General Notices • Algemene Kennisgewings

INDEPENDENT COMMUNICATIONS AUTHORITY OF SOUTH AFRICA

NOTICE 1001 OF 2015

PURSUANT TO SECTION 4B OF THE INDEPENDENT COMMUNICATIONS AUTHORITY OF SOUTH AFRICA ACT 2006, (ACT NO. 3 OF 2006)

HEREBY ISSUES A NOTICE REGARDING THE DISCUSSION PAPER ON THE DRAFT FRAMEWORK FOR DYNAMIC AND OPPORTUNISTIC SPECTRUM MANAGEMENT 2015

1. The Independent Communications Authority of South Africa ("the Authority"), hereby publishes a **Discussion Paper on the Framework for Dynamic and Opportunistic Spectrum Management 2015 for consultation** in terms of sections 2 (c) (d), (e), (i) and 4, read with sections 30, 31(4), and 33 of the Electronic Communications Act (Act No. 36 of 2005) and section 4B of the Independent Communications Authority of South Africa (ICASA Act).

2. Interested persons are hereby invited to submit written representations, including an electronic version of the representation in Microsoft Word, of their views on the **Discussion Paper on the Draft Framework for Dynamic and Opportunistic Spectrum Management 2015** by no later than 16h00 on the 18th December 2015.

4. Written representations or enquiries may be directed to:

   The Independent Communications Authority of South Africa (ICASA)

   Pinmill Farm Block A

   164 *Katherine Street*

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South Africa

Or

Private Bag XI0002

Sandton

2146

Attention:

Mr Manyaapelo Richard Makgotlho

E-mail: rmakgotlho@icasa.org.za

5. All written representations submitted to the Authority pursuant to this notice shall be made available for inspection by interested persons from 22nd December 2015 at the ICASA Library or website and copies of such representations and documents will be obtainable on payment of a fee.

6. Where persons making representations require that their representation, or part thereof, be treated confidentially, then an application in terms of section 4D of the ICASA Act, 2000 (Act No. 13 of 2000) must be lodged with the Authority. Such an application must be submitted simultaneously with the representation on the framework. Respondents are requested to separate any confidential material into a clearly marked confidential annexure. If, however, the request for confidentiality is refused, the person making the request will be allowed to withdraw the representation or document in question.

NOMVUYISO BATYI
ACTING CHAIRPERSON

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Acknowledgements

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1. The Council for Scientific and Industrial Research (CSIR) Meraka Institute
2. The University of Pretoria
3. The University of the Witwatersrand Centre for Telecommunications Access and Services (CeTAS) and the LINK Centre (SLLM)

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1 Executive Summary and Introduction

1. This discussion paper proposes a regulatory framework for dynamic spectrum assignment (DSA)[1] in order to enable the emergence of new technologies and techniques that promote more intensive and efficient use of radio frequency spectrum. The proposal broadly reflects recommendations made in the digital readiness pillar of the National Broadband Policy, SA Connect[2]. This paper proposes the adoption of dynamic spectrum assignment on a geo-location basis as one of the techniques to achieve the stated priorities of SA Connect. In particular, it proposes regulations that would enable broadband service on a secondary user assignment basis in the 470 - 694 MHz band currently utilized exclusively for terrestrial broadcasting service, hereafter referred to as TV white spaces (TVWS) operation, as the first phase of dynamic spectrum assignment in South Africa. This proposal would make up to 168 Megahertz[3] of spectrum available (see Figure 1 below) for innovative wireless communication services such as broadband and machine-to-machine services without displacing incumbent services. ICASA also seeks input on studies to be commissioned for extending dynamic spectrum assignment beyond the TVWS band.

2. Demand for wireless broadband capacity is growing much faster than the availability of new spectrum for supporting wireless infrastructure deployment. The National Development Plan and SA Connect advocate for broadband to reach "a critical mass of South Africans". To meet this demand, future generations of wireless technology and services will not only be required to increase their efficiency in terms of bits per second per Hertz, they will also require new wireless network architectures and new approaches to spectrum management.

3. The SA Connect Policy identifies making significant amounts of otherwise underutilized spectrum available for broadband use as holding promise for increasing South Africa's broadband capacity. The proposed regulatory framework for dynamic spectrum assignment would enable the widespread utilization of this underutilized spectrum and in doing so promote more efficient use of available spectrum

4. It is often said that "spectrum is scarce". This is true, if one continues the existing paradigm of assigning a particular block of spectrum to a particular licensee, once only. Once assigned to that licensee on an exclusive national basis, it is implicit that the same block of spectrum cannot be assigned to others. Since there are a limited number of available blocks, so it follows that spectrum is "scarce". This despite the fact that it is virtually impossible for the licensee to actually use the spectrum in every square km of the country on any viable economic basis. Indeed, in some cases, actual geographic coverage may be measured at around 10% to 15%. In all places where the spectrum is not used by the licensee, this

[1] A note on terminology: DSA is often expanded to dynamic spectrum **access**. However, not only is this incorrect from the point of view of regulatory terminology, but a comparative search for scholarly articles for both terms shows dynamic spectrum **assignment** to be significantly more common. The latter is therefore used throughout in this paper

[2] Government Gazette no. 37119 of December 6, 2013; National Broadband Policy recommended the approval of spectrum sharing between spectrum licensees and across services by ICASA in support of efficient use of spectrum and specifically enabling of dynamic spectrum assignment;

[3] 470 – 694 MHz totals 224 MHz. Currently, up to 93% of this is unused in places. After the analogue to digital migration and subsequent restacking (digital to digital migration), 75% of spectrum will be unused in any one of the 11 regions. Except on the border areas, all of this 168 MHz will be available for TVWS use.

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spectrum is effectively wasted. Dynamic spectrum assignment is a viable mechanism to assign the unused spectrum to other parties, on a secondary basis, such that they don't cause any interference with the primary licensee. Re-using the same spectrum hundreds or even thousands of times over, in many small areas, means that spectrum is no longer "scarce".

5. The UHF TV broadcast band, 470 - 694 MHz, is particularly appropriate for the usage of dynamic spectrum assignment. As there are only a total of 189 DTT broadcast locations, and the location, transmitter power, and antenna height, orientation and characteristics of each are well known, this is the easiest case for calculating the radio propagation characteristics of the broadcast signals, and hence the likelihood of a specific TVWS device causing any possible interference to the viewers of the broadcast DTT signal. This paper therefore focusses on the application of dynamic spectrum assignment in the UHF DTT band.

6. In addition, the UHF TV broadcast bands have an unusually large amount of "white space". This is geographical area where specific channels are unused, either in order to mitigate co-channel or adjacent channel interference, or because of low coverage due to topology or population distribution. Figure 2 below shows this in simplistic terms. A particular channel may not be reused by another TV transmitter or SFN for distances measured in hundreds of kilometres, in order to avoid interference. This is represented as the "sterilised area". Note that this remains true for DTT, although one then considers reusing a channel between multiplexes rather than between single transmitters. Also shown in Figure 2 is the unavoidable fact that not all territory will be covered by transmitters using a particular channel. For our purposes, both of these are termed "white spaces".

7. Dynamic spectrum sharing in the context of this discussion paper refers to the use of automated techniques to facilitate the coexistence of unaffiliated spectrum dependent systems that would conventionally require separate bands to avoid interference. Such coexistence may happen, for example, by authorising targeted use of new commercial systems in specific geographical areas where interference with incumbent systems is not a problem. The need to minimize interference risks in the past has resulted in exclusive allocation of specific spectrum bands for specific purposes. While these models are good for coordination between multiple services and operators to avoid interference, they almost always result in underutilization of spectrum. Therefore, more agile technologies and sharing mechanisms could potentially allow large quantities of special-purpose spectrum to be used for more general purposes. For example, enabling dynamic spectrum sharing in the 700 and 800 MHz bands would enable incumbent mobile broadband operators to access these bands today as opposed to waiting for the conclusion of analogue to digital migration and the subsequent clearing of TV operations in these bands.

8. In the past decade, governments and regulators around the world have embraced the concept of spectrum commons[4] as a way to bring innovative wireless technologies to citizens. Spectrum commons refers to frequency bands, such as those bands used for Wi-Fi technologies, for which regulators do not grant exclusive licenses, but instead protect

[4] Spectrum commons is usually also used interchangeably with license-exempt or unlicensed spectrum, although in South Africa the term "unlicensed" implies illegal use. The correct term is "licence-exempt" for our purposes.

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against interference and achieve important operational safeguards through equipment certification and technical rules for utilizing the spectrum, often limiting transmission power. The result of this shift has been dramatic, noting the uptake of new technologies for nomadic Internet access. Spectrum commons has been, and continues to be, a powerful catalyst for innovation and investment. Today, over ten billion Wi-Fi devices have been shipped, with some 4.5 billion devices currently utilizing spectrum commons on a license-exempt basis to connect to the Internet[5]

9. On the other hand, it is challenging to provide any sort of guarantee for commercial services when anyone can switch on a new access point and interfere with an existing hotspot when using licence-exempt spectrum. This paper therefore also addresses the issue of what form the licensing framework for TVWS should take. Should it be licence-exempt, light licensed, or fully licensed[6] – or some combination of these three?

10. The portion of the radio frequency spectrum under 1 GHz has desirable properties for connecting sparsely populated areas, such as the currently unconnected rural areas, as well as to enable low power and low bandwidth connectivity required by machine-to-machine communication. The recently published IMT roadmap has repurposed the 698-794 MHz (700 MHz) and the 794 – 862 MHz (800 MHz) bands as IMT bands, leaving 470 – 698 MHz as the Digital Terrestrial Television (DTT) band. This paper proposes dynamic spectrum assignment to the DTT band on a secondary-user basis for providing data services, such as broadband and machine-to-machine communication.

The discussion paper further proposes that several studies be commissioned to identify suitable spectrum for the next phases of dynamic spectrum assignment outside TVWS operation. The studies could be in the form of laboratory experimentation, as well as field demonstration, in collaboration with the incumbent holders of spectrum

11. This discussion paper is a result of research carried out by CSIR Meraka Institute[7], the University of Pretoria and the University of the Witwatersrand[8] in collaboration with the Authority. Research contributing to the discussion paper includes the TVWS trial in Cape Town conducted by the CSIR in partnership with Google, TENET, WAPA and the eSchools Network. The trial demonstrated fixed broadband connectivity at data rates higher than the current SA Connect targets for 2016 without causing interference to the primary users. The study went further than other TVWS studies conducted in the USA and the UK, to demonstrate TV white spaces service in channels adjacent to both analogue and digital TV spectrum bands. A learnings and recommendations document[9] arising from this project

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[5] https://www.abiresearch.com/market-research/product/1021330-wi-fi/
[6] http://www.spectrumconsult.net/wp-content/uploads/2015/LE-spectrum-whitepaper.pdf
[7] CSIR signed an MOU with ICASA to collaborate among other things in TV white spaces and cognitive radio studies. Funding for CSIR was provided by the Department of Science and Technology.
[8] The two universities received research funding from ICASA under the Spectrum Research Collaboration Programme
[9] http://www.tenet.ac.za/tvws/recommendations-and-learnings-from-the-cape-town-tv-white-spacestrial

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has recently been cited by the Federal Communications Commission[10] (FCC) as the reason for them to request modification of the technical rules for TV white spaces in the USA[11].

