

**INVESTIGATING POLICY AND REGULATORY APPROACHES  
TO DYNAMIC SPECTRUM ACCESS USING COGNITIVE RADIO**

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## **Abstract**

Dynamic spectrum access (DSA) technologies promise to improve spectrum sharing through efficient spectrum usage, thus making more spectrum available for more communication services and driving innovation in the development of new wireless applications and industries. The author investigated how South Africa can introduce and implement agile liberal policy and regulation for DSA and the use of cognitive radio (CR) technologies. The economic justification and incentives for DSA needs to be studied to assist in the formulation of market and consumer oriented policy and regulation in South Africa. Studying the relevant approaches to the regulation of DSA, required an understanding of (i) the application of geo-location databases and cognitive radio technologies, (ii) potential demand and supply for white space services, and (iii) the various spectrum management regimes deemed essential to addressing dynamic spectrum access inhibitors. This study investigated these three key aspects pertaining to the design of future DSA regulation, using a qualitative, interpretivist methodology.

Globally, regulators have started introducing DSA policies and regulation using White Spaces in specific bands on an unlicensed or spectrum commons regime. There have also been regulators who have introduced DSA using white spaces using licensed bands by introducing sharing between the primary and secondary user. The research found that the South African regulator has been investigating ways of introducing efficient spectrum usage policies, however there have been delays in introducing agile and liberal spectrum policies and regulation. The research has identified three groups with opposing views on how DSA should be approached in South Africa using television white spaces (TVWS). The research respondents support and encourage the introduction of policies and regulation for the use of dynamic spectrum access in a number of spectrum bands. The introduction of DSA policy and regulation would encourage spectrum sharing, leasing and provide significant economic and social benefits to the country as articulated in the South African national broadband policy, known as SA Connect.

## **Declaration**

I declare that this report is my own, unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Arts in the field of ICT Policy and Regulation at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

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**Linda Patrick Canca**

**15 March**

## **Dedication**

Thanks and praises to the Almighty our Creator let your name be glorified always. I would like to dedicate this work to my late grandparents Mr R.S Canca, Mrs A.N Canca, Mr P.L Xaba and Mrs R.M Xaba. To the Canca clan Omjoli, Owhushe, Ojambase, Ononina and to the Xaba clan Oshwabade, oNonkosi nina bakwaLinda.

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## Abbreviations

Abbreviations	Definition
AIP	Administrative Incentive Pricing
ATU	African Telecommunications Union
CRASA	Communications Regulators Association of Southern Africa
CR	Cognitive Radio
CSIR	Council for Scientific and Industrial Research
CPE	Customer Premise Equipment
DoC	Department of Communications
DTPS	Department of Telecommunications and Postal Services
DTT	Digital Terrestrial Transmission
DSA	Dynamic Spectrum Access
DSO	Digital Switch Over
ECA	Electronic Communications Act
FCC	Federal Communications Commission
GDP	Gross Domestic Product
GHz	Gigahertz
ICT	Information and Communication Technology
ICASA	Independent Communications Authority of South Africa
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMT	International Mobile Telephony
ITU	International Telecommunication Union
IP	Internet Protocol
IoT	Internet of Things
M2M	Machine to Machine
MHz	Megahertz
NDP	National Development Plan
TVWS	Television White Spaces
PU	Primary User
RR	Radio Regulations
SDR	Software Defined Radio
SADC	Southern African Development Community
SABC	South African Broadcasting Corporation
SU	Secondary User
WSD	White Space Devices
UHF	Ultra-High Frequency
VHF	Very High Frequency
WRC	World Radio Conference

## Glossary of Terms

**Administrative Incentive Pricing.** A system for calculating annual spectrum fees introduced by the South African regulator (ICASA) with effect from April 2012, which, very roughly, mimics market dynamics. Note the relationship 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 a specific portion of spectrum which is to be used for specific purposes. These purposes are coordinated via the International Telecommunication Union (ITU) on a global basis.

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

**Authorised Service.** Is the usage of spectrum which 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 studio transmitter links (STLs).

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

**Band.** This is a contiguous range of frequencies subject to the same regulatory treatment. Traditionally, most commercial bands have been allocated via static spectrum licenses, which specify a band and grant the licensee protection against in-band interference from third parties. For example, both over-the-air broadcasters and commercial cellular service providers operate in specified bands under restricted use licenses administered by the government

**Broadcast Television Frequency Band.** A frequency range that is primarily allocated to a television broadcasting service, e.g. the 470 – 694 megahertz (MHz) Ultra High frequency (UHF) Digital Terrestrial Television (DTT) band channel. In South Africa, 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.

**Client device.** This is a white space device (WSD) which does not use access to a geo-location database to obtain a list of available frequencies. It may or may not have an automatic geo-location 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 a 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 if 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. The device 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 to ensure interference between users does not occur. This is usually carried out with the help of a radio frequency propagation modelling tool.

**Cognitive Radio (CR).** This is defined as: “Radio in which communication systems are aware of their environment and internal state and can make decisions about their radio operating behaviour based on that information and predefined objectives” (Zhao & Swami, 2007) Some cognitive radio technologies use artificial intelligence techniques, while others use simpler control mechanisms

**Digital Dividend 1 (DD1).** This is the available spectrum due to the digital switch over from analogue to digital terrestrial television. The available spectrum band in the ITU Region 1 is 790-862MHz. It includes Europe, Africa and the Middle East and is also known as the 800MHz band.

**Digital Dividend 2 (DD2).** DD2 was agreed at the World Radio Conference in Geneva 2015, to allocate the 694-790MHz frequency band, also known as 700MHz band, for mobile use in Europe, Russia, the Middle East and Africa.

**Dynamic Spectrum Access** is defined in the Institute of Electrical and Electronics Engineers draft standard: (IEEE) 1900.1 as: “Technique by which a radio system dynamically adapts to select operating spectrum to use available (in local time frequency space) spectrum holes with limited spectrum use rights.” Thus, DSA technology encompasses a wide range of radio system capabilities. A DSA radio may be agile—able to operate in many different bands—and may be flexible—capable of supporting many different transmission standards or waveforms. However, neither of these features is necessary for DSA. Many DSA devices will support only one waveform and operate in a single band

**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.

**Geo-location capability.** The capability of a WSD to determine its geographic coordinates in world geodetic system (WGS84) format, usually using a global positioning satellite (GPS). This capability is used with an approved Geo-location database to determine the availability of frequencies at a WSD location.

**Geo-location database.** A database system that maintains records of all authorised 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. Geo-location databases that provide lists of available frequencies must be authorised by the Authority.

**High Demand Spectrum.** A number of bands, coordinated as integrated microwave technologies (IMT) through the International Telecommunication Union (ITU), are deemed “high demand” because of being of high commercial value. 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 electronic communications act (Act No 36 of 2005). 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.

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

**The Internet Engineering Task Force IETF.** . An organisation with open membership which approves the standards Request for Commission (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 for which specific bands have been assigned for mobile or fixed use.

**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.

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

**Master Device.** A WSD that uses geo-location capability and access to a geo-location database, either through a direct or 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 serve as a database proxy for the client devices with which it communicates; or relay 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.

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

**Primary User.** 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 devices and certain ancillary services, such as radio microphones and STLs. It is essential that these users form an ordered list of priorities, such that users at a higher priority level are protected from interference by users at a lower level.

**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 geo-location 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 geo-location white space database administrators.

**Secondary geo-location white space database.** A database that utilises TVWS availability maps and corresponding power levels calculated by the reference geo-location white space database for the purpose of providing services to end users. Secondary geo-location 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 geo-location 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, a discount of 50 percent 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.** Radio-communication equipment is used in the transmission, emission and/or reception of radio waves of a radio-communication service involving either a station or network.

**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 Point to Multi Point (PtMP) spectrum which they are licensed to use for Point to Point (PtP) links. In the past, these links were not registered with the Authority and were, therefore, 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.

**Ultra-Wide Band (UWB).** Enables underlay sharing of bands through the use of transmission technique using pulse for very short time duration across every large frequency band of spectrum. UWB uses modulated high frequency pulses of lower power with duration of less than 1 nanosecond instead of radio frequency carriers.

**White Space.** The frequency bands not used by their primary licensed users at a specific location or at a specific time.

**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.

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# CHAPTER 1: INTRODUCTION AND BACKGROUND TO DYNAMIC SPECTRUM ACCESS AS A FUTURE REGULATORY APPROACH

## 1 Introduction

In the past two decades, the worldwide demand for wireless networks has increased rapidly, putting a high demand on providing spectrum for more users, more capacity and more services, e.g., internet, mobile phones, the internet of things (IoT) revolution and machine to machine (M2M) wireless communications (Nekovee, Irnich, & Karlsson, 2012). Key drivers for the demand in rapid growth for wireless broadband include the rollout of fourth generation (4G) wireless technologies, increased popularity of Wi-Fi and Wi-Fi enabled smartphones, tablets and other mobile devices.

This demand for spectrum for wireless technologies has driven the industry to produce more technological innovation and governments are looking at ways to manage spectrum more efficiently and effectively (Minervini, 2013). In the context of heightened radio frequency spectrum demand, alternative regimes for spectrum management have been researched by regulators around the globe and dynamic spectrum access technologies promise to improve sharing of spectrum (Chapin & Lehr, 2007). DSA research involves simultaneously advancing policy development, regulatory practices, economic understanding, institutional arrangements and implementation technologies (Freyens, Loney, & Dissanayake, 2014).

The main objective of this research was to study and investigate technical, markets, policy and regulatory approaches for the enablement of dynamic spectrum access using cognitive radio technologies for South Africa. The research is intended to contribute towards the body of knowledge and possibly influence the development of spectrum management policies and regulation by the policy maker and regulator. For the purposes of this study, the author has developed a conceptual framework encompassing the following areas: technology, markets, policy and regulation.

### 1.1 Global coordination of spectrum management process

Spectrum management refers to a national authority's ability to safeguard the interest of the public and private users of radio frequency in accordance with international, regional and national policies, regulation and strategic needs. The ability for each country to realise the full benefits of spectrum depends on spectrum management activities which facilitate minimum interference and implementation of radio systems (ITU, 2005). The national authority regulates spectrum use and related processes in accordance with national laws and policies linked to the country's objectives.

South Africa is a member of the International Telecommunication Union (ITU) and a signatory to various international treaties and administrative bodies such as the World Trade Organisation (WTO) and General Agreement on Trade in Services (GATS) thus making it a participant that adheres to international norms and standards. The ITU convenes the World Radiocommunications Conference (WRC) which is an international treaty making forum where member states and affected stakeholders engage, review and, where necessary, revise decisions made on radio frequency spectrum and satellite orbits. The decisions made at this conference by all member states are recorded and published as Final Acts to which are expected to adhere. (ITU, 2005).

The process of licensing is often referred to as ‘frequency allocation,’ or, ‘spectrum allocation.’ Globally, for all regions of the world, frequency allocation processes are harmonized with the help of the Radiocommunication Sector of the International Telecommunication Union (ITU-The International Telecommunication Union-Radiocommunications Sector (ITU-R) is a specialised agency of the ITU, responsible for the radio-communication sector. It develops and adopts radio regulations that serve as a treaty governing the use of spectrum by allocating spectrum to over forty different services around the world and also acts a central registrar of the Master International Frequency Register (MIFR) (ITU, 2004). ITU-R also coordinates efforts to eliminate harmful interference between radio stations of different countries and develop recommendations on technical and operational matters to improve the use of spectrum and satellite orbits. It convenes the World Radiocommunications Conference (WRC) once every four years to update the radio regulations in response to the needs and demands for spectrum (ITU, 2005). The Radio Regulations (RR) is an international treaty to which the International Telecommunication Union (ITU) Member States make an undertaking to comply when managing the spectrum to avoid harmful interference. The RR is an outcome of the World Radiocommunications Conference (WRC) and is based on member State and interested parties contributions and negotiations (ITU, 2005).

Every member state is required to develop a national Table of Frequency Allocation (TFA) in agreement with the ITU Radio Regulations International Table of Frequency Allocation to guarantee international spectrum harmonisation. However, a country or region can make minor alterations to the table to suit national objectives in consultation with the ITU-RR (ITU, 2008). It is expected that member states should implement the RR provisions in accordance with the country’s objectives. However, national interpretations of the provisions are typically complex, leading to conflicts. Improved knowledge of the rationale behind the provisions would reduce tensions between Member States (ITU, 2008).

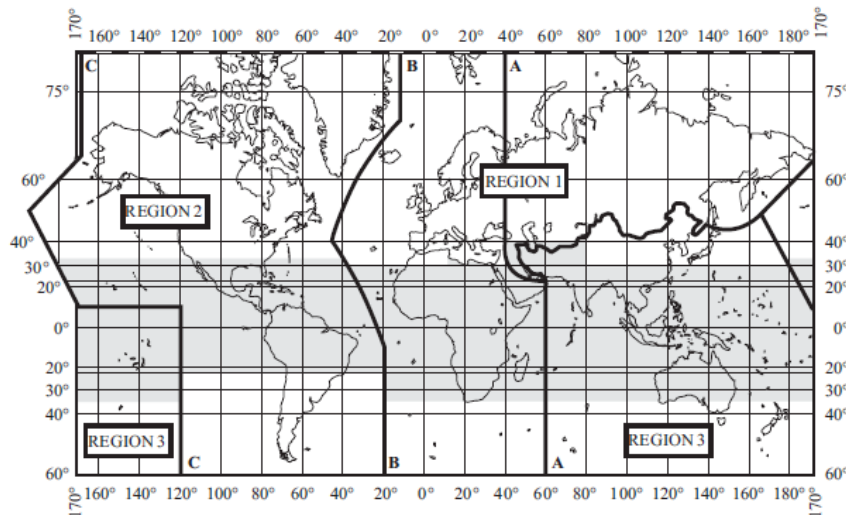
Ofcom is the regulatory authority for the UK and is responsible for the regulation, management, licensing and assignment of radio frequency spectrum (Ofcom, 2007). In the US, the role of spectrum regulation is shared between the FCC and the National Telecommunications and Information Administration (NTIA). NTIA is responsible for all spectrum utilised by government, whilst the FCC

is responsible for all non-government spectrum regulation (FCC, 2010). In Europe, the Electronic Communications Committee (ECC) of the European Conference of post and Telecommunications Administration (CEPT) coordinates spectrum regulation and has 46 member states (Nekovee, Irnich, & Karlsson, 2012). In China, radio spectrum is regulated on two levels, the Ministry of Information Industry and its radio regulatory department (Nekovee, Irnich, & Karlsson, 2012).

The journey towards the introduction of DSA using Software Defined Radio (SDR) and CR was initiated at the World Radio Conference 2007 (WRC-07) where it was deferred to the World Radio Conference 2012 (WRC-12) agenda for further deliberations. WRC-12 came to the conclusion that SDR and CR are related technologies that can be used under any service defined by the Radio Regulations (Mishra & Johnson, 2015). Key concerns raised at the ITU-R were that the implementation of CR technologies in shared services would cause harmful interference to existing services. Further studies were commissioned on CR discussions in the ITU-R Resolution 58, whilst the possibility of introducing CR into mobile services was referred to the ITU-R Study Group 5 (Terrestrial Services). The ITU-R Report M.2242 discussed possibilities and scenarios of CR deployment in the IMT service bands. The ITU-R Report M.2225 discussed CR deployment scenarios in the land mobile services dynamically and flexible radio management and optimisation (Mishra & Johnson, 2015)

South Africa's national regulatory authority, ICASA, regulates spectrum use and related processes in accordance with national laws and policies linked to the country's objectives which may differ from other countries (ITU, 2005). Figure 1 below shows the three regions as defined by the ITU for radiocommunication purposes. The coordination of spectrum is broken into three ITU regions with Region 1 consisting of Africa, Europe and parts of the Middle East, Region 2 comprises North and South America and Region 3 is made up of Asia and Australasia (ICASA, 2013) as illustrated in Figure 1 below.

**Figure 1:** Different regions as defined by the ITU



**Source:** ITU (2015)

Harmonisation of spectrum is done globally as well as regionally. The active regional organisations are the African Telecommunications Union (ATU), Arab Spectrum Management Group (ASMG), Asia Pacific Telecommunity (APT), European Conference of Telecommunications Administrations (CEPT), Inter-American Telecommunication Commission (CITEL) and Regional Commonwealth in the field of Communications (RCC). They help to consolidate and achieve a compromise on different ideas (ITU, 2005). The ATU is responsible for organising the African continent's discussion and the facilitation of research groups which discuss and prepare between the World Radio Conferences. The Communications Regulators Association of Southern Africa (CRASA) is responsible for the coordination and harmonisation of the Southern African Development Community (SADC) region.

## 1.2 National spectrum regulation in the current form

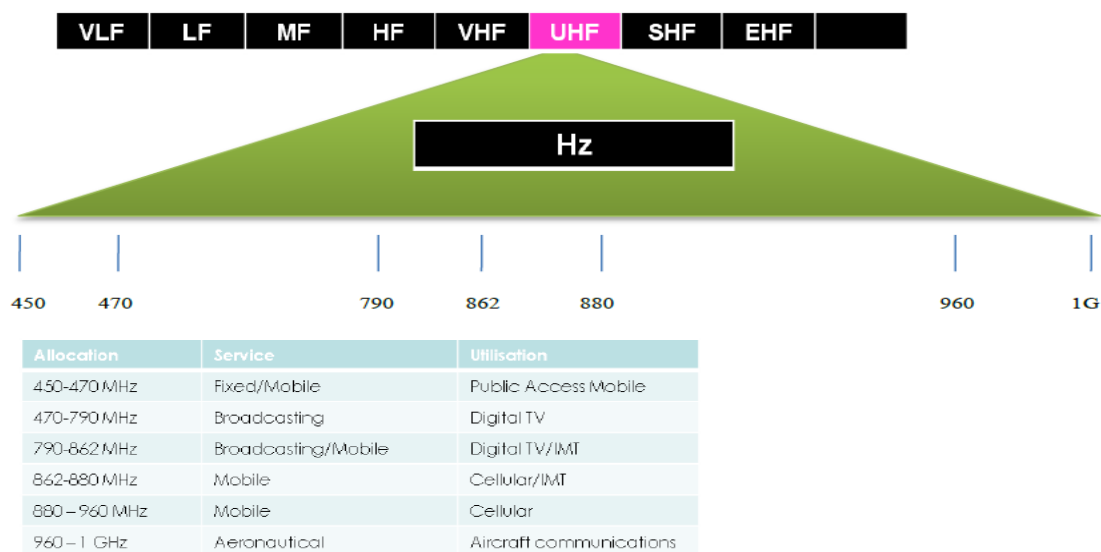
The telecommunications sector in South Africa is regulated by the Electronic Communications Act (Act No.36 of 2005), the ECA with ICASA being an independent regulatory body which was established through the ICASA Act (Act No.13 of 2000). The Southern African Developing Community (SADC) region has been slow in introducing different spectrum management regimes, resulting in a negative impact on primary and secondary spectrum sharing (Research ICT Africa, 2014). South Africa lags behind when it comes to reviewing and introducing more advanced spectrum management regimes and deregulation (Department of Communications, 2013).

The Electronic Communications Act (No 36 of 2005) (the ECA) sets the foundation for the promotion of universal access to ICT. The ECA enacts this through the establishment of an agency, the Universal Service and Access Agency of South Africa (USAASA) and a fund, the Universal Service and Access (USAF) in sections 80 to 91. The National Development Plan (the NDP) establishes further policy instruments such as the National Infrastructure Plan which guides the rollout of infrastructure including

the Presidential Infrastructure Coordinating Commission (PICC) that launched the Strategic Integration Project 15 (SIP15) - “Expanding access to communications technology”. The Competitions Commission regulates competition in the South African economy and is responsible for investigating, controlling and evaluating restrictive practices. The overarching objective of all the policy, legislative and regulatory tools that government has established is to ensure that the underserved and underserved communities gain access to communication and specifically broadband

In March 2015, ICASA published radio frequency spectrum Regulations which seek to establish a framework through which the regulator may allocate and assign spectrum under the South African National Radio Frequency Plan (SANRFP). The SANRFP was updated in 2013 with the inclusion of recommendations made at the International Telecommunication Union World Radiocommunications Conference of 2012. The 2300MHz spectrum has become highly valuable, with the incumbent, Telkom, using it for 2300MHz point to point (PtP) under a previous assignment requiring repurposing for LTE deployment. Telkom has also taken advantage of the 60MHz range and the low cost of dongles to become a serious contender in the mobile broadband market in SA (Research ICT Africa, 2014). The failed plan to auction the 2600MHz spectrum from 2009 has had a negative impact on the mobile broadband market, more so with one third of this band already assigned to Telkom, Sentech and WBS (iBurst) as part of their previously approved license conditions from ICASA (Research ICT Africa, 2014). South Africa needs to be pro-active in developing or adapting DSA regulation to ensure efficient use of radio frequency spectrum. Figure 2 below gives an overview of how spectrum is allocated to different services in South Africa.

**Figure 2:** Illustration of Radio Frequency Spectrum Allocation in South Africa



Source: Zimri (2013)

### **1.3 Trends in dynamic spectrum access**

DSA may offer an alternative solution for efficient and effective spectrum management, due to the potential to increase spectrum sharing and leasing opportunities (Lysko, Masonta, Johnson, & Venter, 2012), which is necessary to address the heightened demand for spectrum in the broadband era. The growth of the telecommunications sector and the demand for more wireless technologies and services has necessitated the improvements in how radio frequency spectrum is effectively and efficiently managed whilst being fully utilised. A paradigm shift is needed in how spectrum access is managed to enable spectrum sharing regimes. DSA improves the inefficiency of static spectrum access by providing opportunistic access to the already allocated spectrum (Zurutuza, 2011). A host of business models and technologies are available which is collectively known as dynamic spectrum access systems (Endesha, 2014). DSA has encouraged regulators and industry to investigate and introduce different licensing and spectrum sharing models. To foster a multidisciplinary approach to the research on DSA, a symposium was held in 2005 under the auspices of the Institute of Electrical and Electronic Engineers (IEEE), referred to as the New Frontier in Dynamic Spectrum Access Networks (DySPAN) which developed standards for DSA. These standards are shown in Table 2.

DSA differs from static spectrum access inefficiency by providing opportunistic access to the available spectrum. Cognitive radio (CR) is a technology that makes dynamic spectrum access possible by providing the capability to share frequency bands with licensed users in an opportunistic manner (Masonta, Makgothlo, & Mekuria, 2012). The Independent Communications Authority of South Africa's draft discussion paper on the framework for dynamic and opportunistic spectrum management 2015 explains DSA as "dynamic spectrum assignment as a mechanism used by regulators to assign the unused spectrum to other parties on a secondary basis, such that they don't cause interference to the primary licensees" (ICASA, 2015).

There has been a growing acknowledgement across the globe that dynamic spectrum sharing enabled by cognitive technologies may increase the availability of wireless broadband access (Masonta, Mekuria, & Mzyece, 2013). DSA has also highlighted the inefficiencies which have been created by traditional methods of assigning radio frequency spectrum through the command and control regime (OFcom, 2007). On 7 April 2014, the South African President approved the amended Electronic Communications Act (ECA) Act No 1, of 2014, which allow secondary sharing of spectrum, however the act may be vague and lacks clarity on what type of secondary sharing is permitted (ICASA, 2015). ICASA also has to approve any form of spectrum sharing and the process of approval could take up to 60 days, should there be no objections from other operators (ICASA, 2015). Table 1 below recommends a few policies and regulatory and process changes that could enable dynamic spectrum access at an international, regional and national level.

