Summary of the Regulatory Framework for TV White Spaces in Kenya

April 2021

Executive Summary

The communications Authority of Kenya (CA) is the regulatory body of the ICT industry in Kenya with responsibilities in telecommunications, e-commerce, broadcasting, postal and courier services as well as Cybersecurity. CA (also referred to as “the Authority”) is responsible for managing the country’s numbering and frequency spectrum resources under its telecommunications mandate. CA also safeguards the interests of consumers of the ICT services in the country.

CA’s experience informed by recent research activities, technical trials and various consultations in collaboration with different stakeholders, both local and international, has identified a need of a new spectrum management paradigm. This is to establish a more efficient way of utilising radio frequency (RF) spectrum based on international best practices and new evaluations of a potential opportunity of sharing the RF spectrum to enhance Internet access for rural Kenya. CA, hence, has established the first dynamic spectrum access (DSA)-based regulatory framework for the country. The framework is to allow opportunistic utilisation of TV white spaces to address the growing demand for new wireless services while balancing the existing services by the incumbents.

DSA refers to a spectrum-sharing concept that allows secondary users to access licensed spectrum bands on condition that they do not interfere with the existing incumbent services. DSA may alleviate spectrum scarcity and increase spectrum utilisation to the unserved and underserved areas. The Kenyan framework is based on the UHF TV band (470-694 MHz). It authorises access to this band for utilisation of TV White Spaces on a non-protected and non-interference basis. TV White Spaces (TVWS) refers to the RF spectrum in the TV broadcasting band that is either allocated for licensed use but not assigned to a particular licensee due to limited demand, or not being used by licensees at all times and in all geographical locations.

Based on the nature of utilisation of the TVWS where the secondary users (Internet service providers) are expected to share the UHF TV spectrum with the primary users (the digital terrestrial television (DTT) service providers), a technique to manage the interference to the primary users (who are the licensed users or incumbents) is needed. Therefore, the framework authorises the use of the geolocation databases (GDBs) technique to manage the secondary utilisation of the 470-694 MHz band and protect the incumbents from interference. The GDBs will be able to do this by obtaining periodic updates from the CA’s existing spectrum management database. They will also be expected to perform coexistence calculations and provide the transmission parameters for the white space devices (TVWS radios) for non-interference operation. As per the requirements of the framework, the white space devices (WSDs) must meet the minimum technical specifications and be Type-Approved prior to installation and use. These WSDs will be authorised to operate based on the parameters determined by the GDBs, predominantly guided by the time, frequency and location. Therefore, the framework provides a lightly licensed model of utilisation of TV white spaces.

Some of the major reference documents guiding the framework include: ETSI EN 301 598 standard for WSDs; ETSI EN 303 145 standard for System Architecture for TVWS usage; ETSI EN 303 143 standard for System Architecture and Information Exchange between different geolocation databases; the Model rules and regulations for the use of TVWS from the Dynamic Spectrum Alliance; IEEE 802.11af standard for Telecommunications and Information Exchange between systems; and the IETF Protocol to Access White Space (PAWS) Database.

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List of Acronyms

ACLR	Adjacent Channel Leakage Ratio
BSD	Broadcast Signal Distributor
CA	Communications CA of Kenya
CAK	Competition CA of Kenya
CR	Cognitive Radio
DFID	Department For International Development
DSA	Dynamic Spectrum Access
DSAL	Dynamic Spectrum Alliance
DTT	Digital Terrestrial Television
DVB-T	Digital Video Broadcasting - Terrestrial
EIRP	Effective/Equivalent Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FPGA	Field Programmable Gate Array
GDB	Geolocation Database
GPS	Global Positioning System
GSM	Global System for Mobile Telecommunications
GSMA	GSM Alliance
HAAT	Antenna Height Above the Average Terrain
ICTA	Information, Communications and Technology CA
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ITU	International Telecommunications Union
MNO	Mobile Network Operator
MTC	Machine-Type Communications
NFP	Network Facilities Providers
NLOS	Non-Line-of-Sight
NRA	National Regulatory CA
PAWS	Protocol to Access White Space Database
PSD	Power Spectral Density
RF	Radio Frequency
SNR	Signal to Noise Ratio
SINR	Signal-to-interference to Noise Ratio
TVWS	Television White Spaces
UHF	Ultra-High Frequency
VHF	Very High Frequency
WLANs	Wireless Local Area Networks
WSDIS	White Space Devices Information System
WSD	White Space Device
WRC	ITU World Radiocommunication Conference

