Innovating for Broadband: The Case of Television White Space Networks in Sub-Saharan Africa

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Abstract

Television white space (TVWS) networks based on geo-location spectrum databases (GLSDs) present an excellent opportunity to provide affordable broadband to underserved rural communities in Sub-Saharan Africa. In this paper, we explore potential pathways to full-scale commercial deployment and diffusion of TVWS/GLSD technology in Sub-Saharan Africa from an innovation perspective. This is our key research contribution since previous works have focused on individual components of innovation in relation to TVWS/GLSD technology in Sub-Saharan Africa and elsewhere. In contrast, we explore the entire innovation process, from invention to commercialisation to diffusion. The case of South Africa is considered, in comparison with several other countries and sub-regions in Sub-Saharan Africa. We explain the technology behind TVWS networks and GLSDs, and the current state of TVWS and GLSD pilots, trials and commercial deployments in Sub-Saharan Africa. We then outline the broadband penetration and policy environment context. We examine the case in terms of four innovation paradigms, namely, inclusive innovation, open innovation, systems of innovation, and diffusion of innovation. We proceed to analyse existing and potential responses in terms of innovation policy and industrial policy. We assess the implementation status and conclude by summarising the paper, drawing key lessons and insights from the preceding discourse, and making recommendations for policy makers and practitioners.

Keywords: Appropriate Technology, Broadband, Innovation, Internet, Mobile, Television White Spaces, TVWS, Wireless.

INTRODUCTION

Studies of the impact of broadband estimate that a 10% increase in broadband penetration can raise economic growth by up to 1.4%; that doubling broadband speed can increase Gross Domestic Product (GDP) by as much as 0.3%; and that these effects are more pronounced in lower income countries than in higher income countries (ITU, 2016). Consequently, a number of governments in Sub-Saharan Africa, including South Africa (DTPS, 2013), have prioritised the rollout of broadband to their citizens.

Due to the global migration of television (TV) transmission from analogue to digital broadcast, a large portion of the very high frequency (VHF) and ultra high frequency (UHF) radio frequency (RF) spectrum bands will be freed up and become available for other uses on a geographical basis. Furthermore, these TV frequencies have favourable propagation characteristics, making them ideal for reaching otherwise economically unviable markets, such as sparsely populated rural areas. Television white space (TVWS) networks therefore present an excellent opportunity to provide affordable rural broadband connectivity in African countries (Masonta *et al.*, 2017). To that end, the Independent Communications Authority of South Africa (ICASA), the country's ICT regulator, recently finalised its regulations on the use of television white spaces (ICASA, 2018a). The challenge of diffusing this new dynamic spectrum sharing technology, its supporting regulations and its enabling policies throughout South Africa and other African countries is of paramount importance. This will help African countries create the necessary environment and market potential for the new unlicensed network technology and for the development of relevant societal broadband Internet services.

Geo-location spectrum databases (GLSDs) are the preferred technique for enabling spectrum sharing between primary users and secondary users, or white space devices (WSDs), in the VHF and UHF TV bands. The technological feasibility of a world-class GLSD solution for the African context has been successfully demonstrated (Mfupe *et al.*, 2014; Mekuria *et al.*, 2016).

In this paper, we explore potential pathways to full-scale commercial deployment and diffusion of TVWS/GLSD technology in Sub-Saharan Africa *from an innovation perspective* – this is our key research contribution. We note that: "Innovation is more than a new idea or an invention. An innovation requires *implementation*, either by being put into active use or by being made available for use by other parties, firms, individuals or organisations. The economic and social impacts of inventions and ideas depend on the diffusion and uptake of related innovations." (OECD/Eurostat, 2018: 44)

Whereas previous works have focused on *individual* aspects of this definition of innovation in relation to TVWS/GLSD technology in Sub-Saharan Africa and elsewhere, in this work we deal with *all* the aspects of innovation in an integrated manner. More specifically, we investigate how to move this new technology from invention to innovation, and from innovation to industrialisation, and how to drive the creation of related local small, medium and micro enterprises (SMMEs), and the establishment of an associated industrial base. In particular, the case of South Africa is considered, in comparison with several other countries and sub-regions in Sub-Saharan Africa.

