The Co-Regulation of TV-White Spaces: The Southern Africa Development Community Approach

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Abstract. TV-White Spaces (TVWS) is among the promising solutions for extending internet broadband reach in the Southern Africa Development Community (SADC). White Spaces are often called the "*gold spectrum resource*", the industry, regulators and academia from SADC have been effervescently working in new ways towards flexible govern the usage of these bands by embracing standards such as IEEE 802.11af, 802.19.1 and 802.22.

This article analyses the deployment of TVWS in six SADC countries namely Botswana, Tanzania, Namibia, Malawi, Mozambique and South Africa, the study, demonstrates the steps and standards adopted to deploy trials and the adoption of co-regulation as an approach for regulating the TVWS.

Keywords: Co-regulation · TV-White Spaces · Broadband
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1 Introduction

The policymakers from the Southern Africa Development Community (SADC), for the last decade have been forced by community-driven service providers and academia, to harness affordable technologies to close the digital-exclusion. The absence of financial resources and land-line infrastructure in SADC brought forward the concept of leapfrogging to the information age with wireless technologies. In the region, wireless technologies became the newest cutting edge, high-speed technology for rural areas internet provision, where the world bank estimates that 65–70% of the populations currently resides.

The universal access policies and approaches are today a public issue, placing pressure on government, regulatory agencies to be more dogmatic and hands-on in ICT regulation to mitigate the digital-exclusion. Nonetheless, the scarcity of government financial and technical resources created conditions for the emergence of co-regulation.

In this study, co-regulation refers to the union of regulatory entities, research agencies, community-driven service providers and ordinary citizens cooperating to deploy, experiment and draft regulation for new technologies in SADC.

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For the International Telecommunication Union (ITU) region 1, there were changes in spectrum regulation mainly in TV broadcast bands where subsists many challenges to use TV bands segment of the spectrum efficiently. The World Radio Congress (WRC-15) established for region 1, the frequency bands 470–694 MHz to be used on a secondary basis by the land mobile service, with an understanding that secondary service should not interfere with primary or incumbent stations.

The history of TV-White Spaces (TVWS) in the SADC stands connected to Digital Migration (DM) and the tacit need to provide sustainable broadband connectivity to rural SADC. White Spaces are often called the "gold spectrum resource", the industry, regulators and academia from SADC have been effervescently working in new ways towards flexible govern the usage of these bands by embracing standards such as IEEE 802.11af, 802.19.1 and 802.22.

It is the authors understanding that TVWS was pushed forward not by the late changes in spectrum regulation possibly the most fundamental ever in the history of spectrum management (WRC-15), it was brought forward by community-driven service providers, academia and corporate giants due to the widening gap in digital inequality and the propagation capabilities of UHF/VHF spectrum.

These changes drove SADC members of the Communications Regulators Association of Southern Africa (CRASA) to opportunistically adopt TVWS as a possible solution to provide broadband in rural areas excluded from broadband coverage. CRASA is a harmonisation body of Postal and Information Communication Technologies regulatory environment in SADC.

The CRASA members perceive, regulation as an abstract concept and do take many forms from legal restrictions, contractual obligations to co-regulation. In the region, cultural aspects such as the African concept of Ubuntu and the approaches joining for an agreement have been adopted since the early days of regulation. Hence there is a link between regulation and human-centred approaches for decision making based on interaction [1]. The SADC approach of co-regulation unintentionally is infused with the Ubuntu concept, allowing the participation of experts and non-experts in the process of regulation to attain mutual understanding and adoption.

The mediation challenges to regulate the communication industry generate distributed theories such as co-regulation, which is rooted in the cultural organisation of society. However, it extends the reach of the individual to encompass interactions between different people with complete disregard for who, and what the individual is.

This study reviews the studies conducted by six distinct CRASA members, namely the Independent Communications Authority of South Africa (ICASA), the Tanzanian Communications Regulatory Authority (TCRA), the Malawian Communications Regulatory Authority (MACRA), Communications Regulatory Authority of Namibia (CRAN), the Botswana Communications Regulatory Authority (BOCRA) and the Communications Regulatory Authority of Mozambique (INCM).