Definition of Terms

Adjacent Channel Leakage Ratio	The ratio of the in-band TVWS device transmit power measured in an eight-megahertz (8 MHz/6 MHz) TV channel, to the out-of-band emission measured in the first 100 kHz in an adjacent channel.
Contact Verification Signal	An encoded signal broadcast by a master device for reception by a portable client device to which it has provided operational parameters, for the purpose of validating the operational parameters and verifying that the slave device is still within its range.
Coupling loss	A measure of the extent to which electromagnetic energy radiated by a WSD antenna gets picked up by a DTT antenna. Coupling gain/loss is typically measured in decibels.
dBm	Unit of power, measured in decibels relative to 1 milliwatt.
Device Emission Class	The classification declared by the manufacturer identifies the level of ACLR for the device.
Equivalent Isotropic Radiated Power	This is the product of the power supplied to an antenna and the absolute or isotropic antenna gain in a given direction relative to an isotropic antenna.
Fixed TVWS Device	A TVWS device that transmits and/or receives radio communication signals at a specified location.
Geolocation Database	A database that contains current information about available spectrum at a given location and time, as well as other types of information related to spectrum availability and usage.
Operating Channel	An available frequency used by a TVWS device for transmission and/or reception.
Out-of-block emissions	Unwanted emissions outside of the TVWS device's operating channel(s) that fall within the other channels in the UHF and VHF broadcast television bands.
TV White Spaces	White Space in the UHF TV broadcast band 470-694 MHz
White Space	A portion of radio frequency spectrum, which is available for a radio communications application (service, system) at a given time in a given geographical area on a non-interfering / non-protected basis with regard to other services with a higher priority on the Table of Frequency Allocations
White Space Device	A radio communications device that uses white space spectrum. For the purposes of this document, a white space device obtains operational parameters from a geolocation database qualified by the Communications CA of Kenya.

1. Mandate of the Communications Authority of Kenya (CA)

Established in 1999 by the Kenya Information and Communications Act, 1998, the Communications CA of Kenya (CA) facilitates the development of the information and communications sectors including broadcasting, cybersecurity, multimedia, telecommunications, electronic commerce, postal & courier services and managing the numbering & frequency spectrum resources[1].

The key responsibilities of CA include:

a) Licensing all systems and services in the communications industry.
b) Managing the country's frequency spectrum and numbering resources. Under article 3 of the Kenya Information and Communications (Radio Communications and Frequency Spectrum) Regulations, 2010, the CA is required to:
   - Promote and support the orderly development and efficient operation of radio communication systems & services to meet the country's socio-economic, security & cultural needs;
   - Ensure proper planning and management of the spectrum resource in accordance with the Act, Government policy objectives and international agreements;
   - Promote the efficient use of frequency spectrum resource through the adoption of technological advances and efficient spectrum allocation and management technology based on operational requirements and technical viability;
   - Ensure the equitable and fair allocation and assignment of spectrum to benefit the maximum number of users.
c) Type approving and accepting communications equipment for use in Kenya: All communications equipment to be used to access public communication networks and radio communications equipment intended to be connected directly or to interwork with a communications network in Kenya to send, process or receive information shall, prior to their use, be submitted for type approval or type acceptance by the CA.
d) Protecting consumer rights within the communications environment.
e) Managing competition to ensure a level playing ground for all operators.
f) Regulating retail and wholesale tariffs for communications services.
g) Monitoring the activities of licensees to enforce compliance with license conditions.

