmitting in used TV channels.

Continuous Access to an Accurate Spectrum Database

The accuracy of the data proved critical to maintaining a zero interference recorded throughout the Trial. The link between the base station radio and the database acts as a "life-line". If the backhaul Ethernet link between the base station and the database goes down, the base station

[10] Informal interviews with wireless internet service providers attending iWeek 2013.

and the associated clients immediately stop transmitting, even in circumstances where the data flows are local within the TVWS network, and are not reliant on backhaul.

Network Design

The Trial network uses directionality to improve performance. Directional antennas installed at the client sites allow the network operator to manage TVWS signals.