The value of the article lies in providing a holistic viewpoint on the approach adopted to regulate the technology using design theories under the current technical and regulatory conditions.

The paper is organised as follows: a review of internet provision in SADC and the emergence of TVWS, the approach adopted to deploy the six TVWS trials, a short

analysis and discussion of how co-regulation was used in the process of regulation and the study conclusions.

2 Methodology

Given the formative nature of both research and regulation concerning TVWS and broadband, the Authors decided it would be best to adopt case study analyses. We aimed at building upwards from the practice of each regulator and understand or frame an original understanding of each approach the steps taken to deploy the technology and regulate.

The case studies were identified iteratively: consulting CRASA to acquire successful implementations and finally consulting the regulators about the process adopted to draft regulatory framework for TVWS.

On an initial stage, the information acquired from regulators was applied a chain-referral sampling technique to identify existing studies among their acquaintances to further investigates deployments of TVWS.

On a second phase, a mix of descriptive and exploratory approach was used. The emotional component would aim to ask "what and when" about TVWS deployments and produce a design and implementation chronology. The exploratory element would be more open and seek to understand the value and outcome of each case deployment.

During the initial stage of this study were identified seven case studies, from which six have materialised in actual trials Botswana, Tanzania, Namibia, Malawi, Mozambique and South Africa. The trial in Zimbabwe until the end of our research was not conducted.

Each case was carefully analysed from the technological approach to applicability, where identified trends and similarities.

3 Co-Regulation

There exists in the SADC region a digital divide, which in recent years academia, researchers, community-driven service providers, practitioners and regulators have been experimenting opportunistic ways to allow communities to have affordable internet broadband.

Co-regulation in this study refers to the relationships among cultural, social, technological and personal sources of influence that together challenge, shape and guide the emergence of new policies. This approach for regulation emerges through participation and validation of social and cultural relationships to address a specific technological problem, typically involving both primary legislation and self-regulation where there exists involvement of bodies representing stakeholders in the regulatory decision-making process [3].

The co-regulation approach adopts an identity as the leading condiment for the personal, cultural and social influence which altogether control, challenge, shape and guide the new character of a group. A group origin and identity is situated across the cultural and heritage backgrounds of its participants.

The important aspect about co-regulation is cooperation and participation where each actor has two roles (expert and novice), in most of the cases one can be expert in the technical aspects of technology but utterly unaware about how communities perceive, the technology and regulation in place for technology usage. In co-regulation, regulatory bodies act as mediators and assemble interactions and process to produce a positive outcome for all parts involved.

Humans as social beings seek a sense of belongingness for self-realisation through participation, hence, in co-regulation cooperation is an essential mediator which enriches critical motives for involvement. In modern social cognitive theories motivated behaviour is considered the result of choices or decisions that an individual make concerning their goals, belief and values [4], while in co-regulation the motivated conduct is entangled with judgment and decision strategies where wishes and desire substitute logical processes [3].

The technologies being co-regulated are not designed or produced in the cultural setting being tested or regulated; instead, most of the cultural background is utterly unaware of the know-how and capabilities of such technical apparatus. The experts on this domain are in most cases academia, corporate giants or regulators.

This factor does not become an inhibitory factor. Instead, it does allow communities field and space for learning.

The technology embeds the cultural practice from designers; the regulators apart from technical specifications have also enhanced public participation in the draft of the regulatory framework, a mechanism to allow community participation in policy discussion.

4 SADC and TV-White Spaces

The SADC region comprises 15 countries and is home for approximately 258 million people. The Democratic Republic of Congo (DRC) is home for 28% of the population.

There has been in the past, a tendency to neglect the link between regulation and social interactions, perhaps because the process of regulating was mostly a top-bottom approach. In recent years regulators have been adopting co-regulation for policy design and implementation.