[1] The Role of the Communications Authority of Kenya - - https://ca.go.ke/about-us/who-we-are/what-we-do/

2. Overview of TV White Spaces and the Pillars of the Framework

2.1. Definition of TV White Spaces (TVWS)

TV white spaces are "portions of spectrum left unused by TV broadcasting services"[2]. In Kenya, this is in the UHF band between 470 MHz – 694 MHz. This band is currently allocated primarily to the broadcasting service for Digital Terrestrial Television (DTT) transmissions in ITU region 1, which includes Africa. CA has noted that not all of the 28 channels of 8 MHz bandwidth (CH21 to CH48) allocated to DTT broadcasting 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 (MFNs). These create an opportunity to leverage the available but unused (inactive) channels by the TV white spaces in a dynamic manner[3].

The opportunity of spectrum sharing is demonstrated by the possibility of the DTT radios to coexist with low power white space radios on the sparsely used channels based on time, frequency and location. Noting this opportunity and the advantage of the UHF band to have impressive propagation characteristics such as a longer distance of coverage, the CA's vision is to build an inclusive society that also guarantees connectivity to the rural areas. The use of TVWS to improve the provision of fixed wireless broadband will benefit communities in rural areas. The UHF frequencies offer enhanced propagation compared with the much higher frequencies used for contemporary broadband service and Wi-Fi networks. The first TVWS pilot in Kenya was conducted in 2013 where the CA issued a trial authorisation to Microsoft East Africa Limited to conduct the trial in the vicinity of Nanyuki, Laikipia County. The pilot demonstrated the technical viability of TV white spaces through dynamic spectrum access (DSA) within the 470-694 MHz band. The trial consisted of a point-to-multipoint setup, which covered 14 kilometres with the TVWS base stations operating at 2.5 watts EIRP. Multiple 90-degrees base stations were used to sufficiently serve 235 sq. kilometres of the area, delivering a throughput of 16 Mbps on a single 8 MHz channel. The TVWS technology-supported various media streaming protocols such as video streaming allowed access to emails (largely enjoyed by the Red Cross) as well as video conferences(Mawingu Networks, 2014). Although there was no utilisation of the geolocation databases as has been eventually developed in the framework for Kenya (released in 2020), there were no interference issues experienced arising from the pilot to degrade the existing network infrastructure. Nevertheless, potential interference to the DTT operators cannot be overlooked for the sustainability of TV white spaces.[4]

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[2] "White Spaces" refers to radio spectrum that is either allocated for licensed use but not assigned to a particular licensee at all times and in all geographical locations. White spaces in the TV band is what is referred to as TV White Spaces - https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8377175.(Nyasulu, Crawford and Mikeka, 2018).

[3] Assigned but unused TV channels demonstrate an existing spectrum inefficiency, which the CA proposes a way to share it in order to increase capacity without disrupting the services incumbent users.

[4] Interference to the incumbent users is the biggest concern for the deployment of TVWS, hence the need for a holistic approach that ensures spectrum innovation is not limited but the existing services are not degraded at the same time despite the many trials worldwide showing no interference even when a geolocation database is not used. https://docplayer.net/5987593-Rural-broadband-trials-laikipia-county-kenya-for-the-communications-CA-of-kenya.html - (Mawingu Networks, 2014)

2.2. Pillars of the Framework

2.2.1. White Space Devices

A white space device (WSD) is a radiocommunication device that can make use of the white space spectrum for Internet access, particularly operating on frequencies that are not being utilised by the broadcasting services. The opportunistic and dynamic use concept, central to the utilisation of the TV white spaces, ensures that the TV white space regulations accommodate changing circumstances. Dynamic use (as proposed by the CA in the framework) is the idea that the TVWS radio technologies should identify and use different frequencies within the defined band, based on what frequency is available for interference-free operation at a given time in a given geographic location. Although, the particular unused TV channels vary from location to location, WSDs have the flexibility and agility to locate and operate on the unused channels, no matter where the devices are located in the country.[5]

2.2.2. Geolocation Databases (GDBs)

The IETF's PAWS protocol used for TVWS defines a geolocation database or a white space database (WSDB) as a geospatial database that can track available spectrum (in accordance with the rules of the regulatory authorities) and make this information available to white space devices (WSDs)[6]. This approach is meant to shift the complexity of spectrum-policy conformance out of the device into the database. The approach simplifies adoption of policy changes, limiting updates to a handful of databases, rather than numerous devices. It opens the door for innovations in spectrum management that can incorporate a variety of parameters, including user location and time. Within this framework, therefore, a GDB/WSDB records and updates information necessary to protect primary users – for example, this information may include parameters such as fixed transmitter's call sign, its geolocation, antenna height, power and periods of operation. The rules that the database is required to follow, including its schedule for obtaining and updating protection information, protection rules and information reported to devices vary according to regulatory domains. In our case, these rules have been spelt by the Communications CA of Kenya (CA).