In the following section, Section 2, we explain the technology behind TVWS networks and GLSDs, and the current state of TVWS and GLSD pilots, trials and commercial deployments in Sub-Saharan Africa. We then provide an analysis of the broadband penetration and policy environment context in Section 3. In Section 4, we examine the case in terms of four innovation paradigms, namely, inclusive innovation, open innovation, systems of innovation, and diffusion of innovation. We proceed to analyse existing and potential responses in terms of innovation policy and industrial policy in Section 5. We review the implementation status in South Africa and Sub-Saharan Africa in Section 6. We conclude, in Section 7, by summarising the paper, drawing key lessons and insights from the preceding discourse, and making recommendations for policy makers and practitioners.

TELEVISION WHITE SPACE (TVWS) NETWORKS AND GEO-LOCATION SPECTRUM DATABASES (GLSDs)

Motivation

There is an ever-increasing demand for RF spectrum to accommodate the massive growth in bandwidth requirements for wireless, mobile and nomadic access to the Internet and, secondly, underutilised spectrum can be repurposed to meet the need for rural affordable broadband access in the forthcoming 5th generation (5G) wireless ICT ecosystem. These two critical factors are driving the surge in research, development and, to a lesser extent, innovation activities in dynamic spectrum access (DSA). There are important technological and policy issues that must be addressed to realise holistic innovation and commercial development based on smart spectrum sharing (S3) technology for emerging economy countries. DSA and S3 technologies, as well as service frameworks for dynamic spectrum broadband networks, must contain software and features which will promote both network deployment and innovative policies to enable affordable broadband in underserved areas. A further function of DSA and S3 technologies is to create a pool of much-needed and underutilised spectrum channels and techniques for use in future wireless 5G Networks. It is thus necessary to develop innovative business models to address the various use cases made possible through smart spectrum sharing.

The main drivers and market potential for developing TVWS and GLSD technologies include the following:

- Migration from analogue TV to digital TV broadcasting standards and the need for efficient utilisation of spectrum resources, and to enable affordable broadband Internet connectivity.
- Meeting the 2020 Vision for broadband for all (DTPS, 2013) – technologies for enabling the design of low-cost broadband networks.
- Becoming a reliable design house for spectrum databases in South Africa, regional Southern African Development Community (SADC) states and other African emerging economy countries.
- Creating a comprehensive tool for shared spectrum broadband network planning and provision.
- Providing an inexpensive platform for the deployment of dynamic spectrum regulatory policy frameworks.
- Additional services such as: (a) wireless broadband infrastructure availability data and spectrum databases, and (b) spectrum monitoring tools, for wireless Internet service providers (WISPs), telecom regulators and government organs.

TVWS networks

Figure 1 depicts a typical TVWS broadband network. The network consists of a TVWS base station (BS) at the high tower with a sectorised antenna, connecting through a white space radio, to customer premises equipment (CPE) with TVWS transceivers at the service stations (located at rural schools, health clinics and public safety facilities, and agri-centres). The network backhaul is a high-bandwidth optical fibre link to the Internet and the GLSD for accessing available spectrum and network parameters. Other roles players that are connected via the Internet and GLSD include the regulator (ICASA), device manufacturers (DM), WISPs and Industry.

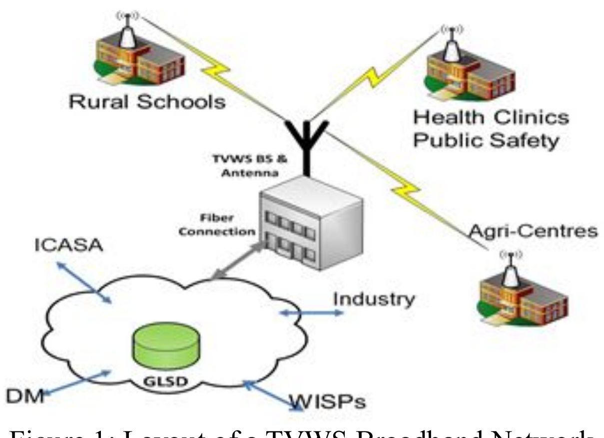

Figure 1: Layout of a TVWS Broadband Network

The role of GLSDs in the TVWS ecosystem

In order to ensure dynamic and efficient utilisation of the RF spectrum, the current trend among spectrum regulators and the wireless industry is to establish an ecosystem of key stakeholders in the TVWS value chain as shown in Figure 2.