The Federal Communications Commission (FCC) published its first notice in 2002 proposing the use of unlicensed devices in the unused TV bands (Nekovee, Irnich, & Karlsson, 2012). In 2004, after much consultation, the FCC published a report that made VHF and UHF available for “new and innovative broadband products and services” (FCC, 2010). The second report and order, released by the FCC in 2008, allowed unlicensed operations in the TV bands where frequencies were not used by licensed services (FCC, 2010). Ofcom introduced a limited application of CR in the unlicensed opportunistic spectrum band, where it proposed to allow devices that sense to be limited to low power limits of 50mW (Nekovee, Irnich, & Karlsson, 2012). This was done after Ofcom broadly consulted and published a number of reports with the 2009 report recommending the introduction of geolocation spectrum databases to facilitate channel allocation without causing interference to licensed users in the white spaces (Ofcom, 2007)

**Table 1:** Different policy, regulatory and processes at all levels

	GLOBAL	REGIONAL	NATIONAL
POLICY	Phasing out old allocations and moving away from exclusive rights regime. Promoting innovation and more license exempt spectrum allocations	Promote innovation and technology neutrality	Lower market entry barriers and introduce flexibility of current licensing frameworks. Proactively adapt policy to meet continuous technology changes and global trends
REGULATION	More drastic changes to the Radio Regulations	Technology neutral recommendations and decisions and encourage regional harmonisation	Changes to laws, policy and regulations need to be expedited
PROCESSES	Accelerate WRC decision making process	Accelerate implementation of decisions taken at the WRC	Ex-post approval of trading and enable quick transfer and change of use

Source: Berggren *et al*(2004)

#### 1.4 Dynamic spectrum access

Spectrum is currently being assigned in an out-dated manner and an urgent need for dynamic spectrum regulations is upon us (Olwal, Masonta, Mfupe, & Mzyece, 2013). Policy makers across the continent need to take cognisance of the need to focus on universal wireless broadband access. The challenge facing implementation of national policies could be linked to bad governance and the lack of dynamic and liberal spectrum regulation policies (Olwal, Masonta, Mfupe, & Mzyece, 2013). The full value of the digital dividend and Television White Space (TVWS) spectrum can be fully realised with the introduction of liberal DSA policies in South Africa. The introduction of these policies will allow spectrum trading which will spur the emergence of disruptive business models which in turn will pose a challenge to the bigger monopolies (Olwal, Masonta, Mfupe, & Mzyece, 2013).

The SADC region has conducted a number of studies to look at the advantages brought by CR, TVWS and DSA. Studies done in the United States (US) and some countries within ITU Region 1 have also proposed moving away from out-dated and static spectrum regulations (Olwal, Masonta, Mfupe, &

Mzyece, 2013). The proposed DSA regulations include using license exempt spectrum for TVWS, secondary spectrum licensing.

Freyens *et al.*, (2014) contend that dynamic spectrum access offers a way to enhance both productive and allocative efficiency of the highly valuable natural resource. The South African National Development Plan (2012) emphasises the importance of a robust broadband and telecommunications network and a lower pricing model which will lead to greater economic and employment benefits for the country. This could be achieved more quickly and efficiently through a rollout of wireless broadband network which is highly reliant on radio frequency spectrum and effective spectrum management regimes.

### **1.5 Cognitive radio an enabler of dynamic spectrum access**

Dynamic spectrum sharing has created an enabling environment for the introduction of software defined radio and cognitive radio to enhance the efficiency of radio frequency spectrum usage for next generation mobile and wireless devices. CR is able to observe, learn, optimise and intelligently adapt to achieve optimal frequency band usage. This process allows the cognitive radio to adapt and dynamically transmit and receive data in a continuously changing environment without causing interference to other devices. For full benefits of dynamic spectrum access, nations through their governments and regulators, need to adapt policy and regulation with technological advances in cognitive and opportunistic radio and continuous application needs (ICASA, 2015). The introduction of software defined radio and cognitive radio to enhance the efficiency of radio frequency spectrum usage for wireless services and applications.

### **1.6 TV white space standards**

The demand for spectrum sharing across the globe has led to innovation in spectrum management using cognitive technologies which have significant potential to increase broadband access (Freyens, 2009). The global migration of television (TV) broadcast from analogue to digital or digital switch over (DSO) in South Africa will result in additional unutilised spaces or white spaces in the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands being available for wireless broadband use (Lysko, Masonta, Johnson, & Venter, 2012). The heightened demand for spectrum for wireless broadband has led to an increase in the number of trials conducted across the African continent in countries such as Kenya, Malawi, South Africa and Ghana. TVWS have been explored as an alternative to the provisioning of access networks for bridging the digital divide in underserved and rural areas by providing wireless broadband efficiently at a lower cost than fixed broadband (Mfupe, Masonta, Olwal, & Mzyece, 2013). South Africa has launched two TVWS trials, one on the 25 March 2012 in Cape Town and the second in Limpopo province in July 2013 (Carlson *et al* 2014). The research results emerging from these trials have been shared and used to inform policy direction and regulation by both the policy maker and ICASA. In order to create certainty about the use of TV white spaces (TVWS),

the discussion paper published in 2015 by ICASA soliciting comments and opinions on the framework for dynamic and opportunistic spectrum management, highlights three major discussion points. The adoption of dynamic spectrum assignment on a geo-location basis, the proposed regulations that would enable broadband services on a secondary user assignment basis in the 470-694 MHz range is currently used exclusively for terrestrial broadcasting services as the first dynamic spectrum assignment in SA (ICASA, 2015).

There has been an emergence of TV white space communication standardisation around the world and these include frequencies IEEE 802.22, 802.11af, ECMA-392 and Weightless. The IEEE 802.22 is designed to focus more on providing long distance connectivity in rural areas of 30km, whilst the 802.11af and ECMA-3392 is used mostly in providing range and improved penetration for wireless networks in urban areas (Mishra & Johnson, 2015). Table 2 below explains the different IEEE standards and their application to the area of DSA and other wireless networks.

**Table 2:** Communication Standards

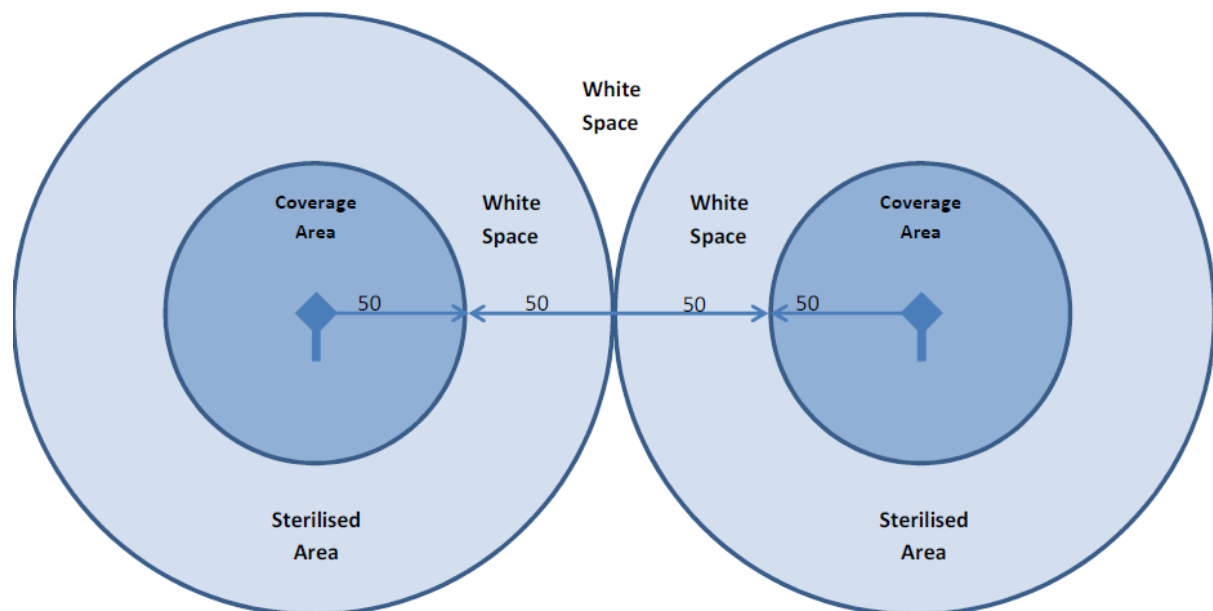
Standard	Scope
802.16.2-2001 Initiation: 9/1999 Completion: 11/2001	One of the first coexistence standards, this recommended practice provided guidelines for minimizing interference in fixed broadband wireless access (BWA) systems. It addressed pertinent coexistence issues and recommended engineering practices, as well as provided guidance for system design, deployment, coordination, and frequency usage. It covered frequencies of 10 to 66 GHz frequencies in general, but focused on 23.5 to 43.5 GHz. It has been superseded by 802.16.2-2004.
IEEE 802.15.2-2003 Initiation: 1/2000 Completion: 6/2003	This standard provides recommended practices for coexistence of IEEE 802.15™ wireless personal area networks (WPAN) with other selected wireless devices operating in unlicensed frequency bands. It suggests recommended practices for IEEE Std. 802.11™, 1999 edition devices to facilitate coexistence with IEEE 802.15 devices operating in unlicensed frequency bands, and suggests modifications to other IEEE 802.15 standards to enhance coexistence with other selected wireless devices operating in unlicensed frequency bands.
IEEE 802.15.4-2003 Initiation: 12/2002 Completion: 5/2003	This standard defines the protocol and interconnection of devices via radio communication in a personal area network (PAN). The standard uses carrier sense multiple access with a collision avoidance medium access mechanism and supports star as well as peer-to-peer topologies. It includes dynamic channel selection (DCS) and operates at low power, among other techniques, to support coexistence with other wireless devices.
802.11h-2003 Initiation: 12/2000 Completion: 9/2003	This amendment to IEEE std. 802.11-1999 provides mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in the 5 GHz band in Europe. However, it also is applied in other regulatory domains. This document has been superseded by IEEE std. 802.11-2007.
802.16a-2003 Initiation: 2/2002 Completion: 4/2003	This amendment to the 802.16-2001 standard expands its scope by extending the WirelessMAN air interface to address operational frequencies from 2–11 GHz. It also added DFS and TPC techniques (see 6.3.15 and 8.3.7.4, respectively). The standard includes an Annex (B.2) that discusses coexistence in license-exempt bands and provides interference analysis.
802.16.2-2004 Initiation: 9/2003 Completion: 3/2004	This revision of the 802.16.2-2001 added treatment of coexistence in the 2–11 GHz bands to the 802.16.2-2001 standard.

**Source:** Wireless Innovation Forum (2014)

As a result of heightened global demand for spectrum, several regulators commissioned studies with the aim of optimal management of available spectrum. The majority of the studies revealed that large portions of assigned and licensed spectrum were either not used or sparsely utilised most of the time,

concluding that the problem is not the scarcity of spectrum but the inefficient fixed spectrum assignment regime of command and control and also the exclusive assignment of spectrum. The heightened demand for spectrum has led to a paradigm shift in most developed countries in introducing different assignment regimes and the primary and secondary sharing of under-utilised spectrum through dynamic and opportunistic spectrum access models. The radio frequency spectrum band 392-400 MHz is currently reserved for analogue television transmission in South Africa. In this frequency band, 93 percent of spectrum is unused at any given point due to onerous interference related matters. In the 224 MHz frequency band, which has been reserved for television broadcasting, 75 percent is also available at any point (ICASA, 2015). These unused frequency bands are referred to as TVWS as illustrated in Figure 3 below. These bands could be used for dynamic spectrum access using cognitive technologies as an efficient way of utilising spectrum by wireless service devices (Mfupe, Mekuria, & Mzyece, 2014).

**FIGURE 3.** Illustration of Co-Channel and unused TV White Spaces



**Source:** ICASA, 2015

### **1.7 Cape Town TV white spaces trial demonstrates high quality Internet access**

There has been an increase in the number of trials across the continent, looking at alternative and best possible solutions to deliver broadband efficiently and effectively. TVWS, using geo-location databases and cognitive radio, have been candidates to be the most cost effective with ease of deployment. The objective of the trials was to ascertain the demand and supply side of broadband internet connectivity using TVWS to the hospital, schools and provisioning of government e-services as per the objectives of the SA Connect broadband policy. The trial also proposes for a regulatory framework to ICASA recommending the use of TVWS in South Africa and providing the policy maker with information to meet policy objectives on universal services, broadband access and efficient spectrum management

(Carlson *et al*, 2014). The Cape Town trials offered reliable broadband access over a 6.5 km distance at speeds of 12Mbps with potential for more improvements following more tests and with the introduction of advanced equipment. The geo-location database enabled the TVWS devices to operate in allocated spaces without a single incident of interference being reported by Carlson *et al* (2014). The trial concluded that, even in an area with high potential for interference such as Cape Town, TVWS devices were able to provide broadband access to the necessary pilot sites without interference (Carlson *et a* 2014).

### **1.8 Limpopo TV white spaces trial demonstrating wireless internet propagation**

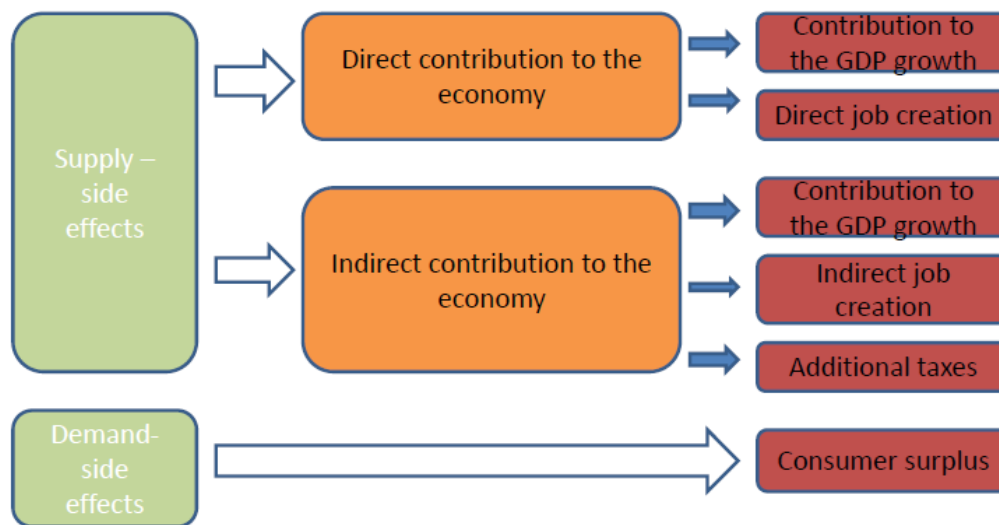
The emergence of TV whitespace as an alternative solution to wireless broadband provided an opportunity for countries to conduct academic research, commercial studies by manufacturers and trials by research institutions. After the approval by the FCC in the United States for unlicensed use of white spaces in 2008, many countries such as Canada, the UK, Malawi, Kenya, India and South Africa conducted trials. The objective of these trials was to ascertain if there were any grounds and benefits for white spaces to provide advantages for new markets such as rural wireless broadband and wide area M2M communication (Mishra & Johnson, 2015). For the success of any research, study or trial, a conceptual framework needs to be developed or adopted.

The Council for Scientific and Industrial Research (CSIR) Technical report (2014) discusses the outcome of the Limpopo TV Whitespaces trials which were conducted through the use of the Ultra High Frequency (UHF) TV bands to connect schools in the rural areas, which has truly tested the long distance capability of this band. The outcome of the trials showed that the UHF TV bands are well suited for the provisioning of wireless broadband access over distances beyond 30km (ICASA, 2015). With more advancements and innovation in technology occurring all the time, this could be provided over even longer distances.

### **1.9 The supply and demand of dynamic spectrum technology**

The demand for spectrum will be driven by potential high demand sectors such as public education, health, e-government and social media services. With the current broadband diffusion need driven by technologies such as WIFI and WiMAX which provide the infrastructure platform for broadband enabled services such as voice over internet protocol (VOIP), internet protocol television (IPTV), e-government services and eBooks (Abrahams, Kedama, Naidu, & Pillay, 2014). There have been ongoing commercial TVWS trials across the globe, notably the United States develops the majority of the TVWS radio equipment used in these trials. An opportunity arises where local manufacturers, installers and support and maintenance companies could position themselves as industry experts with the potential to supply the whole of the SADC region. The introduction of DSA enabled regulation will encourage the market to manufacture white space devices which would create employment locally and create a potential export market and contribute to the growth of the GDP as illustrated by Figure 4.

**Figure 4:** Illustration of value proposition that could create by introducing DSA



**Source:** GSMA (2016)

Economic theory and global experience suggest the international spectrum-management system may be enhanced by employing economic methods to supplement the existing technical and regulatory principles, in particular the introduction of fees for use of the spectrum resource (Henri & Nozdrin, 2012). Sharing of frequencies is necessary for the fullest utilisation of radio spectrum. This may involve acceptance of some level of interference but does not mean acceptance of harmful interference (Wireless Innovation Forum, 2014). The literature review has also discovered that the use of license-exempt in the broadcasting bands for TVWS has been permitted in Canada, Singapore, the United Kingdom and the United States. The lessons learnt and detailed engagements on the dos and the don'ts could be thoroughly discussed and South Africa could benefit immensely from such collaboration.

### 1.10 Value of telecommunications in South Africa

In 2014, the Wireless Innovation Forum (WIF) introduced the idea that “regulation cannot proceed without a clear understanding of technological capabilities and business potential, business investment cannot proceed without a clear understanding of technology and the regulatory environment under which it will be deployed and technology development cannot proceed without business investment and an understanding of the regulatory constraints”. A World Bank study in 2009 indicated there is a direct link between the increases in broadband penetration and economic growth, putting a figure of 1.4 % Gross domestic product (GDP) increase linked to 10 % increase in broadband penetration for middle income developing countries (World Bank, 2009). A separate study by World Wide Worx in 2012 attribute 2 % of GDP contribution to the internet economy, including infrastructure investments, internet access as well as government and retail internet spending in South Africa (Endesha, 2014).

The market size of the internet service providers and Wi-Fi hotspots has been quantified to be around US\$200 and 250 million as demonstrated in the study done by Renaissance Capital in 2012 (Renaissance Capital, 2013). According to Richard Thanki licence-exempt Wi-Fi offload alone is predicted to generate US\$250 billion in economic value globally over the years 2012 to 2016 (Thanki, 2012). Thanki (2012) calculates that making TVWS spectrum available for use on a license-exempt basis could generate over US\$100 billion in value to the South African economy over the next ten years by making broadband more affordable, increasing adoption of broadband connectivity and driving economic growth from increased use of the Internet.

South Africa ranks at number 5 among countries in the BRICS group of countries with an average connection speed of 3.7 Mbps. According to the StatsSA 2016 general household survey (i) 55% of South Africans saw internet access as a basic human right, thus more than half of South Africans believe that access to the internet is essential as they carry out their daily lives; (ii) this poses a significant opportunity for digital services providers, as 88% of South African consumers claim they make daily use of mobile handsets for accessing digital services, going up to 95% on a monthly basis; (iii) 61% of South Africans are unsatisfied with their current mobile internet connection, with 36% saying it is “slow” and 25% describing it as “unreliable”; (iv) 69% of South African consumers would like free access to limited basic internet in order to reach family and friends abroad; and (v) 47% of local consumers would like more localised and international content on their devices. According to statistics produced by BMI (2016) the South African telecommunications sector generated revenues of about R147 billion whilst e investments (CAPEX) amounted to R23 billion, with mobile communication services contributing R16 billion of that figure. South Africa has about 86 million mobile cellular subscriptions, comprised of 72 million prepaid and 14 million postpaid subscriptions and these figures continue to grow on a monthly basis.

### **1.11 The role of South Africa’s broadband policy**

The National Development Plan of South Africa (2012) emphasises the importance of a robust broadband and telecommunications network and lower internet access prices which will lead to greater economic and employment opportunities for the country. The South African Broadband Policy seeks to lay a foundation for future broadband project rollout success, by ushering in policies that enable competition and growth in the Information Communications and Technology (ICT) sector. To realise this goal, flexible policy and regulations are required to respond to the dynamic and agile nature of the industry as well as the supply and demand of the market (Department of Communications, 2013). Wireless access technologies have been identified as the *de facto* solution for the provision of cost effective broadband internet access over fixed or wired network infrastructure. To this effect, ICASA has commissioned spectrum audits across the country which have revealed gross underutilisation, by up to 99%, of this scarce natural resource by licensed operators in more than five

major cities, namely, Johannesburg, East London, Bloemfontein, Polokwane and Durban (Mfupe, Mekuria, & Mzyece, 2014).

South Africa's broadband policy, which is referred to as "SA Connect", has set targets seeking to provide over 90 percent broadband connection by 2020 whilst aiming for 100% penetration with download speeds of 100Mbps by 2030 (Department of Communications, 2013). This makes wireless broadband the candidate to be the most efficient technology to assist in meeting some of the South Africa Connect targets. The policy maker and the regulator need to develop and implement policies and regulations that are necessary for adoption of dynamic spectrum assignment and utilisation to meet the SA Connect targets (Mfupe, Mekuria, & Mzyece, 2014). SA Connect proposes for efficiently managed spectrum in order to create an environment where wireless broadband access could be achieved cost effectively (ICASA, 2015). This has become a reality which needs to be employed through the introduction of policy and regulation for dynamic spectrum assignment and management.

### **1.12 Convergence and its effect on policy and regulation**

Policy and regulatory intervention are needed for developing countries that are still grappling with challenges of universal access and services obligations to their citizens (RSA, 2012). The inefficient use of spectrum caused by the traditional command and control allocation regime has meant that only licensed users may utilise high demand spectrum in a particular band and geographic location. The demand is there, however, the current policy and regulation framework does not allow immediate rollout of DSA technology solutions. Convergence and the introduction of disruptive over the top (OTT) technologies like WhatsApp, Skype, Facebook and other social media platforms necessitate that a country be adaptable and fast moving with its policies and regulations to meet the needs of a dynamic evolving ICT industry (Manner, 2003). The trend amongst the developed countries has been to deregulate the industry rather than over regulate, as is the case in most developing countries, including South Africa. DSA is enabled by a number of technical, business, policy and regulatory factors, not forgetting the importance of institutional arrangements (Chapin & Lehr, 2007).

Policy and regulation are a cornerstone for dynamic spectrum access devices and cognitive radio technologies to become a reality, and the lack of dynamic spectrum access policy and regulation will, and has, delayed the rollout and deployment of cognitive next generation technologies that effectively and efficiently use spectrum (Freyens, 2009). An urgent policy and regulation intervention is needed, particularly for developing countries that are still grappling with challenges of universal access and services obligations to their citizens. There is a need to combine DSA based radio technologies and license-exempt policies in designated bands for the provision of universal access and services (Mfupe, Masonta, Olwal, & Mzyece, 2013). The licensed operator also needs to conform to predetermined conditions and is limited by lack of improvement and absence of policy and regulation on dynamic spectrum access and its use of cognitive technologies. The removal of all hindrances to the digital

migration to allow access to both the digital dividend 1 and digital dividend 2 and the re-allocation and assignment of unused spectrum, as well as introducing and protecting more spectrum commons.