12. This discussion paper argues that it is in the best interests of South Africa's digital future and in accordance with the strategic objectives of the National Development Plan (NDP) and SA Connect to increase broadband access and usage, and that a regulatory framework designed for dynamic spectrum assignment for TVWS and other spectrum bands advances this interest. The consultation process invites comment on this regulatory perspective and, in particular, on the specific approaches, requirements, challenges and concerns that would have to be addressed in introducing such spectrum regulatory reform.

[10] USA communications regulator
[11] https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-144A1.pdf

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Figure 1: View of available DTT spectrum across geographic areas, for four out of seven multiplexes

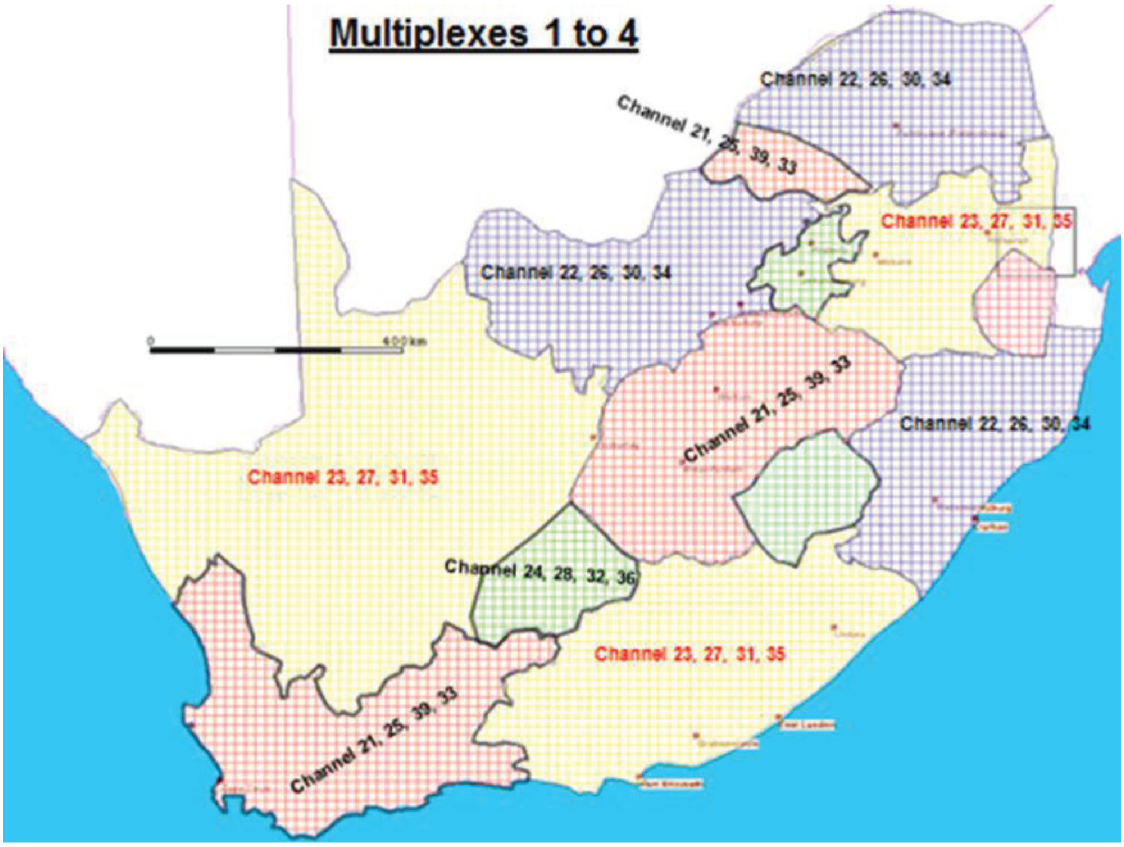
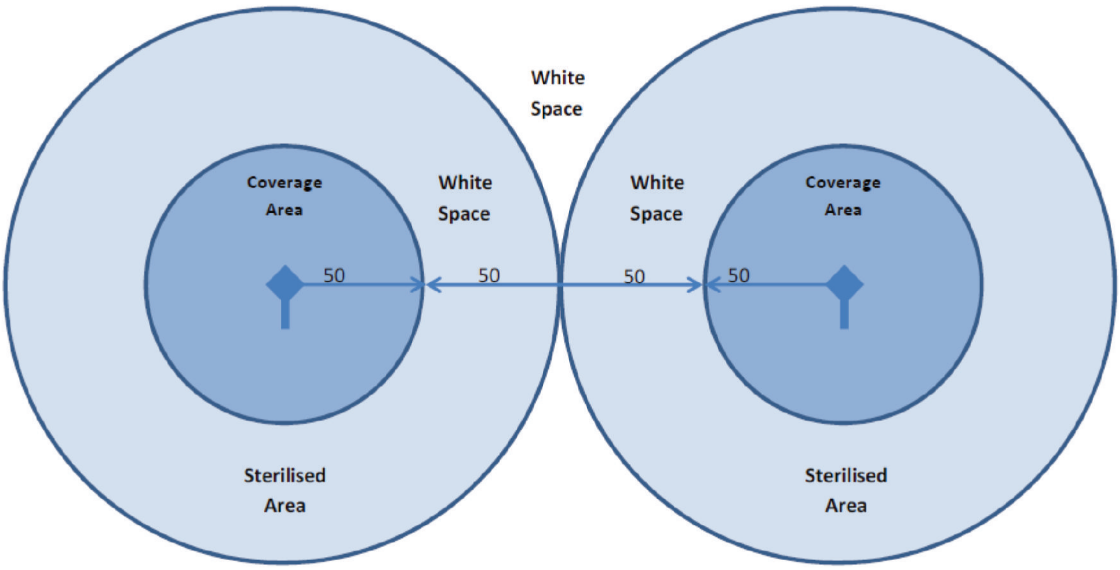


Figure 2: Illustration of Co-Channel and unused TV White Space



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2 Definitions

Administrative Incentive Pricing (AIP). A system for calculating annual spectrum fees introduced by the Authority with effect from April 2012 that very roughly mimics market dynamics. Note that the relation between the AIP fees and actual market value is tenuous at best. Nevertheless, it has led to considerable rationalisation of spectrum holdings by various licensees.

Allocate. In spectrum terms, allocate means to determine that a specific portion of the spectrum is to be used for specific purposes. These purposes are coordinated via the ITU on a regional or global basis.

Assign. In spectrum terms, spectrum that is allocated for a specific purpose may be assigned to a specific user of that spectrum, and the user provided with a spectrum licence by the Authority.

Authorised Service. Any usage of spectrum that is authorised by the Authority, either directly or indirectly. This includes the long term assignment of spectrum for broadcasting purposes (primary use), licensed TVWS devices and light licensed TVWS devices. It may include or exclude licence-exempt TVWS device and certain ancillary services, such as radio microphones and STLs.

Available Frequency. A frequency range that is not being used by an authorized service of a higher priority at or near the same geographic location as the WSD and is acceptable for use by a White Space Device under the provisions of this framework. Such frequencies are also known as White Space Frequencies (WSFs).

Broadcast Television Frequency Band. A frequency range that is primarily allocated to television broadcasting service, e.g. the 470 – 694 MHz UHF DTT band

Channel. A single DTT broadcast channel is 8 MHz wide. When discussing Available Frequencies, these will always be in blocks of 8 MHz, within the DTT band. Used synonymously with "Available Frequency". Other channel widths may apply in other bands.

Client device. A WSD that does not use access to a geolocation database to obtain a list of available frequencies. It may or may not have an automatic geolocation capability. A client device must obtain a list of available frequencies on which it may operate from a master device. A client device may not initiate a network of WSDs nor may it provide a list of available frequencies to another client device for operation by such device. Used synonymously with Slave WSD

Contact verification signal. An encoded signal broadcast by a master device for reception by client devices to which the master device has provided a list of available frequencies for operation. Such signal is for the purpose of establishing that the client device is still within the reception range of the master device for purposes of validating the list of available frequencies used by the client device and shall be encoded to ensure that the signal originates from the device that provided the list of available frequencies. A client device may respond only to a contact verification signal from the master device that provided the list of available frequencies on which it operates. A master device shall provide the information needed by a client device to decode the contact verification signal at the same time as it provides the list of available frequencies.

Coordination. In the context of spectrum management, coordination is the process of analysing spectrum usage in order to ensure that interference between uses does not occur. This is usually carried out with the help of a radio frequency propagation modelling tool.

Fixed device. A WSD that transmits and/or receives radio communication signals at a specified fixed location. A Fixed WSD may be either a Master or Slave WSD.

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Geolocation capability. The capability of a WSD to determine its geographic coordinates in WGS84 format, usually using GPS. This capability is used with an approved Geolocation Database to determine the availability of frequencies at a WSD's location.

Geolocation database. A database system that maintains records of all authorized services in the frequency bands approved for WSD use, is capable of determining available frequencies at a specific geographic location, and provides lists of available frequencies to Master WSDs. Geolocation databases that provide lists of available frequencies must be authorized by the Authority.

High Demand Spectrum. A number of bands, coordinated as IMT through the ITU, are deemed "high demand" because they are coordinated in sufficiently large markets to mean that device manufacturers find it worthwhile to design and manufacture equipment in sufficient quantities to mean that consumer equipment is easily and cheaply available. These bands include the 700, 750, 800 and 850 MHz bands, as well as the 1.8, 1.9, 2.1, 2.3, 2.6 and 3.5 GHz bands. Section 31(3) of the ECA obliges the Authority to define procedures and criteria for assigning this spectrum. Despite several attempts, this has not yet happened in South Africa.

IEEE. The Institute of Electrical and Electronic Engineers. A US-based organisation with global membership. It plays an important standard-making role, generally with many competing vendors of equipment negotiating common standards for equipment.

IETF. The Internet Engineering Task Force. An organisation with open membership which approves the standards (RFCs) that govern the way in which the Internet operates. Its motto is "Rough consensus and running code". It falls under and is funded by the Internet Society.

IMT. International Mobile Telephony is a definition by the ITU of certain bands for mobile or fixed use, primarily today for broadband access to the Internet.

Interleaved spectrum. Interleaved spectrum means permitting the co-use, or sharing, of spectrum band(s), subject to obtaining the prior permission of the Authority. In the context of this paper, it refers to enabling secondary (or lower) use of spectrum for other purposes than the primary authorisation. Thus, broadband TVWS use of unused broadcast spectrum.

ITU. International Telecommunications Union. A global body (falling under the United Nations) to which member states subscribe and negotiate various things, including spectrum allocations.

Master device. A WSD that uses a geolocation capability and access to a geolocation database, either through a direct connection to the Internet or through an indirect connection to the Internet by connecting to another master device, to obtain a list of available frequencies. A master device may select a frequency range from the list of available frequencies and initiate and operate as part of a network of WSDs, transmitting to and receiving from one or more other WSDs. A master device may also enable client devices to access available frequencies by (1) querying a database to obtain relevant information and then serving as a database proxy for the client devices with which it communicates; or (2) relaying information between a client device and a database to provide a list of available frequencies to the client device.