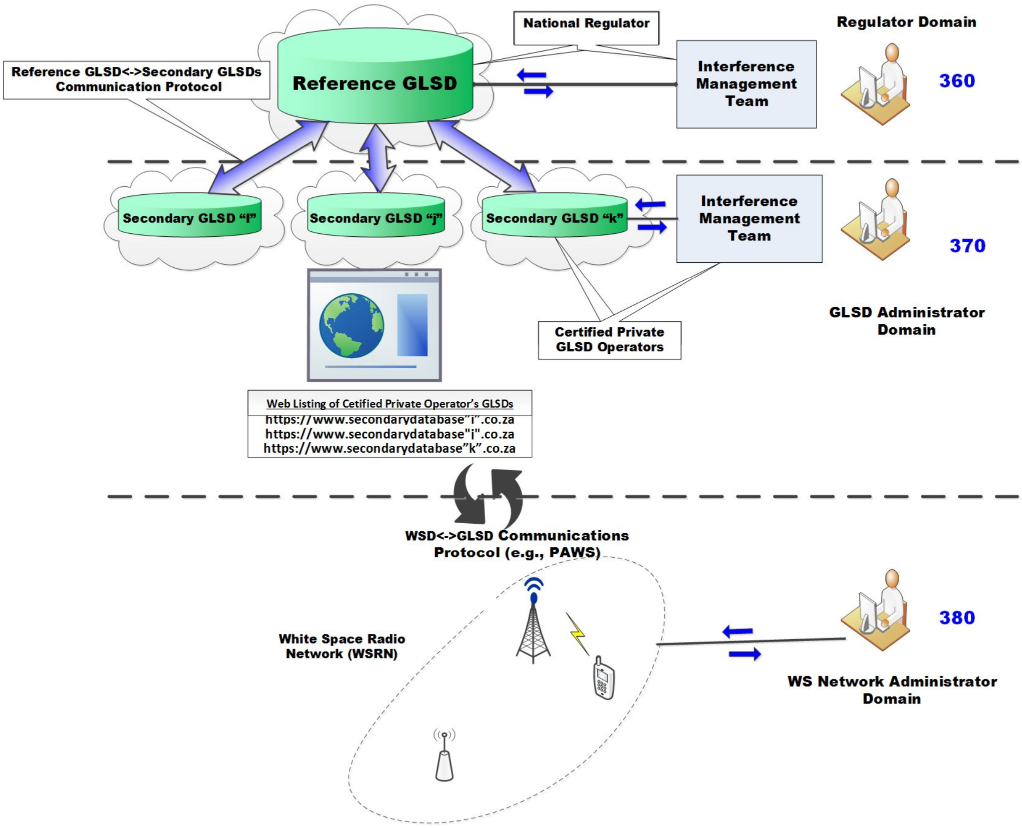

Figure 2: Typical TVWS ecosystem comprising: (360) the Reference geo-location spectrum database (R-GLSD) operated by the regulator, (370) Secondary GLSDs (S-GLSDs) operated by commercial entities and, (380) the TVWS wireless network operated by WISPs. (Source: Mfupe, 2016)

GLSDs are an enabling technology for the first phase in the cognitive radio network (CRN) evolution. The two major functionalities of CRNs are cognitive capability and re-configurability. Cognitive capability is the ability of a CRN device to sense the unused (white space) spectrum information from its ambient radio environment. However, GLSDs are currently the preferred means to implement spectrum sharing networks and guide dynamic spectrum access regulations by leading regulators due to their higher reliability compared with other options such as spectrum sensing and beaconing.