CA outlines that the operation of the WSDs must be controlled by the GDBs. The GDBs will be qualified by the CA upon meeting particular requirements. These requirements are described later in this summary. A WSD will initially contact the GDB based on the IETF's PAWS protocol. The GDB will in turn respond to the WSD with a set of parameters including the frequencies and maximum powers at which the WSD can transmit. It should be noted that the world over, TVWS deployments has taken the approach of utilising the GDBs to protect the primary users from harmful interference.

2.2.3. Listing Server

According to the IETF's protocol to access white space (PAWS) database, database discovery is a required component for the master WSD. This component outlines the configuration necessary to

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[5] White Space Devices (WSDs) are expected to have geolocation capability with which they report their location to the database(s) in order to access the available TV channels. The geolocation determination is through horizontal geographic coordinates (in WGS84) or the vertical geolocation (WGS84 datum). https://espectro.org.br/sites/default/files/downloads-legislacao/Model-Rules-and-Regulations-for-the-use-of-TVWS.pdf.(Alliance, 2017)

[6] To achieve interoperability among multiple WSDs and GDBs, IETF has developed a standardised protocol which defines the rules by which the WSDs communicate to the GDBs and vice versa. The GDBs record and update information necessary to protect the DTT users while reporting the availability of usable spectrum to the WSDs – https://tools.ietf.org/html/rfc7545 (Internet Engineering Task Force, 2013)

allow the WSD to initiate communication with the GDB(s)[7]. The regulatory approach defined for Kenya makes it open for more than one GDB to operate in the country. In such a case, the CA has provided an inclusion of a listing server which is meant to store all the qualified database(s). The master WSDs will hence be preconfigured with the URI to the listing server which they will connect to during database discovery to select the GDB to be used. This is also meant to enable the WSDs to validate or update its list of certified GDBs. If the device is unable to validate its list of certified GDBs within the required period, regulatory rules may require the device to treat this inability as equivalent to the device having no available spectrum.

3. Licensing Models for the Use of TVWS

Three possible licensing regimes were considered in the Kenyan regulatory framework; license-exempt, light licensing or full licensing

In a license-exempt regime, no regulatory record is kept of which devices are using RF channels. The disadvantage of this regime is that it poses a risk of interference to broadcasting services if it is to be applied to a TVWS network because it is not possible to identify and locate a device if it causes interference and no protection is provided between TVWS devices.

Full licensing, according to the regulatory framework, means a WSD is charged a fee as a function of the area covered and the duration of usage, the parameters are calculated by a GDB, populated with technical data. In such a model, protection is provided between WSDs. Thus, if one device causes interference to another licensed device, the interfering device may be instructed to change channels or to cease transmission.

In a lightly-licensed model, every master WSD is registered and fully controlled by a GDB. In the event of interference to the primary licensee being detected, the offending devices can be instructed to cease transmission on a particular channel. The network operator requires annual authorisation to operate and pays for the GDB service and a nominal fee for the use of the RF spectrum.

CA has adopted a lightly licensing model of service for TVWS applications. Under such a model, a master WSD shall consult any GDB qualified by CA and submit parameters describing its location, operational and device parameters. The database would then provide details of the frequency channels and power levels the WSD is allowed to use.[8]

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[7] A Listing server provides the Uniform Resource Identifiers (URIs) for one or more Spectrum Databases (GDBs). For the Kenyan rules, the CA intends to operate a Database Listing Server to publish the list of authorised GDBs for Kenya.