SADC with its many problems of hunger, epidemic, war, and socioeconomic issues manages to provide internet to approximately thirty-nine percent of the population mostly residing in urban areas. The Internet diffusion has mainly been confined to major cities, where a minority of the population lives although a growing number of countries have points of presence (POPs) in rural areas.

The South African Internet market, a well-consolidated market, has approximately 100 POPs and three primary Internet Service Providers (ISPs) who together have 90% of market share and other 75 small ISPs have the remainder 10%.

The remaining SADC countries started the diffusion of the internet for e-Government, e-Health, e-Banking late, mainly because it was a phenomenon driven by developed countries. Developed initiatives in the region viewed wireless communications as the financially sustainable approach to bridge the north to the south gap and to allow local governments to meet obligations to deliver, care, education, monitor

public services, complex coordinate activities, ensure quality and foster collaboration by empowering rural communities [5–7].

The access to the Internet in the region was hindered by the lack of local expertise, resources to acquire infrastructure and a regulatory environment capable of creating policies for equity diffusion of the technology. Wireless communications for Internet depend on spectrum availability, a finite resource which has an enormous impact on the cost of infrastructure and quality of the service provided. Fiber to the Home (FTTH), Asynchronous Digital Subscriber Lines (ADSL), Very Small Aperture Terminals (VSAT) and WiMAX are the technologies widely adopted in the urban and rural SADC to provide access to the Internet [4]. With these technologies there exists a mix of realities that continues a story of inequality, unbalance and asymmetry on usage, cost and quality of the Internet service provided.

The low-cost and robust broadband connectivity in the SADC region is often unaffordable for the ordinary citizen if it is affordable is restricted to urban areas.

The Regulators from the region have been experimenting the usage of White Spaces to provide access to the Internet in areas deprived of reliable electricity. Dosch et al. suggested that the so-called white spaces are not clean bands as they result from pollution due to low-power emissions coming from Digital Television (DTV) or analogue allotments [8].

The white spaces signals are the source of interference for Cognitive Radios (CR). Nonetheless, they do not degrade the actual value of white spaces [8].

Reusing the White Spaces can reduce the cost of wireless broadband access by accessing dynamically high-quality spectrum below 1 GHz. Spectrum bellow 1 GHz is considered valuable due to the ability to cover large areas, requiring lower power signal from the transceiver to get the same output power signal at the receiver compared to other spectrum bands. Additionally, devices placed at the sub 1 GHz spectrum band can handle interference better because they operate at a lower frequency where fewer applications use spectrum, and also these bands enable transmissions to weave between buildings in an urban environment better [7].

Recently in sub 1 Ghz spectrum cognitive radios and Internet of Things (IoT), wireless applications have been experimented, turning into an exciting paradigm for wireless communication in which either a network or a wireless node changes its transmission or reception parameters to communicate efficiently, avoiding interference with licensed or unlicensed users [9]. Hence TVWS refers to segments of the TV-Spectrum in the TV operating frequencies known as VHF/UHF band, especially from 470–790 MHz when the bands are not used by licensed users in a given location [10].

The name TVWS comes from broadcast coverage maps while plotting the coverage areas, and different colours indicate different signal levels, the areas without signal are left with the white intensity [11].

Licensing protects the incumbent users of the TVWS band from interference, for that reason unlicensed white spaces devices operating in the TVWS band are not permitted to create interference with any licensed (incumbent) user.

A typical free Wi-Fi signal travels about 100 m versus TVWS signals that may extend to 400 m at the same power level, or up to as far as 10 km at high power [12]. This impressive reach has spawned the nickname "Super Wi-Fi" with frequency allocation, spectrum sensing techniques and geo-location spectrum databases being the most used techniques for spectrum allocation and protection of incumbent systems [13].

In the early days, the spectrum allocation technique is no longer used, most of the incumbent systems are allocated spectrum by sensing-only methods and geo-location databases techniques. While the sensing-only mode faces performance, design issues challenges due to the need of: first determine if an incumbent is present; second by detecting if the incumbent signals above −116 dBm and; third by reducing the transmission power downward to avoid interfering with the incumbent signal levels.