GLSDs enable interference mitigation and quality spectrum sharing between WSDs and licensed TV broadcasters in the VHF and UHF bands. GLSDs have two primary roles. First, to translate WS spectrum usage regulations taken as an input from the national spectrum regulatory authorities. Secondly, GLSDs provide a static technical mechanism for enabling WSDs to access TVWS spectrum without causing any harmful interference to the incumbent TV stations.

There are two dominant GLSD design approaches preferred by leading Western regulatory bodies (Mfupe *et al.*, 2014):

- The *Vectorised Approach*, a deterministic based approach favoured by both the Federal Communications Commission (FCC) in the United States and Innovation, Science and Economic Development (ISED) Canada (formerly Industry Canada).
- The *Pixelated Approach*, a statistical based approach proposed by the European Conference of Postal and Telecommunications Administrations (CEPT) and the UK's Office of Communications (Ofcom).

It is important to note that in most cases these two approaches produce almost identical results on spectrum availability. For the purposes of this paper, the pixelated approach will be assumed in combination with the ITU’s method for point-to-area radio propagation predictions for terrestrial services in the frequency range 30 to 3000 MHz (ITU, 2009).

Pilots, trials and commercial deployments

There is no single authoritative, comprehensive repository of up-to-date information on TVWS and GLSD pilots, trials and commercial deployments in Africa, or anywhere else for that matter. Instead, the required information is scattered across multiple sources, such as the Dynamic Spectrum Alliance website[1], which lack one or more of the necessary elements of authority, comprehensiveness or up-to-dateness. Figure 3 presents our understanding of the current and historical status of TVWS or GLSD pilots and trials across Africa, based on our own analysis of multiple sources. To the best of our knowledge, while Africa is relatively well-represented globally in terms of TVWS or GLSD pilots and trials (13 countries across all major regions of Africa), up to now there has been no full-scale commercial deployment of TVWS/GLSD technology anywhere in the continent. It is this gap in full-scale commercial deployment of TVWS/GLSD technology that this paper addresses.

Figure 3: African countries where either TVWS or GLSD has been piloted or trialled (Source: Authors’ own analysis)

[1] http://dynamicspectrumalliance.org/pilots/

Figure 4 shows a screenshot from the longest-standing of Africa's pilots and trials of TVWS/GLSD technology, the Geo-Location Spectrum Database at CSIR Meraka Institute in South Africa, with which two of the authors are directly affiliated.