### **1.13 Problem Statement**

The inefficient way spectrum has been managed and the worldwide proliferation of technologies making use of wireless communication has necessitated for alternative ways of accessing and managing spectrum has been identified as a major problem. The problem of spectrum scarcity and inefficient management will potentially be a problem of the past with the introduction of DSA and CR technologies. DSA has been researched and proposed by the communications sector regulator, ICASA, as a potential solution to effectively and efficiently manage spectrum through primary and secondary sharing of spectrum in specific bands using CR technologies. Cognitive radio technologies enable efficient management of spectrum using dynamic spectrum access, thereby requiring new policy and regulation to meet national objectives. This work investigates the required enablers for the introduction of DSA using cognitive technologies in South Africa, with a specific focus on policy and regulation with respect to the supply and demand sides. The limited application of the theories and concepts for DSA in sector policy and regulation in the electronic communications sector in South Africa, has posed a challenge in realising the maximum benefit from the effective and efficient use of spectrum. The demand for wireless network capacity has increased drastically, caused by the demand created by video and data traffic requiring more efficient and effective use and management of spectrum. Access to radio frequency spectrum is a key input to many electronic communications and Internet-based services, which have become part of our daily activities. DSA research involves simultaneously advancing implementation technologies, economic understanding, regulatory practices and institutional arrangements. The research problem studied in this work is that there is little clarity with respect to how technology, markets, policy and regulation provide the rationale for or against DSA in South Africa. Therefore, this study investigates the state of policy and regulation associated with supply and demand for dynamic spectrum access based wireless services, as well as stakeholder views on these matters. The researcher also hopes that the technical analysis and policy recommendations taken from this study will be able to contribute to the debate and discussions on DSA in South Africa.

### **1.14 Purpose Statement**

The economic justification for DSA and the required incentives need to be studied to guide the formulation of policy and regulation that balances economic and social interests, where DSA is considered necessary. Studying the relevant approaches to the regulation of TVWS and geo-location databases, cognitive radio technologies, the supply and demand of white space devices, as well as different spectrum management regimes, is deemed essential to addressing this challenge. The introduction of DSA policy and regulation may provide significant economic and social benefits to the

country by promoting the rollout of broadband; however the case has not yet been made. In particular, the study investigates the challenges, the enablers and supply and demand for DSA.

The method of the research is to review existing policy and regulation and consider the case for or against South Africa formulating and implementing agile and liberal policy and regulation for dynamic spectrum access using cognitive radio.

### **1.15 Research Question**

How do technology, markets, policy and regulation provide the rationale for the introduction of dynamic spectrum access in South Africa?

### **1.16 Research Sub-questions**

- (1) How can the use of TVWS increase the supply and demand of cognitive radio technologies?
- (2) What are the challenges facing the industry and the regulator in introducing dynamic spectrum access regulatory approaches that support cognitive radio technologies?
- (3) What are the enabling policy and regulatory factors for dynamic spectrum access in South Africa?

### **1.17 Chapter outline**

Chapter one gives a background on how spectrum is managed globally, regionally and nationally. This chapter also introduces the South African broadband policy, ICASA the regulator and key TVWS trials done in the country to prove the successes of DSA.

Chapter two explores the body of knowledge that surrounds the research problem and consists of definitions and detailed explanation of DSA, spectrum sharing, CR, geo-location databases and different spectrum bands identified for DSA.

Chapter three introduces the research question and sub-questions that address the research problem. This chapter further provides an outline of the research methodology, research methods as well as the sample group that the researcher interviewed. It further provides an approach to data analysis.

Chapter four provides the presentation of insights elicited from the data collected through interviews and document analysis. The chapter seeks to highlight key issues identified by the participants.

In chapter five the researcher provides an in-depth analysis of the results recorded in chapter four.

Chapter six is the conclusion of the research and also provides recommendations based on the analysis.

### **1.18 Chapter summary**

The chapter introduces the research by looking at the current policy, regulation, technology and economics of dynamic spectrum access. It also touched on the trials which have been conducted in South Africa on TVWS, both in Cape Town and Limpopo. The trial results showed there is an opportunity for dynamic spectrum access using TVWS to meet the objectives of the country's broadband policy viz, SA Connect, by providing cost effective and efficient 100 percent wireless

broadband access to the rest of South Africa by 2020. The chapter also introduced how spectrum is managed from a global, regional and national perspective and trends and terminology which have led to the introduction of CR and geolocation spectrum databases. This chapter also introduces the research problem, research purpose and the main question followed by sub-questions which this research report seeks to address.

## CHAPTER 2: LITERATURE REVIEW TO DYNAMIC SPECTRUM ACCESS

### 2 Introduction

The formation of a technology policy is usually guided by the country's objectives and other relevant national policies whilst restrictions are imposed by political institutions, state structures, interest groups and policy networks (Atkinson, 2011). South Africa has adopted a technology orientation policy, similar to other developing countries, which puts an emphasis on acquisition, diffusion and assimilation of existing matured foreign standards, technologies and policies (Yu, Zhang, & Cao, 2012). Policy, regulation and standardisation play a critical role in the introduction and commercialisation of the use of cognitive and other spectrum sharing technologies (Durantini & Martino, 2013). King (1994) also alludes to the increased uptake and introduction of innovation in technology in the market as a result of both the technology provider's push and the users pull, subject to the influence of different institutions. This model has its positives and negatives and has led to developing countries adopting a "wait and see" approach. The result of the wait and see approach by emerging markets has stifled the decision making processes as well as affecting the ability for developing countries to innovate and create new markets and develop new technologies (Yu, Zhang, & Cao, 2012).

There is a high demand for radio frequency spectrum by wireless applications and services. This prompted a re-examination of the way spectrum is managed, leading to policy and regulatory changes (Endesha, 2014). The paradigm shift in policy focused more on improving the flexibility of spectrum usage, support for efficient use of spectrum and all matters relating to spectrum management (Hossain, Niyato, & Han, 2009). A policy change has brought about different spectrum management regimes, focusing on flexibility, and has created opportunities for newer wireless technologies that utilise the radio spectrum more efficiently. The globally used spectrum management regimes are command and control, commons or unlicensed spectrum and market based spectrum management, also known as spectrum property rights (ITU, 2005).

#### 2.1 Cognitive radio enabled spectrum sharing

There has been demand and use of the highly valuable Ultra High Frequency (UHF) band (470-862 MHz) for technological and propagation reasons (Baldini, et al., 2012). An introduction of innovative ways to dynamically use spectrum has enabled the sharing of this scarce resource, hence its efficient use (Durantini & Martino, 2013). A number of technologies have been investigated for the provision of spectrum sharing in various frequency bands where different spectrum authorisation schemes apply and heterogeneous access arrangements are in force. However, for these technologies to be commercially

viable, specific policies and regulations need to be in place as well as the introduction of relevant spectrum management models. Zhao and Swami (2007) introduced three dynamic spectrum access models, namely the dynamic exclusive use model, spectrum commons model and hierarchical access model, based on the different licensing regimes.

The dynamic exclusive model suggests spectrum bands are allocated to certain services and assigned to licensed users. However dynamic and flexible access by third parties is allowed through administrative and market based spectrum access methods to improve spectrum efficiency (Zhao & Swami, 2007). This model is supported by the spectrum property rights regime and dynamic spectrum allocation and can only succeed by introducing flexibility in the spectrum assignment and technology neutrality (Durantini & Martino, 2013). CR and other spectrum sharing technologies increase spectrum usage by exploiting information about the statistical nature of wireless traffic in the various frequency bands. This is the collective use of spectrum model and it allows an undetermined number of independent users or devices to access spectrum in the same band at the same time and in a particular geographic area under a certain predetermined set of conditions aimed at avoiding interference (Zhao & Swami, 2007). This model thrives in the commons and open access regimes.

Under the hierarchical access model, secondary unlicensed users or devices can utilise the same spectrum band that has been assigned and licensed to the primary user (Zhao & Swami, 2007). CR works exceptionally well in this model as it is opportunistic in how it accesses available bands. The approach employed in this model is referred to as vertical sharing or opportunistic spectrum access (Durantini & Martino, 2013). TV WhiteSpace is among the most popular technology for accessing spectrum in this model. Regulations play an important role in allowing and supporting the efficient use of spectrum and how the industry introduces commercially successful solutions. This is achieved in countries and markets that have successfully introduced different spectrum sharing models. The success of CR technologies on a secondary basis in TV bands is dependent on successful detection of TVWS and the ability to avoid harmful interference to incumbent operators (Masonta, Johnson, Mzyece, 2013).

## **2.2 Cognitive radio as a solution to efficient spectrum use**

The term cognitive radio was coined by Mitola (2000) over a decade ago and has been a widely researched topic in the field of wireless research (Medeisis & Minervini, 2012). The number of conferences and publications dedicated to the subject have increased significantly with little implementation, however. With a plethora of definitions for Cognitive Radio, as the IEEE defines Cognitive Radio (CR) “as a radio in which communication systems are aware of their environment and internal state and can make decisions about their radio operating behaviour based on information and predefined objectives”. Accordingly, some CRs use artificial intelligence techniques while others use simpler control mechanism (Chapin & Lehr, 2007).

Berlemann and Mangold (2009) explain “CR as radio systems that automatically coordinate the usage of spectrum by identifying unused spectrum by incumbent radio systems”. Once the unused spectrum has been identified, other services intelligently use this spectrum in time, space and or location; this may be referred to as whitespaces or spectrum opportunity. The predictability and dynamic nature of spectrum usage contributes to the challenge of identifying spectrum opportunities and the more predictable the usage is, the higher the success in identifying and efficiently using this spectrum (Berlemann & Mangold, 2009).

CR technologies will play a fundamental role in the shift from static to dynamic spectrum access and management (Radio Spectrum Policy Group, 2010). The majority of the research conducted on CR technologies has focused on how CR could identify unused portions of spectrum and share that spectrum without interfering with existing users. Other alternatives that have been researched are how operators can improve the management of their assigned spectrum (Forde & Doyle, 2012). CR technologies could respond to spectrum scarcity by allowing near simultaneous band sharing and potentially changing the market for devices, services and how policy is developed and implemented (Huigen & Cave, 2008).

CR provides a new option in the highly competitive wireless market by contributing to a variety of competing technological solutions (Mitola, 2000). Metcalfe (1994) suggests that sustainable economic development is linked to dynamic interplay between the process of variety and selection. The delays in full scale introduction of cognitive radio could be attributed to two distinct yet complimentary strategic forces. The first force is the technology push which explains technology transfer as motivated by means. The second force is the demand pull or market pull which refers to the intensity of a market proposition and commercialising the new technology (Nemet, 2009). The effectiveness of the technology push and market pull process is cross dependant and the market pull strongly prefers clearer technological scenarios rather than experiments (Medeisis & Minervini, 2012).

“CR is aware of its environment and uses this information to decide on its transmission behaviour” (Mitola, 2000). As technology improves, it is envisaged that CR will make its decisions not only by using radio intelligence and geo-location but by using other important factors like user needs, operational costs of services or other pre-defined criteria employed by the licensed operator and/or the spectrum band manager. There are already technologies in circulation that use dynamic frequency systems to detect intelligent services (Radio Spectrum Policy Group, 2010). Forde and Doyle (2012) suggest that regulation and policy should not limit dynamic spectrum access only to TVWS. This statement is supported by the fact that cognitive radio has artificial intelligence for them to operate successfully in the vacant licensed spectrum band (Forde & Doyle, 2012).

The United States has introduced policies and regulations that are proponents of databases as a preferred form of dynamic spectrum access moving away from using the cognitive radio. Forde and Doyle (2012) consider this to be a more limited instantiation of what is meant by cognitive. However, this trend has

increased in the developed nations along with the United Kingdom, which is considered to be the leading country in Europe on issues related to spectrum opting for the non-sensing paradigm. The trend adopted in the United Kingdom has been introduced by the rest of the European countries who have all opted for policies that support geo-location databases to access TVWS (Forde & Doyle, 2012). Tables 4 and 5 summarise the benefits and disadvantages of the use of CR technologies on governments, manufacturers, incumbents and ordinary users. Australia has also introduced regulations which use UHF whitespaces on a licensed basis by using a sense and avoid technique and a geo-location database. The database uses a centralised mechanism that provides permission to devices to transmit in a particular time and location. CR can deal with the challenge that exists in licensing the landscape of TVWS. Geo-location database functionality will be possible for both mobile and fixed devices as it will not be dependent on frequent updating algorithms. The database should contain information for each intended frequency band with a table of users, their regulatory status, interference protection parameters and other critical regulatory requirements.

**Table.3** Benefits of CR for different stakeholders.

<b>Government</b>	<b>Manufacturers</b>	<b>Incumbent/ Operators</b>	<b>Users</b>
Improved spectrum utilisation	New market opportunities	Possibility of spectrum trading/auctioning	Improved access to wireless services & apps
Support innovation	Support evolution of communications technology	Adaptability of changing traffic demand	Lower cost-per-bit
Could minimise the burden of spectrum management whilst maximising spectrum efficiency	Quicker technology lifecycle	Reduced barriers to entry for smaller operators e.g. virtual network operators becoming real network operators	Greater competition could lead to lower costs and value added services
Potentially significant economic benefits	New end user equipment manufacturing an increase in the amount of hardware	Spectrum costs decrease	General economic improvements and ease of life/business
Potential for new government income streams by charging for secondary access	New infrastructure equipment e.g. database managers	Improved spectrum utilisation	General economic growth and ease of life/business

**Table.4** Disadvantages of CR for the different stakeholder.

Government	Manufacturers	Incumbents/ Operators	Users
More complex regulatory regime	Increased technical complexity	Risk of Wireless Interference and less certainty for investing into spectrum	Potentially higher costs for devices
Complexity in evaluating new hardware/software and certification	Higher costs to validate hardware to meet specific regulatory requirements	Commercial benefits in spectrum sharing not clearly identified	Potentially lower communication QoS due to interference
Risk of lowering the value of spectrum and decrease revenue streams	Potentially a negative effect on sales of legacy hardware	Increased competition as barriers to entry are reduced	Potential reduction in battery life for the new technologies
Need to create new certification schemes and economic models for trading and markets	Shift from hardware to software manufacturing and node of problems shadowing sensing functionality	Operators may miss trends and more value chain participation	
Monitor and control risks of wireless interference		Greater competition reduced income per-bit user	

**Source:** (Freyens, Loney, & Dissanayake, 2014)

### 2.3 Global trends in secondary access to white spaces

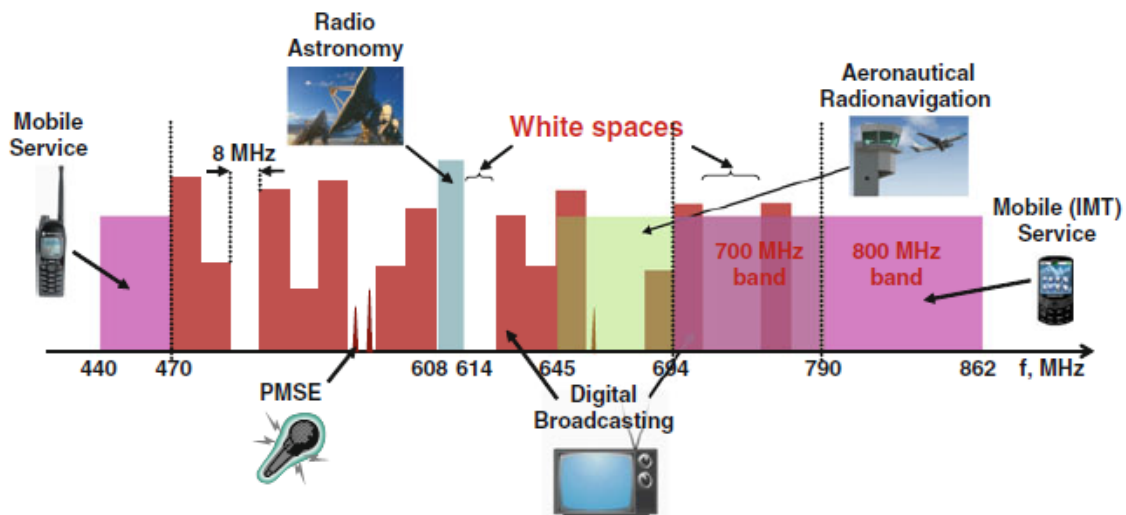
Cognitive radio (CR) is being evaluated by the majority of regulators across the globe as a technology to enable dynamic reuse of licensed but spatially used spectrum; this will potentially increase spectrum availability for new applications (Nekovee, Irnich, & Karlsson, 2012). In both the US and the UK, the regulators have developed regulatory frameworks for dynamic access to unused TV bands also known as TVWS, whilst other countries are in the process of developing or concluding research and trials on the use of TVWS (Masonta, Makgothlo, & Mekuria, 2012).

In 2004, the FCC proposed secondary access by CR devices in the TV white spaces, whilst issuing a second report which allowed unlicensed operations in the TV bands at locations where frequencies were unused by licensed users (Nekovee, Irnich, & Karlsson, 2012). This was preceded by regulations that allowed sensing and geo-location techniques with the aim of ensuring minimum interference to the incumbent licensees. The conditional licensing of nine commercial entities to operate as secondary users was concluded in 2011 (Nekovee, Irnich, & Karlsson, 2012). These entities were granted conditional operating licenses between TV channels 2 and 51 with exceptions to channels 3, 4 and 37, whilst being given strict conditions which included not operating in the same and adjacent channels (FCC, 2010). The FCC also imposed strict emission conditions to avoid unnecessary interference caused by high emissions (Nekovee, Irnich, & Karlsson, 2012).

Ofcom in the UK issued a statement in 2007 allowing the use of interleaved spectrum by exempt devices on condition that the devices would not cause harmful interference to licensed users (Ofcom, 2007). This was followed in 2009 by the publication of a report which supported three techniques for TV bands; the use of beacons, sensing and geo-location databases. However, the use of beacons was

subsequently found to be inferior thus Ofcom supported the sensing and geo-location database techniques. There was also support for master and slave device white space sharing with strict conditions on WSD transmission levels per device (Nekovee, Irnich, & Karlsson, 2012). Figure 5 below illustrates how spectrum is used and how whitespaces could be reused for other services in both time and space. At any given time they will always be a channel that is unused for one reason or the other but mainly to protect the opposite channel. These could be used for wireless broadband.

**Figure 5:** Illustration of TVWS Channels and Use



**Source:** ECC Report (2013)

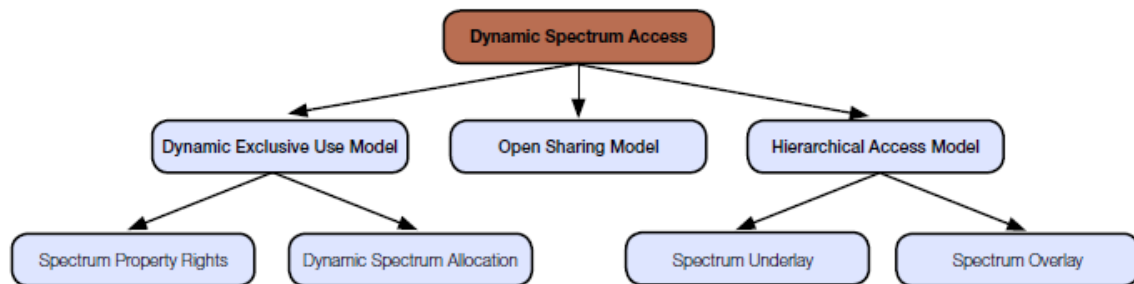
## 2.4 A case for dynamic spectrum sharing

There have been two categories of spectrum sharing that have been identified as being used by most countries in the world, namely homogenous and heterogeneous spectrum sharing (Wireless Innovation Forum, 2014). In homogenous spectrum sharing, the same radio communication technology can only be used within a specific band assigned to provide a specific service. Multiple mobile operators cooperating in providing a service in the same frequency band are considered to be homogeneous spectrum sharing. The licensee manages the sharing of resources and is protected from harmful interference which could be created by non-participating operators or users (Radio Spectrum Policy Group, 2010). This model works on an exclusive license regime within licensed wireless service bands and in bands that will be re-farmed or cleared for alternative use (Wireless Innovation Forum, 2014).

As previously stated by Zurutuza (2012), DSA improves the efficiency of static spectrum access by providing opportunistic access to already available spectrum using three strategies. Dynamic exclusive use maintains the structure of property rights use to licensed users whilst giving more flexibility to the assignment and use of spectrum (Zurutuza, 2011). This model allows licensed users to lease out unused spectrum. The open sharing model allows the use of spectrum among peer users or spectrum common

to unlicensed Industrial, Scientific and Medical (ISM) bands (Zurutuza, 2011). This could be done in a form of centralised or distributed sharing model. The hierarchical access model uses a master and slave sharing technique which allows a Secondary User (SU) to access the same band as the Primary User (PU) (Zurutuza, 2011). This is allowed on condition the SU does not cause harmful interference to the PU. All these models are illustrated in Figure 6 below.

**Figure 6:** Dynamic Access Classifications



**Source:** Zurutuza (2011)

Heterogeneous spectrum sharing allows for different radio services to operate in the same radio band at the same time (Wireless Innovation Forum, 2014). Alternative communication technologies can coexist in the same radio band. TV whitespaces exemplify this type of spectrum sharing with the ability to provide wireless broadband services on the same radio frequency band as that of broadcasting. In these arrangements, TV whitespace devices play a secondary role to that provided for the primary user, in this case broadcasting, without any form of interference to the primary user. Future bands could also include different technologies operating in the same band such as WiMAX, LTE and Wi-Fi operating on the 3550MHz band (Wireless Innovation Forum, 2014). Regulatory policy, usage priority, secondary market structure and other innovative rules and technologies provide a symphony for successful heterogeneous spectrum sharing. The coexistence of signals may be managed through personal or commercial infrastructure points (Wireless Innovation Forum, 2014).

A policy and regulation intervention is needed, particularly for developing countries that are still grappling with challenges of universal access and service obligations to their citizens. The inefficient use of spectrum caused by the traditional command and control allocation regime has meant that only licensed users can utilise high demand spectrum in a particular band and geographic location. TVWS, using geo-location databases and cognitive radio, have been candidates for the most cost effective with ease of deployment. The demand is there, however, the current policy and regulatory framework do not allow immediate rollout of these solutions. Figure 7 below illustrates alternative ways to license spectrum by the regulator and still achieve the desired outcome of spectrum sharing.

