Proceedings of the Sustainable Research and Innovation Conference
JKUAT Main Campus, Kenya
6 - 7 October, 2021

The Authorization of the use of TV White Spaces: The Kenyan Scenario

E.Mureu, P. Kihato and P. Langat

[1]***Abstract*—**The TV White Spaces (TVWS) are "portions of spectrum left unused by TV broadcasting services", in the Ultra High Frequency (UHF) band. One of the proposed application of the TVWS is in the provision of fixed wireless broadband connectivity to homes, businesses, public services like education and health facilities more so in the underserved rural and semi-urban areas.

The aim of this study is to bring to the light the proposed framework by the Communications Authority of Kenya (CA) for the use of TVWS in Kenya. The CA has adopted a framework for authorization of TV white space applications which is part of the Dynamic Spectrum Access (DSA), that includes specific device requirements, operational parameters, channel usage parameters, coexistence calculations and procedure for qualification of geolocation databases. Effective implementation of a spectrum sharing approach will enable efficient utilization of the spectrum while protecting existing primary users from harmful interference.

The spectrum occupancy measurements previously carried out in Kenya in the UHF bands both in rural and urban areas have shown occupancy by the primary users of about 25% and 50% respectively. This is an indication that there is an ample fallow spectrum that could be utilized for TVWS applications and hence the need for a formal framework and authorization for its utilization as it happening elsewhere in the world.

***Keywords*—** Dynamic Spectrum Access, Communication Authority of Kenya, TV white spaces, Ultra High Frequency band.

I. Introduction

THE Communications Authority of Kenya is the regulatory authority for the Information and Communication Technology (ICT) sector in Kenya with responsibilities in telecommunications, e-commerce, broadcasting, postal/courier services and cybersecurity. The Authority is responsible for managing the numbering and frequency spectrum resources for the country as well as safeguarding consumers of ICT services [1].

The increase in radio communication devices and services has resulted in greater demand for access to the radio frequency spectrum. A new spectrum management paradigm is required for some services to balance spectrum utilization by incumbents and the growing demand from the new services.

Dynamic spectrum access (DSA) is a spectrum sharing concept that allows secondary users to access spectrum in licensed spectrum bands on condition that they do not cause harmful interference to incumbent users [2]. DSA may alleviate spectrum scarcity and increase spectrum utilization especially in rural underserved areas. The authority proposed to authorize dynamic access of the UHF band 470-694 MHz on a non-protected, non-interference basis by white space devices (WSDs). In establishing the regulatory requirements for TVWS in Kenya, the Authority set limits that would offer the protection required to prevent harmful interference to the Digital TV Terrestrial (DTT) broadcasting service [3].

The Authority proposed to authorize the operation of geolocation databases in the country which would receive periodic updates from the Authority's spectrum management database, perform coexistence calculations and provide transmission parameters to the WSDs for non-interference operation. The WSDs must meet the minimum technical specifications and be Type Approved prior to installation and use, they should be authorized to operate at specific locations and times determined by the geolocation database.

The rest of the paper is organized as follows; section II details the spectrum sharing opportunity for Television White Spaces (TVWS) applications, section III presents the framework for the use of TV white spaces, section IV presents results for TV white space trials and spectrum occupancy measurements, section V gives requirements for devices operating in TV white spaces, section VI gives a comparison between the Kenyan scenario with international standards and other national regimes, section VII draws conclusions and give recommendations.

II. Spectrum Sharing Opportunity for TVWS Applications

TV white spaces are "portions of spectrum left unused by TV broadcasting services", in the Ultra High Frequency (UHF) band. The UHF band between 470 MHz – 694 MHz is allocated, on a primary basis, to the broadcasting service for DTT transmissions in ITU region 1 which includes Africa. Each multiplex requires an 8 MHz channel and the multiplexes are transmitted on various frequency channels at designated broadcast sites [3].

There are 28 channels of 8 MHz bandwidth (from CH21 to

[1] *E. W. Mureu, Department of Electrical and Electronic Engineering, JKUAT (P.O. Box 62000-00200 Nairobi; e-mail: emureu@jkuat.ac.ke ; Tel: +254724264675).*

P.K. Kihato, Department of Electrical and Electronic Engineering, JKUAT (email: pkihato@jkuat.ac.ke) and P.K.Langat, Department of Telecommunication Engineering, JKUAT (e-mail:kibetlp@jkuat.ac.ke)

CH48) are available for DTT broadcasting in Kenya, though not all 28 channels are activated at each transmission site due to varying signal coverage areas and irregular terrain. High-power TV transmissions on the same frequency channel require geographic separation between their coverage areas to avoid interference in multi-frequency networks. Channels that are not activated for DTT transmissions at a given location, at a particular time may be available for use by low power WSDs on a dynamic basis.