[8] Various terminologies are commonly used to qualify the type of “regulatory regime” or “licensing regime” that is applied: unlicensed, licence-exempt, license free, general licence, general authorisation, light licensing, licensed, individual licence as well as individual authorisation among other terms. Light licensing can be described as a mechanism whereby the users of a band are awarded non-exclusive licences which are typically available to all, and are either free or only have a nominal fee attached to them. There may be further obligations associated with the provision of a licence such as the need to register the location of any transmitters and possibly to coordinate their deployment with other registered users. Obtained from https://docdb.cept.org/download/87ccb237-fa9a/ECCREP132.PDF

4. Operational Framework for TV White Spaces in Kenya

4.1. Key provisions of the Framework

The following are key provisions of the regulatory framework:[9]

a. **Eligible Operators**: CA shall permit interested service providers who hold either a Network Facilities Provider License (Tiers 1, 2 and 3), a Broadcasting Signal Distributor License or a Self-Provisioning Broadcasting License to use TVWS spectrum.
b. **Device authorisation**: 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. **DSA method**: Geolocation database is the chosen DSA method.
e. **Database Service Providers:** CA shall qualify 3rd party databases that would be capable of taking the data provided by the CA and providing responses to WSDs that accurately identify available channels and acceptable power levels.

Figure 1 illustrates the operation framework for TV White Spaces in Kenya.

[9] The framework outlines key provisions for the operation of TV white spaces which looks at the potential TVWS operators, the incumbents, the method of managing interference (through the GDBs) and the coexistence requirements. The key provisions are studied from the dynamic spectrum alliance model rules, Ofcom TVWS rules as well as the GE06 Agreement.