**Figure 7:** Different licenses models.

Individual authorisation (individual rights of use)		General authorisation (no individual rights of use)	
Individual license	Light licensing		License-exempt
Individual frequency planning / coordination	Individual frequency planning / coordination	No individual frequency planning / coordination	No individual frequency planning / coordination
Traditional procedure for issuing licenses	Simplified procedure compared to individual licensing	Registration and/or notification	No registration nor notification
Command and control	With limitations in the number of users	No limitations in the number of users nor need for coordination	Commons / Unlicensed

**Source:** CEPT ECC Report 132

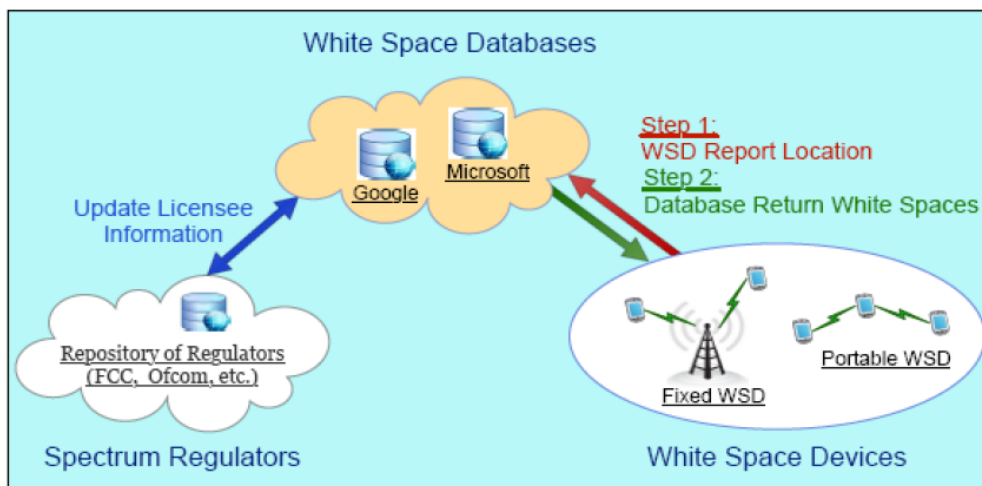
## 2.5 Ultra-wide band radio usage

The heightened demand for spectrum to support the growing number of wireless devices has necessitated that the manufactures of devices introduce newer technologies to support dynamic spectrum access and sharing. Ultra-Wide Band (UWB) radio technologies have recently played an integral part in the short range wireless application space by providing solutions in spectrum management and radio systems engineering (Porcino & Hirt, 2003). The technology used by UWB employs sharing on the already occupied spectrum by means of overlay principles, rather than looking for available, but unsuitable, new bands. UWB radio technology uses short-range frequencies in communicating in the already occupied spectrums bands. This technology is currently used for imaging systems (e.g. ground penetrating radar, wall imaging systems, medical and surveillance systems) to vehicular radar systems, communications and measurement systems. The technology can reduce its power emission which in turn allows a large number of transmitters to operate simultaneously, producing increased spectral reuse (Porcino & Hirt, 2003). To utilise spectrum sharing and optimal, efficient intelligent use of this technology, wireless networks can be developed as well as peer to peer networks. These networks will support commercial use of UWB devices as portable and fixed appliances, entertainment equipment, personal computers and gaming devices. The FCC in the United States has approved and given a legal opinion on the use of UWB radio technology, while Europe and Asia are in the process of approving this method of spectrum sharing (Porcino & Hirt, 2003).

## 2.6 Geo-location database use for DSA

The advent of TV whitespaces saw a trend amongst research institutions and manufacturers towards filling the void with unlicensed and low-powered radios. This allowed unlicensed devices to operate in the TV bands which were previously assigned to analogue TV, creating an opportunity to deploy opportunistic dynamic spectrum access-enabled cognitive radio (Forde & Doyle, 2013). For the success of TV whitespaces, regulators need to promote service and technology neutrality, where no frequency bands are set aside for a specific service by a specific technology. Many regulatory tools already exist in the US and Europe which support unlicensed spectrum use by cognitive radio. CR in TV whitespaces has been investigated, with policy and regulation supporting the database cognitive radio access approach (Forde & Doyle, 2013). The database approach uses a centralised mechanism that provides permission to devices to transmit in a particular location or geographic area. The database functionality will be possible for both fixed and mobile devices; however, it will be more practical for fixed devices as it would not require frequent updating of location as is required for mobile devices. The database solution should also contain information for each intended frequency band with a table of users, their regulatory status, interference protection parameters and other related regulatory requirements (Chapin & Lehr, 2007). The use of geo-location databases has given rise to a number of regulatory and policy issues such as the need for CR to provide its accurate position, data concerning spectrum used in each location and standardised protocols to access the dataset (Forde & Doyle, 2013). Figure 8 below illustrates how DSA uses white space devices and a geo-location database to manage spectrum sharing and minimise interference.

**Figure 8:** TVWS Architecture



**Source:** Ofcom (2010)

## **2.7 Supply and demand for white space devices**

Connecting the unconnected has the potential to grow the economy as previously discussed in studies done by the World Bank (2009) and developing new skills for communities and the need to develop new industries for the country. The Internet supports development by transforming a younger generation's ability to acquire knowledge and skills in order to contribute productively to national growth. It can also help an ageing population to remain active and access cost-effective health care.

Connectivity is transforming transport, manufacturing, logistics and environmental management. All forms of government can achieve greater efficiency and cost-effectiveness through their citizens being online and connected (Thanki, 2012). White Space technologies will also make deployment of last-mile connections in hard-to-serve rural areas more affordable. These benefits, in turn, have significant economic and development benefits. Even though many of the world's citizens lack reliable Internet access in 2014, the Internet already contributed an average of 1.9 percent or US\$366 billion in GDP in thirty emerging markets (World Bank, 2009). With greater access to the Internet and to affordable devices, this number is certain to grow. White spaces access can be deployed quickly and takes advantage of the otherwise unused spectrum.

According to a study conducted by the World Bank in 2009, a 10 percent increase in the penetration of broadband services in low and middle-income countries accelerates economic growth by around 1.4% and a 10% increase in household penetration delivers a boost to a country's GDP that ranges between anything from 0.1 to 1.4% (World Bank, 2009). The literature also links these studies to other industry studies which put a 10% increase in broadband penetration translating into a 1.5% increase in a country's labour productivity over the following five years and argues that countries with 80% broadband penetration are more than twice as innovative as countries with 40% penetration. The consideration of these statistics and the introduction of dynamic spectrum access will definitely help to unlock South Africa's potential and improve the socioeconomic conditions of its citizens.

## **2.8 Economics of DSA globally**

Spectrum economics are based on the value of the service provided to the users or spectrum (Broadband Centre of Excellence, 2014). Operators need to determine how much profit can be derived by providing a particular service prior to them purchasing an exclusive use spectrum license. Another model is to analyse alternative ways of providing the same service on unlicensed spectrum, higher frequency reuse or on fixed infrastructure (Wireless Innovation Forum, 2014). With the introduction of spectrum sharing, it has been established that it is better and more cost effective to provide a service through spectrum sharing rather than acquiring an exclusive use license. The assignment of spectrum bands by the regulator is currently based on the old regime of exclusive license use also known as "command and control". While this model works well for the regulator and is effective in avoiding interference between different frequency band users, it does result in inefficient use of spectrum. The exclusive use

model goes against the concept and idea of efficient and effective utilisation of spectrum as a scarce natural resource.

Spectrum sharing makes more economic sense with the cumulative spectrum spread across all users in the same bands being greater than the value that any single exclusive operator can achieve. The high spectrum economic value in the currently unlicensed frequency bands which are used for Wi-Fi and ISM where the operators, or users, don't have to incur license costs in order to provide a service (Manner, 2003). However, the downside to operators using these bands is the fact that there is no protection against interference (Wireless Innovation Forum, 2014).

## **2.9 Economic opportunities and business models for DSA**

Lack of access to wireless spectrum is a critical barrier to the development of affordable rural access and the encouragement of entrepreneurs and SMMEs. Fibre optic infrastructure plays an important role in the development of the national backbone, whilst wireless technologies become the ideal solution for the last mile communication (Mishra & Johnson, 2015). Regulators around the globe have explored and introduced a number of spectrum access models which have moved away from the old command and control model with the view to taking advantage of new spectrum assignments or available spectrum in unlicensed or underutilised bands. Cave and Webb (2011) proposed the release of licenses found in the Ultra-Wide-Band (UWB) with an interference assignment for use at a reduced price (Cave & Webb, 2011). This proposal prompted Holland *et al.* (2012) to review and recommend a completely pluralistic licensing scheme at a DySPAN conference in Washington D.C whereby licenses are awarded on a sliding scale (Wireless Innovation Forum, 2014). The cost of the license is tied to the level of interference tolerance the user is willing to accept from other users in the same band. License holders who are not willing to accept interference and are willing to pay a premium for guaranteed interference protection from other users would buy at a higher cost (Reed & Lansford, 2014).

The pluralistic licensing concept provides an economic motivation for license holders to accept the risk of interference that comes with sharing spectrum. It would also provide economic incentives to those users that are willing to share their spectrum with others (Lehr, 2014). This also creates new opportunities for more players to enter the market thus creating more options for services and applications for the consumer. Companies would have to make decisions when procuring spectrum licenses on whether to spend more money on restrictive licenses or on equipment that can enable optimal spectrum sharing with other users on the same band, thus spreading the cost and risk with others (Wireless Innovation Forum, 2014).

## **2.10 Public-private partnerships for dynamic spectrum access**

Different spheres of government hold licenses to highly valuable spectrum bands for use by different services on behalf of the public; this could be for disaster management, public safety purposes and

scientific research. It is important that government has access to these spectrum bands, but their use could be limited to time and/or space, thus rendering the majority of the spectrum underutilised (Wireless Innovation Forum, 2014). Dynamic Spectrum Sharing (DSS) can be used to assign the unused bands to a secondary user based on the principle of time and or space. This could be done through leasing of unused spectrum by using a system that utilises a static database to manage the user rights (Lehr, 2014). Within the leasing agreement, pre-conditions and rules could be included where priority is assigned according to pre-emption rules which would state that the incumbent primary license holder always has access to the spectrum it needs at whatever time or space it is needed (Lundborg, Reichl, & Ruhle, 2012). Different business models can be employed with one model based solely on cost, whereby the more you pay for a high priority service the higher the guaranteed Quality of Service (QoS) to your users. The less you pay for a service, the less your QoS to your users. Another model is based on social factors, where priority is the license holder that provides services to the public in accordance with the country's objectives and policies (Lehr, 2014).

## **2.11 Rural Broadband**

Improving access to broadband in rural areas has been a priority of many governments across the globe. This has also been on the agenda of the United Nations and World Bank with broadband access being enshrined as a basic human right in most country's constitutions (Lysko, Masonta, Johnson, & Venter, 2012). However, the high cost associated with the rolling out of fixed line broadband through fibre optic and copper, as well as the long distances involved, have been a major deterrent to investment by the private sector. The cost of investment does not make business sense for these operators to put in huge investments in the rural areas, even though they might have a license to operate in such areas. Wireless technologies are a candidate for the best solution for the rollout out of broadband in the rural areas, particularly in connecting government institutions, schools, hospitals and other much needed services through the use of unlicensed or shared spectrum technologies in South Africa and in other African countries (Lysko, Masonta, Johnson, & Venter, 2012). However, the long distances that are usually involved in the provisioning and/or transmission of internet based services do not suit the use of traditional Wi-Fi signals. TV Whitespaces have better transmission characteristics and have proved that it can provide superior wireless internet services in the rural areas through successful pilots that have been conducted across a number of countries (Wireless Innovation Forum, 2014). The Limpopo TV Whitespace trial has proved to be successful and could be rolled-out to the rest of the country with specific focus on rural areas to accelerate and meet the objectives of South Africa Connect (Department of Communications, 2013). The benefits would increase the participation of people in the rural areas, both economically and socially as well as creating new opportunities for broadband providers in a new market by introducing new services without huge capital investments (Mishra & Johnson, 2015).

## **2.12 Spectrum management regimes and regulatory approaches**

Spectrum management refers to how well a national authority safeguards the interest of the public and private users of radio frequency spectrum in accordance with international, regional and national policies, regulations and strategic needs. The ability for each country to realise the full benefits of spectrum depends on spectrum management activities that facilitate minimum interference and the implementation of radio systems (ITU, 2005). The standard spectrum allocation approach proposes three alternative models: exclusive use or command and control, unlicensed or commons and market-driven regime. The body of knowledge demonstrates that the conventional approach conflates access regimes and requires moving away from the case by case administrative allocation by the regulator to a general regime of competitive markets (Minervini, 2013). The command and control regime assigns spectrum exclusivity to an operator through a centralised mechanism, usually done by an administrator and including auctions. This is a commonly used global method and allows the administrator to determine the type of allocation to an assignment (Basaure, Marianov, & Peredes, 2014). The commons or license exemption is one of the popularly used regimes internationally where part of the spectrum is allocated on a license-free or unlicensed spectrum basis, allowing free access (Basaure, Marianov, & Paredes, 2014). However, Faulhaber and Forber (2003) maintain that the commons regime will eventually lead to spectrum scarcity. In the previous decade, developed markets introduced a new method of spectrum acquisition, known as property rights, which allowed for spectrum trading between operators, market-based reassignment and reallocation (Basaure, Marianov, & Paredes, 2014).

The market allocation model of spectrum works well in advanced and developed countries where the policy maker and the regulator are sufficiently capacitated with the required technology and requisite human capital skills to ensure oversight of the industry. Policing and enforcement are daily activities undertaken where there is spectrum band abuse, interference and the resolution of consumer complaints. This model generates income for the regulator through awarding and renewal of licenses and penalty fees that would be imposed on transgressors (Cave, 2004). The policy makers are given priority in allocating certain spectrum bands for security, marine, space, research, innovation and other future governmental needs, based on the national objectives and in line with the countries policies and legislation (Department of Communications, 2013).

Conditional assignment of spectrum to the market, but not limited only to universal access, would encourage the operators to invest in expanding current network infrastructure and the rollout of new infrastructure in rural and semi-rural areas (Loo & Ngan, 2012). The regulator or government would also encourage expanded infrastructure rollout to cover the length and breadth of the country through incentives from the universal services fund. This allocation model would encourage the industry to introduce more advanced wireless services and next generation technologies and introduce self-

regulation in the market through spectrum leasing and re-farming, thus guaranteeing optimal and efficient use of spectrum (Loo & Ngan, 2012).

According to Peha (2010), regulatory policies directly affect the adoption of certain technologies in specific countries, hence a detailed scan on how technology is being used and adopted will give guidance to the policy maker in developing spectrum management policies and the implementation of regulation that will benefit both the industry and the citizens of the country. The key to note the role of the policy maker is to develop and issue policy and policy directives on all matters relating to radio frequency spectrum, whilst the role of the regulator is to implement policy.

**Table 4** High-Level Adaptive Benefits

High-Level Behaviour (external)	Mechanism/Parameter	Considerations
Prohibited	Limit access to defined spectrum space regions (frequency bands, time, location, directionality)	May be used to protecting existing systems during introduction of adaptive systems or for protecting critical systems
Casual (if-then)	Given location in the spectrum space(physical location and frequency), access may be permitted with specific constraints	May require mandated existence and availability of databases
	Given measured environment, access may be permitted with specific constraints	Requires system to measure environment and react accordingly (DFS)  May also include limits based on the overall environment (interference temperature)
	Given signal identification, access may be permitted with specific constraints	Use both databases and measured environment to determine actions
Interactive (negotiated or shared control)	Negotiated access using spectrum space dimensions.	Behaviour enables regulatory constructs like secondary markets  Less interactive mechanism such as beacons can be used
Dynamic	Rather than pre-defined actions, systems can automatically determine what criteria and actions are needed based on measurements, share information and requirements	Enables innovative concepts based on dynamic system needs and conditions

**Source:** (Baldini, *et al*, 2012)

Inefficient spectrum usage, caused by the traditional command and control assignment regime, has meant that only licensed users can utilise spectrum on a particular band and geographic location. It also meant that the licensed user needed to conform to a set of pre-determined conditions imposed by the regulator as part of the license agreement (Hossain, Niyato, & Han, 2009). There are scholars like Faulhaber (2003) and Bauer (2002) that are proponents of managing spectrum as a commons pool rather than a licensed commodity. The unlicensed, or commons regime, would pursue having more sophisticated devices leading to more access to spectrum which, in turn, would lead to the provisioning of more services to more users (Bauer, 2002). Table 3 above gives us a breakdown of the different spectrum regime pros and cons.

However, property rights proponents foresee tragedies under the open commons regime, citing that exclusive rights to spectrum are needed to ensure market efficiency and long-term viability. Faulhaber (2003) argues that the commons regime will eventually lead to radio frequency scarcity which could be true for developed countries with vast competition and smaller markets (Bauer, 2002).

### **2.13 Dynamic spectrum access classifications**

Dynamic spectrum access enables the efficient and effective use of radio frequency spectrum by enabling sharing of this scarce resource by different devices to provide services to end users. IEEE 1900 defines DSA as “a technique by which radio systems dynamically adapt to select operating spectrum to use (in local time-frequency space) spectrum holes with limited spectrum use rights” (Chapin & Lehr, 2007). According to Chapin & Lehr, (2007), DSA technologies may be agile, flexible and capable of supporting many different transmission standards or waveforms. Whereas Freyens *et al* (2014) contend that dynamic spectrum access offers a way to enhance both productive and allocative efficiency of the highly valuable 400 MHz spectrum. This is considered to be narrowband and is characterised by bandwidth, geographic coverage and its availability over time, compared with better-known concepts of whitespaces (Freyens, Loney, & Dissanayake, 2014). The new trend in the US, UK and Australia has been to deploy white space technologies in the UHF band with the hope of realising economic benefits for using narrowband for efficient spectrum access.

The available license-exempt ISM bands in the 2.4GHz and 5GHz range have provided fertile ground for innovation in wireless communications. However, the low propagation makes the above bands unsuitable for broadband connectivity in the rural areas (Olwal, Masonta, Mfupe, & Mzyece, 2013). The introduction of radio frequency-aware CR and the availability of the TVWS has shifted the focus to dynamic spectrum access policies and the regulatory framework with CR technology promising intelligent and efficient use of RF spectrum, whilst TVWS provides propagation features which will cover large areas wirelessly (Olwal, Masonta, Mfupe, & Mzyece, 2013).

DSA technologies provide an alternative solution to spectrum management and access by introducing devices that increase spectrum sharing and intelligent radios that enable the use of spectrum effectively and efficiently. Successful commercialisation of DSA will contribute significantly to economic and social benefits of any country or region (Chapin & Lehr, 2007). However, for this to happen, major policy and regulatory changes need to occur which will lead to market evolution. Chapin and Lehr (2007) suggest that the success of DSA is dependent on the co-evolution of policy, regulation, market and technology.

#### **2.14 Chapter summary**

The chapter above follows the conceptual framework which has been adopted for this research report. The conceptual framework focuses on four key areas that enable the introduction of dynamic spectrum access, namely technology, markets, policy and regulatory analysis. The literature review looks at the spectrum management regimes, engineering and technical perspectives, markets and the policy and regulatory perspectives. This global perspective contextualises and assists the researcher to build a case for the research as not a lot of literature is available on this subject in South Africa. This chapter reviewed mostly literature and studies done globally on the phenomenon of DSA, spectrum management, CR, TVWS and geo-location databases.

The method followed for the research is to review existing policy and regulation and consider the case for or against South Africa formulating and implementing agile and liberal policy and regulation for dynamic spectrum access using cognitive radio. The chapter also reviewed research done on the economics, supply and demand of DSA and related technologies.

## CHAPTER 3: INTERPRETIVISM METHODOLOGY

### 3 Introduction

Spectrum management regimes and supporting technologies are the enablers for dynamic spectrum access. The concepts identified in this research paper describe the inter-link between technologies, markets, policy and regulation and how they need to be studied collectively in order to provide solutions to the current spectrum scarcity many scholars have alluded to in Europe, the USA and many other developed countries which have led to cognitive technologies being recommended as a solution for the efficient and effective use of spectrum. The research intended to unearth challenges and problems that needed to be solved in order to introduce and increase the diffusion of dynamic spectrum access technologies in South Africa. For the purposes of this research report, a number of study concepts have been researched which include technical, markets, policy and regulatory analysis.

The author identified a list of respondents to interview with the assistance of the supervisor, who is a spectrum specialist and also received advice from fellow students who work in the industry and deal with matters of spectrum on a daily basis. Out of the twenty-one respondents identified, the author was only successful in interviewing thirteen respondents. A table with the list of participants interviewed, the interview dates and position in the organisation is found in Annexure C on page 94. A list of questions which were broken into four main categories linked to the conceptual framework and supported by the literature review of the following areas (i) Technology, (ii) Markets (iii) Policy and (iv) Regulation will be found as Annexure B on page 93. The questions were emailed to the respondents with the participation information sheet, which is Annexure A on page 92, and a consent form prior to the interview taking place. This was done to ensure that the participant is aware of the topic of the research, the reasons behind the research, the institution conducting the research and who will be conducting the research.

All the thirteen interviews were recorded and transcripts were developed by the researcher to allow for systematic data structuring which will assist in presenting the research findings in a sequence and understandable format to the reader of the research without identifying who said what in line with the anonymity ethics code of conduct. Although the respondents tried their best to answer the questions as honestly as possible, thirty percent did not feel comfortable answering all the questions whilst being recorded out of the fear of being victimised by the employer, even after reassuring them that their responses will be kept anonymous. This question had to do with the policy section of the interview questions in particular when it came to probing questions.

### **3.1 Research Question**

How do technology, markets, policy and regulation provide the rationale for the introduction of dynamic spectrum access in South Africa?

### **3.2 Research Sub-questions**

- (1) How can the use of TVWS increase the supply and demand of cognitive radio technologies?
- (2) What are the challenges facing the industry and the regulator in introducing dynamic spectrum access regulatory approaches that support cognitive radio technologies?
- (3) What are the enabling policy and regulatory factors for dynamic spectrum access in South Africa?

### **3.3 Research Limitations**

The research did not seek to address detailed technological issues that are specific to particular radio frequency bands. The emphasis was on how policy and regulation can support dynamic spectrum access using cognitive technologies. A significant amount of technical research has been done and the results on the use of TVWS and geo-location database have been documented. This research does not interrogate or make reference to the National Integrated ICT Policy White Paper published on the 3<sup>rd</sup> of October 2016, as the research had been completed before this paper was published and the discussions on this whitepaper may change the direction of this research report.

Another key limitation of the research was the small sample size as the researcher was unable to get key participants due to their unavailability and work commitments. The researcher also encountered that the participants interviewed had limited technical and economic expertise and know-how in DSA and CR technologies.