Radio frequency spectrum in the UHF band has highly desirable propagation characteristics and TV white spaces are particularly suitable for delivering Internet access in rural and underserved semi-urban areas. Possible applications include the provision of fixed wireless broadband connectivity to homes, businesses, public services like education and health facilities as well as Internet of Things (IoT) applications.

III. FRAMEWORK FOR THE USE OF TV WHITE SPACES

The Authority has adopted a lightly licensed model of service for TVWS applications. Under such a model, a master TV white space device shall consult any geolocation database qualified by the Authority and submit parameters describing its location, operational and device parameters. The database would then supply details of the frequency channels and power levels the WSD is allowed to use. Figure 1 illustrates how access to white spaces based on geolocation would work in practice [3].

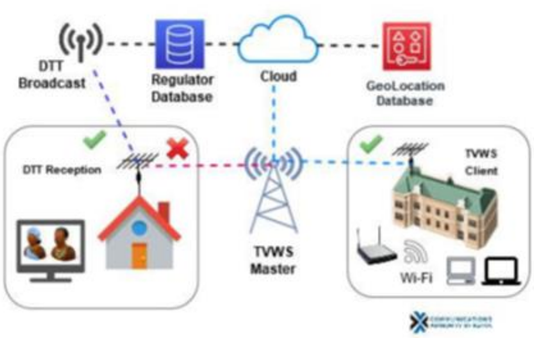

Figure 1: Simple diagram of TV White Space Network

The topology is a point to multipoint with a Base Station (BS) and several clients, the Consumer Premise Equipment (CPEs). The BS can serve fixed or portable CPE units equipped with outdoor directional antennas. Target service capacity is to deliver to a CPE at the edge of coverage a minimum throughput, 1.5 Mbit/s downlink and 354 kb/s in the uplink. The total capacity of the Base Station is up to 22 Mbit/s per channel.

Key Provisions of the TVWS Framework

For the purpose of implementation of the framework, the following are key provisions:

a. **Eligible Operators**: The Authority shall permit interested service providers who hold either a Network Facilities Provider License (Tiers 1, 2 & 3), a Broadcasting Signal Distributor License or a Self-Provisioning Broadcasting License to use TVWS spectrum.

b. **Device authorization**: Every white space device model must meet the minimum technical requirements for equipment type approval prior to deployment

c. **Coexistence framework**: The use of TV white spaces shall be controlled in accordance with the rules, conditions, and calculations stipulated in the framework.

d. **Database Service Providers:** The Authority shall qualify 3rd party databases that would be capable of taking the data provided by the Authority and providing responses to WSDs that accurately identify available channels and acceptable power levels.

Master and Client WSDs

Under the TVWS framework, a distinction is made between master WSDs and client WSDs. A master WSD is a device that is able to communicate with and obtain parameters directly from a geolocation database and a client WSD is a device that is only able to operate when under the control of a master WSD. Deployments of WSDs would involve a master WSD as a base station or an access point, which controls a number of clients within its coverage area in point to multipoint mode.

Device Parameters

Once a master WSD has selected a qualified database, it will report to that database its “device parameters” which identify specific characteristics of the WSD, including its location and other information about the device. A master WSD shall also communicate to the geolocation database the device parameters of all client WSDs under its control.

The harmonized European Telecommunications Standards Institute (ETSI) standard describes the parameters required for the operation of WSDs, including the nature of the data exchanged between WSDs and the database [4]. If the WSD setup is compatible with the standard, then the database shall initiate the determination of channel usage parameters.

Operational Parameters

The geolocation database would use device parameters together with DTT information provided by the Authority, to determine what frequencies are available for that particular device and at what powers it is able to transmit on a specific channel. This information is known as the “operational parameters” and will be communicated to the device. These operational parameters would only be valid for a short period of time so the device would have to query the database on a regular basis in order to ensure that it can transmit in accordance with valid operational parameters.