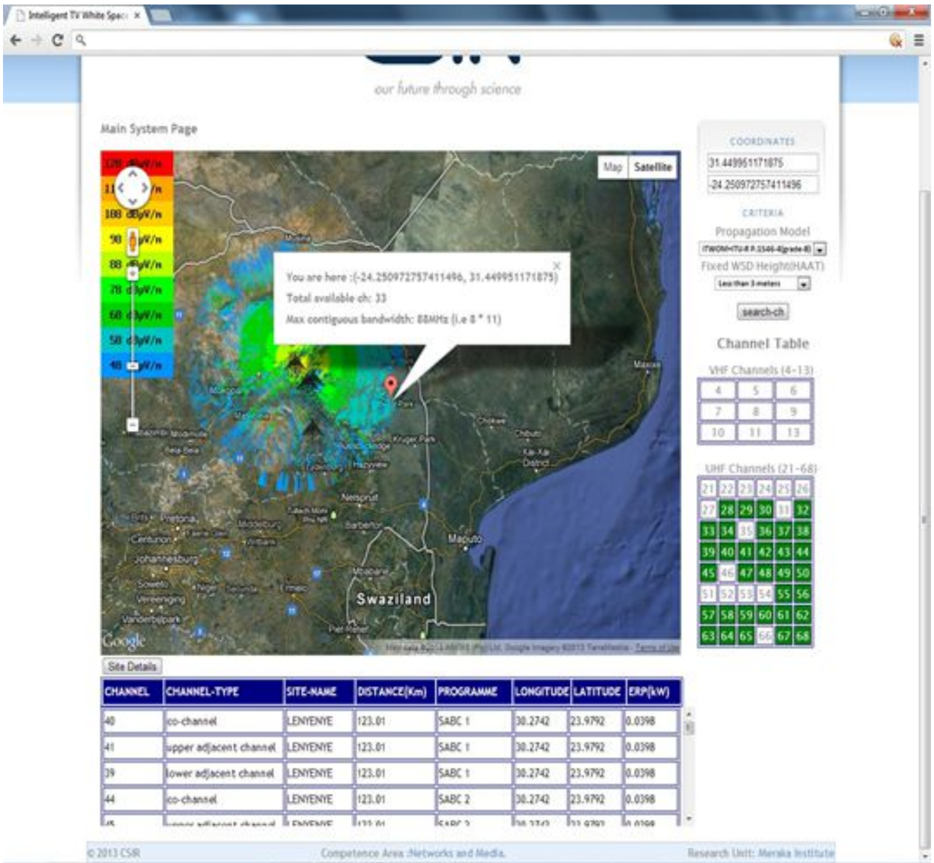

Figure 4: Results from CSIR Meraka Institute's GLSD (Source: http://whitespaces.meraka.csir.co.za/)

CONTEXTUAL ANALYSIS

Broadband penetration

Figure 5 shows active mobile-broadband subscription penetration rates across the world, where broadband is defined as a speed of at least 256 kb/s. Globally, active mobile-broadband subscriptions have exhibited strong growth over the past seven years, increasing from 11.5 per 100 inhabitants in 2010 to 56.4 in 2017 (ITU, 2017). For comparison, the active *fixed*-broadband subscription penetration rates in 2017 were 13.1 per 100 inhabitants for the global average versus 0.4 for Africa (ITU, 2017). South Africa's 2017 statistics are 70 per 100 inhabitants for active mobile-broadband subscriptions, and 3.1 per 100 inhabitants for active fixed-broadband subscriptions[2]. Africa has the lowest regional broadband penetration rates both for mobile-broadband and fixed-broadband subscriptions, far below the global averages. South Africa's mobile-broadband penetration rate is well above the global average and, in that sense, it is a positive outlier on the African continent. However, broadband affordability remains a significant challenge in most Sub Saharan African countries, including South Africa (Broadband Commission, 2018).

[2] https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx

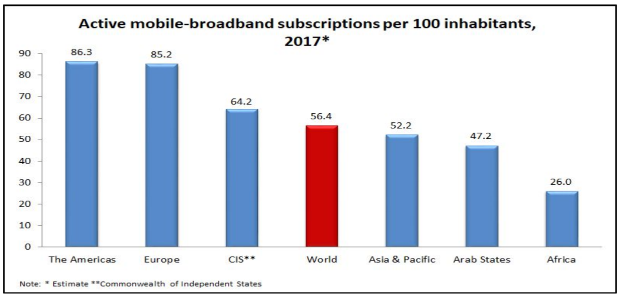

Figure 5: Global mobile broadband penetration rates (https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx)

Policy environment

Of the 54 African countries, 45, about 83%, have a national broadband policy, a higher proportion than the global average of 81% (Broadband Commission, 2018). However, as noted in Section 3.1, Africa lags behind the rest of the world in *implementation* of broadband policy as shown the poor penetration rates. Broadband availability and affordability continue to be serious challenges in Africa. Turning to the specific instance of full-scale commercial deployment and diffusion of broadband based on TVWS/GLSD technology in South Africa, the country has a highly complex and fragmented policy environment. There are at least five South African government departments that have some direct bearing on the issue:

- The Department of Communications (DoC), which oversees ICASA, the ICT regulator;
- The Department of Telecommunications and Postal Services (DTPS), which is responsible for South Africa's broadband policy (DTPS, 2013) as well as its national integrated ICT policy (DTPS, 2016);
- The Department of Science and Technology (DST), which funds high-tech research and development in areas like TVWS/GLSD and is responsible for South Africa's National System of Innovation (NSI) (DST, 2018);
- The Department of Higher Education and Training (DHET) which directs tertiary education and skills development and training; and
- The Department of Trade and Industry (DTI) which formulates industrial policy and localisation policy.