### **3.4 Methodology**

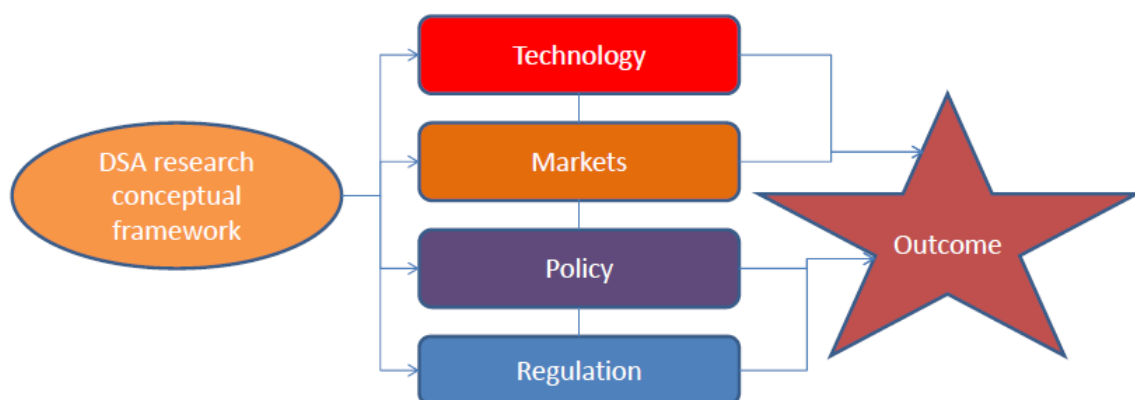
#### **3.4.1 Research Design**

In this research study, the research design was borrowed from Bryman (2012), who distinguishes between this term and research strategy. Bryman (2012, p.715) defines research strategy as “the general orientation of the conduct of research”. Generally, there are three research strategies to choose from, however, for the purpose of this study, the researcher chose a qualitative research strategy which carries an interpretive epistemological orientation. It is descriptive and inductive (Bryman, 2012), which afforded the researcher an opportunity to understand the policymaker, regulator, industry associations, manufacturers and other respondents’ perspective on why there is a lack of policy and regulation on dynamic spectrum access and what the emerging plans were. This strategy allowed for observing policy and regulation by data triangulation. The qualitative case study research ensured that an issue is not explored only through one lens, but a variety of lenses which allow multiple facets of the phenomenon to be revealed and understood (Baxter & Jack, 2008).

Research design has a distinct meaning and, according to Bryman (2012), is defined as the “framework for the collection and analysis of data”. On page 46, Bryman states that “a choice of research design reflects decisions about the priority being given to a range of dimensions of the research process”, and this, of course, will affect how the lower-level methodological procedures, such as sampling and statistical packages are influenced. In order to determine the reasons for the lack of policy and regulation on dynamic spectrum access and emerging plans, a cross-sectional qualitative research strategy will be deployed for this research.

The aim of the research was to investigate the economic and regulatory consequences of dynamic spectrum access and management regimes. The research outcomes would provide recommendations to future policy and regulation for efficient and effective spectrum use. Similarly, this research intended to investigate agile policies, regulations, technology and economics globally for adaptation and successful implementation of dynamic spectrum access and supportive technologies in South Africa. The Wireless Innovation Forum in 2014 issued the following statement “It is obvious that regulation cannot proceed without a clear understanding of technological capabilities and business potential, business investment cannot proceed without a clear understanding of technology and the regulatory environment under which it will be deployed, and technology development cannot proceed without business investment and an understanding of the regulatory constraints” which supports the research conceptual framework of this research paper. The research also proposes continuous research be commissioned by both the policy maker and the regulator in South Africa to ensure that the country keeps abreast of international norms and standards whilst looking at ways to innovate. Figure 9 below is a pictorial view of the conceptual framework discussed above.

**Figure 9:** Dynamic spectrum access conceptual framework



**Source:** Canca (2016)

### 3.4.2 Data collection methods and analysis

Data was collected through interviews and document analysis. The area being researched required respondents who are wireless network access providers, the regulator, research scientists, mobile operators, broadcasters, manufacturers, industry associations and the policy maker; however only thirteen participants were available for interviews. The rest of the identified participants felt they would not be able to assist, citing their inexperience and lack of confidence in discussing DSA and CR technologies. The research was done using a cross-sectional questionnaire and data which was collected through one-on-one interviews with respondents guided by semi-structured questions. The interview guide contained direct, indirect and probing questions. The interview guide had four sections, policy, regulatory, technology and market-related matters in the Telecommunications and broadcasting industries. Secondary data was collected through the reviewing of the ICASA draft DSA discussion paper on dynamic and opportunistic spectrum access in South Africa and the suggested technical rules and regulations for TV white spaces, mini case study of the trials on TV white spaces carried out in South Africa (Limpopo and Cape Town) and relevant documentation from ICASA including the responses to the DSA discussion paper on dynamic and opportunistic spectrum access.

The interviews were all recorded. The researcher continuously conducted on-going data analysis once the interviews started and which ran concurrently with data collection. Once all interviews were completed, the information was transcribed and themed, categorised and coded according to thematic content and keywords in context, using a computerised coding system (Brymans, 2012). Connectors between themes and categories were useful for understanding the thinking of the respondents and towards the production of the research report (Hiemstra, n.d). The informants were selected from a sufficiently broad, yet representative, set of different communities: the mobile operators, broadcasting sector, science and research institutions, the regulator, the policy maker, technology manufacturers and industry associations. A request was also made to industry experts and commentators that have an interest in the topic of dynamic spectrum access technologies.

### 3.4.3 Data Analysis

Analysis began when the data was being collected by observing the interviewee and the sites where the interviews took place. Interview transcripts, responses to open-ended questions, policy, regulatory and strategic documents formed the data set analysed. Before undertaking the analysis of results, the researcher checked for internal consistency of the measures. The interpretation of the data by the researcher had to pass the validity test as the respondents come from different quarters of the ICT sector and their roles inform their expectations of the findings i.e. policymakers versus the regulator, industry association, manufacturers and operators.

The data sets mined were coded for ease of use when searching the data and identifying emerging patterns requiring further investigation and analysis.

#### **3.4.4 Validity, reliability and ethical issues**

It is paramount that the research findings are valid and reliable through the recording of interviews and the use of relevant secondary data. Gillham (2005) argues that the validity of an account of a research interview is not so much in whether it gives a true picture of the person, but whether it is a balanced account of the interview that took place. The interviews took the form of unstructured interviews to allow the experiences of the respondents to emerge in the findings (Bryman, 2012). The interview guide in each case was the relevant questionnaire prepared for the policy maker, the regulator, and industry specialist, manufacturers of technology and incumbent telecommunications operators.

#### **3.4.5 External validity**

To address the deficiency, the researcher gave the fullest description of the data collected as possible, and as detailed in the findings by Merriam, (1995).

#### **3.4.6 Internal Validity**

The researcher ensured that the required objectivity and balance was maintained through subjecting himself to constant self-examination and thoughtful review throughout the data collection and analysis process (Hiemstra, n.d). The researcher undertook member checks and triangulated with all interviewees to ensure that the interpretation of their reality is consistent with that reality (Merriam, 1995). Member checks will assist in validating for the plausibility of the researcher's interpretation of their interviews. What policy makers said differed with the experiences of the regulator, wireless access service providers and incumbents? The researcher consulted peers in the field to review the data and comment on the plausibility of emerging findings and in particular researcher's supervisors.

#### **3.4.7 Ethical Issue**

Before embarking on this research, the researcher was cognisant that human beings are the informants of this study and therefore there is a possibility that unique ethical challenges might emerge that could jeopardise the study. To avoid any ethical dilemmas the researcher ensured that, before informants participated in the interviews, they were fully aware of the purpose of the research and were assured of their privacy as well as the confidentiality of the information they would be providing. The researcher gave all respondents assurances that their interview responses would remain confidential. Consent forms were given to the respondents to sign prior to any interview commencing. Only then would they be asked to sign and they were informed about their right to withdraw from the processes at any time if for any reason they want to opt out and they were assured that there would be no consequences for them for exercising this choice.

#### **3.4.8 Anonymity**

Anonymity and confidentiality have continued to be a priority and has been adhered to in accordance with the requirements and conditions of the Wits Human Research Ethics Committee (Non-Medical). Barnes (1979) states "data should be presented in such a way that respondents should be able to

recognise themselves, while the reader should not be able to identify them”. It is in the same spirit that all participant rights to privacy and anonymity have been catered for and they have been given general identity tags to ensure that their identity remains anonymous.

### **3.5 Chapter summary**

This chapter gives a summary of all the tools and instruments that were used during the process of completing this research report. The objective of this research report is to give input and to influence the policy and regulatory direction taken by the state in this case the policy maker and regulator ICASA in proactively developing policy and regulation for dynamic spectrum access and management. The foundation for the research is laid in this chapter by introducing and explaining the research method, process taken in collecting data and design. Chapters Four and Five are written following the architecture detailed in this chapter.

## **CHAPTER 4: INSIGHTS ON DYNAMIC SPECTRUM ACCESS AND EFFICIENT MANAGEMENT OF SPECTRUM**

### **4 Introduction**

This chapter summarises the interviews conducted with participants selected for their extensive knowledge of the subject from different perspectives. The informants were selected from the regulator, policymaker, product manufacturer, research institutes, industry associations, telecommunications operators and industry specialists as captured in Annexure C on page 94. The interviews have been conducted in line with the research questions and sub-questions with basic general industry questions being asked at the beginning of the session to lighten the mood and put the informant at ease.

There were a few questions asked at the end of the session to get the participant's view on where they see the future of DSA and cognitive radio in South Africa's economic growth and being a global contender in the ICT sector. These questions are listed in Annexure B on page 93 of this research report. This chapter presents responses to the research questions from the thirteen respondents who were interviewed and document analysis which was conducted as part of data collection for this research report. Efficient spectrum management may provide benefits to the citizens of the country by serving the national interest, promoting the country's economic and social development. Technology neutrality is a key driver to the successful implementation of any spectrum management policy and regulatory framework to ensure the efficient management and effective usage of radio frequency spectrum (RSA, 2010).

#### **4.1 Overview of the responses with respect to the need for dynamic spectrum access and assignment**

##### **4.1.1 Spectrum Licensing and Interference**

Traditionally spectrum sharing falls within the following broad approaches: A licensed spectrum, authorisation approach and a licence exempt spectrum. One way that spectrum management could be explored is through a licensed shared access and/or shared licence exempt bands (Regulator 1). However, in the case of DSA, as it is viewed as a new approach to accessing the shared spectrum bands between primary and secondary users new regulations need to be introduced whilst protecting incumbents from interference (Policy 1). Spectrum sharing makes it potentially harder to manage interference between different spectrum users in dedicated spectrum bands but research and trials done on DSA using CR and geo-location databases can limit potential interference (Regulator 2). Advances in DSA technologies could enable devices to make more intelligent decisions about how to operate (e.g. which frequency, power level etc.) in a given location to minimise interference (Policy 1). The proposed licensed approach in the ICASA discussion document proposes that all services sharing access to the

same spectrum band are licensed and are subject to a centralised technical coordination process. This makes it potentially much easier to manage interference between different spectrum users, enabling, for example, services to operate at higher power and provide wide area coverage whilst maintaining a good service quality (Policy 1). In the licence-exempt approach, some of the devices sharing access to a spectrum band do not require a licence. This reduces barriers to spectrum access, helping to support innovation in new services and devices. The main drawback of this approach is that there is no centralised control over who can access the spectrum and licence-exempt devices usually need to operate at low power and hence over short distances to minimise interference (Policy 1).

#### **4.1.2 Technical trials and capability**

Manufacturer 1 explains that recent trial projects in Cape Town, Limpopo, and elsewhere in the world have demonstrated the technical viability and potential economic and societal benefits of dynamic spectrum assignment. The Cape Town and University of Limpopo trials were both successful proof-of-concept for the use of TVWS to provide internet access at low cost to schools in both urban and rural locations within South Africa (Manufacturer 2). The Cape Town trial confirmed that interference could be avoided successfully in a metropolitan area with a variety of licensed users through the use of a geo-location database to manage dynamic assignment in combination with transmitter power limits (Regulator 1). The University of Limpopo trial showed how effective TVWS technology could be successful in providing hard-to-reach schools in rural South Africa with access to the Internet for the first time (Regulator 1). Policy 1 believes the outcome of both of these trials is consistent with the results of six other TVWS pilot projects conducted in Africa since the beginning of 2013. These projects have shown that TVWS can provide low-cost and reliable broadband access to students, medical workers and researchers without causing harmful interference to licensed users of the spectrum band (Regulator 1).

Manufacturers 1 and 2 explain that spectrum above 50 GHz can be used for license-exempt lower-power, high-bandwidth, relatively short-range fixed and mobile communications for indoor and outdoor use., License-exempt higher-power devices can be used for outdoor use utilising very high gain antennas for wireless backhaul and point-to-point broadband systems. Due to the nature of rural topography and the lack of available grid power in SA, TVWS, being a Sub 1G technology, will have far better propagation across this terrain and will be able to operate in a "near line of sight" (NLOS) mode (Manufacturer 2). This will allow areas to be reached in a far more economical manner so as to be able to provide affordable internet access and reliable grid power, especially renewable energy power solutions, to potential users at the bottom of the income pyramid (Industry 1). The broadcasting respondents believe that it is important for the regulator to establish a framework for dynamic spectrum assignment that is flexible enough to work in multiple bands where spectrum sharing between, and among, licensed and license-exempt users is required. For spectrum bands where there are no licensed services to protect, Manufacturer 2 believes a license-exempt approach is best.

The regulator may want to review the history of the FCCs proceedings regarding ‘Broadband over Power Lines’ (Manufacturer 2) as another option for DSA. Licensed-exempt spectrum plays a critical role in today’s communications networks. Almost half of the mobile data traffic globally is offloaded over license-exempt spectrum bands using relatively ubiquitous DSL and FTTH networks. For this reason, Manufacturer 2 believes that the regulator needs to examine ways of increasing the amount of both licensed and license-exempt spectrum available to South Africans, as well as methods for making more efficient use of spectrum.

Policy 1 and Regulator 2 believe TVWS has the potential to provide low-cost broadband connections for personal/portable devices as well as extend broadband coverage to underserved areas over a wireless connection where broadband is not currently available or is severely limited, and where deploying other wireless technologies are not cost-effective. Industry 1 argues the fact that the interference-free coexistence framework approach with Digital Terrestrial Transmission (DTT) primary incumbents that TVWS advocates in the UHF band, coupled with the geo-location database governed opportunistic spectrum sharing and usage by White Space Devices (WSD) on a secondary assignment basis, is the best contribution by TVWS technology towards achieving the goals of ensuring the most efficient uses of radio spectrum.

Industry 1 supports the view that a structured use of the DTT planning tool and the propagation analysis model of choice for SA, with real-life sample testing of WSDs interference using actual transmitters in use per location, should be adopted in order to obtain reliable data so as to avoid the risk of overprotecting DTT incumbents and therefore resulting in unnecessary spectrum sterilisation. The application of new TVWS operators must include the region of interest, a brief business plan and follow the normal ICASA application procedures for sub 1 GHz frequencies but also incorporate further detailed information on the WSD devices and radio equipment to be used to ensure technology compliance and hence lower the risk of interference to other incumbent operators (Industry 1).

#### **4.2 Proposed technology and spectrum bands for dynamic spectrum access**

Numerous trials around the world have shown that dynamic spectrum access can facilitate broadband access and innovative data services while managing potential interference with incumbent spectrum users (Association 3). Manufacturer 2 believes dynamic spectrum assignment should be used on the VHF as well as UHF bands, as underutilised VHF spectrum can provide additional capacity for extending broadband Internet coverage due to its superior propagation characteristics compared to above-1 GHz frequencies. The introduction of licence-exempt managed access to TVWS may increase the magnitude of the available radio frequency spectrum available in South Africa (Manufacturer 1). Addressing spectrum scarcity in sub-1GHz bands will ultimately be to the benefit of consumers who will enjoy lower costs realised through competition and the non-passing on of high spectrum fees. Consumers will also see innovation through the Internet of Things and countless other new services

which, in turn, will drive demand for, and the uptake of, broadband in South Africa (Manufacturer 2). Manufacturer 1 argues that, while the regulator should focus in the near future on extending broadband Internet coverage using databases for DSA, the rules adopted for TVWS use should allow for other services, such as M2M and Internet of Things applications, and future technologies, such as spectrum sensing.

It is the view of Manufacturer 2 that licenses should not be required for use of TVWS, that licensing creates barriers to entry for providers, drives up end-user costs for services and introduces complexity in database administration. Moreover, a hybrid or mixed licensing regime does not provide the same advantages as a license-exempt framework (Manufacturer 2). Manufacturer 1 believes operational rules for devices should recognise differences in TVWS equipment and, accordingly, allow for differences in geo-location capabilities and power levels, amongst others. In addition, arbitrary restrictions on operating parameters should be avoided as much as possible, whilst white space databases are capable of setting operational parameters such as power levels as may be required in particular channels for specific locations to eliminate harmful interference (Manufacturer 1).

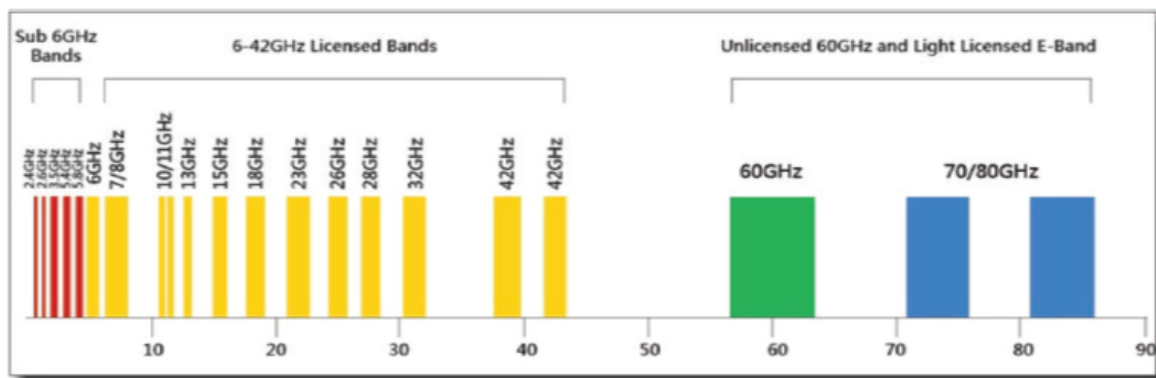
The FCC in 2013 authorised the frequency range 57-64 GHz ('60 GHz band') for license-exempt mobile use, except in aircraft (Manufacturer 2). The technical rules allow for both lower power portable devices and higher power fixed devices exclusively for outdoor use. In October 2015, the FCC released a Notice of Proposed Rulemaking for spectrum bands above 24 GHz, which, among other things, proposes to extend this license-exempt band to 71GHz. Manufacturer 2 supports the extension of the current band to 71 GHz for license-exempt use.

The groundwork has been laid for the commercial development of the 60 GHz band. The standards organisation, the IEEE established a standard 802.11ad protocol for ad hoc WLAN use in the 60 GHz band. The Wi-Fi Alliance has created a Wi-Gig trademark to denote devices that operate in the band and are interoperable with other devices (Regulator 1). Over the next year or so, we expect to see a considerable number of devices equipped with tri-band unlicensed radios operating in the 2.4, 5 and 60 GHz bands. Manufacturers 1 and 2 acknowledge that, at the recent ITU WRC-15 conference, it was agreed that the spectrum band 66-76 GHz should be studied as a potential band for IMT-2020. Based on the yet to be established IMT-2020 requirements for 5G wireless services and recommendations coming as a result of the studies, the 66-76 GHz frequency band may or may not be identified as a frequency band for IMT-2020 at WRC-19. Regardless of any potential future ITU actions, Manufacturer 1 and 2 suggest that the regulator pursues spectrum reform above 50 GHz by authorising license-exempt use in the spectrum range 57-71 GHz. It was indicated by manufacturer 1 that there are already some bands available that need to be considered for spectrum sharing the V-band and E-band. Thus the regulator would essentially provide a platform to manage and coordinate licensing; there is also a minimal fee proposed which is the administrative fee that will be paid by the users. There will be

type approval for the equipment to be used which will have to comply with specific regulations that will be passed by the regulator which will include maximum permissible power. This is illustrated in the figure below and published in the ICASA discussion paper on the use and licensing of the E-band and V-band. Policy 2 believes there could be opportunities created for license-exempt spectrum sharing in both the V-band and the E-band for ISM, innovation and other wireless services. This could be an opportunity as these bands are not considered to be high demand bands as they don't provide the propagation and latency required by mobile operators and other services that need to guarantee the quality of service to their customers (Policy 2). With regards to TVWS, Policy 2 believes that an opportunity could be realised, but it was early to pursue such an opportunistic sharing model. There were lower levels of interference detected in the Cape Town trials which could be achieved as it was only a pilot, however, we don't know what levels of interference will be experienced once this technology becomes commercial, especially as an unlicensed service, Industry 3.

How and what is the proposed management scenario for DSA without causing major interruptions to the TV bands, broadcasting and ancillary services? In a scenario where TVWS using geo-location databases becomes free for all, it is bound to create disruption, hence how would one be able to provide a commercially viable service without the guarantee of QoS (Policy 2 and Industry 3).

**Figure 10:** V-band and E-band with regards to other licensed bands



**Source:** (ICASA, 2015)

Industry 1 believes the regulator should consider getting into contractual arrangements with White Space 3rd party database providers who are able to demonstrate that their databases meet certain requirements and are able to provide information on TV White Space availability to devices by taking the data provided by the regulator and providing responses to WSDs that accurately identify available channels and acceptable power levels. The database providers will need to go through a process of qualification in which the regulator tests a database to gain assurance that the database is capable of operating in accordance with the terms of which it has been appointed. Hence, a key component of the qualification process will be testing that the database is capable of implementing ICASA's coexistence

framework. The regulator should consult fully in advance of introducing any charge to database providers (Industry 1).

Respondent Industry 2 argues for the designation of multiple database administrators and proposes an open market structure which will be driven purely by market forces to shape the structure of the database administration functions and service offerings, subject to the various requirements set forth in the rules. The multiple database administrators will offer services on a competitive basis; this will prevent a single party from obtaining monopoly control over the database and could provide an incentive for database operators to provide additional services beyond those required by the rules which could result in lower costs to consumers (Industry 2). In addition to providing devices with a list of available channels for use, databases offer two advantages in ensuring protection against harmful interference. First, the database allows operating parameters to be changed—for example, to accommodate changes in incumbent operations—without upgrading devices in the field. Second, because devices report their location to the database, “[n]on-functioning or interference-causing devices [can be] quickly located and isolated, allowing speedy resolution of interference complaints” (Industry 2). Both of these features make databases an attractive option for managing access to the TVWS spectrum (Industry 1 & 2). The use of sensing as an additional method of interference protection can be used alone and as an enhancement to database-enabled sharing. Although sensing has not been widely used in the TV bands, some companies are exploring stand-alone sensing solutions. Others have expressed an interest in using sensing combined with databases to expand spectrum availability in the broadcast bands (Industry 2). The propagation model used to calculate the presence of incumbent broadcast signals dramatically affects the amount of spectrum authorised for use by TVWS devices. It is a given that incumbents must be protected effectively. Within that parameter, in order to maximise spectrum use and effectively protect incumbents, ICASA should require database providers to use propagation models that rely on point-to-point modelling and take into account the variability in terrain when calculating propagation and spectrum availability. In 2013, a trial conducted in Cape Town, South Africa used terrain-based, point-to-point modelling to protect incumbent broadcasters and no interference was detected. Indeed, terrain-based, point-to-point models, like the Longley-Rice propagation model or the ITU-R Recommendation P. 1812-3 model, are often used to calculate broadcaster-to-broadcaster interference protection. An approach, such as the one relied on by the FCC, is not preferred. The FCC has chosen to rely on the F (50, 50) curves propagation model to protect incumbents from interference from white space devices. This model calculates a circular contour around each incumbent installation, regardless of the terrain in and around the transmitter location. Because it fails to take terrain into account, it can both over- and under- protect incumbent users, unnecessarily limiting spectrum availability in some areas, while risking potential interference to protected entities in others.