Channel Usage Parameters

The channel usage parameters are reported by a WSD to inform a database of the actual frequencies and powers that it intends to use for transmission which will enable a database to log the information for spectrum management purposes. The Channel Usage parameters describe the radio resources (frequencies & powers) that a WSD intends to use which may be a subset of the resources indicated by the database in the Operational Parameters.

Exchange of Parameters between WSDs and Geolocation Databases

The exchange of parameters between WSDs and the databases could be as follows [3]: Once a master WSD establishes a communications link with a qualifying database it will communicate its device parameters to that database. The database will then be able to calculate the operational parameters the master WSD may use. This set of operational parameters will include a number of channels and the maximum power allowed in each channel. The master WSD will select the channels and powers to use and report this to the geolocation database as the channel usage parameters.

If a master WSD is part of a network comprising client WSDs, it will now be able to obtain operational parameters for its clients as follows. First, the master WSD will request generic operational parameters from the geolocation database. These are the channels and powers that a generic client device within the coverage area of the master. Generic operational parameters are quite restrictive, as they are calculated making cautious assumptions about the client devices. For instance, the master WSD will assume that the client WSD could be anywhere in the coverage area of the master. The geolocation database will estimate the coverage area of the master, and subsequently, calculate the generic operational parameters.

Second, the master WSD will broadcast generic operational parameters. Client WSDs must listen to the master's broadcast before transmitting and decode the generic operational parameter information. They will use it for their initial transmissions to the master, to report their unique device identifier and possibly other device parameters.

The client WSDs could continue using the generic operational parameters for user data transmissions or could provide the master with location information for determination of operational parameters. The master would then relay this information to the geolocation database, which would calculate operational parameters specific for a particular client. These specific operational parameters are less restrictive than generic operational parameters.

Regardless of whether the client WSD operates according to generic or specific operational parameters, the master WSD serving it will also have to report the client WSD's channel usage parameters to the geolocation database from which it has obtained operational parameters.

Interference Management

While the coexistence rules are sufficient to ensure a low probability of harmful interference, the implementation of this framework will also include procedures to enable the Authority to manage any interference that does occur based on the key elements below:

1) The geolocation databases will make available to the Authority information for the purposes of resolution of any interference cases. This information includes the frequencies and radiated power of WSDs in a particular location and time. The Authority shall identify WSDs potentially causing interference and act accordingly.

2) The Authority may instruct databases to shut down any WSD.

3) For some geolocation databases, a portal for regulator could provide real time access for monitoring and possible deactivation of non-conforming WSDs.

Adjustments to Maximum Transmit Power

The Authority shall specify the maximum power limits for a particular location and channels to the geolocation databases. This may be used to implement changes required in a particular area as may be determined by the Authority, based on a review of the coexistence calculations.

IV. Results for TV White Space Trials and Spectrum Occupancy Measrurements

Table 1 summarizes the trials authorized in Kenya indicating operators, partners and the status [3]. From the table it could be seen that three trials that employed TVWS to offer internet access have been successfully completed.

Table 1: Summary of White Space Trials in Kenya

	Start (& Duration)	Operator	Affiliate Network Facilities Providers	Authorised Locations	Database Provider & Equipment Vendors	Outcome
1.	September 2013 (1 year)	Microsoft East Africa	Indigo Telecom	Kajiado & Laikipia	6Harmonics & Adaptrum	Trial Completed
2.	November 2014 (1 year)	Mawingu Networks	-	Laikipia	6Harmonics Adaptrum & Nominet	Trial Completed
3.	November 2016 (1 year)	Pan Africa Network Group Kenya	-	Countrywide	Static Model Proposed (No database)	Extension Requested
4.	November 2016 (1 year)	Signet Signal Distributors	Mawingu Networks	Countrywide	Static Model Proposed (No database)	Extension Requested
5.	March 2019 (6 Months)	Mawingu Networks	-	Embu	Adaptrum Redline & Fairspectrum	Trial Completed

The authors in [4] also conducted spectrum occupancy measurements in the UHF DTT band in Kenya at a rural and an urban location which showed occupancy by the primary users of about 25% and 50% respectively. This further reinforces the viability of the TVWS to enhance the internet access penetration more so in the underserved rural areas.