Network initiation. The process by which a master device sends control signals to one or more WSDs and allows them to begin communications.

Operating frequency. An available frequency or channel used by a WSD for transmission and/or reception.

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Personal/portable device. A WSD that transmits and/or receives radio-communication signals at unspecified locations that may change.

Primary. A primary spectrum licensee has protection, via the Authority, from all other users of the spectrum, whether licensed, licence-exempt or unlicensed.

Priority. Where multiple users of spectrum may be sharing that spectrum, such as for broadcasting purposes, licensed TVWS devices, light licensed TVWS devices, licence-exempt TVWS device and certain ancillary services, such as radio microphones and STL, it is essential that these uses form an ordered list of priorities, such that uses at a higher priority level are protected from interference by uses at a lower level.

Protection. The term "protection" means that a licensee who is experiencing interference has the right to require the Authority to investigate and ameliorate the cause of the interference.

Reference geolocation white space database. A master database that performs baseline calculations for the country-wide maps of available television white space ("TVWS") channels and their corresponding maximum allowed power levels for WSDs. The maps are to be utilised as regulatory limits by the authorised secondary geolocation white space database administrators.

Secondary geolocation white space database. A database that utilises TVWS availability maps and corresponding power levels calculated by the reference geolocation white space database for the purpose of providing services to end users. Secondary geolocation white space databases are allowed to perform their own calculations for available TVWS channels and corresponding maximum allowed power levels of WSDs provided that their results are identical to or do not exceed the results produced by the reference geolocation white space database.

Secondary User. A user that is only authorised to use spectrum when the spectrum will not cause interference to a primary user. Also usually provided with protection by the Authority against interference caused by others.

Sensing only device. A WSD that uses spectrum sensing to determine a list of available frequencies without reference to a geo-location database.

Shared. When spectrum is shared between two or more licensees at the same level or priority, they are obliged to coordinate their usage in such a way as to not cause interference to each other. Note that in terms of the AIP spectrum fees that a discount of 50% is allowed in this case. Note also that assignment at different priority levels, e.g. Primary and Secondary, does not count as "sharing".

Slave device. A WSD that obtains its available channels and authorisation to operate via a Master device

Spectrum sensing. A process whereby a WSD monitors a frequency range to detect whether frequencies are occupied by a radio signal and to what extent.

Studio – Transmitter Link (STL). It has been the practice in the past for broadcasters to make use of the PtMP spectrum which they are licensed to use for PtP links. In the past, these links were not registered with the Authority, and therefore were not entitled to any protection. The Authority has set in motion a process of migrating these to alternative bands.

Tertiary User. A Tertiary User of spectrum falls lower than a Secondary User in terms of the Priority list.

White space. The frequency bands not used by their primary licensed users at a specific location or at a specific time. See Figure 2

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White space device ("WSD"). A device designed to detect the available frequencies, usually making use of a geo-location database, and utilise these unused channels to transmit signals for Internet connectivity.

3 Background

3.1 Analysis of legislative framework (mandate)

Two pieces of legislation are relevant to framing this discussion paper, namely the Electronic Communications Act No. 36 of 2005 ("the ECA") as amended and the ICASA Act No. 13 of 2000, as amended. Chapter 5 of the ECA provides guidance on the approaches to be adopted with respect to control and management of spectrum (section 30), radio frequency spectrum licences (section 31), control or possession of radio apparatus (section 32), frequency co-ordination (section 33) and regulatory arrangements pertaining to the national radio frequency plan (section 34). Other important sections of the ECA are section 2 on Objects of the Act; section 4 on Regulations by Authority; section 6 on Licence Exemption; section 8 on Terms and Conditions for Licences; and sections 35 and 36 in respect of type approval and technical standards.

The relevant legislative mandate from the ICASA Act No. 13 of 2000 as amended is the duty to manage the radio-frequency spectrum (section 4(3) (c)), the responsibility to conduct sector-relevant research (section 4(3) (h)) and the power to make regulations (section 4(3) (j)). Also relevant is section 4B of this Act, which sets out the power of the Authority to conduct enquiries and the requirements pertaining thereto.

For the purposes of this discussion paper, the most important sections of the relevant Acts are the Electronic Communications Act section 2, section 4, section 30 and section 33; and the ICASA Act section 4(3)(c) and section 4B. In terms of these particular sections of the Act, the Authority can conduct research on topics designed to achieve the objects of the Acts. The relevant object of the Electronic Communications Act is section 2(e) "*ensure efficient use of the radio spectrum*" and the relevant object of the ICASA Act is section 2(b) "*regulate electronic communications in the public interest*".

This clarifies that the Authority has the legislative foundation to propose, request comments, decide on and publish regulations on dynamic spectrum assignment, under the relevant sections that apply to spectrum management and advancement of the electronic communications sector.

The ICASA Strategic Plan for the fiscal years 2015-2019 and Annual Performance Plan for the fiscal year 2014-2015 sets out the following objectives of the Authority in respect of spectrum management reform:

3.2 Spectrum management

Strategic Objective: Establish innovative approaches to technology and dynamic spectrum usage.

	Key Output	Indicator	Baseline 2013/4	Target 2014/5	Target 2015/6
Radio Frequency spectrum and	Framework for the use of 'white space' and a	Position paper on opportunistic spectrum	Model on opportunistic spectrum management and	Position Paper on opportunistic spectrum	Management of research collaboration on selected themes on

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favourable regulatory frameworks for a variety of services including broadband.	Position Paper on implications of cognitive radio technologies published.	management approved and results published in Government Gazette.	International Mobile Telephony (IMT) occupancy measurements and recommendations presented to ICASA Council in March 2014.	management approved and results gazetted.	opportunistic spectrum management prioritised to include innovative trends and knowledge on Policy and Regulations. Leading to Modernised Regulatory Policy and Regimes by 2018/2019.

Key Questions:

Q1. Do you agree that ICASA has the appropriate legislative mandate to address the issues of dynamic and opportunistic spectrum management and TV White Spaces and to build a suitable framework? If the answer is no, please elaborate.

3.3 Key Issues, Purpose and Goals

Regulatory reform is intended to create an environment for efficient utilisation of electronic communications resources, to foster competition, to harmonise local regulation with global and regional regulatory arrangements, and to promote technological innovation for sector advancement. In terms of the NDP, in 2015, sector advancement is specifically about increasing access to the Internet for firms, households, individuals and communities, in order to advance supply and usage of Internet-based services. Future spectrum licensing approaches should therefore seek to promote a wider range of access opportunities to Internet-based services for all citizens, regardless of their geographical locations and their socio-economic status.

3.3.1 Current state of spectrum regulation

Currently, the Authority manages the assignment of spectrum in the same manner that most regulators do, and have done so since the 1960's. There are in fact seven different mechanisms:

i) For spectrum which is licence-exempt, the equipment used must be Type Approved and follow the appropriate limits on output power, etc. Indeed, all radio equipment must be Type Approved. No specific permission is required from the Authority, and no protection is provided by the Authority. The Authority keeps no records of who is using what spectrum where, only what equipment is type approved and therefore allowed for use in South Africa. No radio spectrum licence fee is payable.

ii) For specified spectrum bands in which no protection is provided, and licensees must share channels, such a Citizen Band (CB) radios and ski boats, a simple application is required and authorisation is almost guaranteed. The Authority keeps records of who is using what spectrum, but not where it is used. The minimum annual spectrum licence fee (currently R120) is payable.

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iii) For point to point (PtP) links in various bands, the Authority will check that the proposed link does not interfere with existing users before issuing the licence. Protection from interference is provided. The Authority keeps records of who is using what spectrum and the exact location and transmitter / antenna characteristics. The annual spectrum licence fee, calculated in terms of the AIP PtP formula, is payable.

iv) For point to area (PtA), sometimes called point to multipoint (PtMP), uses, the Authority will authorise usage in a specific geographical area. This may be on a primary or a secondary basis. The assumption is that once assigned, the area involved is “sterilised” and cannot be assigned again in the same area.. A Primary user is protected against all other users. A Secondary user is obliged to avoid interference with the Primary user, but is protected against all other users. The Authority keeps records of who is using what spectrum and the exact location and transmitter/antenna characteristics. The annual spectrum licence fee, calculated in terms of the AIP PtMP formula, is payable.

Similarly, spectrum may be assigned on a “shared” basis within a specific geographical area. In this case the licensees are obliged to coordinate between themselves to avoid interfering with each other. If they are at the same time secondary users, for example, they would also be obliged to avoid causing interference to the primary user, but would be afforded protection by the Authority against other users. Their annual spectrum fees are reduced by 50% in terms of the AIP formula as a result of the sharing.

v) Certain licensees have “bulk assignments”, usually as an artefact of history – from before ICASA was managing spectrum. In these cases, the licensee typically has a national licence for PtP usage, but since the coverage is national, he pays spectrum fees as if it were PtMP. The licensee self-coordinates his own links, and informs the Authority after the fact of which links are installed where. This becomes economic for the licensee if it has many links. It also reduces the delays involved in obtaining a license from the Authority for each link prior to deployment.

vi) In instances where there is insufficient spectrum to accommodate demand, the Authority may prescribe procedures and criteria of assignment. This has never happened in South Africa, but is widely expected to include an auction.

vii) The Authority has recently introduced a new arrangement with the introduction of the Radio Frequency Spectrum Fees Amendment Regulations 2015 for PtP links at frequencies above 50 GHz. The minimum fee (currently R120 per annum) is payable, and the Authority merely needs to be notified of the details of the link. No formal approval process is required, but given full disclosure, the Authority can still investigate interference complaints if necessary.

The exclusive assignment of PtMP spectrum, often on a national basis, can result in significant areas of the country where a particular assigned channel is not used. This may be because there is no commercially viable demand in those areas, or to avoid interference between adjacent base stations in an area, including dense urban areas. These areas where a particular channel is unused are referred to as white spaces – in both the geographical and frequency domains. See Figure 2 again.

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Key Questions:

Q2. Are there any existing licensing models overlooked here?

3.3.2 Four areas of spectrum reform – DSA, above 30 MHz, Power Line Communications (PLC), and Licence- Exempt

At present, the Authority has a defined and workable Spectrum Licensing Framework, up to 50 GHz. There are four main areas where additional work is required: -

(i) Above 50 GHz, the existing Spectrum Fee Regulations, if simply extrapolated, would mean that high bandwidth short distance links would be prohibitively expensive in terms of annual spectrum fees due. In addition, there are several bands above 50 GHz that could usefully be designated licence-exempt, in common with the practice in other countries.

(ii) The Authority has no defined framework for dynamic spectrum assignment, which is the subject of this Discussion Paper.

(iii) Power Line Communications (PLC) is a mechanism that holds some promise for last mile connectivity – an issue that remains a broadband delivery bottleneck in South Africa, but is of critical importance in connecting every citizen. Unfortunately, a long pair of wires over which a high frequency signal is passed is by definition an antenna. Regulations and standards are required to govern the assignment of spectrum for this purpose, without causing interference to other licensees.