The geo-location databases gain a relative advantage in performance and design issues compared to sensing-only, as the database is already built-in knowledge regarding the bands and the exact incumbent's services presented in the location where the device is aspiring to transmit [10, 14]. The geo-location database offers a dynamic approach for spectrum allocation as different TV channels become available TVWS translates to higher network capacity, allowing a more significant number of users in a given area while protecting incumbent users [15].

The TVWS can enable a variety of use cases ranging from low-power in-building media distribution to machine-to-machine applications, but they are mainly well-suited for delivering low-cost broadband access to rural and other unserved communities. Radio signals in the TV bands, in particular, the 470 MHz to 698 MHz range of UHF frequencies travel over long distances and penetrate more obstacles than other types of radio signals, enabling non-line-of-sight wireless connectivity and requiring fewer base stations to provide ubiquitous coverage [16].

5 Technical Trials

In this section a description of the TVWS deployments in SADC will be provided with attention to the year of deployment, the location of implementation, the TVWS equipment used and the highest throughput reached.

Table 1 demonstrates the trials conducted in SADC, and it is possible to grasp that most of the deployment in SADC were performed in 2013 with the objective being the provision of Internet Broadband for Education. The 4Africa Initiative, a Microsoft project which focused on universal access and innovation was one of the key proponents of TVWS in the African continent; the project allowed the implementation of TVWS trials in Botswana, Ghana, Kenya, Tanzania, Namibia and also a second trial in South Africa (Cape Town).

Research and Development cases were led by the regulators while in 4Africa Initiative regulators were invited to participate, the Adaptrum Base transceiver station (BTS) followed by 6Harmonics were the most used type of equipment in the region.

Table 1. SADC TVWS trials.

Year	Country	Project name	Application	Throughput/Distance	Equipment
2013	South Africa, Polokwane	4Africa Initiative	Education	12 Mbps/6 km	Carlson Wireless
2013	Dar Es Salaam, Tanzania	4Africa Initiative	Education	12 Mbps/6 km	Adaptrum
2013	Zomba, Malawi	Research and Development	Health and Education	2mbps/7.5 km	Carlson Wireless
2014	Oshana, Ohangwena and Omusati, Namibia	4Africa Initiative	Education	10 Mbps/10 km	Adaptrum
2015	Francistown, Lobatse and Maun, Botswana	4Africa Initiative	Health	5Mbps/3 km	Adaptrum
2015	Maputo, Mozambique	Research and Development	Education	4 Mbps/8.5 km	6Harmonics

5.1 South Africa

The first ever technical trial conducted in the SADC region was conducted in South Africa (Polokwane), the experiment started in March 2013 with more than five partners including Google, Carlson Wireless Technologies and the Open Spectrum Alliance [13]. The Internet broadband was provided to ten schools stood supported by three BTS from Carlson Wireless Technologies [17].

The study provided, as a result, a throughput as high as 12 Mbps and latencies lower than 100 ms. To acquire such findings were used directional antennas with gains of 11 dBi to ensure good quality, and the links were of distances not higher than 6 km with line of sight to reduce interference.

It has to be noticed that later in September 2013 ICASA conducted another TVWS trial in Cape Town with the support of 4Africa Initiative, this trial lasted for six months, and is aimed at addressing spectrum field measurements to demonstrate non-interference or interference, traffic (upload and download throughput) and latency.

The study used google GLSDB; as a result, the download throughput reached 12 Mbps, and the upload throughput was 4.5 Mbps. The latency stood at 120 ms and the measurements done did not provide evidence of interference to primary stations or incumbent [18].

5.2 Tanzania

In 2013 was conducted the second trial of TVWS in the region, with Tanzania and Microsoft under the 4Africa Initiative partnering with UhuruOne a local internet service provider, the Tanzanian Commission for Science and Technology (COSTECH) deploying a network aspiring to provide affordable Internet broadband for education in Dar Es Salaam [15].