V. Requirements for Devices Operating in TV White Spaces

Authorization

The Authority shall authorize lightly-licensed operation of WSDs in the UHF band on a secondary basis. The exemption requires the TVWS devices to operate on a non-protected and non-interference basis. The operation of Type Approved WSDs on a lightly licensed basis is unlikely to lead to harmful interference to DTT provided that the devices are controlled by geolocation database approved by the Authority and comply with the technical and operational requirements. Master WSDs shall only use operational parameters that have been generated by an authorized database.

Device Technical and Operational Requirements

Devices will need to comply with minimum technical and operational requirements to mitigate the risk of harmful interference under a license exemption regime. Compliance with the requirements in the ETSI Standard is the primary way of ensuring compliance with the regulatory requirements for license-exempt authorization of WSDs.

Transmitter Unwanted Emissions

These are unwanted emissions from a WSD outside the nominal channels (out-of-block) within the 470 MHz to 694 MHz band when the WSD is in the transmit mode. The out-of-block EIRP spectral density, P_{OOB}, of a WSD shall satisfy the following limit shown in equation 1:

$$P_{OOB}(dBm/(100\ kHz))) \leq max\left\{P_{IB}\left(\frac{dBm}{8\ MHz}\right) - ACLR\ (dB, 84\ (\frac{dBm}{100\ KHz})\right\}..1$$

where P_{IB} is the measured in-block EIRP spectral density over 8 MHz, and ACLR is the adjacent channel leakage ratio for different Device Emission Classes outlined in Table 2 and measured in dB [3]. Each out-of-block EIRP spectral density is examined in relation to P_{IB} in the nearest (in frequency) DTT channel used by the WSD. Where there are two nearest (in frequency) DTT channels used, the one with the lower P_{IB} shall be considered.

Table 2**:** Adjacent Channel Leakage Ratios

Δf	n= ±1	n= ±2	n= ±3	n= ±4
Class 1	55	60	65	68
Class 2	55	55	55	64
Class 3	45	55	65	68
Class 4	35	45	55	64
Class 5	24	34	45	55

Where P_{OOB} falls within the n^{th} adjacent DTT channel (based on 8 MHz channels)

Device Communication with a Geolocation Database

These devices communicate to a database the information necessary in order for a database to be able to calculate the frequencies and powers at which a WSD may transmit so as to avoid harmful interference to other spectrum users and to ensure that the database obtains from devices the information necessary for interference management purposes. These requirements can be summarized as follows:

a. A master WSD shall only transmit in accordance with parameters that it has received from a geolocation database that has been qualified by the Authority.

b. A client WSD shall only transmit in accordance with parameters that it has received from a master WSD and shall not operate independently.

c. A master WSD or a client WSD that requires specific operational parameters from a geolocation database must report certain specific characteristics ('device parameters') to the geolocation database.

d. A client WSD that intends to use the generic operational parameters broadcasted by a master must report its unique identifier.

e. A WSD must report back to the database the actual channels and powers it intends to use (referred to as the 'channel usage parameters') and the WSD must only transmit in accordance with the channels and powers it reports to the database.

VI. COMPARISON BETWEEN THE KENYAN SCENARIO WITH INTERNATIONAL STANDARDS AND OTHER NATIONAL REGIMES

The framework for the use of TV whitespaces that Kenya has adopted is similar to the one adopted by the European countries [6]. In this report the Geo-location technique was adopted as the appropriate method to provide the required protection for the incumbent users. Geo-location is an approach, where White Space Devices (WSD) determine their location and make use of a geo-location database in order to get information on which frequencies they can use at their location. In [7], technical characteristics and methods of measurements for TV white space devices (TVWSDs) controlled by a TV white space database (TVWSDB) and which operate in the TV broadcast band 470 MHz to 790 MHz are specified in respect to [6] above. In [5], Use Cases for the Operation of Reconfigurable Radio Systems within White Spaces in the UHF 470 MHz to 790 MHz frequency band are described and an overview on methods for protecting the primary/incumbent users like TV broadcasts and wireless microphones are described. The [8][9] and [10] defined the high level system requirements for operation of Reconfigurable Radio Systems within UHF TV band White Spaces based on the Use Cases described in [7]. The authors in [11] outlines the Model White Spaces rules designed to be a template on which to base rules for license-exempt use of TV White Spaces. The IEEE in [12] gives a standard that defines one medium access control and several physical layer specifications for wireless connectivity for fixed, portable, and moving stations within a local area which is applicable to the WSD. In [13] Office of Communications of the United Kingdom sets out the decision to allow a new wireless technology access to the unused parts of the radio spectrum in the 470 to 790 MHz frequency band. In [14] the Independent Communications Authority of South Africa prescribes the Regulations on the use of Television White Spaces. In [15], Canada sets out the technical requirements for the designation of a database capable of identifying available channels for use by white space devices. In [16], the Federal Communications Authority of United States amended the rules to accommodate the white space devices in the white space frequency bands (i.e. 54-72 MHz, 76-88 MHz, 174-216 MHz, 470-608 MHz and 657-663 MHz).