(iv) License-exempt spectrum. There are strong arguments that more license-exempt spectrum should be made available. One of the candidate bands is the balance of the 5 GHz band, where it is possible to create 700 contiguous MHz of spectrum – ranging from 5 150 to 5 850 MHz

Key Questions:

Q3. Do you have any comments about these four areas of spectrum reform?
Q4. Do you favour making more licence exempt spectrum available in the 5 GHz band?
Q5. And in any other bands? Be specific, please, and support your recommendations.

3.3.3 Dynamic Spectrum Assignment Approach

Dynamic spectrum assignment (DSA) is one of a range of regulatory approaches that are appropriate to advancing spectrum assignment through licensed and licence-exempt assignment. In this discussion paper, DSA applies only to TV white spaces (TVWS). The report on the Cape Town TV White Space trials recommended that regulators should recognise the potential value of TVWS technology and spectrum sharing (interleaving) enabled by geo-location databases, as a means to promote wireless broadband access for users in “hard-to-serve areas”.

The South Africa Connect Policy specifically motivates that spectrum be “managed efficiently in order to optimise its potential to provide broadband access”. Section 12 of this Policy specifically

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advances the priorities in future spectrum management as “approval of spectrum sharing” and “dynamic spectrum allocation”[12].

Two main uses of radio-frequency spectrum are pertinent to this discussion paper (i) point to point links, for example connectivity at schools over tens of kilometres; (ii) point-to-multipoint links, to provide wireless commons for schools, libraries, clinics, community spaces and private homes.

At present, there is limited spectrum available to provide data services to the individual consumer, whether at a fixed location or mobile, especially in rural areas. This is due to three main factors: Available but unassigned spectrum, e.g. High Demand Spectrum; the unsuitable nature of the spectrum currently assigned to the incumbent mobile operators, most of which is > 1 GHz, and thus not economically viable for their business model in sparsely populated low income rural areas – although it may well be viable for other business models; and the fact that suitable spectrum has not been assigned to anyone else.

The spectrum considered in this Discussion Paper – the UHF TV bands – is firstly, admirably suited to provide cost effective connectivity in rural areas, due to its longer effective propagation distance. It can thus be used for long – over 30 km – point to point links, such as those used to connect schools in the Limpopo TVWS trial. It can also be used over longer distances for point-to-multipoint fixed wireless uses than higher frequencies, around 10 km radius versus 3-5 km such as in the Western Cape TVWS trial. Larger cells with fewer customers become viable and reduce the cost of providing connectivity.

Secondly, the TV bands have good penetration characteristics through buildings and walls. This makes them useful for incumbent operators and others in dense urban areas. It also makes them useful to the consumer, who can achieve a greater range than he can currently with his home Wi-Fi connection. Hotspots can be larger, and may even cover entire small towns and villages. However, the existing limitations on the number of connected users per access point will remain.[13]

3.3.4 Engineering approaches to reducing interference in Dynamic Spectrum Assignment

One of the opportunities in building this innovative approach to spectrum sharing is the current level of advancement of engineering competence available in South Africa with respect to building geo-location databases[14], promoting the accuracy of the relevant data, the accuracy of the algorithms to be applied, the capacity to increase the number of monitoring stations, to prepare accurate propagation models, and to effectively manage dynamic spectrum access. This is not a trivial exercise, but it is necessary to build South Africa’s innovation capacity in the field of electronic communications technologies in general and in spectrum engineering and regulation in particular.

The process of predicting whether interference between licensees using spectrum is likely – and conversely, whether effective communications can be achieved over a specific link by a licensee - depends on complex mathematical modelling, known as radio propagation analysis. There are a number of competing models, all based on variations of the Friis Transmission Equation[15], which

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[12] By which is meant, of course, “dynamic spectrum assignment”

[13] “Standard” 802.11 Access Points can handle a maximum of about 25 connected devices. More recent and advanced technologies have increased this limit. Nevertheless, a limit remains.

[14] A CSIR-developed and locally hosted geo-location spectrum database is in the process of being certified to provide services in the UK by OFCOM.

[15] H.T. Friis, "Proc. IRE," vol. 34, p. 254. 1946

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describes the power received by one antenna when transmitted to another over a distance. The various models are optimised for different situations, such as frequency band, modulation type, range, terrain and "clutter" – buildings and trees. These affect the significance of reflections, refraction and absorption by obstacles in or near the path between the antennas. Each makes use of several tuneable constants, or "fudge factors", to optimise their accuracy. For this reason, field measurements are usually required to verify the accuracy of the prediction.

In addition, the "known" data required for accurate modelling may itself be inaccurate or incorrect. This includes such parameters as the transmitter power, the cable losses to the antenna, the height, orientation, tilt and radiation pattern of the antenna, the receiver sensitivity, etc. All these reasons mean that careful verification of predicted results must be carried out.

It is due to these complexities that the US DSA model is predicated on very simplistic propagation modelling – based on contours. This has been taken to another level by the UK trials – based on 1-hectare blocks, and it is hoped that South Africa will further improve on these. The UHF TV bands are also ideal from this point of view, as there are only 189 main transmitters for the DTT signals. The >1000 analogue Self Help Stations – many of whose characteristics are quite unknown – will all fall away after the switch off of the analogue signal.

The advent of dynamic spectrum assignment thus represents not only a step change in regulatory practice, but is also an opportunity for increasing engineering knowledge and competence in South Africa.[16]

The Authority currently has a handful of (analogue) fixed spectrum monitoring stations around the country. It is in the process of upgrading these to more accurate digital devices with a wider frequency range, but is constrained by the availability of capital. These may be very useful in verifying the calculations carried out by the white space database. Indeed, if the WSDs themselves have even a rudimentary sensing ability, they can also be used very effectively for sensing and verification. It is worth pointing out that they would also be very useful in identifying unlicensed transmitters. By way of illustration, the Hungarian Regulator has a national network of some 2000 spectrum monitoring points, and derives its revenue entirely from selling this service to the mobile and other operators.

When DSA is sufficiently mature, it should be possible to extend the principle to other bands. However, it will be much more challenging to model some 20,000 GSM Base Stations, each with multiple radios and antennas, for example.

Key Questions:

Q6. Do you believe that the Dynamic Spectrum Assignment approach is viable and worthwhile?

Q7. Do we have enough data about the TV broadcast transmitters to be able to model their propagation accurately?

[16] ECA objectives 2(i) and (l)

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4 Comparative Analysis of TVWS Rules and Regulation

4.1 Introduction

Dynamic spectrum assignment, especially TVWS, has received a lot of attention in many countries in recent years. They all have different processes. In general however they have sought inputs from all stakeholders to answer the following questions:

- Does enabling the use of TVWS further objectives of encouraging investment and innovation in the communications sector and ensure efficient use of radio frequency spectrum?
- If so, should devices be subject to a licence-exempt managed assignment spectrum regime or should they be licensed or some combination thereof?
- If a licence-exempt managed assignment spectrum approach is adopted, how should TVWS databases and TVWS database service providers be managed?
- What technical standards and rules should be adopted?

Section 5 introduces discussions on the above and many related questions and request responses to these within the South Africa context.

4.2 United States Federal Communications Commission (FCC)

The FCC process was quite a drawn out, with the initial notice of inquiry issued in December 2002, leading to final TVWS rules being adopted in September 2010, and subsequently revised in 2014. The following are the key milestones in the FCC process:

- In December 2002, the Commission opened a notice of inquiry seeking general comment on the possibility of allowing license exempt devices to operate in the TV broadcast bands at locations and times when the spectrum is not being used by authorized services. *Additional Spectrum for Unlicensed*[17] *Devices below 900 MHz and in the 3 GHz Band,* ET Docket No. 02-380, Notice of Inquiry, 17 FCC Rcd 25632 (2002).

- The Commission adopted a Notice of Proposed Rulemaking with more detailed proposals in 2004. *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No 04-186; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, Notice of Proposed Rulemaking, 19 FCC Rcd 10018 (2004).

- The initial rules were adopted in 2006. These were fairly high level. *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No 04-186; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, Report and Order and Further Notice of Proposed Rulemaking, 21 FCC Rcd 12266 (2006).

- The Commission has elaborated and modified its rules three times since 2006 -- in 2008, 2010, and 2012. *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No 04-186; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd 16807 (2008); *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No 04-186; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz*

[17] In FCC terminology, “unlicensed” is equivalent to our “licence exempt”, whereas in South Africa, “unlicensed” means illegal.

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Band, ET Docket No. 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd 18661 (2010); *Unlicensed Operation in the TV Broadcast Bands*, ET Docket No 04-186; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, Third Memorandum Opinion and Order, 27 FCC Rcd 3692 (2012).

- As mentioned above, the FCC has recently proposed additional changes based on the outcome of the Cape Town trial.

The publication of the final rules for the use of TVWS in September 2010[18] has influenced a number of key activities leading to increased investment in TVWS ecosystems globally. The IEEE has since ratified two technical standards; IEEE802.22 and IEEE802.11af, the adoption of which will lead to investment in manufacturing of standardized equipment for TVWS. The IETF has also ratified a protocol for communication between geo-location databases and TVWS devices, PAWS – RFC 6953[19]. Even before these standards could be ratified, a number of start-up companies as well as existing RF device manufacturers started shipping out proprietary devices and geo-location database companies emerged.

The final rules provide for the following:

- Both fixed and personal/portable devices may operate in the white spaces in the TV bands on a license-exempt managed assignment basis.
- The devices were precluded from transmitting on channels adjacent to the assigned TV channels.
- 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. The Commission must certify databases, but they may be managed by private entities.
- A propagation model based on contours was prescribed for all databases to be certified.

On 26 January 2011, the FCC designated nine companies to provide the database services required for use by TVWS devices[20]; further designations have followed. 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.

On 30 September 2014, the FCC released a notice of proposed rulemaking, which proposes modification to Part 15 of Title 47 of the U.S. Code of Federal Regulation which include proposed use of adjacent channels. This notice cited the Cape Town trial report as one of the studies that influenced the FCC to consider the change of their rules.

Useful links:

- FCC TV Band Device Rules: Title 47 C.F.R. Subpart H
  http://www.ecfr.gov/
- White Space Database Administration

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[18] 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
[19] https://tools.ietf.org/html/rfc6953
[20] 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

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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

4.3 United Kingdom Office of Communications (OFCOM)

Ofcom initiated a consultation entitled "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[21]. Ofcom initiated a further consultation: "TV white spaces - A consultation on white space device requirements" on 22 November 2012[22]. The November 2012 consultation included 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. To mitigate for possible interference, Ofcom has developed an interference management protocol, which enables it to identify devices that can potentially cause interference and may instruct such devices to cease transmission. This approach could increase the amount of spectrum available to TVWS devices without increasing the risk of harmful interference.

Ofcom has completed a pilot of TVWS technology in the United Kingdom (the "Cambridge Trial"). This pilot provided an opportunity for database, service, and equipment providers to conduct further trials using the proposed framework. It demonstrated a proof of concept of Ofcom's proposed framework while gathering further evidence prior to publishing final rules[23].