One could argue, quite plausibly, that, besides these five, there are many other relevant government departments. For example, just at national level: the Department of Planning, Monitoring and Evaluation (DPME) which manages the National Planning Commission (NPC) and the National Development Plan (NDP); the Department of Rural Development and Land Reform (DRDLR) whose mandate is to uplift rural communities; and the Department of National Treasury which administers the nation's finances. Our analysis would become even more complicated if we tried to take into account all relevant departments and agencies across all three spheres of South African government: national, provincial, and local. Therefore, as a starting point, we will limit our discussion to the above five national departments. Even restricting our attention to just these five national departments, we observe numerous overlaps and interdependencies involved with many elements of implementing TVWS/GLSD-based broadband commercially. For instance, successfully implementing just the GLSD itself requires: regulatory policy to enable TVWS (DoC); broadband policy to stimulate demand (DTPS); research and development on GLSD technologies (DST and DHET); skills development and training in engineering and computer science (DST and DHET); and industrialisation and localisation initiatives for the TVWS/GLSD sector (DTI).

INNOVATION PARADIGMS

In this section, we examine our case in terms of four innovation paradigms: inclusive innovation, open innovation, systems of innovation, and diffusion of innovation.

Inclusive Innovation

Inclusive innovation is "the inclusion within some aspect of innovation of groups who are currently marginalised" according to a 6-level "ladder of inclusive innovation": intention, consumption, impact, process, structural, post-structural (Heeks *et al.*, 2014). In our case, the marginalised group are rural communities and, arguably, inclusion levels 1 to 4 (intention, consumption, impact, process) have been achieved. Structural inclusion (innovation created within a structure that is itself inclusive) and post-structural inclusion (innovation created within a frame of knowledge and discourse that is itself inclusive) constitute work in progress.

Open Innovation

Open innovation has two distinct definitions in the innovation studies literature. One definition, "open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation" (Chesbrough, 2015), focuses on how ideas flow across organisational boundaries and are used by firms to create commercial value. Business models are essential to this definition. A second definition is "*open user innovation* … [whereby] economically important innovations are developed by users and other agents who divide up the tasks and costs of innovation development and then *freely* reveal their results" (von Hippel, 2014). This definition emphasises user-centred innovation driven by end users and user organisations, as opposed to producer-centred innovation. Both forms are potentially useful in our scenario and should be utilised in the journey towards full-scale commercialisation of TVWS/GLSD technology in Sub-Saharan Africa.

Systems of Innovation

The concept of a system of innovation is essential to understanding the characteristics and performance of innovation: "Although to some the word [system] connotes something that is consciously designed and built, this is far from the orientation here. Rather the concept is of a set of institutions whose interactions determine the innovative performance, in the [economic] sense above, of national firms. There is no presumption that the system was, in some sense, consciously designed, or even that the set of institutions involved works together smoothly and coherently. Rather, the "systems" concept is that of a set of institutional actors that, together, plays the major role in influencing innovative performance." (Nelson, 1993)

The set of institutional actors whose interactions will determine the practical achievement of the innovative potential of TVWS/GLSD technology includes, among others, R&D institutions like the CSIR, universities, government departments, SMMEs, private sector financiers, and civil society and community organisations.

Diffusion of Innovation

Diffusion is integral to innovation because it is not only the process by which new technologies spread throughout a population, but it also an essential part of the innovation process itself since the original innovation is invariably enhanced through the imitation, learning, feedback, adaptation and modification that occurs as the new technology spreads (Hall, 2004). The rate of diffusion of new technologies is influenced by four main groups of factors: *factors that affect the benefits received* (e.g. degree of improvement over previous technologies, network effects, technological standards); *factors that affect the costs of adoption* (e.g. price, complementary investments in training and equipment, absorptive capacity); *factors related to the industry or social* *environment* (e.g. regulation, market structure, cultural attitudes); and *factors due to information and uncertainty issues* (e.g. suitability for potential adopter's situation, longevity and trajectory of new technology, reversibility and resaleability). In our case, complete diffusion corresponds to full industrialisation of TVWS/GLSD technology. The key diffusion determinants that have been influenced positively thus far are network effects and technological standards by creating and promoting common technology in South Africa and other African countries; tackling information and uncertainty through technical trials and pilots; and the adoption of clear technical regulations. These determinants should be strengthened, while addressing the remaining determinants.