### **4.3 Supply and demand**

There is really no substitute for the regulator reviewing spectrum on a band-by-band basis to see which frequency ranges may be suitable for DSA. In its analysis, the regulator should consider whether the potential use is compatible with existing licensees in South Africa for each DSA candidate band, whether mitigation technologies are necessary and available, and have the potential for global harmonisation. Association 3 supports an approach under which TVWS databases should be authorised to provide database services using a certification process developed by the regulator. Certification is required as a mechanism to ensure that the database is able to operate within the parameters of the technical rules to be applied. Under this arrangement, the regulator would retain the ability to ensure compliance of TVWS databases and, through them, white space devices which could potentially lead to local manufacturing of these products (Association 3).

#### **4.3.1 Potential market opportunity**

Licence-exempt wireless technologies currently contribute significantly to the economy by expanding network reach and improving network management. 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 (Policy 1). Whilst Thanki (2012) argues that licence-exempt regimes decrease the costs of delivering broadband and increase the quality of the product, these benefits have, to date, been limited “by the lack of a harmonised globally available broadband-capable band of licence-exempt spectrum in the 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 (Association 3).

Both Industry 1 and 2 argue that access to TVWS could enable the rollout of more powerful public internet connections and Wi-Fi hotspots with extended range and improved speeds as a result of reduced congestion on existing networks. Whilst Manufacturer 1 and 2 agree that many other applications could be possible, such as broadband access to schools and home networks, that would support real-time video streaming applications, remote sensing of water supplies by municipalities and support a smart grid. Association 3 strongly believes the attractiveness of TVWS and economic viability is dependent on TVWS superior range and physical penetration coupled with unlicensed access to spectrum.

#### **4.3.2 The role of dynamic spectrum in socio-economic development**

Based on the views by Manufacturer 1, the dynamic spectrum is defined as a market-oriented spectrum management framework because it moves the control of the spectrum from central coordination by the government which is the command and control and puts it somewhere between market and technology orientation. Broadcasters are going to be paid and incentivised through a new licensing model to vacate certain spectrum and some of that spectrum will be used for dynamic spectrum, therefore there is a

market and technology element. In the case of South Africa, it is very unlikely that we will have the technology implemented (Regulator 3). In most of the discussions in the developing markets, the focus is mainly on a technology orientated framework based on what can and cannot be used. Deployments and trials leveraging TV white space technologies have now been successfully completed on five continents (Africa, Asia, Europe, North America, and South America). The USAID programme and Microsoft supported the Philippines TVWS deployment in Palo and Tacloban after Super Typhoon Yolanda (Industry 1). The social value of TVWS spectrum may be considered in terms of the opportunities that it provides to content creators and consumers, and in terms of the ability to communicate with friends, family and business partners. From an empowerment point of view, the communications that make use of additional spectrum might bring opportunities to take advantage of e-government services, including online health advice and e-education.

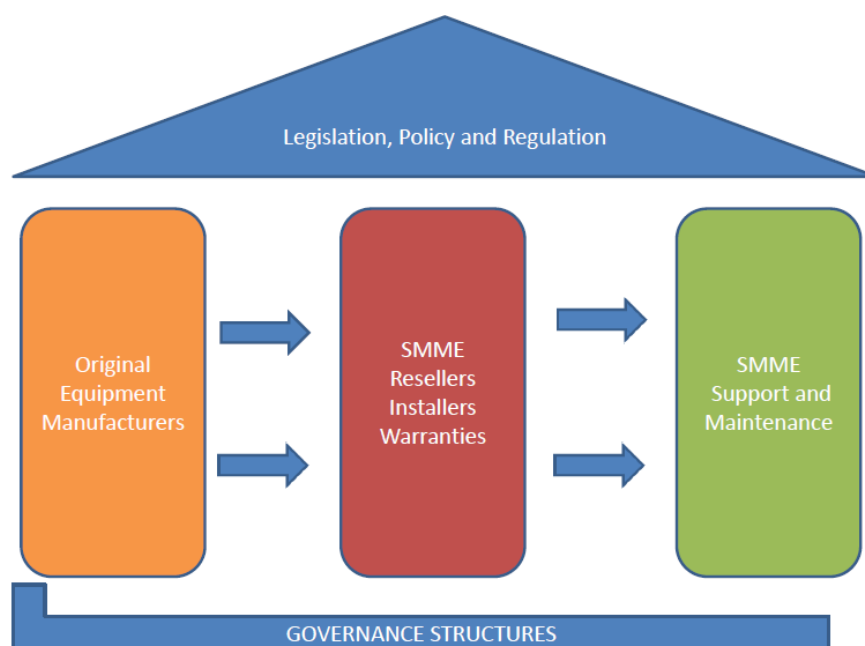
#### **4.4 Market and innovation opportunities for dynamic spectrum access**

Regulator 2 echoes the sentiments which suggests DSA using cognitive radio and geo-location databases may provide an alternative spectrum management regime and much needed broadband access. The introduction of devices that increase spectrum sharing will create a market for manufacturers to develop new communication service devices, create new commercial opportunities and thus contribute significantly to job creation and economic development (Regulator 1). Association 3 believes that enabling access to TVWS on a licence-exempt, managed basis will, in turn, enable greater competition in the provision of network access and backhaul services, particularly in rural areas, while creating opportunities for innovation in service delivery across the value chain. Allowing access in this manner would be a game-changer in addressing the bottleneck in affordable access services outside the major metropolitan areas (Association 3). Manufacturer 2 believes if the regulator rules in line with supporting license-exempt use from 57-71 GHz, this will allow South Africans to benefit from the economies of scale presented by such devices starting to come onto the market. Similarly, the industry believes that higher-powered outdoor 60 GHz devices will be able to leverage the technology and infrastructure being developed for lower power use, should the regulator rule supporting higher-power outdoor use in the 60 GHz band be approved, this would allow South Africans to benefit from the increased scale of such devices as they start coming onto the global market.

Association 3 believes that making the TVWS available will lead to the development of new wireless services that leverage the greater range and penetration possible in the lower frequency range compared to higher frequencies, as well as enable existing broadband services to be delivered at lower prices with higher quality. As an increasing number of countries around the world adopt TVWS rules, the price of TVWS operator equipment and user devices will fall, reflecting the increasing economies of scale (Association 3). The growth of global markets for TVWS equipment is expected to drive down costs for South Africa's electronics communications sector, making further investments in TVWS-based

broadband deployments more profitable, even as the service provides low-cost access to under-served areas, which will create a cycle of increased investment in TVWS deployments within South Africa (Manufacturer 2). Industry 1 believes TVWS availability will spur industry to come up with a varied range of potential use cases and applications, such as database systems development, cognitive technology systems development, Super Wi-Fi and Wi-Fi offload, webcam backhaul, CCTV monitoring, remote sensor monitoring, M2M (machine to machine communications), digital signage, mining, marine and rural broadband, to name but a few. For South Africa, rural broadband is probably the most important. Association 3 believes access to TVWS spectrum will benefit both rural and urban areas. However, the challenges of providing rural connectivity, together with the greater amount of unused spectrum in rural areas, means that the introduction of TVWS on a licence-exempt basis is likely to have more impact in rural areas in the short-to-medium term (Association 3). Figure 12 below illustrate how the industry could participate in a new value chain as proposed by the respondents to this research

**Figure 11: Proposed DSA Value Chain**



Source: Canca (2016)

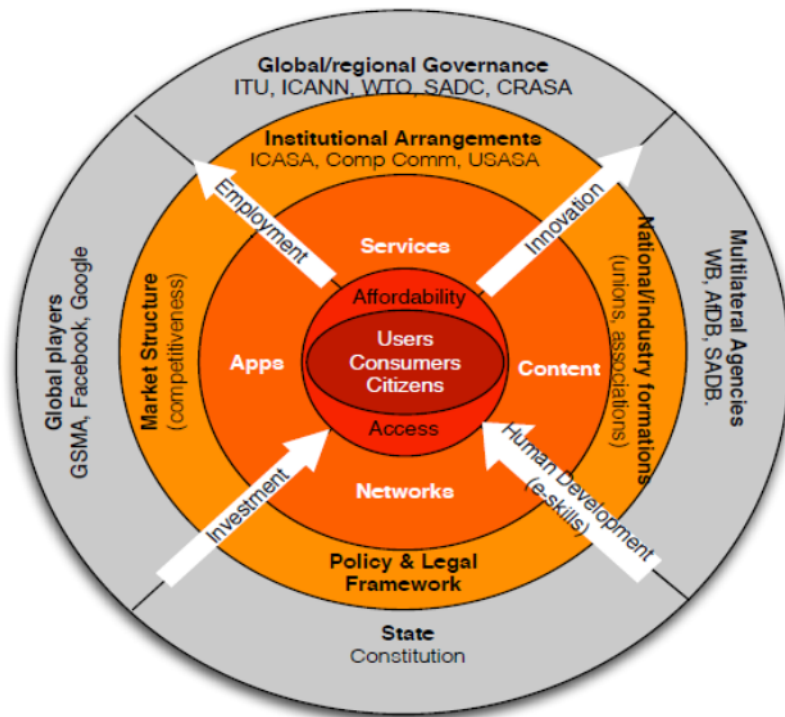
Thanki, in an introduction to his recent work on the role of enabling access to TVWS in South Africa on broadband rollout, makes the following statement attesting to the potential for TVWS technology to bridge the connectivity gap in South Africa “As I began my research and started writing I quickly came to the conclusion that there are probably few countries to which TVWS technology is better suited, especially for delivering affordable broadband in rural areas” (ICASA, 2015). Association 3 is in full agreement with Thanki’s views that enabling access to TVWS on a licence-exempt, managed basis will

address the bottleneck in the delivery of access services in rural areas (ICASA, 2015). It is in the last-mile of service delivery that the majority of the cost to the consumer is situated and it is in the last-mile of service delivery that there is the greatest scarcity of spectrum for the delivery of broadband services (Association 3). Access to TVWS can act as a complement to the existing mix of access options: fixed (wired, wireless), mobile and satellite (Operator 2). Manufacturer 1 believes the use of TVWS on a licence-exempt basis will reduce the cost to the operator of deployments and thereby promote more widespread provision of high-quality, low-cost broadband services. In urban areas – where there is less focus on establishing connectivity – benefits will flow from improvements in connectivity which can be captured by the government, commercial and private users. TVWS technology will also help to meet growing demand for smart-city applications such as traffic control, public safety and service delivery (Association 3).

#### **4.5 Key areas of collaboration and improvement with respect to policy development**

Manufacturer 1 strongly supports the efforts of ICASA to adopt dynamic spectrum assignment in the TV white spaces (TVWS) in order to make broadband more widely available across South Africa. They also commend the Authority on its leadership in the development of dynamic spectrum assignment through its support of trials in Cape Town and Limpopo and related research by the Meraka Institute, the University of Pretoria and the University of the Witwatersrand. Through ICASA activities, South Africa is well-positioned, not only to serve as an important example for other nations in how best to implement more efficient spectrum use but also to make significant progress on South Africa's national broadband goals (Policy 1). Industry 1 believes in the establishment of a TVWS Technical Working Group whose focus will be on providing the regulator with technical evidence to assist in ensuring that the coexistent framework continues to result in a low probability of harmful interference and, consistent with that objective, facilitating the use and development of the TVWS framework. If the results prove beyond a reasonable doubt that the TVWS framework works, it can then start to be implemented in other bands in a phased approach. SA ICT ecosystem, as illustrated in Figure 11, has matured compared to other developing countries and has excellent institutional arrangements and high levels of transparency.

**Figure 12:** South African ICT Ecosystem



**Source:** SA Connect (2013)

After the analogue to digital migration and the subsequent restacking, there will be a significant increase in the available channels for TVWS as digital TV is far more efficient in the use of each channel. About 75 percent of the spectrum will remain unused in any one of the 11 regions in South Africa as only four channels are required to receive the 4 multiplexes at any given location and this could be licensed. Except on the border areas, 168 MHz will be available for TVWS use. Since it has also been shown that TVWS can exist in adjacent channels to existing high-density analogue Terrestrial Broadcasting as demonstrated in the Western Cape TENET pilot project, the Digital switch over will reduce the number of Transmitter sites to the planned 189 DTT sites. This means that most of the >1000 analogue sites may be switched off, thus increasing the spectrum resource (Industry 1). Operator 1 argues that spectrum sharing techniques offer a potential solution to provide opportunities for operators to gain access to additional spectrum, which is typically allocated to other radio services and inefficiently utilised (such as the 470-694MHz spectrum band) and thus not available via traditional exclusive licensing models. Operator 1 recommends that the regulator must adopt spectrum management practices that ensure the protection of primary services from harmful interference. Such protection is imperative to enable the delivery of Quality of Service (QoS) as demanded by many end users and/or applications, as well as the objectives set out in SA Connect.

What has been important over the past ten years are the advances in geo-location database technology which are making it easier to exploit spectrum sharing opportunities (Policy 1). Here, databases hold information on the frequencies available for sharing in different locations, known as white spaces. White space devices query the database to determine suitable channel frequencies and powers (Policy

1). In principle, different devices can be allocated different shared access rights to the spectrum, depending on the type of service and where they are operating. TVWS which focused on the UHF spectrum traditionally harmonised for television broadcasting and SAB/SAP including PMSEs (Policy 1). Therefore, in ITU Region 1, one should focus on TVWS where there is intense competition for spectrum in 470-694 MHz between digital terrestrial TV, PMSEs and TVWS themselves. On frequencies for Wi-Fi (for instance WRC-19), a proposal to increase the amount of spectrum at 5 GHz available to Wi-Fi devices will be discussed in preparation for the World Radio Conference 2019, (WRC-19) under agenda item 1.16. The proposals put forward so far look at frequency bands between 5 150 MHz and 5 925 MHz (Regulator 2).

#### **4.6 Legislative framework and the current state of regulation**

The research has found that the majority of respondents are in agreement that ICASA, as the regulatory authority, has the legislative mandate to address the issue of dynamic and opportunistic spectrum management. The exception is found in a submission made by TV broadcasters and the National Association of Broadcasters (NAB) in response to the published discussion paper on the framework for dynamic and opportunistic spectrum management 2015 by ICASA. However, all respondents support the efficient use of spectrum and the introduction of innovative solutions in both technology and regulation to ensure effective and efficient management of radio frequency spectrum as a scarce natural resource. There is a belief by respondents that it should be done in accordance with the two main pieces of legislation, namely, the Electronics Communications Act, (Act No 36 Of 2005) ECA sections 2,4,30 and 33 and the Independent Communications Act of South Africa, (Act No 13 of 2000), (ICASA ACT) sections 4(3) (c) and 4(b). The respondents are also in agreement that the Regulator should be guided by the National Radio Frequency Plan of 2013 (NRFP) and the Radio Frequency Spectrum Regulations of 2015 (RFSR) in developing the framework for dynamic and opportunistic assignments. Section 1.7 details the current regulatory framework in South Africa, whilst explaining the different sections of the ICASA Act which support efficient use of spectrum.

#### **4.7 Gaps in policy and regulation with respect to dynamic spectrum access**

The NAB argues the Discussion Paper appears to overlook the distinctive roles played by the Minister and the Authority on the spectrum and related issues. The Minister is responsible for representing the country at the ITU and other international forums. Furthermore, in terms of section 3(1) (a) and (b) of the Electronic Communications Act 36 of 2005 (the ECA), the Minister is responsible for setting policies on matters of national policy applicable to the ICT sector in relation to the frequency band and the Republic's obligations and undertakings under bilateral, multilateral or international treaties and conventions, including technical standards for frequency matters (Broadcaster 1). It is only after determinations have been made at the ITU and adopted into national policy, that the Authority may formulate regulations on the assignment and licencing of spectrum in the specified bands (Broadcaster

2). The Authority's role therefore is to "control, plan, administer and manage the use and licensing of the radio frequency spectrum in accordance with bilateral agreements or international treaties entered into by the Republic" Furthermore, section 30(2) of the ECA requires that in controlling, planning, administering, managing, licensing and assigning the use of the radio frequency spectrum, the Authority must comply with the applicable standards and requirements of the ITU and its Radio Regulations, as agreed to or adopted by the Republic, as well as with the national radio frequency plan contemplated in Section 34 of the ECA. It is against this background that the Association 1, Broadcaster 1 and 2 believe since the Minister has not set any policy for spectrum use for dynamic and opportunistic purposes, the Authority has no legal basis to proceed with this process. ICASA is responsible for implementing a policy which has been developed by the Department of Communications. The assignment of radio frequency to licensees and the development of national assignment plans reside with the regulator (RSA, 2010).

The broadcasting digital migration (BDM) process which has been planned by the country in agreement with the ITU seems to have been neglected or is being given second place consequent to the favouring of TVWS which seem to be promoted as the solution for wireless broadband access (Broadcaster 1). Broadcaster 1 argues that the objectives of the 2010 radio frequency spectrum policy promote transparency and openness and principles of spectrum management, whereas the process undertaken by ICASA undermines these values. Broadcaster 1 also believes that there is a high possibility of implementing DTT with a multi-frequency scenario, thus leaving no space in the broadcasting bands to share with any other technology, let alone TVWS. Both Broadcasters 1 and 2 also emphasise that all broadcasting bands should be safeguarded for broadcasting and only open discussions of sharing TVWS once all the migration of all broadcasting ancillary services and the DTT agreement have been concluded. Broadcasters 1 and 2 believe these services will include, but not be limited to, digital audio broadcasting plus (DAB+) and digital radio Mondiale (DRM) while the authority develops a digital radio plan. There is also a concern that the discussion paper makes reference to the 4Mux plan and not the 7Mux plan as the latter has the potential to accommodate channel sharing (Association 1). In relation to Section 2 (t) of the ECA of 2005, the regulator is tasked with ensuring the protection, integrity and viability of public broadcasting services (Broadcaster 1). Broadcaster 2 feels the regulator must, in controlling, planning, administering, managing, licensing and assigning the use of the radio frequency spectrum, comply with the applicable standards and requirements of the ITU and its Radio Regulations, as agreed to or adopted by the Republic, as well as with the national radio frequency plan contemplated in Section 34 of the ECA.

#### **4.8 Concerns on the use of broadcasting spectrum bands for TVWS**

It is important to note the concerns raised by the broadcasters, industry associations and some product manufacturers on the use of broadcasting spectrum bands. Whilst all support innovation and the

introduction of newer technologies and are aware of the advances made in cognitive radio technology which brings about improved efficient use of spectrum, they do raise pertinent issues for consideration. The WRC15 was clear that the regional administration and the ITU differ in their understanding of the challenges resulting in delays in broadcasting digital migration (BDM) in most countries in region 1 - which covers, among others, Europe and Africa. To this end, a resolution was taken at the Conference that frequencies from 470MHz to 694MHz will continue to be allocated exclusively for broadcasting services to allow the migration from analogue to digital broadcasting (Association 1). This decision is valid until the next World Radio Conference set for 2019, "In our view, this resolution reconfirms the importance of the uninterrupted availability of spectrum during the BDM" (Association 1).

Broadcaster 1 brings to attention the fact that in 2007, broadcasting services relinquished 800MHz and, in 2012, did the same in the 700MHz bands for IMT services. This decreased spectrum allocated to broadcasting and its ancillary services. This point is supported by Broadcaster 2 who feels the 470-694 MHz bands should be protected and used purely for broadcasting and its ancillary services. Broadcaster 2 raises concerns that the Discussion Paper's proposals with respect to the UHF band below 694MHz are premature, legally impermissible, exceed the Authority's statutory powers and contravene the Republic of South Africa's international obligations. Association 2 believes the introduction of TVWS networks operating on a license-exempt basis will introduce distortions in industry competition by eliminating the cost of acquiring licensed spectrum. Association 2 also notes the careful consideration required in making available broadcasting bands for TVWS as services ancillary to broadcasting (SAB) and services ancillary to programme (SAP) are unpredictable and will vary widely from day to day and from place to place and may result in high levels of interference should the regulator proceed with implementing the use of TVWS for other services.

Looking to other jurisdictions, the regulator should be aware that in countries such as the United States of America (USA), for example, the roll-out of white space cognitive radio was implemented after a successful DTT migration (Association 1). In the USA the switchover from analogue to digital broadcasting was completed in June 2009, and it was only after the completion of digital migration that the FCC published a Memorandum Opinion and Order (MOO) outlining the final rules for the use of white space for unlicensed wireless devices (Broadcaster 2). Association 1 highlights the fact that a similar approach was adopted by Ofcom in the UK, where the introduction of white space technologies commenced in 2011 when the analogue switch off date was imminent.

#### **4.9 Chapter summary**

This chapter presents different inputs and views as interpreted from the 13 interviewed respondents and documents analysis from the different primary and secondary sources which are articulated in Chapter

3. The responses have been coded and presented in a way that seeks to answer the research question and sub-questions. The chapter structure also presents views according to those that are for DSA introduction from a technology, markets, policy and regulatory perspective, whilst also capturing the views of those that are in support of DSA with conditions and, finally, those that are against the introduction of DSA in the TV bands. The researcher has tried to present a balanced view and provided as much data as recorded from the different respondents. It also important to highlight that most of the participants that were interviewed were authors to response to the ICASA draft DSA discussion paper on dynamic and opportunistic spectrum access in South Africa on behalf of their organisations. The researcher also wants to highlight that most of the respondents did mention that they were not experts in DSA as this was a new way of managing spectrum and not much practical work has been done in South Africa, with the exception of the technical tests or trials which were done in Cape Town and Limpopo. Therefore one could find a lot of similarities between the participants' responses when they were interviewed and when doing the secondary document reviews of their organisational responses to ICASA.

## **CHAPTER 5: ANALYSING THREE PERSPECTIVES ON THE FUTURE OF DYNAMIC SPECTRUM ACCESS**

### **5 Introduction**

The purpose of this research report was to study and identify policy and regulatory changes in terms of DSA and CR and how these changes may be introduced for effective enablement of the development of wireless communication solutions. For DSA and CR to be commercially successful and to be used for real world application in South Africa, both the technological development and economic market realities had to be studied. After interviewing thirteen informants, reviewing three primary documents and reviewing eight secondary documents which were the responses to the ICASA discussion paper on dynamic and opportunistic spectrum access in South Africa, the researcher has been able to understand and interpret the different views and arguments which were presented by those that are for DSA on TVWS and those that are against it.

According to 2/3 of the respondents interviewed, the issue of the lack of political stability contributed to a dearth of political direction in the Department. They pointed out that, over a period of five years (2009 – 2014), the South African Ministry of Communications has experienced a high turnover of ministers leading to administrative instability. Although the respondents believe this made it impossible for policy development and policy approval to occur in the Department, they all agreed that this was also due to a lack of strong administration as, when politicians are replaced, the bureaucrats should be able to continue with the tasks at hand. The stated respondents argue that this has delayed the country in making major improvements when it comes to introducing efficient spectrum management policies. The lack of policy direction has led to a situation whereby the industry has had to navigate and influence the regulator in which industries and services are a priority and not necessarily guided by the country's objectives.