Companies that participated in the Ofcom pilot were required to comply with the "ETSI Harmonised European Standard for White Space Devices" published in July 2013[24]. The ETSI standard defines the technical specifications of TVWS devices that operate on a license-exempt basis and are controlled by geo-location spectrum databases and to devices that are intended only for fixed use. It also provides a procedure for testing for device compliance.

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[21]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

[22] TV white spaces - A consultation on white space device requirements, 22 November 2012, http://stakeholders.ofcom.org.uk/consultations/whitespaces/,

[23] 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

[24] "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

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The pilot was deemed successful by OFCOM through a statement released on the 12th February 2015[25], which also indicates that Ofcom is ready to move to implementation of final rules.

A further consultation, "TV white spaces: approach to coexistence" was published by Ofcom on 4 September 2013[26]. This document proposes a set of parameters and algorithms designed to ensure a low probability of harmful interference from TVWS devices.

Useful links

- Spectrum management strategy: Ofcom's approach to and priorities for spectrum management over the next ten years http://stakeholders.ofcom.org.uk/binaries/consultations/spectrum-management-strategy/summary/spectrum_management_strategy.pdf.
- TV white spaces: approach to coexistence http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/
- The future role of spectrum sharing for mobile and wireless data services - Licensed sharing, Wi-Fi, and dynamic spectrum assignment http://stakeholders.ofcom.org.uk/consultations/spectrum-sharing/

4.4 Canada

In August 2011, Industry Canada launched a "Consultation on a Policy and Technical Framework for the Use of Non-Broadcasting Applications in the Television Broadcasting Bands below 698 MHz"[27].

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).

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 following:

1. Possible introduction of licence-exempt TV band white space devices;

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25 http://media.ofcom.org.uk/news/2015/tvws-statement/
26 http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/summary/white-spaces.pdf
27 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

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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"[28] 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. The detailed technical and operational rules were published in February 2015, the database rules and TVWS devices technical specifications largely mirror those that were adopted in the United States in order to promote regional harmonisation and capture device economies of scale.

[28] 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, .

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5 Discussion Points

This section highlights key issues and questions for resolution as the Authority considers opening up vacant spectrum in the TVWS frequencies as the first phase of dynamic and opportunistic spectrum management in South Africa.

5.1 Spectrum flexibility

The National Broadband Policy, SA Connect, envisions a widespread communication system that will be universally accessible; such infrastructure providing an enabling platform for economic enterprise, active citizenship, social engagement and innovation. It carries out the NDP and the New Growth Plan, both of which identify the knowledge economy as one of the drivers of job creation. The National Development Plan[29] proposed a roadmap to reach the 2030 vision of "widespread use of ICT by all", that has three phases:

- Phase 1 (2012-2015) removing the constraints to reaching effective regulated telecommunication markets;
- Phase 2 (2015-2020) reaching 100 percent broadband penetration; and in
- Phase 3 (2020-2030) government makes extensive use of ICT to engage with and provide services to citizens.

It is important to note that as we reach the end of the first phase (i.e. 2015) progress has been limited with regard to addressing most of the constraints that have been identified as requiring attention in this phase. The following are the areas that the NDP identified as requiring attention, which are lagging far behind schedule and that the programme we are proposing seeks to facilitate:

i) Adjust the market structures and remove legal constraints to enable full competition in services.

ii) Implement a service and technology-neutral flexible licencing regime to allow flexible use of resources in dynamic and innovative sectors, especially for spectrum that should be made available urgently for next generation services.

iii) Free up spectrum for efficient use, to drive down costs and stimulate innovation.

iv) Spectrum can be allocated with "set asides" or obligations to overcome historical legacies and inequalities in the sector, but this should not delay its competitive assignment.

v) Identify alternatives to infrastructure competition through structural separation of the national backbone from the services offered by the historical incumbent to create a common carrier with open access policies to ensure access by service competitors.

Flexibility with regard to management and usage of spectrum is a fundamental challenge that has to be resolved in order to unlock industry developments and advancements around the issues listed above. This discussion paper proposes a framework for enabling TVWS operation in the frequency range of 470-694 MHz that directly addresses the second and third constraints from the above list, while also indirectly addressing the first and the last constraints. It also broadly reflects recommendations made in the SA Connect policy.

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[29] http://www.gov.za/issues/national-development-plan-2030

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A further motivation for enabling TVWS operation is the advent of industries utilizing massive industrial data to drive Machine to Machine (M2M) or Internet of Things (IoT) connectivity. With these emerging industries, spectrum is becoming an even more critical resource. It is therefore critical that new systems utilize all available frequency bands as efficiently as possible with revolutionary technologies at the cutting edge of future wireless communications. Thus advanced but cost effective ICT infrastructure such as TVWS Networks become an imperative for industrialization, economic development and job creation.

Key Questions:

Q8. Does enabling the operation of TVWS contribute to the objective of ensuring efficient use of radio frequency spectrum?
Q9. Do you believe that it will also further objectives of encouraging investment and innovation in the electronic communications sector?
Q10. What are the benefits that could be expected from making TVWS available?
Q11. What are the disadvantages that could be expected from making TVWS available?
Q12. Do you foresee any risks?
Q13. Does it support SA Connect goals regarding the deployment and adoption of broadband?
Q14. What mechanisms should be put in place for dynamic spectrum assignment in meeting future demand for spectrum?
Q15. Could TVWS provide increased consumer value and/or improved social and economic inclusion?
Q16. What impact is the digital switchover expected to have on the use and availability of TVWS?
Q17. Do you believe white spaces should be utilised without authorisation or licensing?
Q18. Should there be rules for such usage?
Q19. Does the advent of TVWS have the potential to remove the existing "spectrum scarcity", at least in some bands?

5.2 Licensing Models for TVWS

Many authors conflate the runaway success of the unmanaged, license-exempt Wi-Fi model with the potential for license-exempt TVWS. This is a false analogy, as no current TVWS model allows **unmanaged** TVWS usage. The US, UK and Canadian models discussed in Section 4 above, all support **managed** license-exempt TVWS operation.

While Wi-Fi has been extremely successful as an anarchistic model from the point of view of spectrum licensing, its success has depended crucially on the global adoption of IEEE standards for the technical operation, as well as certification by the Wi-Fi Alliance[30] of interoperability of devices. Any Wi-Fi Alliance certified device will talk to any other Wi-Fi Alliance certified device.

The fundamental concept behind TVWS operation is that it is enabled with very strict rules that ensure that no interference with the incumbent broadcasting usage of the spectrum is allowed, while at the same time vastly increasing the efficiency of spectrum usage, by allowing it to be re-used many times over.

[30] http://www.wi-fi.org/

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There are five potential licensing regimes that could be considered for TVWS. These are:

- License-exempt, unmanaged
- License-exempt, managed
- Light-licensed
- Fully licensed
- A mixture of models

An automated licensing can be introduced with any of the managed licensing regimes. The first two regimes are license-exempt regimes and a further case for license-exempt operation is made in section 5.3. Each of these licensing regimes will be briefly discussed below.

Q20.

5.2.1 License-exempt, unmanaged regime

In this model, no record is kept of what devices are using which channels, where. As mentioned above, no one is currently using – or proposing - this model. The reason is that an unmanaged licensing model does not easily lend itself to interference mitigation with existing broadcasting services. If a device is causing interference, it then becomes a nearly impossible task for one to identify that device, locate it, and ameliorate the interference, since there is no record of the device.

In this model, no protection is provided between TVWS devices. Thus, if one WSD causes interference to another WSD, that is a matter between them. The Authority will not intervene on behalf of either party. The only requirement here is that any equipment used must be Type Approved. No spectrum fee is due.

5.2.2 License-exempt, managed regime

Most of the literature that advocates a "license-exempt" TVWS licensing regime is in fact referring to this model. In this case, every TVWS device – or only some of them, in some cases – is registered with the geo-location database. This is the "managed" part. In the event of interference with the primary licensee being detected, the offending Master WSD and its Slave devices can be instructed to cease transmitting on a specific channel.

The "license-exempt" part refers to no specific fee payable for the use of the TVWS device and its associated spectrum and / or that there is no requirement to apply for an explicit licence from the Authority for each device. Nevertheless, WSDs are automatically authorised by the geo-location database to operate on a per-device basis.

In this model, no protection is provided between TVWS devices. Thus, if one WSD causes interference to another WSD, that is a matter between them. The Authority will not intervene on behalf of either party. The equipment used must be Type Approved as in the unmanaged model and no fee is due to the Authority for each device.

5.2.3 Light-licensed regime

In the light licensed (or "Lite", in American terminology) regime, every TVWS device is registered with the geo-location database, but no formal approval process requiring human intervention is required, and a standard low fee is payable to the Authority. As discussed in section 3.2.1 above, this would typically be the minimum fee, which is currently R120 per annum for each device. This would apply whether the device operates for 5 minutes or an entire year.

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In this model, no protection is provided between WSDs. Thus, if one WSD causes interference to another WSD that is a matter between them. The Authority will not intervene on behalf of either party.

5.2.4 Fully licensed regime

In this model, the fee due per device is a function of the area covered and the duration of usage. These parameters are easily calculated by the geo-location database in terms of the existing AIP formulae, as the database has all the data to hand. It would no doubt be appropriate to modify the AIP formula by dividing the spectrum fee by half, for example, in exchange for the undertaking by TVWS devices to immediately vacate any channel where interference is detected.

In this model, protection is provided between TVWS devices. Thus, if one WSD causes interference to another licensed WSD, the interfering WSD may be instructed to change channels, or to cease transmission immediately.

This is of considerable significance, in terms of commercial services. In Wi-Fi in the 2.4 GHz band, for example, the range of an Access Point (AP) is severely limited. Users within range are able to make use of the service with relative ease. Interference can be mitigated – at least to some extent – by the operator adjusting channels and antennas. However, with the lower frequencies involved in TVWS, the range is considerably larger. This increases the potential for interference between WSDs and WSD networks by an order of magnitude. If we hope to make use of TVWS to address the objectives in the SA Connect Policy, then operators must be in a position to not only offer services of a defined quality, but be able to guarantee that quality. This is impossible if any third party can start to transmit on channels used by the operator without either warning or authorisation.

One of the reasons that there is a lot of support for the license-exempt model in the literature comes from the disadvantages of the traditional licensing regime. This is in essence a centralised "command and control" approach that inevitably results in delays as a result of the need for human intervention. In addition, if the traditional methods of enforcement are used, with Inspectors sent into the field to track down rogue transmitters, there is a question of sufficient capacity.

Fortunately, the advent of automated geo-location databases allows us to avoid these problems, as will be developed in the next section.

5.2.5 Mixed Regime

There is therefore a case to be made for some mixture of these models. Perhaps one should consider a regime where we have a hierarchy of uses:

1. Incumbent broadcasters, with permanent spectrum licences recorded in the geo-location database. While no fee is payable by broadcasters at present, they are provided with protection
2. Licensed WSDs, licensed via an automated process, with a fee payable and provided with protection
3. License-exempt WSDs, authorised to operate via an automated process, with no fee payable and no protection

In this case it could be argued that one can achieve the best of all worlds. The incumbent broadcasters are protected in all cases. Those operators who wish to pay the appropriate fees are in

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a position to provide services of a specified quality to their customers, with an appropriate SLA[31], and are provided with protection in exchange for a fee payable. Those who have no desire to provide a specific quality of service, or perhaps more appropriately, those who are using TVWS technology for an expanded home network – "Super Wi-Fi" – are under no obligation to pay any fee, but at the same time have no guarantee of service.