POLICY RESPONSES

In this section, we consider appropriate responses from innovation policy and industrial policy perspectives.

Innovation policy

Innovation policies are policies that have an important impact on innovation, and are of three main varieties (Edler and Fagerberg, 2017):

- *Mission-oriented policies* aimed at providing practical new solutions to specific challenges on the political agenda;
- *Invention-oriented policies* which focus narrowly on the R&D/invention phase, leaving exploitation and diffusion to the market;
- *System-level policies* which focus on features and improvements at the innovation system level.

In our case, up to now, we have been heavily focused on mission-oriented policies (affordable rural broadband) and invention-oriented policies (research on TVWS and GLSDs). More attention and effort should be directed towards system-level policies. Table 1 presents a catalogue of policy instruments that can be applied to our scenario. For instance, we can stimulate both supply and demand for TVWS/GLSD by using standards, regulation and technology foresight (policy instruments 13-15).

Table 1: Taxonomy of innovation policy instruments (Edler and Fagerberg, 2017)

	Overall orientation		Goals						
Innovation policy instruments	Supply	Demand	Increase R&D	Skills	Access to expertise	Improve systemic capability, complementarity	Enhance demand for innovation	Improve framework	Improve discourse
1 Fiscal incentives for R&D	●●●		●●●	●○○					
2 Direct support to firm R&D and innovation	●●●		●●●						
3 Policies for training and skills	●●●			●●●					
4 Entrepreneurship policy	●●●				●●●				
5 Technical services and advice	●●●				●●●				
6 Cluster policy	●●●					●●●			
7 Policies to support collaboration	●●●		●○○		●○○	●●●			
8 Innovation network policies	●●●					●●●			
9 Private demand for innovation		●●●					●●●		
10 Public procurement policies		●●●	●●○				●●●		
11 Pre-commercial procurement	●○○	●●●	●●○				●●●		
12 Innovation inducement prizes	●●○	●●○	●●○				●●○		
13 Standards	●●○	●●○					●○○	●●●	
14 Regulation	●●○	●●○					●○○	●●●	
15 Technology foresight	●●○	●●○							●●●

Notes: ●●● = major relevance, ●●○ = moderate relevance, and ●○○ = minor relevance to the overall orientation and stated innovation policy goals of the listed innovation policy instruments.

Industrial policy

Industrial policy relates to building out the TVWS/GLSD industrial base by economic and technological catch-up (Lee, 2013), and by exploiting Africa's unique characteristics and opportunities, as was done so successfully in the African mobile communications industry (Ibrahim, 2012). It is important to note that this requires a strong element of emergent policy – akin to emergent strategy (Mintzberg and Waters, 1985) – and therefore policy makers and practitioners must remain flexible and results-oriented in their approach. The limits of what we might term "deliberate policy formulations" and the value of emergent policy are evident in South Korean and Taiwanese economic history: "This book often uses Korean and Taiwanese firms and industries as examples of successful catch-up, leaving us with an intriguing question: did the policy makers in these countries have the criterion of short cycle time firmly in mind as they planned and conducted industrial policy? While the answer to this question is no, they were in fact always asking themselves, "what's next?" They looked keenly at which industries and businesses were likely to emerge in the immediate future and thought carefully about how to enter the emerging ones. Without specifically planning to do so, in effect the policy makers were always pursing the short-cycle industries as these were often the ones that relied less on existing technologies." (Lee, 2013: xviii)

IMPLEMENTATION STATUS

Implementation status in South Africa

R&D on TVWS networks has been going on in South Africa for close to a decade, an effort to which the authors have contributed over the years (ICASA, 2015). Despite this decade's worth of R&D, it was only in March 2018 that the TVWS regulations were promulgated (ICASA, 2018a), and in October 2018 that the process of establishing a national Reference GLSD (see Figure 2) was initiated (ICASA, 2018b). This is an important step forward which must be enhanced by additional regulatory innovation. Other aspects of the innovation system around TVWS/GLSD technology, such as other government departments, SMMEs, private sector financiers, and civil society and community organisations have yet to be mobilised.