The research has identified three groups with varying ideas or perspectives on DSA. The first group are the proponent of DSA technologies in TVWS bands and on any other band on a license-exempt model. The second group supports the efficient management of spectrum and the introduction of DSA on a licensed basis, whilst the third group is against such a move by the regulator, citing the timing to the introduction of the discussion paper and questioning the motive and role of the regulator. Understandably so, those that support the introduction of DSA technologies in the TVWS bands reflect the regulator, manufacturers, research and academic institutions as well as industry associations representing the smaller internet service providers.

It is important to note that, even though the research found that there are those that are for and those that are against the introduction of DSA, all informants agree and support initiatives that will increase

efficient use of spectrum and encourage innovation that will improve effective spectrum management and create new opportunities through the introduction of new services and applications for wireless broadband. Tables 3 and 4 on pages 34 and 35 provide a detailed breakdown of both the benefits and disadvantages for DSA for different stakeholders such as government, manufacturers, incumbents and users.

Those that are against the use of DSA technologies in the TVWS bands are broadcasters, the industry association that represents the interests of the broadcasters, mobile operators and a few industry specialists. The reasons cited by these respondents is the regulator might have been ahead of itself by publishing the discussion paper on the framework for dynamic and opportunistic spectrum management without first awaiting the completion of the digital switchover (DSO). On completion of the DSO, the industry would identify which bands will not be used and a digital broadcasting policy needs to be developed related to that and thereafter, once these tasks have been concluded, only then could the regulator publish such a discussion paper. They have also raised concerns that the discussion paper only focuses on the TV bands and should be looking at broader opportunities for spectral sharing in all bands.

## **5.1 Technology Opportunity**

The introduction of CR was the result of trying to curb spectrum scarcity as well as dealing with the challenge of underutilisation of the spectrum. The research has also found that other respondents have raised the issue of a spectrum coordination agency which would be responsible for advising the policy maker, the regulator, in all spectrum-related matters. Other respondents have highlighted the need to introduce spectrum leasing urgently within the country's regulations which would allow incumbents to lease spectrum on a primary and secondary user basis, depending on the regional and time usage. This regulation would be supported by the DSA technologies which include the use of cognitive radio and geo-location databases. The introduction of license-exempt spectrum assignment in the E-band, V-band and L-band was also proposed by the respondents.

Radio Frequency Spectrum Assignment Plan (RFSAP) supersedes any previous spectrum assignment arrangements for the same spectrum location. However, if it happens that on the date a provision of the RFSAP comes into effect, there is a conflict between the RFSAP and the latest versions of the National Radio Frequency Plan (NRFP) and Terrestrial Broadcasting Frequency Plan, the NRFP and the Terrestrial Broadcasting Frequency Plan will prevail. Spectrum sharing in TVWS and other bands may be useful in extending the availability of high-speed internet access to previously disadvantaged communities and hard to reach areas. Advances in radio technologies have enabled radio frequency spectrum to be accessed dynamically in time, frequency and space helping in the overall improvement in spectrum efficiency through sharing. DSA based radio technologies and license-exempt policies specifically, can assist in bridging the digital divide in underserved and rural areas. The best measure of the promise of White Spaces technologies is the history of Wi-Fi. Worldwide, approximately 439

million households use Wi-Fi networks, a number that is expected to grow to nearly 800 million by 2016. There are also millions of publicly available Wi-Fi hotspots, according to studies done by the World Bank. The current Wi-Fi developments were all made possible due to the availability of smart, globally-harmonised, license-exempt spectrum rules. The favourable propagation characteristics of the TVWS promise to make White Spaces devices (WSD) even more powerful than their Wi-Fi ancestors. The dynamic use concept, central to license-exempt White Spaces use, ensures that this radio technology will identify and use different frequencies within a defined band, based on what frequency is available for interference-free operation at a given time in a given geographic location through the use of the geo-location database as illustrated in Figure 8 on page 39. The use of geo-location databases gives rise to a number of policy and regulatory concerns, such as the accurate positioning of the CR, accurate and valid information on spectrum used by incumbents in each band and location and access to available and reliable standardised protocols to access all deployed databases.

This means that previously unused spectrum becomes a valuable resource. It also means that both the technology and the rules will be able to operate before, during and after the planned digital television transition, the regulator merely has to provide the industry with information regarding occupied channels, switchover timeline and new channel assignments and locations, and devices will be able to avoid broadcast operations and other licensed uses.

Digital terrestrial television (DTT) will lead to the clearing of the broadcasting bands which were used for analogue TV. To avoid interference to co-channel or adjacent channel DTT transmitters, the bands will be geographically interleaved forming the TV white spaces. A few respondents refer to the fact that bandwidth depends on how much white space is available in a given area and how many devices make use of that bandwidth at a given time. Rural areas have an estimated 20 vacant TV channels, while suburban areas have around 10. This means that the bandwidth capacities of the white-space frequencies are higher in rural areas than in urban ones, simply because there are more available channels and fewer subscribers per square mile. Each available TV channel consists of 8 MHz of bandwidth. One channel, sharing the upstream and downstream traffic usually has the potential to carry 8 to 16 Mbps. Due to this sheer availability of bandwidth in the VHF/UHF Spectrum in rural areas, white-space frequencies have the capacity to carry wireless data at speeds far greater than Wi-Fi, earning white-space technology the nicknames “Super Wi- Fi” and “Wi-Fi on Steroids” as per the arguments by respondents at the regulator.

The national frequency plan shows the UHF range from 470-854 MHz; however, recent developments show that this will be reduced to 470-694MHz. The DoC declared the upper UHF band 790-862 MHz as the first digital dividend (Lysko, Masonta, Johnson, & Venter, 2012). South Africa’s analogue TV broadcast standards and frequency plan are similar to those used by the CEPT due to SA being part of Region 1. The Bergvliet study by Lysko *et al* (2012) focused on the availability of spectrum occupied by analogue TV broadcasting bands. They used the free space loss formula, with a line of sight

conditions applied to the information about the location and power of the TV transmitters around the area. The study showed 61% correlation between the measurement and prediction which indicated that 3-12 television channels were available out of the 39 channels tested.

The use of geo-location database systems to determine the available frequencies in a given time and location seems to be a preferred technique to the beacon or sensing solution. In order to know which channel is available for use, a WSD accesses and queries a geo-location database which responds by indicating which channel is available at a particular time and/or location. This technique minimises the chances of causing harmful interference to the primary user. Whilst the sensing technique tries to detect radio signals and estimate the relative location of the primary user in order to avoid causing any harmful interference. This becomes practically impossible to detect and determine the exact location of a primary user at any given time. That is why the geo-location database technique has been used in trials around the world and it is being commercialised by the likes of Microsoft, Google and Spectrum Bridge.

A greater opportunity exists with the introduction of software-defined radio (SDR). Although research is being done at labs without any actual commercial testing being done on the SDR, this technology could revolutionise how spectrum is managed per the arguments by the regulator. SDR technology needs to be able to adapt its transmission parameters over time, space and frequency bands to take optimal advantage of unused bands without causing harmful interference to primary users. This is explained in detail in Chapter 2. The beacon method uses the cognitive radio to transmit only if it receives an enabling beacon providing it access to use vacant channels. Alternatively, it may transmit as long as it has not received a disabling beacon signal denying its use of the channel. This method is similar to a hidden node problem which is prevalent and which can cause major interference to primary users and requires an extensive investment in laying out beacon infrastructure which comes at a high cost. The current urban development of South Africa and socio-economics allow for spectrum sharing and the introduction to the market of smaller medium enterprises that will operate in the areas that are currently not considered commercially viable by larger licensed operators. The demand has been created by the requirements of education, health, social services and the broader public service sectors.

## **5.2 Spectrum management and licensing**

SA Connect argues for spectrum to be “managed efficiently in order to optimise its potential to provide broadband access” with Section 12 advancing priorities for future spectrum management as “approval of spectrum sharing” and “dynamic spectrum allocation”. ICASA has a mandate as stipulated in the ICASA Act No. 13 of 2000, as amended, which is the duty to manage the radio frequency spectrum (section 4(3)(c)), the responsibility to conduct sector-relevant research and the power to make regulations (section 4(3)(j)). As a result of this legislation, ICASA entered into a Memorandum of Understanding with the CSIR, the University of Pretoria and the University of the Witwatersrand to, among other things, conduct research and demonstrate dynamic spectrum sharing and cognitive radio

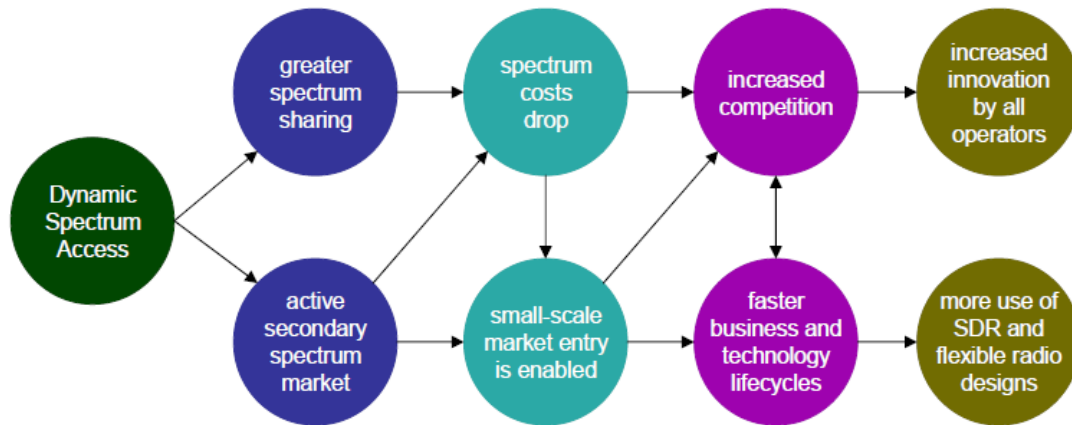
networks in order to inform policy and regulations for South Africa (ICASA, 2014). The result of this partnership has led to the publication of the Discussion Paper on the Framework for Dynamic and Opportunistic Spectrum Management 2015 and TVWS trials in Cape Town and Limpopo. In the discussion paper, DSA refers to dynamic spectrum assignment and only TVWS where researched and piloted. Spectrum is allocated by the ITU to services and, at any given time and place, there will always be unused spectrum which could be used through the concept of DSA for other services. This will continue happening unless countries start introducing the optimum use of spectrum through DSA on all frequency bands and look at certain considerations like the QoS and interference protection.

Cognitive radio technology could be considered as a disruptive technology as it enables spectrum to be accessed dynamically and in an opportunistic manner. This has led to regulators across the globe having to innovate and come up with alternative ways of managing and licensing spectrum. Spectrum management and licensing are core functions of the regulator as it allows for revenue collection and ensures that assignment of bands is done in accordance with international norms and standards whilst ensuring global harmonisation of the spectrum. Each country develops a set of licensing conditions in alignment to country-specific objectives and the national frequency plan guided by the ITU allocation table. An introduction of spectrum trading and leasing could be an attractive way of encouraging competition while promoting a market-driven spectrum management regime in SA. Spectrum assigned to operators in a licensing process could be regulated in such a way that the operators can resell underutilised spectrum. Due to regulatory arrangements, the process of spectrum assignment in the primary market is often lengthy and inflexible. As the secondary market is not controlled by the government or the regulator, it can be seen as an attractive tool to promote efficient use of the radio spectrum. For DSA to be fully realised and successfully implemented a study and review of all assigned bands needs to be conducted by the regulator and the results would need to be published to solicit comments from the public and the industry at large. On conclusion of such a consultative process, the regulator must be willing to take drastic measures and make difficult decisions which must always be in the best interests of all South African citizens, the ICT and broadcasting industries.

A number of standards have been developed for TVWS technologies which the regulator can adapt as part of their framework for DSA implementation. The IEEE 802.22 for data links, which specifies the air interface and important functions like access control, QoS and security, with the 802.11af defining international specifications for spectrum sharing among unlicensed white space devices and licensed services within the TVWS bands. The IEEE 802.15TG4m is a newer study group formed to evaluate and develop specifications for lower-speed and longer-range WRAN in wireless bands. There are also other initiatives like the IEEE 802.19 which aims to specify radio technology independent methods for coexistence among independently operated wireless devices and networks for better use (Nekovee, Irnich, & Karlsson, 2012). Table 2 in Chapter 1 (page 26) provides a detailed list of approved standards by the IEEE and have been adopted for DSA and TVWS. Standards for coexistence have been around

for many years, such as the 802.15.2 which refers to the ability of one system to perform tasks in a given shared environment without causing interference to other systems performing their own tasks in the same environment.

**Figure 13:** Market dynamics expected as a result of widespread DSA implementation



**Source:** Chapin & Lehr (2007)

One of the critical success factors for DSA is sufficient customer demand in the secondary spectrum access market. The initial drivers of this market could be equipment manufacturers and internet service providers. Over time it is expected that end-user devices will be produced and made easily available to consumers through normal retailers. Chapin and Lehr (2007) argue that the level of demand for DSA enabled services will be determined by the QoS and how the equipment is priced in the market. This research paper supports and agrees with this argument, based on the feedback received from all the respondents, especially on the issue of how the industry will guarantee QoS on a secondary basis. The research argues that QoS will be compromised, even in the desirable bands like the UHF TV channels, which is expected to be caused by competing services in these bands, for example, all legacy and ancillary services occupying the TVWS.

However, Chapin and Lehr (2007) recommend that more research needs to be conducted on how to improve the QoS in unlicensed DSA enabled bands. Their research proposes the creation of a derivative securities market where operators can hedge the risk of losing spectrum and/or a solution where service providers choose to bundle DSA based services with services that have guaranteed spectrum access. On 23 September 2010, as part of its National Broadband Strategy, the FCC approved a proposal that will enable mobile device manufacturers to use whitespace portions of the television broadcasting spectrum for unlicensed mobile broadband operations. The whitespace signal spectrum spaces were freed up as part of the United States' transition from analogue to digital television broadcasting. Chapter 2 shows that a number of research studies and contributions have been made available through peer reviewed literature and academic reports on spectrum management approaches and their socio-economic justifications. The command and control, commons and property rights have been generally

accepted as the three spectrum management regimes globally, with more evolved economies or developed countries commonly implementing the property rights regime which is driven by the market and seems likely to address spectrum scarcity that is being experienced in these developed nations. There is a lot of ambiguity on what constitutes a socially efficient management regime, whilst the introduction of dynamic spectrum access, using cognitive radio technology, has created an opportunity for the regulator, policymaker and industry embracing a hybrid of the three spectrum regimes.

An introduction of TVWS on an unlicensed basis could increase the design and development of user devices that could be introduced to the market at a cheaper cost. This could also cause an increase in a number of smaller network operators entering the market as the exorbitant license cost that would have hampered them entering a market where the QoS is critical could be resolved by the TVWS opportunity. More geographical locations such as the ones previously not considered lucrative markets for the incumbent operators would be a good place for new entrants to start as they would not have the major infrastructure and licensing costs to hinder their entrance. The potential low cost of internet access which could be brought by the introduction of TVWS would also increase the number of services provided by both the private and public sector to the rural areas such as government, telemedicine, education and others.

### **5.3 Policy Analysis**

The Electronic Communication Act, 2005 provides for the control of radio frequency spectrum and in carrying out its functions and related legislation, the authority controls, plans, administers and manages the use and licensing of the spectrum (ICASA, 2013). In the South African context, allocation refers to entry in the table of frequency allocation of a given frequency band, while allocation is an entry of a designated frequency channel in an agreed plan, adopted by a competent conference for use by one or more administrators for a terrestrial or space radiocommunication service in one or more identified countries or geography under specific conditions. Lastly, the assignment process refers to authorisation given by an administrator for a radio station to use a radio frequency or radio frequency channel under specific conditions (ICASA, 2013).

ICASA regulates spectrum use and related processes in accordance with national laws and policies linked to the various country objectives which may differ from other countries. It is anticipated that future demand for spectrum will be driven by both the need to provide broadband coverage in unserved and underserved areas and the need to provide greater broadband capacity in areas that already have access. Foster (2010), argues that, with the introduction of the digital dividend arising from the migration from analogue television to digital broadcasting, spectrum should be managed differently. This research has constructed a case 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-utilised, the spectrum efficiency of dynamic and opportunistic management can be extended to

these bands. It is technically possible to share these bands using combinations of administrative means (including an assignment in time and geography and interference management constraints) and technical solutions (ICASA, 2015). The 802.11af protocol also referred to as ‘White-Wi-Fi and Super Wi-Fi, which was ratified in December 2013, specified the international standard for spectrum sharing among unlicensed white space devices and licensed services in the TVWS band. This standard provides the architectural scheme, communication and control structure permitting TVWS devices to share spectrum with incumbent services (Broadband Centre of Excellence, 2014). The Philippines, Canada, the US (FCC) and the UK (Ofcom) regulators, have already passed rules allowing the license exemption use of TVWS to deliver broadband.

The policy maker’s role is not to play catch-up with technology, the role is to develop high-level policies which focus on concepts such as spectrum efficient management, sharing, pricing and improving the environment for the regulator to manage technology and services to be deployed, as well as assignment of spectrum to the relevant users. The current skills set at both the policy maker and the regulator needs to be continuously improved as there are a number of skills required for spectrum management such as economics, legal, policy and engineering skills. The Minister of Communications appoints a delegation which includes staff from the policy makers, regulator, industry bodies and sector specialist to represent the country at the ITU and an opinion by respondents is that the Department does not have the requisite skills to deal with all the necessary question or panel discussions which require a broader team to engage and ensure the requirements of the country are met. However, as part of the preparation in between conferences, there would be people from the industry working collectively with the regulator and the policy maker in defining a position that will be adopted as the country position. Ultimately, the Minister will make the final decision after taking consideration of all the different inputs from the mobile operators, broadcasters and all relevant stakeholders. This is determined by the spectrum value chain as one would need to take into consideration the research and academic institutions, the industry associations which will represent a number of respondents and industry experts. As part of the preparatory process, the country would have to participate in regional and national preparatory conference where open discussions and consultation are held prior to any formal representation being made to the Minister.

The regulator needs to develop a regulatory framework that allows spectrum sharing and opportunistic dynamic spectrum access while increasing internal capacity to monitor, regulate and administer issues related to spectrum interference and spectrum hoarding by both primary and secondary operators. The policy needs to be clear on different licensing regimes and the introduction of more spectrum commons to encourage participation by smaller players who cannot afford the high costs associated with the Ultra High-Frequency high demand spectrum bands. Convergence needs to be taken into consideration when developing policy. Spectrum licensing in South Africa has generally followed the traditional route of first come first served, beauty contest also known as auction, command and control which has allowed

exclusive rights for high demand spectrum to a limited number of operators. An introduction to DSA would encourage spectrum sharing and spectrum trading thus creating an enabling environment that is conducive to competition. South Africa Connect, which is the national broadband policy, motivates that spectrum should be “managed efficiently in order to optimise its potential to provide broadband access”. In section 12 of the South African national broadband policy, it advances future spectrum management as “approval of spectrum sharing” and “dynamic spectrum allocation” (ICASA, 2015).

In essence, there is a shortage of spectrum management resources in the country, not just at the regulator and policy maker, but the whole industry lacks these necessary resources that can deal with the complex issue of spectrum management. One of the issues when it comes to preparing and attending the WRC is a lack of continuity which is caused by people not staying in one job as most people get headhunted or recruited from the regulator and policy maker by the operators. There is a need for academic institutions to develop programmes that will produce more spectrum experts in policy, regulation, technical and economics. Table 1 in Chapter 1 explains in detail the roles and regulations of an international, regional and national position where it promotes lower market entry barriers and introduces flexibility of current licensing frameworks and proactively adapts policy to meet continuous technology changes and global trends.

#### **5.4 Regulation Analysis**

There are concerns that the regulator seems to be focusing on a particular technology and band which does not sit well with the broadcasting sector. It is the view of the broadcasters that an introduction of DSA as a solution for efficient spectrum management should be looked at across all bands. Whilst an understanding of how the introduction of cognitive radio technology can significantly improve the efficient use of spectrum and allow for spectrum sharing and leasing opportunities, it is important to take heed of concerns raised by some of the research respondents. This could assist in avoiding protracted legal battles against the regulator, as well as ensure the regulator develops technology neutral regulations that look at introducing spectrum band sharing across all available bands. The economics of spectrum and related business models are undergoing major changes across the globe in response to the enabling capabilities of cognitive radio. This means that there is a case for the regulator to study more closely the developments of DSA and CR technologies globally and implement the best possible solution for South Africa.

The regulator is required by law and international conventions to review the National Radio Frequency Plan (NRFP) from time to time for purposes of regional harmonisation with its neighbouring countries. In turn, the NRFP informs the regulator about developing Radio Frequency Regulations, the Radio Frequency Licensing framework and the Radio Frequency spectrum Assignment coordination procedures. As part of the monitoring and compliance mandate required by law, the regulator is required to monitor and clear all interference incidents between incumbents and other service providers. The

regulator's role is very important, for instance, if you look at the spectrum in developing countries. It is a critical resource to deliver broadband services because of the lack of infrastructure in many areas so it has to be treated with the utmost prudence. Therefore, when regulators license spectrum, they have to attach socio-economic objectives and obligations to those spectrum licenses. It wouldn't help to license spectrum and expect that the socio-economic and political agendas of the countries will be met because the markets/operators will look for the minimum requirements that they can get away with. Once they have established those they mostly wouldn't go beyond that, anything else would be dependent on social and co-operator responsibility which is not helping our challenges. Most of the developing countries are looking at very low broadband penetration, especially in poor and urban areas. To address those issues, the regulator has to ensure there are conditions that whoever uses the spectrum have to fulfil. This could be a challenge with the proposed dynamic spectrum framework because it is a bit divorced from the licensing conditions originally sought to promote competition to the market, and an environment where almost anyone can come and play. Perhaps in the case of South Africa, the regulator would need to strengthen its monitoring and policing capability and introduce strong conditions and obligations.

The ITU-R in its recommendations for possible deployment of DSA based technologies in the TV bands, provided guidelines which encouraged a view that each country had the responsibility to develop regulations and is the prerogative of each country's regulator (Mfupe, Masonta, Olwal, & Mzyece, 2013). This clarifies the matter raised by those against the regulator publishing the discussion paper on the framework on dynamic and opportunistic spectrum management, citing that the ITU had not published or recommended the use of DSA enabled technologies on the TV bands. To such an extent that, in the USA, the FCC and the National Telecommunications and Information Administration (NTIA) proposed and developed several spectrum guidelines and regulations on how DSA enabled technologies can exploit both government and commercial spectrum in co-primary sharing and primary user/secondary user scenarios. These regulations also allowed unlicensed operations in the 5GHz bands using dynamic frequency selection (DFS) techniques and allowing shared licensed operations in the 3.65 – 3.7GHz bands using contention based protocols (Mfupe, Masonta, Olwal, & Mzyece, 2013).