The trial was part of 4Africa Initiative, a Microsoft effort to bring connectivity, devices and technology to African entrepreneurs, developers and college graduates, in

Tanzania UhuruOne was to offer, wireless broadband connectivity, a laptop or tablet on the first phase to 50 000 students and faculty members and a later stage expand coverage to several other Universities.

The primary beneficiaries of this initiative were the Open University of Tanzania, Institute of Finance Management, College of Business Education and Dar Es Salaam School of Journalism which together they had approximately 74,000 students.

The TVWS experimenting centred on access with the lowest levels of interference using spectrum allocation to offer affordable wireless broadband. The initiative was the first ever urban TVWS deployment in SADC; the study provided understanding about the usage of such spectrum in an urban and congested location.

The download throughput reached was 8.5 Mbps, and the upload was on average 2.5 Mbps, the most extended link had a distance of 6 km.

5.3 Malawi

MACRA, the University of Malawi, the International Centre for Theoretical Physics (ICTP) and the Universal Access Fund of Malawi [9], conducted in Zomba, Malawi, on September 2013 a TVWS trial.

The trial was designed to evaluate the performance and usage of TVWS in a rural setting to support potential guidance for commercial regulation of white spaces spectrum eventually.

The trial followed research and development to provide regulators in-depth understanding of the technology coverage and performance while at the same time provide access to internet broadband to unserved rural areas and services.

The trial had as beneficiaries the Saint Mary's Girl Secondary School, the Malawi Defense Force Air-wing, and the Seismology Department.

In conclusion, the trial demonstrated to be able to provide 2.6 times better data rates given adequate weather conditions, the Internet for this trial was supplied through a dedicated 2 Mbps wireless backhaul. The download throughput registered was 400 Kbps at each beneficiary with a latency of 125 ms using Carlson Wireless Technologies (rural Connect).

5.4 Namibia

Namibia trial was denominated Citizen Connect was a 4Africa Initiative having as partners My Digital Bridge Foundation and Microsoft. The test was conducted in September 2014; it had coverage of approximately 9,424 km^2 covering the regional council of Oshana, Omusati and Ohangwena [15, 19].

The project connected 28 schools, aiming to use the TVWS technology efficiently for bridging the digital divide faced by Namibia were only 12.9% of the population in 2012 had access to the Internet. The vast network was deployed using Adaptrum (ARCS 2.0) BTS with links ranging from 8 km to 12 km providing download throughput speeds of 10 Mbps and upload throughput of 6 Mbps. In addition to the long-range non-line-of-sight links, the network relayed on extended multiple short links providing throughput of 10 Mbps allowing schools to have the voice, video, and data communications including high resolution, 3way skype video conference for remote learning.

5.5 Botswana

The Botswana Communications Regulatory Authority (BOCRA) in the first trimester of 2015, in collaboration with the Botswana Innovation Hub, Microsoft, the Botswana - Upen Partnership, USAID and BoFiNet a local ISP, partnered in the implementation of Project Kgolagano.

The project aimed at providing access to specific maternal medicine information to improve the livelihood of women located in small towns and rural areas. The network connected hospitals in Maun, Lobatse and Francistown and the system is used to combine technical studies, surveys, observational studies and focus groups to investigate the value and capabilities of TVWS for telemedicine.

The research group conducting this trial was not implicitly interested in the physical aspects of the technology, they were more interested in the applicability (benefits, challenges and perceptions) of the technology for telemedicine.

5.6 Mozambique

In 2014, the INCM conducted in Mozambique research and development having as partners the ICTP, Universal Access Fund of Mozambique, the University Eduardo Mondlane and the Network Startup Resource Centre (NSRC) aimed at providing internet broadband to one University and two vocational schools in the Boane Municipality.

The maximum throughput reached was 4 Mbps with a latency of 108 ms for a link with 8.5 km given simultaneous usage of three client stations from a TVWS BTS backhauled by a 6 Mbps internet bandwidth. The network was deployed using 6 Harmonics (GWS 3000) [16].