It's important to note that whichever model – or combination of models – is chosen, no change is required to the devices themselves. Thus, whatever models South Africa adopts, "standard" WSD may be used. The differences lie in the back-end of the operation of the databases and the licensing regimes that they implement.

[31] Service level Agreement

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Key Questions:

Q21. Is there a space for license-exempt, unmanaged use of TVWS?
Q22. Is there a space for license-exempt, managed use of TVWS?
Q23. Is there a space for licensed use of TVWS?
Q24. If so, should licensed users pay the minimum annual fee, or a fee proportionate to use?
Q25. Does the combination give us the best of both worlds?
Q26. Which of the licensing regimes do you favour? Why?
Q27. Rank the licensing regimes in order of preference with reasons for your preferred order.

5.2.6 Automated Licensing

The central concept behind the operation of a geo-location database for dynamic spectrum assignment is as follows: The Authority defines certain rules that govern the operation of the database, as well as the characteristics of the WSDs that may be used. In addition, the Authority defines an interference mitigation protocol. All this is typically done using a consultation process with interested parties, who would include broadcasters, equipment manufactures and operators.

The appropriate data is supplied to the database, and calculations based on the defined rules are carried out by the database in an automated manner. WSDs are registered with the database, following a defined protocol.

When WSDs are deployed in the field, they are matched with the pre-existing registration data and provide their locations and bandwidth requirements. The database carries out the appropriate calculations and authorises the WSDs to operate on specific channels, as a fully automatic process, ensuring that no interference is caused by the WSD to any higher priority uses.

Thus, there is no need for human intervention during the normal running of the system. Spectrum is assigned dynamically and automatically, as needed. The database records the locations of all WSDs for which locations are provided, and if WSDs without geo-location capability are allowed, the Master Devices to which they are attached, which provides an indication of their approximate location. The database has full information about which devices are where, what their operating range is, and for what durations they are operating on which channels. It is then a simple matter for the database to also calculate the AIP spectrum fees that would be due, if any.

In the event that interference is experienced, whether by a TV viewer or by a licensed WSD, the Interference Protocol is invoked, and the offending WSD may be located via the database and instructed, again via the database, to cease transmitting on the offending channel. The WSD can, of course, request an alternative channel.

Key Questions:

Q28. Do you see this as possible? Why / why not?
Q29. **Does this provide a significant improvement on the status quo?**
Q30. If some form of this approach is adopted, how should TVWS databases and TVWS database service providers be managed?

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5.3 Licence-Exempt Use of spectrum

Wireless access to the Internet is a key enabler of 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 both consumers and businesses.

A number of studies have analysed the potential value to be derived from allowing licence-exempt access to spectrum[32]. Thanki quantifies the value of Wi-Fi to fixed broadband and mobile network operators by country. 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 1: Economic value generated by Wi-Fi through fixed broadband value enhancement

[32] See, for example,
(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 .
(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 .
(3) "The Case for Unlicensed Spectrum" by Paul Milgrom, Jonathan Levin and Assaf Eilat, http://www.stanford.edu/~jdlevin/Papers/UnlicensedSpectrum.pdf (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 .
(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 .

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He further presents the value of Wi-Fi to mobile network operators in terms of additional base stations which would need 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 2: 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

Thanki argues that 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-1 GHz spectrum". He therefore concludes that TVWS operation 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.

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

Licence-exempt wireless technologies currently contribute significantly to the economy by expanding network reach and improving network management[33]. 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, to support the expansion of cellular offload, and to network the millions of devices that will compose the coming "Internet of Things"[34]. As noted

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[33] 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.

[34] "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. Developed by Kevin Ashton in 2009, the concept describes a system where the

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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.

Key Questions:

Q31. From a South African perspective what will be the socio-economic benefits of TVWS?
Q32. Will TVWS be of the most benefit to rural or urban areas? Please provide reasons – technical and socio-economic

5.4 Creating a Regulatory Framework for Dynamic Spectrum Assignment

As discussed above, a large fraction of the UHF DTT broadcast bands are unused at any one place. We term these TV White Spaces. By defining the rules of operation of a geo-location database and related processes (see section 5.2.5), the Authority can implement a regulatory framework for dynamic spectrum assignment.

This in turn will allow otherwise unused UHF spectrum to be used – often many times over in different areas – thus relieving the so-called "spectrum scarcity". More particularly, it will assist South Africa in achieving its objectives in SA Connect of providing fast, cheap broadband connectivity to the entire population.

Regulators can enable the use of Dynamic and Opportunistic Spectrum Assignment by designating selected bands as 'interleaved' or shared spectrum. This paper proposes that the UHF DTT bands should be the first candidate for this. However, given the successful demonstration of this approach, the methodology may be extended to other bands.

Specifically, regulators should establish the technical parameters for TVWS operation and establish procedures and rules for TVWS devices to access available spectrum. This approach would allow devices to use available channels in this band, based on a set of rules and supporting technologies, and doing so without causing harmful interference to licensed users.

Key Questions:

Q33. Please provide proposals on the regulatory framework (including none at all) for TVWS
Q34. What are the advantages and disadvantages of different methods?
Q35. How should South Africa define TVWS?
Q36. How will the rules for non-compliance apply?

5.5 On What Basis should TVWS Usage be allowed?

A regulatory framework must address whether or not 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.

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.

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An argument is advanced above for adopting a mixed licensing model managed assignment approach (i.e. licensed and licence-exempt assignment managed by a database that provides information on which channels are available in a given location) on the basis that this could have significant benefits to the economy, businesses and consumers by allowing the development of new and innovative types of White Space Devices.

Key Questions:

Q37. On what basis should white space use in the 470–694 MHz band be authorised?
Q38. Do the benefits of adopting a licence-exempt managed assignment approach apply?
Q39. If a licence-exempt managed assignment approach is adopted, what registration requirements, if any, might apply?
Q40. Do you think that licensed use of TVWS requires the operator to have an ECNS licence?

5.6 White Space Databases and Spectrum Sensing

Introducing TVWS requires that the Authority develops appropriate technical standards and specifies appropriate operating parameters to mitigate the potential for harmful interference.

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

This implies that, under a managed spectrum assignment approach, the Authority need not be as conservative when establishing power restrictions, and can allow considerably more flexibility when developing technical rules applicable to TVWS devices, as compared to unmanaged services, such as Wi-Fi.

Spectrum sensing techniques can be used to enhance the accuracy in the detection of incumbent services performed by spectrum databases. The techniques when combined with spectrum databases have the potential to minimise the possible under-protection of incumbent services - "false-vacancy" error, or the over protection of incumbent services - "false-occupancy" error - that might be caused by radio propagation models when spectrum databases are used alone. In order to augment spectrum databases, some strategically positioned measurement devices can improve the databases' accuracy significantly with only a modest amount of measurements[35].

As noted above, 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:

Q41. Should the white spaces database approach be adopted and or is there an alternative system?

[35] Chakraborty, Ayon, and Samir R. Das. "Measurement-Augmented Spectrum Databases for White Space Spectrum." (2014).

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Q42. What additional measurements should be adopted for greater accuracy?
Q43. Should the Authority allow – or require - sensing as an option at this time?

5.7 Provision of Information Regarding Incumbent Operations

Database providers in other jurisdictions, in order to protect incumbent operations, have relied, partially or entirely, 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

Key Questions:

Q44. What mechanisms should be put in place to ensure that database providers obtain information required to protect incumbent operations (e.g. location of TV transmitters)?
Q45. What mechanisms should be put in place to ensure that broadcasters and/or signal distributors provide the Authority and database operators with accurate updated information?

5.8 Management of White Spaces Databases

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

The Authority must, however, retain ultimate authority and responsibility for the operation of TVWS databases in order to protect licensed users against harmful interference. The Authority, therefore, must develop and implement a set of criteria for officially recognising a white space database; including the circumstances under which such recognition may be suspended or withdrawn.

The regulatory framework should permit multiple databases to operate simultaneously and the Authority is to consider imposing a regulatory obligation for white space databases to share information or otherwise cooperate with each other.

Management options for white space databases include the following:

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

Key Questions:

Q46. What parameters should the Authority set forth for TVWS databases?
Q47. What criteria should be used to certify, recognise, or authorise TVWS databases?

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Q48. How should the Authority approach issues such as non-discrimination, security, and quality of service?

5.9 Technical Issues

5.9.1 Types of White Space Devices

Under the FCC and Industry Canada approach, white space devices 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**[36]: the WSD transmits and receives communications while moving or from different unspecified fixed points. Mobile WSDs can in turn be categorised as follows:
  - Mode I mobile WSDs ('Client WSDs') which do not use an internal geolocation 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 geolocation capability to access a white space database either directly or through another Mode II WSD.

Ofcom's proposed rules 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.

<u>Key Questions:</u>

Q49. Should the Authority require the registration of some or all devices? If only some, which devices?
Q50. Should mobile devices be obliged to have geolocation determination capability? How should the regulatory framework differentiate among devices types?
Q51. What rules should be attached to each type of device?
Q52. Should operating parameters differ by device type or technology?

5.9.2 Operational Parameters

5.9.2.1 Power Output

The Cape Town trial followed the FCC's approach, which had a fixed power of 4 W for the devices used (these are fixed devices in the FCC's classification or Type A in Ofcom's classification). An

[36] Mobile devices can be nomadic or transportable.

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alternative approach has been adopted by Ofcom, which 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 significantly increase the amount of spectrum available to TVWS devices without increasing the risk of harmful interference.

The Authority is of the view that in order to increase the potential range and utility of TVWS devices, transmitter power levels should be determined and limited by the database and that when there are no TV broadcasters in adjacent channels, transmission power higher than 4 W should be allowed.

Key Questions:

Q53. Should transmit power levels be different for different device types?
Q54. Should the Authority consider a variable power limit which could increase the utility of spectrum for devices?
Q55. Should there be a maximum power output and what maximum power level should the Authority consider?
Q56. Should licensed devices be allowed a higher power limit than licence-exempt devices?

5.9.2.2 Channels Available for Use

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) and in both cases no interference was detected.

Key Questions:

Q57. Recognising that allowing adjacent channel use would significantly improve spectrum utilisation and increase the amount of spectrum available for use by TVWS devices, should the Authority permit TVWS devices to operate in channels adjacent to incumbent operations? Please substantiate
Q58. Are there any substantiated concerns regarding harmful interference associated with adjacent channel operation?

5.9.2.3 Out-of-Band Emissions

The devices used in the Cape Town Trial were developed to meet FCC rules, have been tested in the lab by the CSIR Meraka Institute, and operate very tightly within the band. Use of devices that conform to these standards reduces the chances of interference and increases channel availability.

Key Questions:

Q59. Should the Authority establish out of band emissions limits in order to improve spectral efficiency? If so, what are your recommendations to protect incumbent operators? What out-of-band emissions rules will best improve spectral efficiency and protect incumbent operations?