VII. CONCLUSION AND RECOMMENDATION

In this paper five things have come out. Firstly, the technology of the TVWS has continued to be adopted world over and hence Kenya is not exception in adopting this technology. Secondly, the technology that Kenya has adopted is quite similar to what many other countries world over have adopted and hence it is safe since it has been tested. It is also in-line with the international standards. Thirdly, the results of the TVWS trials conducted in Kenya, have been successful in offering internet access without causing harmful interference to the primary licensed users in the same radio frequency band. Fourthly, the spectrum occupancy measurement conducted in Kenya, showed that TVWS spectrum is abundant both in rural and urban areas thus reinforcing the viability of this technology. Lastly, since CA has proposed to offer it on lightly-licensed regime, then it would enable a cheaper internet that is affordable to most people that would in turn spur development.

The recommendation of this study is that Kenya should adopt the TVWS technology and roll it out to enhance the internet access penetration, more so in rural areas which largely remain underserved by the other conventional technologies.

REFERENCES

[1] Communications Authority of Kenya, (2021).[Online].Available https://ca.go.ke/about-us/who-we-are/what-we-do/

[2] S. Wirsing and P. Reichl, "Dynamic spectrum access and the current spectrum management paradigm: On the challenges of dynamic licensing," *2015 13th International Conference on Telecommunications (ConTEL)*, 2015, pp. 1-8.

[3] *Authorisation of the Use of TV White Spaces as part of a Dynamic Spectrum Access Framework*, Communications Authority of Kenya, February2020.Available: https://www.google.com/search?client=firefox-b-d&q=authorisation+of+television+white+spaces+in+kenya

[4] E.Mureu, P. Kihato and P. Langat. *"Spectrum occupancy measurements based on itu-r SM.2256-1 recommendations in the context of cognitive radio",* The 13th JKUAT scientific and technology conference - November 2018.

[5] Reconfigurable Radio Systems (RRS); Use Cases for Operation in White Space Frequency Bands, ETSI TR 102 907 V1.2.1 -2012

[6] *Technical and operational requirements for the operation of white space devices under geo-location approach*. ECC report 186 – January 2013.

[7] *White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz frequency band,* ETSI standard ETSI EN 301 598 V2.1.1 - 2018.

[8] *Reconfigurable Radio Systems (RRS); System requirements for Operation in UHF TV Band White Spaces,* ETSI standard ETSI TS 102 946 V1.1.1-2014.

[9] *Reconfigurable Radio Systems (RRS); System Architecture and High Level Procedures for Coordinated and Uncoordinated Use of TV White Spaces,* ETSI standard ETSI TS 103 145 V1.1.1-2015

[10] *Reconfigurable Radio Systems (RRS); System architecture for information exchange between different Geo-Location Databases (GLDBs) enabling the operation of White Space Devices (WSDs)*, ETSI standard ETSI TS 103 143 V1.1.1-2015.

[11] *Model Rules and Regulations for the Use of Television White Spaces*, Dynamic Spectrum Alliance (DSA) v2.0- December 2017.
v2.0, December 2017.

[12] *Standard for Information Technology -- Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks -- Specific Requirements - Part 11: Wireless Local Area Network (LAN) Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, IEEE standard P802.11 – 2021.

[13] *Implementing TV White Spaces, Office* of Communications, United Kingdom, -February, 2015.

[14] Regulations on the use of Television White Spaces, Independent Communications Authority of South Africa – 2018.

[15] *White Space Database Specifications* , DBS-01 Issue 2 -January 2020

[16] *Amendment of Part 15 of the Commission's Rules for Unlicensed White Space Devices,* Federal Communications Authority FCC-19-24- March 2019.