## **5.5 Chapter summary**

The concept of DSA is relevant and is supported by the necessary international policy and regulation principles which advocate the efficient use of spectrum, let alone the use of TVWS. The research findings backed by literature, the country's legislation (ECA amended 2014), the National Development Plan and South Africa Connect, do allow and support the efficient use and management of radio frequency spectrum. The trials done in both Cape Town and Limpopo provide sufficient evidence that spectrum can be managed dynamically in the TV bands without causing any or major interference to the incumbents on occupied bands. There is also an opportunity to explore other bands which are not

used efficiently for primary and secondary user sharing as presented in Chapter 4. Although consideration needs to be taken to continuously protect the primary user, the researcher believes that this report has presented empirical evidence that South Africa is ready to introduce DSA in the TVWS. This has been done taking into consideration the concerns of the broadcasters; however, the efficient use of state resources for the greater good of its citizens is the most important point to consider.

Different licensing models, from exclusive, unexclusive and unlicensed models, have been proposed by the research respondents for the successful implementation of spectrum sharing dynamically. A hybrid licensing model could be adopted to satisfy the concerns of the current licence holders, whilst creating an enabling environment for new entrants to participate in the market without having to provide high capital investments for licence cost and infrastructure. An opportunity also presents itself for SMMEs to participate in the broader value chain from equipment sales, installing, servicing the equipment, component manufacturing and support and maintenance. This will have a direct impact on job creation and contribute towards the GDP of the country as illustrated Figure 4 in (page 29). Tertiary institutions will also need to develop or tailor-make a curriculum that will assist in the technical training of radio frequency experts. A detailed demographic and economic scan of how technology is being adapted and which spectrum bands are not efficiently utilised will allow the policymaker and the regulator to develop policies and regulation which will benefit both industry and the community at large. Technology neutrality should be a driver for the successful implementation of DSA in South Africa. The successful implementation and use of TVWS would be a testbed for the introduction of policy and regulation to spectrum sharing in other bands such as the IMT bands.

The researcher believes the main research question and the three sub-questions have been addressed by analysing the data collected and presented in chapter four and the analysis presented in chapter five. It is the researcher's view that a case for the introduction of DSA using CR technologies in the current legislation, policy and regulation has been sufficiently made in this research report.

## **CHAPTER 6: CONCLUSION AND RECOMMENDATIONS: THE CASE FOR DYNAMIC SPECTRUM ACCESS POLICY AND REGULATION**

### **6 Dynamic Spectrum Access for South Africa**

The national objective for the ICT sector is to facilitate the provision of affordable universal access to broadband infrastructure to citizens, business, communities and other spheres of government. It is responsible for stimulating the usage of broadband services in order to promote economic development, growth and act as an enabler for social benefits through its policies and regulations. Spectrum sharing is an enabler for the success of these technologies and the amendments to the ECA of 2014 allow for spectrum sharing by operators in South Africa. However, the inability of the government to meet the DSO deadline of 17th June 2015 is a missed opportunity and the continuing lack of clarity by the government has hampered the freeing of high demand spectrum currently used for analogue television broadcasting for other services. This spectrum has already been earmarked for wireless broadband. One of the main handicaps to the economic development and growth of South Africa has been the high cost of communication services and the impact this has on conducting and attracting investments, both local and international. TVWS have been identified and have proved to be an alternative to the provisioning of broadband through wireless networks. Consultation, regular reviews and continued analysis of existing policies, regulations and laws are needed to be able to drive competition which would lead to lowering the cost of telecommunications and universal services access (Melody, 1997). Opportunities in regulation need to be investigated to provide a springboard for accessing TV Whitespaces and licenced spectrum using cognitive radio as a preferred solution in South Africa.

The success of DSA is dependent on the co-evolution of policy, regulation, markets and technology. The published radio frequency spectrum regulations introduce a process to follow for spectrum sharing and regulations associated therewith. However, the Department of Communications is yet to publish the latest policy on spectrum management. There have been serious delays in this process, started in 2011, resulting in reliance on or guidance being sought from a policy document that is more than six years old. The lack of policy development in an ever-changing world of Information Communications and Technology could be attributed to a number of political and departmental challenges which have resulted in the country losing a lot of ground in the rollout of technology and services. The split in the ministry of communications which gave birth to two departments being concurrent custodians of broadcasting, ICT and telecommunications in the country has taken the country backwards after the 2009 inauguration of President Zuma. The research has identified a general shortage of highly competent and technically skilled people in both government and the regulator, who can deal with the legal and economic aspects of spectrum. The country's academic and research institutions have not produced enough work on the topic of spectrum to stimulate debates and discussions on this subject.

It is against this backdrop that a lot more on policy and regulation needs to be done urgently by the policy maker and the regulator to encourage greater use of spectrum efficiently and optimally. The introduction of different spectrum regimes would encourage and support the introduction of dynamic spectrum access technologies which will also assist the state in providing broadband universal access to its citizens more quickly and cheaply. It is important to note that ICASA has commissioned work on DSA through development of a discussion paper with the intention to stimulate and encourage a conversation from the industry on how best to tackle the issue.

ICASA has adopted spectrum assignment and licensing, as most regulators have done, from the 1960s with little innovation to the currently used regimes. There are seven categories to assign spectrum, namely the license-exempt spectrum where the equipment used must be type approved with appropriate limits on power output. This operates on bands that are not protected by any regulation but an application process needs to be followed with the regulator. There are also license share channels and a semi-automatic authorisation process. For point to point licensing in various bands, the regulator evaluates whether the proposed link interferes with existing licensed users prior to approving or rejecting the application. Records are generally kept for all licensed users and interference is continuously monitored with licensing fees calculated on an administrative incentive pricing for point to point formula. For a point to multipoint licensing, the regulator issues a geographic area based authorisation.

The regulator allows for primary and secondary user licensing with the primary user getting interference protection from the secondary user. Where applicable, the primary user can lease its license to a secondary user in a particular geographic area and this will allow for self-regulation between a master and slave user. In the license-exempt case, an infinite number of users can access the spectrum band and there is no guarantee that signals will not be interfered with. There is a need for more flexibility and a dynamic handling of events that occur. The main issue is the interference management which requires a sense of measuring the environment and from there, to take action when we are subject to interference and to respond to situations where we cause interference. Several sophisticated solutions may be considered; frequency hopping, adaptive antennas, software defined and agile radios and ad-hoc mesh networks. This system concept demands frequency adaptive systems that can change operating frequency on a daily, hourly or even millisecond basis.

Prior to the creation of ICASA, there used to be a bulk assignment where an incumbent operator was licensed for point to point links which had national coverage and was only billed as a point to multipoint service. The regulator is yet to specify licensing of the high demand spectrum which is currently in demand mostly to the mobile operators, however, it is anticipated that auctioning will be one of the most popular methods. The point to point licensing for links at frequencies above 50GHz has been introduced and no formal approval is currently required, however, a full disclosure and an

administrative fee are required. The regulator should implement a workable TVWS framework based on the Ofcom model but tailored for SA. This would act as an appropriate starting point for proceeding with implementing the authorisation of use of WSDs in the UHF TV band. It will offer a viable way forward that can be implemented now but one which is anticipated can be refined in the future to meet the objective of ensuring efficient use of the UHF TV band. There should then be a follow up a general review of the effectiveness of the TVWS framework and the researcher suggests doing this within the first 18 months of operation. Making TVWS available is not only attractive for the innovation, investment and economic benefits it will unleash, but because of the competitive edge, it will offer. Many technology companies are already investing in research and development of super Wi-Fi and cognitive technologies. Now they can take these technologies out of the labs and onto the market.

Peha (2013) recommends the deployment of multiple devices in a frequency band and geographic location where there is not much activity to pilot this mechanism and see the number of opportunities that this will create, mostly in countries where spectrum has become a scarce commodity. This could also test the capabilities of the policy maker and regulator in dealing with new regimes of assigning spectrum and the ability to monitor and regulate spectrum (Freyens, 2009). More research needs to be done on how policy and regulations could be improved to support this paradigm shift in assigning spectrum. This could also encourage more competition by giving new entrants access to prime spectrum at a lower cost and increasing wireless access solutions and their availability to the rest of the country.

The UHF TV band is suited to provide cost-effective connectivity in rural areas, due to its longer effective propagation distance. It can thus be used more effectively 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 better used over longer distances for point-to-multipoint fixed wireless use than can higher frequencies, which are effective around a 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. The portion of the radio frequency spectrum less than 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 the 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. The ICASA discussion paper proposes a framework for enabling TVWS operation in the frequency range of 470-694.

Denning (2005) explains transformational innovation as a transition from a mode that is known, secure and predictable to one that is unknown and chaotic. In the case of DSA and CR technologies, the policy maker, regulator and industry must prepare and be willing to enter into the unpredictable and unknown territory and move away from doing things the traditional way. The regulator and policy maker need to be more proactive, agile and embrace change, which is how they will move the country and the ICT

and broadcasting sector forward. By accepting change and welcoming the era of transformational innovation, South Africa could be among the leading countries around the globe and early adopters of DSA using CR technologies and have the invaluable knowledge to share on the provisioning of wireless broadband through the TVWS bands and other bands where sharing is allowed. The country has a good chance of being a leader on the continent when it comes to wireless broadband penetration, the deployment and development of newer applications and services when it comes to TVWS and a provider of skills which could be outsourced to other developing countries. In the South African context, the radio frequency scarcity will not apply as the country is a developmental state with high levels of unemployment and a government that has a social responsibility to provide services to its citizens (Research ICT Africa, 2014). For the success and growth of the industry, all three regimes need to be deployed and monitored.

## **6.1 Recommendations**

This research paper has adopted a conceptual framework which includes technical, markets, policy and regulatory analysis of dynamic spectrum access using cognitive technologies. To understand the interlink between technology, policy, regulation and markets, the researcher has had to study the past and present spectrum management regimes and how spectrum sharing becomes a foundation for the successful introduction of DSA.

Enabling spectrum access for white spaces devices does not require relocating incumbents and, because the rules protect those incumbents, a license-exempt framework for access to TV white spaces can be adopted and put into use without disruption to incumbent operations. TVWS has the potential to emerge as a lower-cost, high-performance solution for delivering broadband access and its implementation could be well suited to support the “Internet of Things”. The attractiveness of TVWS is its ability to broadcast signals over long distances and permit more expansive reach than conventional Wi-Fi networks. This could be the perfect remedy to South Africa’s challenges, whilst assisting in meeting the objectives set out in the SA Connect of having 100% broadband penetration by 2020.

The government must seriously consider the importance of spectrum to the country as an infinite national natural resource and start allocating more resources and prioritise issues relating to spectrum in the country. An introduction to a geo-location database technique should be introduced. Firstly because the database allows operating parameters to be changed, for example, to accommodate changes in incumbent operations—without upgrading devices in the field. Secondly, because devices report their location to the database, “[n]on-functioning or interference-causing devices can be quickly located and isolated”, allowing speedy resolution of interference complaints from incumbents (Wireless Innovation Forum, 2014). The regulator should establish one set of baseline requirements for all databases and allow database providers to innovate in provisioning value-added services, rather than establishing two classes of databases. ICASA should permit the use of sensing as an additional method of interference

protection, both used alone and as an enhancement to database-enabled sharing. The propagation model used to calculate the presence of incumbent broadcast signals dramatically affects the amount of spectrum authorised for use by TVWS devices. It is acknowledged that incumbents must be protected effectively. Within that parameter, in order to maximise spectrum use and effectively protect incumbents, ICASA should require database providers to use propagation models that rely on point-to-point modelling and take into account the variability in terrain when calculating propagation and spectrum availability.

DSA is in its early days and requires the resolution of a number of complex issues which are technical, policy, regulatory and economic in nature. To fully understand how best to implement DSA as an opportunistic way of accessing spectrum efficiently, the four factors needed to be researched. Although there has been some work in the engineering or technical aspects of DSA through the trials done in Cape Town and Limpopo yielding positive results in the use of TVWS for provisioning of wireless internet services, more work and research needs to be done on how policy, regulation and market demand can aid DSA policies and regulation. Zhoa and Sandler (2006) argue that the importance of policy and regulatory parameters for cooperation and joint usage between primary and secondary users is critical for socio-economic development.

South Africa needs to develop a spectrum policy that will not only advance market interest but introduce a balance between market and social needs. A dynamic spectrum sharing policy and supportive regulation which encourages opportunistic spectrum access principles will be a good start. Chapin and Lehr (2007) allude to the fact that progress has been made in technological and engineering aspects of DSA and radio technology. However, more work still needs to be done for structuring and dynamics that is required for wireless services market to evolve.

A clear and predictable policy and regulatory path for DSA needs to be developed and implemented. The industry needs to manufacture devices and solutions with a clear understanding on which licensing regime will be adopted for TVWS and other band sharing in South Africa. A primary to primary user spectrum sharing and trading should be introduced, whilst also introducing a master and slave sharing and leasing model. The policymaker and regulator need to create an environment that enables transformational innovation for SMMEs and industry to develop next-generation solutions that are able to resolve social and economic challenges that the country is facing. Customer premises equipment with plug and play technology needs to be manufactured to allow end users to have access to the CR technology. The type approval of all equipment and QoS needs to be clearly defined as part of the conditions for allowing the DSA cognitive radio technologies into the market.

An opportunity exists for collaboration and strategic partnerships between the policymaker, regulator, research and academic institutions in developing human capital that will move the country forward when it comes to radio frequency spectrum management. The importance of radio frequency spectrum

and how it is efficiently utilised as a key strategic asset to economic growth and development can never be over emphasised (Cave, 2004). A flexible regulatory framework and regime, an agile and proactive policy maker and an ever evolving and innovative industry are necessary for propelling any nation to being a market/industry leader on next generation technologies.

South Africa, like countries such as Singapore, Japan and Ghana, has taken the approach of allowing testing and evaluation by the industry and research institutions of cognitive radio techniques, sensing and geo-location database on the TV bands prior to adopting any regulations. With the positive results having been presented by both the Cape Town and Limpopo TVWS trials, the regulator has started with the process of consultations with the publishing of the discussion paper on the phenomenon that is dynamic and opportunistic spectrum management. It is of paramount importance that South Africa, in deciding which regulation to implement on DSA and TVWS, should review the current and emerging trends in regulation of secondary access and spectrum trading in the US, UK and mainland Europe.

South Africa should, however, avoid the development of technology-centric regulation but rather focus on a technology agnostic regulation. This has been a major point of contention by the broadcasters who feel the regulator is focusing on specific technology in the published discussion document and in this instance referring to the TVWS which are found in the broadcasting bands. The broadcasters argue that DSA should be looked at broadly in all the bands including the IMT, E-band and V-band. With this in mind, the introduction of DSA regulation must focus on protecting the primary user from secondary interference. The industry, policy maker and regulator must make a decision that focuses on the customer and the market. A coherent spectrum policy strategy needs to be developed such that it introduces competition and allows for the participation of new previously disadvantaged individuals in the mainstream ICT economy.

Wireless broadband could provide ubiquitous and all-inclusive internet connectivity to the African continent efficiently and more cost effectively than wired networks (Olwal, Masonta, Mfupe, & Mzyece, 2013). However, policy and regulation play a vital part in the successful implementation of wireless broadband. The proposed next steps are as follows; (i) Identification of more spectral bands where the introduction of more flexible spectrum management could be adopted over and above the TVWS identified in the research (ii) the introduction of CR and SDR technologies in specific allocated bands within the current legislation and regulation of South Africa, (iii) continued support and increased funding for research projects done by academic and research institutions within the activities of DSA and CR, and (iv) removal of spectrum trading and leasing barriers and introducing spectrum re-farming for more services that are currently unused which may create opportunities for SMMEs to participate in the industry.

## **6.2 Future research**

Based on the above and findings of the research, the researcher proposes future research seeks to a study on the current skills and the current organisational structure at the policymaker and the regulator responsible for spectrum policy development and the assignment of spectrum. This has been raised a challenge for the future direction of the country and efficient spectrum assignment.

Future research could also contemplate researching different solutions in automated spectrum assignment and management. This will assist in improving and increasing spectrum sharing and leasing which will lead to efficient and effective spectrum management.

Additionally a study on the capability of the South African manufacturing sector to manufacture next generation technologies particularly white space devices and the potential linkage to economic growth. This will need to focus on both the supply and demand side.

Although according to a joint submission made to ICASA by the CSIR, Microsoft, WAPA and others who were partners in the Cape Town trials “ There is a growing recognition that dynamic spectrum sharing enabled by geo-location databases has significant potential to increase the availability and ubiquity of broadband acces.Geo-location databases such as those now being developed to access TV whitespaces, indicate via a database query which TV channels are available for data communication based on the geographical location of the radio” support the introduction of DSA. More research work needs to be done on other spectrum bands using different services.

## **6.3 Conclusion**

Wireless access technologies have been a candidate for the provision of cost-effective broadband internet access over fixed or wired infrastructure. It is, therefore, the responsibility and objective of the South African government to find solutions and investigate practical policies and approaches in assigning radio frequency spectrum. The demand for spectrum sharing across the globe and the use of cognitive radio and geo-location has significantly increased, creating the potential to effectively and efficiently manage usage of spectrum. TVWS could be a starting point in introducing DSA as this has been proven technically that the available bands could be exploited as broadcasting in its nature is static and currently in its analogue form there have been a lot of gaps identified for other uses. The regulation could also look at how spectrum leasing could be best utilised in the country and encourage the market to self-regulate through an economically viable spectrum leasing model. There is a good case for introducing spectrum sharing in a licensed, license-exempt and a hybrid model which looks at the requirements of both incumbents and the introduction of new entrants without overly disrupting regulation. The regulator will have to improve its ability to monitor and police the industry and encourage an open market spectrum management regime. The VHF and UHF frequencies used by TVWS devices have good propagation characteristics over longer distances, and, hence, may be exploited to provide broadband coverage at a lower cost, provided that the chosen regulatory model is

sufficiently flexible and does not increase costs unduly. Furthermore, the concepts of dynamic spectrum assignment may be extended to other IMT bands thereby reducing spectrum scarcity and achieving the objectives mentioned. With exclusive use, there is only one license to the spectrum band. The licensee should not experience any intersystem interference. For shared use, there are a few license holders. Depending on the co-operation ambition among licensees, there may be intersystem interference.

The two successful trials carried out in SA on TVWS, both in Cape Town and Limpopo province, have provided a credible test case for alternative ways of providing wireless broadband access in both urban and rural areas without causing any harmful interference. However, it is important to note the reservations and concerns raised by some industry experts, associations and the broadcasting industry as a whole in delaying taking any drastic policy or regulatory decisions before the completion of the DSO. Whilst the trials proved successful in ascertaining the demand and supply side of internet connectivity using TVWS and providing data for ICASA to develop a regulatory framework, more research needs to be carried out for SA to comfortably implement such a solution commercially. Successful commercialisation of DSA and WSD would contribute significantly to economic development and social benefits; however, this is dependent on agile policies and a strong regulator to introduce market evolution. More research needs to be done to establish the business case for the demand and possible adoption of such technology by consumers. The researcher believes this paper has met the research objectives as introduced in Chapter 1 in the introductory paragraph in a modest but not tentative way. Having expressed the challenges in Chapter 3 with regards to getting a larger sample size, the researcher would like to iterate that the research findings in this paper are similar to that presented by the ICASA's findings document on the framework on dynamic and opportunistic spectrum management published in June 2016 with a similar sample size. The responses published as part of the findings were from 19 respondents.

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## **Annexure A Participant Information Sheet**

### **MASTERS RESEARCH TOPIC**

INVESTIGATING POLICY AND REGULATORY APPROACHES TO DYNAMIC SPECTRUM ACCESS USING COGNITIVE TECHNOLOGIES

Dear Participant

I am a student at the University of the Witwatersrand currently undertaking a Masters of Arts in the field of ICT Policy and Regulation. In part fulfilment of this Masters program, I am in the process of conducting a research study on policy and regulatory approaches to dynamic spectrum access using cognitive technologies in South Africa. You are invited to take part in this research study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please read the following information carefully.

### **Background and overview of the study**

This study is being conducted by Linda Patrick Canca in partial fulfilment of the requirements for a Master of Arts in the field of Policy and Regulation at the University of the Witwatersrand.

The research investigates the inter-link between policy and regulation associated with the supply and demand of dynamic spectrum access technologies for South Africa. Dynamic spectrum access (DSA) technologies promise to be the best solution for spectrum sharing and thus assist in overcoming spectrum management challenges and monopolies. An urgent introduction of spectrum policies and regulation will provide significant economic and social benefits to South Africa (Chapin & Lehr, 2007). In the past two decades the worldwide demand for wireless networks has increased drastically putting a high demand on spectrum to more users, more capacity and more services. In the context of heightened radio frequency spectrum demand, alternative regimes for spectrum management have been researched by regulators across the globe and DSA technologies promise to improve sharing of spectrum (Chapin & Lehr, 2007).

The main objective of the research is to investigate policy and regulatory approaches for dynamic spectrum access using cognitive technologies. For the purposes of this study the researcher has developed a concept that will focus on the following areas policy, regulation, business model and technology or engineering perspective. The selected concepts should reveal problems or challenges that need to be resolved to enable dynamic spectrum access in South Africa

### **The organisation and funding of the research**

Linda Patrick Canca is a private student and the study does not require funding.

### **Deciding whether to participate**

Taking part in the research is entirely voluntary and you may withdraw your consent and participation at any stage and without giving a reason. If you decide to take part you will be given this information sheet to keep and be

asked to sign a consent form. Additionally, if you do agree to take part in this study, you will be asked to take part in an interview that will last for a maximum of 60 minutes. The interview may be recorded and the researcher may request to use your premises for the interview. There are no direct risks in participating in this study and interview. There will be no direct monetary benefits to you for your participation.

### **Anonymity and confidentiality**

Any personal information collected about you will be kept strictly confidential. Identifiers will be removed from data when the research findings are consolidated into a report and will not be included in any subsequent publications. The anonymised data generated in the course of the research will be kept securely whether on paper or electronic format for a period of five years after the completion of the research. It may be used for further research and analysis. This report can be made available to you upon your request.

### **Research Ethics**

If you have concerns about the research, its risks and benefits or about your rights as a research participant in this study, you may contact the program director or supervisor, see contact details below.

### **Contact for Further Information**

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**Annexure C                      List of Informants**

<b>Informant</b>	<b>Organisation</b>	<b>Interview Date</b>	<b>Position</b>
Industry 1	Morai Technologies	03/02/2016	Executive
Industry 2	WAPA	04/02/2016	Engineer
Regulator 1	ICASA	04/02/2016	Spectrum Management
Manufacturer 1	Product Manufacturer	04/02/2016	Regulation Management
Operator 1	Mobile Operator	09/02/2016	Regulatory Executive
Regulator 2	ICASA	21/02/2016	Ex-Councilor
Industry 3	Mobile Operator	09/03/2016	Regulatory Executive
Policy 1	DTPS	23/03/2016	Regulatory Director
Association 3	GSMA	31/03/2016	Director
Operator 2	Mobile Operator	11/04/2016	Regulatory Executive
Industry 3	Broadcasting	17/05/2016	Regulatory Director
Policy 2	DTPS	18/05/2016	Broadcasting Expert
Regulator 3	ICASA	24/05/2016	Ex-Chairperson