5.9.2.4 Propagation Model for Interference Calculations

Availability of frequencies for use by TVWS devices may be determined based on the geolocation and either the database method or on the spectrum sensing method or a combination of both

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methods. The database method implements propagation algorithms and interference parameters to calculate operating parameters for the devices at a given location.

Key Questions:

Q60. Should the Authority mandate a particular propagation model for database providers?
Q61. Which propagation model or models are most accurate for this application?
Q62. Which model or models maximise spectral efficiency?
Q63. Which models best protect incumbent operations?
Q64. Overall, what is the appropriate method of determining the required protection from authorised users in the TV bands?

5.9.3 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 occurred in November 2013[37].
- IEEE 802.22 is a standard for wireless regional area network (WRAN) using TVWS[38]. It is focused on rural broadband connectivity.
- The Protocol to Access White Space (PAWS V.1 IETF release) is a standard for a communications protocol between WSD and spectrum databases.
- Some vendors developed proprietary technologies for use in TVWS spectrum. For example, the Cape Town Trial used a proprietary radio technology from Carlson Wireless.
- Some trials have used the Time-Division Long-Term Evolution standard in deploying white space devices[39].

5.10 General

Key Questions:

Q65. On balance, do the potential benefits of permitting licence-exempt managed assignment TVWS devices outweigh any potential risks?
Q66. Do the techniques discussed above adequately mitigate any interference potential?
Q67. Should we oblige every device to have GPS location capability?
Q68. In the US model, only latitude and longitude was required of GPS location. Is there any reason why we shouldn't demand full 3D location?

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[37] "Official IEEE 802.11 Working Group Project Timelines", http://www.ieee802.org/11/Reports/802.11_Timelines.htm
[38] See "IEEE 802.22 Working Group on Wireless Regional Area Networks", http://www.ieee802.org/22/
[39] 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

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Q69. What about the situation where a fixed device is professionally installed with an external antenna and an internal unit. Should we accept the location details provided by the installer? Using what mechanism?

5.11 Process for authorizing TVWS operation

Following this consultation process, if the decision is taken to authorize the TVWS operation, the following regulatory and technical documents will need to be developed or revised in light of that decision:

TVWS devices and databases:

- A new Radio Standard Specification (RSS) for certification of TVWS devices;
- TVWS database requirements document;
- A procedure document for becoming a TVWS database administrator, including the associated agreement;
- A defined process for registering WSDs prior to deployment; and
- An interference mitigation protocol.

These documents will be developed or revised using the Authority's established processes, including consultation with stakeholders

5.12 Roadmap for dynamic and opportunistic spectrum management in South Africa

A case has been made in this paper on the potential of dynamic and opportunistic spectrum management to improve efficiency in the TV bands. Given that there are still other bands that remain under-utilized, the spectrum efficiency of dynamic and opportunistic management can extended to other bands. It is technically possible to share these bands using combinations of administrative means (including assignment in time and in geography, and interference management constraints) and technical solutions (including smart transmitters such as Software Defined Radios and cognitive radios)[40]. This discussion paper further proposes that, in preparation for wider application of dynamic and opportunistic spectrum management beyond TVWS operation, studies be commissioned to identify candidate spectrum bands for this mode of spectrum sharing. The following questions should be included in the study:

- How far to zoom in to specific bands?
- What are the current activities in specific bands?
- What are specific propagation characteristics in specific bands?
- What is the value of DSA in specific bands?

<u>**Key Questions:**</u>

Q70. Do you believe that Dynamic Spectrum Assignment should be applied to other bands, beyond the proposed TVWS operation? Plea/se provide reasons?

Q71. If so, which bands should be considered next?

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[40] http://www.ictregulationtoolkit.org/5.4

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Q72. Are the study questions above the most relevant?
Q73. Are there additional study questions that you would propose?

5.13 Other spectrum users

Certain other uses of the UHF TV band also exist, such Studio-Transmitter Links (STL) and short range devices, including wireless audio systems. These are largely allocated in the 862-890 MHz band.

Key Questions:

Q74. Are there any additional devices or services in the 470-698 MHz UHF DTT band that should be considered in authorising use of TVWS?

6 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/

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Appendix A: Spectrum Research Collaboration Contributions

A.1 CSIR Research in Dynamic and Opportunistic spectrum Assignment

The CSIR has carried out research, development and innovation (RDI) in dynamic spectrum utilization and cognitive radio for the past several years. Research on cognitive radio platforms, dynamic spectrum management, future wireless and spectrum management research has been carried out to understand the state of the research field in dynamic spectrum assignment (DSA) technologies, policy and regulation. The CSIR has also driven research, development and innovation in geo-location white space spectrum databases (WS-GLSD), DSA methodologies and propagation rules. This was focussed on enabling dynamic spectrum TV white spaces broadband networks (TVWS-BN), resulting in two experimental TVWS-BNs, which have been launched as experimental test-bed networks. The following are the main contributions from the CSIR on the Development of an Opportunistic and Dynamic Spectrum Management Framework. A more detailed description can be found in the non-exhaustive list of peer-reviewed publications listed below.

- A national geo-location spectrum database allocation system for enabling TV white space broadband networks in South Africa.
- Two trials of the TV white spaces technologies in South Africa that attracted participation by local industry and funding by two large multinational corporations (Google and Microsoft) and experimentation with wireless mesh network techniques in the TV white spaces spectrum bands
- Support for three PhD studies – one conferred and two on-going
- Publication of one book, five book chapters, three journal papers and twenty conference papers
- Development of a TV white space mesh capable radio that connects to the CSIR-developed Geo-location spectrum database and is able to build mesh networks over both Wi-Fi and TV white space channels.

1. Publications Indicators:

I- Spectrum Policy and Dynamic Spectrum Frameworks (Papers 1-4,8-11,14,15)

The publications under this column, deal with Dynamic Spectrum Assignment policy and regulatory frameworks and technology standards underpinning them. The papers also include perspectives and best practices on dynamic spectrum networks, spectrum sharing and emerging spectrum licensing regimes from the regulator, broadcaster and telecommunication(s) operator viewpoint.

II- Spectrum Databases as a Dynamic Spectrum toolbox (Papers 4-7,18,20)

The publications under this column describe spectrum databases as a toolbox for dynamic spectrum regulation and interference mitigation. The papers also describe the development of the South African national geo-location spectrum database (GLSD) as an enabler to TVWS networks and a co-existence planning tool. The papers describe the development focussing on the TV band frequencies and interference protection of incumbent TV broadcasters. Cloud infrastructure for hosting spectrum databases, PAWS protocol development for device access to databases is another area addressed in the list of papers.

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III- Cognitive Radio & White space networks (Papers 12-13,16-17,19-21)

The publications under this column describe spectrum sensing and dynamic spectrum measurements using cognitive radio platforms. Comparative study of cognitive radio platforms and good practices in spectrum sensing and cognitive spectrum decision frameworks is described in these list of papers.

Conference Papers:

[1] Mfupe L, Mzyece M, Masonta M, Olwal T, and Dynamic Spectrum Access: regulations, standards, and Green radio policy Considerations, Proc. Conf. Southern African Telecommunication Networks and Applications (SATNAC), George, South Africa, September 2012.

[2] Mfupe LP, Mzyece M, Mekuria F, TV White Spaces for Wireless Broadband in Rural Areas: the regulator, broadcaster and telecommunication(s) operator viewpoint, Proc. Int. Conf. IST-Africa, Dar es Salaam, Tanzania, May 2012.

[3] Olwal T, Mfupe L, Masonta M, Mzyece M, Broadband ICT Policies in Southern Africa: Initiatives and Dynamic Spectrum Regulations, Proceedings International Conference. IST-Africa, Nairobi, Kenya, May 2013.

[4] Mfupe L, Mekuria F, Montsi L, Spectrum Databases-as-a Service for Broadband Innovation and Efficient Spectrum utilization. Proceedings of International Conference, World Congress on Multimedia and Computer Science (WCMCS- 2013)*,* ISBN: 978-9938-9511-6-5, pp. 185-191, Hammamet, Tunisia, October 2013, Available from: http://searchdl.org/index.php/conference/view/728

[5] Mfupe L, Mekuria F, Montsi L, Spectrum Resource-as-a-Service: Cloud Architecture Framework for Dynamic Spectrum Request Response Networks, AFRICOMM 6th International Conference on e-Infrastructure and e-Services for Developing Countries, Kampala, Uganda, November 2014.

[6] Mfupe L, Montsi L, Mzyece M, Mekuria F, Enabling Dynamic Spectrum Access through Location Aware Spectrum Databases, Proceedings. Int. Conference. IEEE-Africon, Mauritius, September 2013.

[7] M. T. Masonta, T. Olwal, F. Mekuria and M. Mzyece, “Standard Compliant Channel selection scheme for TV white space networks”, *SATNAC 2014*, 31 Aug – 03 Sep. 2014, Port Elizabeth, South Africa.

[8] M.T. Masonta, A. Kliks and M. Mzyece, “Framework for TV White Space Spectrum Access in Southern African Development Community (SADC)”, *Proc. of 24th IEEE Int. Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, London, UK, 08-11 September 2013.

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[9] M.T. Masonta, A. Kliks and M. Mzyece, "Television White Space (TVWS) Access Framework for Developing Regions", *Presentation at the Workshop in IEEE Africon,* Mauritius, 9-12 September 2013.

[10] M.T. Masonta, F. Mekuria and M. Mzyece, "Analysis of THE AUTHORITY Broadcasting Frequency Plan for Possible use of TV White Space for Broadband Access", *Proc. of the* Southern Africa Telecommunication Networks and Applications Conference (SATNAC), Stellenbosch, South Africa, 1-4 September 2013.

[11] T. Olwal, M.T. Masonta, L. Mfupe, and M. Mzyece, "Broadband ICT Policies in Southern Africa: Initiatives and Dynamic Spectrum Regulation", *Proc. of IST Africa*, Nairobi, Kenya, 29-31 May 2013.

[12] M.T. Masonta, M. Mzyece & F. Mekuria, "A Comparative Study of Cognitive Radio Platforms", *Proc. of ACM Int. Conference on Management of Emergent Digital EcoSystems (MEDES),* pp. 145-149, Addis Ababa, Ethiopia, 28-31 October 2012.

[13] M.T. Masonta, Y. Haddad, L. De Nardis, A. Kliks & O. Holland, "Energy Efficiency in Future Wireless Networks: Cognitive Radio Standardization Requirements", *Proc. of IEEE Int. Workshop on Computer-Aided Modelling Analysis and Design of Communication Links and Networks (CAMAD),* Barcelona, Spain, 17-19 Sep. 2012.

[14] L. Mfupe, M.T. Masonta, T. Olwal & M. Mzyece, "Dynamic Spectrum Access: regulations, standards and green radio policy considerations", *Proc. of SATNAC,* 02-05 Sep. 2012.

[15] M.T. Masonta, R. Makgotlho & F. Mekuria, "Setting Scene for TV White Spaces and Dynamic Spectrum Access in South Africa", *Proc. IST Africa*, Dar es Salaam, Tanzania, 09-11 May 2012.