6 Discussion

Independently, since 2013 CRASA members conducted research on TVWS, aiming to find an alternative technology to bridge the digital divide. Results of R&D were published in journals, conferences with proceedings and also as position papers on TVWS.

The South African (ICASA) white spaces regulation approach is the product of interactive consultations between the Regulator, industry and several academic institutions such as the Meraka Institute. The process spanned several years resulting in the publication of the regulation in 2018.

In the middle 2018, Mozambique (INCM) also published the norm to govern the usage of TVWS using an approach similar to ICASA, with the difference that the norm in Mozambique being vigent for approximately 5 years.

Ubuntu “I am because you are” is the cultural idea of interconnectedness of humanity, can also be used to look at policies and regulations. Due to the inherent interdependence of CRASA members, they have influenced each other on the race for affordable internet access with the industry and communities bringing forward TVWS.

The interconnectedness provides changes in policies, which imply how communities adopt or embrace technologies.

Independently CRASA members have noticed perhaps innocently that most of the heritage value and legal heritage are getting weather-beaten by forces of the western civilisation and globalisation, the lack of Ubuntu (African group solidarity) between CRASA regulators and project stakeholders is primarily due to an inappropriate project organisational structure [1].

There is not seem to exist any universal pattern in this community participation, and it appears that the primary drive behind this approach is to acquire policy advice and public policy more directly accessible and responsive to citizens. The method does provide policymakers with a more extensive variety of ideas, perspectives and suggestions than traditional policy advice can offer. This form of community participation is in many ways entirely consonant and consistent with emerging technologies or services which aim at improving communities access to decision processes and strengthening the position of the citizen vis-a-vis the policy maker.

7 Conclusion

Our intent in this article was to clarify the nature of the approach adopted by CRASA regulators for the new TVWS technology to provide internet broadband. SADC countries have very communities' dispersal located, creating difficulties to offer comprehensive coverage, hence TVWS is one of the most wireless technologies researched for bandwidth delivered in recent years as it covers large areas at a lower cost, and reuses spectrum better compared to other wireless technologies such as WiMAX and iBurst.

The case studies here presented without creating inference to primary users of spectrum. Coexistence can be attained efficiently with the use of geolocation database.

The studies performed in Namibia, Malawi, Mozambique and South Africa, on an early stage, adopted frequency allocation, the IEEE 802.22 wireless network standard and advanced on a second stage to geo-location database (GLSD) with the IEEE8 02.11af wireless standard being an option. Moreover, for the four regulators, the initiative to integrated into the policy process participation of the state vis-à-vis private think-tanks, policy institutes, and other organisations brought conditions to harmonise the regulatory framework of TVWS in the region.

The TVWS is receiving overwhelming interest in the wireless industry and academia, with position papers composed independently and uncorrelated by regulators and academia addressing the principle of conserving resources and efficient use of spectrum [10, 20]. Since the deployment of 3G, the telecommunication sector has been experiencing fundamental changes in its regulatory treatment, most of them to safeguard the public interest. The deregulation of telecommunication sector is a consequence of the revolution in technology, hence a minuscule portion of the spectrum is open for license-free operation.

The co-regulation has been gaining momentum in recent years most case studies are performed by academia, practitioners and corporate giants having as beneficiaries of such actions communities deprived of ICT access.

The participation of external actors in the process does align with participatory approaches in our case co-regulation where the participant's identity changes from experts to non-experts of technology. The participation of this actions has different perceptions of the case and transmission protocols while methods required for regulating are exclusive to regulators and perhaps corporate giants. In most of the case studies analysed corporate giants kept a high degree of discretion in structuring and participating in trials.

While current white spaces radios use proprietary technology implementations, the various database is being developed as this area of research matures, there is an increasing need to move beyond frameworks to actual region TVWS database. One of the problems that were common to most of the case studies in the sample might be alleviated by more collaboration between CRASA members about their trials objectives and research plans.

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