Implementation status in Sub-Saharan Africa

At innovation system level, other countries in Sub-Saharan Africa are substantially behind South Africa in TVWS/GLSD technology, although there are excellent instances of innovation in some other countries (Nyasulu, 2018).

CONCLUSIONS

Summary

This paper describes an innovative spectrum sharing technology designed to significantly improve the effective utilisation of national radio frequency (RF) spectrum resources. The technology uses television white space (TVWS) broadband networks based on geo-location spectrum databases (GLSDs) to enable efficient RF spectrum sharing. It has been deployed on several experimental test-beds in South Africa and other African countries. This technology has the potential to support affordable broadband networks, particularly to address the demand for broadband connectivity in underserved rural communities. This technology is potentially of revolutionary benefit to the emerging economies of Africa. However, African telecom regulators are still lagging behind the rest of the world in enacting the necessary dynamic spectrum regulations required to enable the TVWS broadband Internet industry and associated services to flourish and provide the necessary socio-economic benefit. Spectrum sharing is also a technology being considered for future wireless 5G wireless network standards.

Hence this technology is future secure and expected to have extremely high market potential.

Key lessons and insights

The key lessons and insights emerging from this paper are as follows:

- *Complete innovation process.* To reap the full benefits of innovation, African countries must implement and practise all elements of the entire innovation process: invention (R&D), commercialisation, and diffusion. In particular, the critical importance of diffusion, and the factors that influence it, has been underappreciated. It is important to realise that innovation is *not* a linear or sequential process and that all three elements will, in some sense, be in a constant state of flux as the innovation itself is being developed and deployed.
- *Systems of innovation.* Successful innovation requires fully functioning systems of innovation at national, regional and organisational levels.
- *Local knowledge and capabilities.* Developing strong knowledge of local characteristics and innovation opportunities, and creating strong local technological and commercial capabilities, is key to the development of technology-based sectors such as TVWS/GLSD. Good examples include the African mobile industry and the Asian tiger economies.

Recommendations for policy makers and practitioners

Our main recommendations for policy makers and practitioners are as follows:

- *System orchestration (policy makers).* Focus on orchestrating – identifying, integrating and coordinating – the key actors in the innovation system. At a granular level, this involves formulating and implementing effective system-level innovation polices that will stimulate both supply and demand for innovation. The key challenge in any system of institutional actors is how to align intentions, interests and incentives. Policy makers should become skilled in designing incentives, in the form of regulations, market mechanisms, and so forth, in such a way as to positively influence the behaviour of the various actors and enhance the performance of the innovation system as a whole.
- *Emergent innovation and industrial policy (policy makers).* Due to the complexity of modern societies and economies, it is impossible for policy makers to control or foresee all the consequences or nth-order effects of their decisions. Consequently, successful innovation policy and industrial policy requires flexibility and an unremitting focus on results.
- *Commercialisation (practitioners).* Practitioners should be keenly aware of the need to commercialise their ideas in the form of viable business models. This applies equally to researchers, entrepreneurs and intrapreneurs alike. Without a viable business model, no new technology is sustainable in the long term.
- *Aspiration (practitioners).* Raise the level of aspiration beyond mere consumption, adoption or imitation to the level of production and creation. Practitioners whose aspirations and ambitions remain low cannot expect to survive, let alone succeed, in this highly competitive, rapidly evolving global economy.
- *Education and circulation (policy makers and practitioners).* Help build understanding and linkages by educating each other about their respective worlds and encouraging the circulation of people between the various institutional parts of the innovation system. Most policy makers have little first-hand – or even second-hand – understanding of the true objectives, concerns and motivations of practitioners. And, of course, the same is true of practitioners in

relation to policy makers. And yet the work of both sets of actors is vital to the success of the innovation enterprise.

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