[16] M.T. Masonta, T. Olwal, M. Mzyece & N. Ntlatlapa, "Spectrum access games for cognitive radio networks", *Proc. SATNAC*, Spier Estate, South Africa, pp. 102-107, Sep. 2010.

Journal Papers:

[17] M. T. Masonta, M. Mzyece and N. Ntlatlapa, **"Spectrum decision in cognitive radio networks: a survey"**, *IEEE Communications Surveys and Tutorials*, vol. 15, no. 3, pp. 1088-1107, Q3-2013.

[18] Mfupe L, Mekuria F, Mzyece M, **Geo-location White Space Spectrum Database: Models and Design of South Africa's First Dynamic Spectrum Access Coexistence Manager,** KSII Transaction on Internet and Information Systems, Journal, ISSN: 1976-7277, November 2014.

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Book Chapter(s):

[19] A.I. Aderonmu, A. H. Rotimi, M. T. Masonta & Mjumo Mzyece, "VHF Spectrum Monitoring Using Meraka Cognitive Radio Platform", In *e-Infrastructure and e-Services for Developing Countries: Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, K. Jonas, I. A. Rai & T. Tchuente (Eds.), vol. 119, Springer, pp. 55-64, 2013 (ISBN: 978-3-642-41178-6).

[20] L Mfupe, F Mekuria, L Montsi, M Mzyece, Geo-location White Space Spectrum Database: A Review of Models and Design of Dynamic Spectrum Access Coexistence Planner and Manager. In *White Space Communication: Advances, Development and Engineering Challenges*, Ed. A., Kumar and D. Johnson, pp 153 -194, ISBN: 978-3-319-08747-4, October 2014. Springer International, Available from: http://link.springer.com/chapter/10.1007/978-3-319-08747-4_6

[21] M.T. Masonta, D. Johnson and M. Mzyece, "The White Space Opportunity in Southern Africa: Measurements with Meraka Cognitive Radio Platform," In *Springer Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, R. Popescu-Zeletin, K. Jonas, I. A. Rai, R. Glitho, A. Villafiorita (Eds.), vol. 92, Part 1, pp. 64-73, Feb. 2013.

A.2 University of Pretoria Research in Dynamic and Opportunistic Spectrum Assignment

Publications emanating from the collaboration between the University of Pretoria (UP) and the Independent Communications Authority of South Africa (the authority), over the period 2011 to 2014, are listed below. Four articles have been published in peer reviewed and accredited journals, eight either peer reviewed or invited conference papers have been presented and three technical reports have been submitted to the authority. Other publications are currently under review or will be submitted for review in the near future. These research outputs fall under the broad topics relating to spectrum efficiency, television white spaces (TVWS), cognitive radio (CR) and dynamic spectrum assignment (DSA).

Publications [2, 12 – 16, 17] are related to a number of spectrum measurement campaigns that were carried out at either UP or the Authority's offices at Pinmill Farm. The occupation of various South African commercial frequency bands were measured and analysed. The average occupancy of the TV broadcast band was found to be fairly low, with a fair amount of spectrum potentially available. On the other hand, the cellular bands were found to be fairly well utilised, with very little spectrum available. The results of this study suggest that spectrum in the TV broadcast bands could be better utilised, thus providing motivation for the use of TVWS technologies in these bands.

Publications [1, 5, 7 – 9, 10, 11] cover theoretical work to do with proactive and DSA for the secondary users of CR networks. The prediction of spectrum holes for proactive access was the main focus of the work. Some of this work was validated using the data obtained from the measurement campaigns. Results indicated that proactive access in CR networks may benefit secondary users both in terms of improved throughput and reduced power consumption. Collaboration amongst secondary users was found to improve the prediction process, which is also of benefit to primary spectrum users due to potentially lower levels of interference. This work may prove important in future DSA based networks.

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Publications [3, 4, 8, and 12] are on theoretical work related to location estimation and the geographical positioning of secondary users in CR networks. Knowledge of a user's location as well as the surrounding environment type may enhance various CR tasks, such as spectrum sensing, dynamic channel allocation and interference management. Multiband time-of-arrival positing techniques were thus explored. These techniques were found to perform well even under poor signal-to-noise ratio environments and provide a simple alternative to other approaches to location estimation, e.g. satellite based positioning systems. Some of this work was also validated using the data obtained from the measurement campaigns.

Future publications, based on work currently underway, will include topics relating to the provision of broadband services for rural areas using long range Wi-Fi, spectrum aggregation, cooperation amongst secondary users and power efficiency in CR networks.

PEER-REVIEWED JOURNAL ARTICLES

[1] S.D. Barnes and B.T. Maharaj, "Prediction based channel allocation performance for cognitive radio," *International Journal of Electronics and Communications*, vol. 68, no. 4, pp. 336-345, Apr. 2014.

[2] S.D. Barnes, P.A. Jansen van Vuuren and B.T. Maharaj, "Spectrum occupancy investigation: Measurements in South Africa," *Measurement*, vol. 46, no. 9, pp. 3098-3112, Nov. 2013.

[3] R.R. Thomas, B.T. Maharaj, B. Zayen and R. Knopp, "Multiband TOA positioning technique using an UHF bandwidth availability model for cognitive radio", *IET Journal of Radar, Sonar and Navigation*, vol. 7, no. 5, pp. 544-552, Jun. 2013.

[4] R. R. Thomas and B.T. Maharaj, "Towards a bandwidth efficient cognitive positioning system," *IET Electronics Letters*, vol. 48, no. 12, pp. 736-737, Jun. 2012.

PEER-REVIEWED CONFERENCE PAPERS

[5] S.D. Barnes and B.T. Maharaj, "Spectrum opportunity forecasting for energy efficient sensing in cognitive radio networks," *IEEE ISTT*, Langkawi, Malaysia, November 2014.

[6] S.D. Barnes and B.T. Maharaj, "A comparison of spectrum occupancy in the South African 900 MHz GSM cellular bands," *IEEE AFRICON*, Mauritius, September 2013, pp. 1-5.

[7] S.D. Barnes and B.T. Maharaj, "An occupancy window approach to primary user traffic modelling for cognitive radio," *SATNAC*, Stellenbosch, South Africa, September 2013, pp. 395-399.

[8] R.R. Thomas, S.D. Barnes and B.T. Maharaj, "TOA location estimation based on cognitive radio channel occupancy prediction," *IEEE WiMOB*, Barcelona, Spain, October 2012, pp. 733-738.

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[9] S.D. Barnes, K. Dhuness, R.R. Thomas and B.T. Maharaj, "Proactive dynamic spectrum access based on energy detection," *SATNAC*, George, South Africa, September 2012.

[10] K. Dhuness and B.T. Maharaj, "A cognitive radio application of OM-OFDM for implementation in DVB-T2," *IEEE AFRICON Conference*, Livingstone, Zambia, September 2011.

[11] S.D. Barnes and B.T. Maharaj, "Performance of a Hidden Markov channel occupancy model for cognitive radio," *IEEE AFRICON Conference*, Livingstone, Zambia, September 2011.

[12] R. R. Thomas, B. Zayen, R. Knopp and B.T. Maharaj, "Multiband TOA positioning technique for cognitive radio systems," *IEEE PIMRC conference*, Toronto, Canada, September 2011, p.p. 2315-2319.

OTHER CONFERENCE PAPERS AND PRESENTATIONS

[13] S.D. Barnes and B.T. Maharaj, "Spectrum occupancy and modelling: A South African case study," *South African IEEE Joint AP/MTT/EMC Chapter Conference*, Pretoria, May 2014, Pretoria, South Africa.

TECHNICAL REPORTS

[14] S.D. Barnes, P.R. Botha and B.T. Maharaj, "Final report: Spectrum measurement and performance for cognitive radio," Pretoria, South Africa: University of Pretoria, November 2013.

[15] B.T. Maharaj and S.D. Barnes, "Final report: Spectrum measurement and performance for cognitive radio," Pretoria, South Africa: University of Pretoria, September 2012, ISBN 978-1-77592-021-2.

[16] B.T. Maharaj, S.D. Barnes, M.J. Prinsloo, R. R. Thomas and P.A. Jansen van Vuuren, "Final report: Spectrum measurement and performance for cognitive radio," Pretoria, South Africa: University of Pretoria, August 2011.

PUBLICATIONS UNDER REVIEW

[17] S.D. Barnes, P.R. Botha and B.T. Maharaj, "Spectral occupation of TV broadcast bands: Measurement and analysis," *International Journal of Electronics and Communications*, submitted for review.

A.3 University of Witwatersrand: CeTAS and LINK Centre: Research in Spectrum Sharing, Dynamic and Opportunistic Spectrum Assignment

The Centre of Excellence in Telecommunications Access and Services (CeTAS) and the LINK Centre have created the Wits spectrum engineering and regulation research group (Wits SERRG), which has the following purposes (i) providing a knowledge base in radio-frequency spectrum matters for the benefit of the policy-maker, regulator and industry; and (ii) had various spectrum management topic papers published in the period 2013 to 2015, including those listed below.

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PUBLISHED ARTICLES AND CONFERENCE PROCEEDINGS

[1] Jide Julius Popoola and Rex van Olst: "A Survey on Dynamic Spectrum Access via Cognitive Radio: Taxonomy, Requirements, and Benefits", Universal Journal of Communications and Networks, Vol 2, No 5. July 2014
[2] Jide Julius Popoola and Rex van Olst: "Effect of Training Algorithms on the Performance of a Developed Automatic Modulation Classification using an Artificial Neural Network" IEEE Africon 2013 Conference Proceedings, 9 – 11 September 2013
[3] Elicia Naidu and Rex van Olst: "The Impact of Regulation and Policy on Secondary User Pricing in a Cognitive Radio Environment in South Africa", SATNAC 2014 Conference Proceedings, Port Elizabeth, 1 - 3 Sept, 2014
[4] Luci Abrahams, Yolisa Kedama and Elicia Naidu: "Regulating Radio Frequency Spectrum for the Digital Economy: Issues of Economic Regulation for the Electronic Communications Sector", SAERC 2014 Conference Proceedings, 18 – 19 March 2014
[5] William Stucke: "The Economic Value of Television White Spaces", SAERC 2014 Conference Proceedings, 18 – 19 March 2014

PUBLISHED POSTGRADUATE RESEARCH REPORTS: SPECTRUM ENGINEERING AND REGULATION

[6] Thobela Frans (MEng): Dynamic Spectrum Access in DTV Whitespaces in South Africa [supervisor: Prof Rex van Olst]
[7] Yolisa Kedama (MM ICT Policy and Regulation): Advantages and Disadvantages of ICASA's 2011 Proposed Spectrum Licensing Models [supervisor: Luci Abrahams]
[8] Elicia Naidu (MTelecomEng): Secondary User Pricing Strategies in a Cognitive Radio Environment [supervisor: Prof Rex van Olst; co-supervisor: Luci Abrahams]
[9] Peter Zimri (MM ICT Policy and Regulation): Radio Frequency Spectrum, The Out of Sight, Out of Mind, National Strategic Resource [supervisor: Luci Abrahams]
[10] William Stucke (2015) "Case notes: Considering possible regulatory approaches to television white spaces (TVWS): A view from South Africa", AJIC http://www.wits.ac.za/linkcentre/ajic/
[11]

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