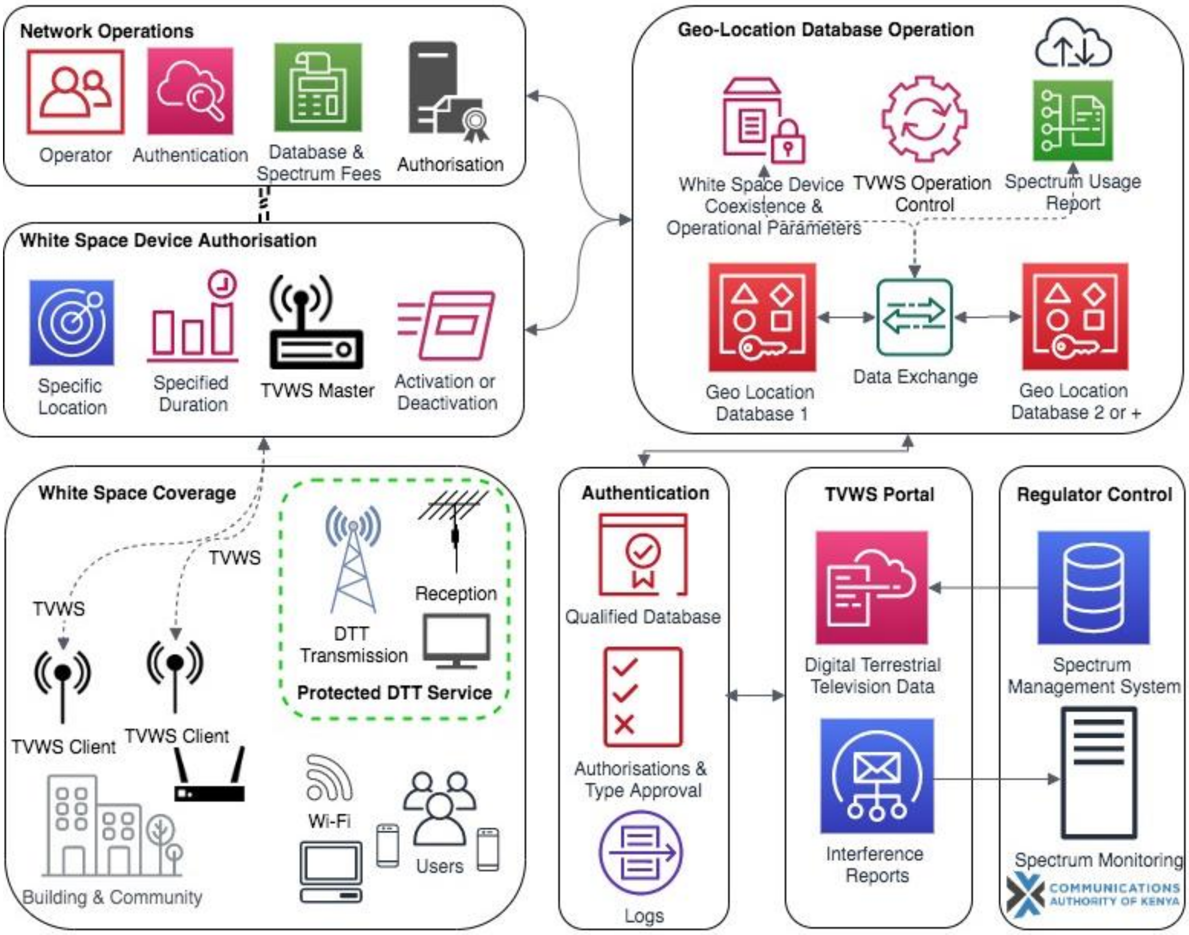

Figure 1: Operation Framework for TVWS in Kenya

4.2. Authorisation and Type-approval of the WSDs

The CA authorises lightly-licensed operation of WSDs in the UHF band on a secondary basis which permits the TVWS devices to operate on a non-protected and non-interference basis. All WSDs have to be type-approved by the CA. This means all devices manufactured by different vendors will be allowed to operate in a TVWS network only after verification by the CA.

4.3. Framework Parameters

The following are definitions of some parameters used in a TV white space network operation.

4.3.1. 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.

4.3.2. Operational Parameters

The geolocation database will use device parameters together with DTT information provided by the CA, 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 will only be valid for a short period of time so the device will have to query the database on a regular basis in order to ensure that it can transmit in accordance with valid operational parameters.

4.3.3. 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 and powers) that a WSD intends to use which may be a subset of the resources indicated by the database in the operational parameters.

4.4. Exchange of Data between WSDs and GDBs

The exchange of parameters between WSDs and the databases could be as follows: 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 to be used by 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.

Secondly, 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 transmissions or could provide the master with location information for determination of operational parameters. The master will 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 channel usage parameters of the client WSD to the geolocation database (GDB) from which it has obtained operational parameters.

4.5. Requirements for the Operation of the White Space Devices

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 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.

The technical requirements stipulate that the WSDs need to comply with the requirements outlined in the ETSI standard for license-exempt operation.

The following set of requirements outline the considerations of operation by the white space devices together with the geolocation databases.[10]

- WSDs must comply with the emission limits specified in ETSI EN 301 598 standard[11].
- WSDs shall rely on the geolocation database (GDB) method to determine available frequencies and only transmit using the maximum transmit powers provided by the GDBs[12].
- A master WSD will only initiate transmissions in the UHF TV band upon receiving operational parameters from a GDB.

[10] The WSDs will be required to comply with minimum technical and operational requirements that are necessary to mitigate the risk of harmful interference under the lightly licensing regime. The CA's primary references for the operation of WSDs include ETSI standards (ETSI - EN 301 598, EN 303 143 (TS 103, 143), TS 102 946, TS 103 145) and the IEEE 802.11af Standard for Information Technology – Telecommunications and Information Exchange Between Systems.

[11] The ETSI EN 301 598 Standard looks at the operation of the WSDs in the TV broadcast band 470 MHz to 790 MHz controlled by a TV white space database and applies to the master and slave WSDs with integral, dedicated or external antennas. https://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.01.01_60/en_301598v010101p.pdf

[12] The scope of the ETSI EN 303 143 defines the system architecture for the information exchange between different Geo-location Databases (GDBs) enabling the operation of WSDs for the protection of the incumbent service. https://www.etsi.org/deliver/etsi_en/303100_303199/303143/01.01.02_20/en_303143v010102a.pdf

- A client WSD will only initiate transmissions upon receiving generic or specific operational parameters from the master WSD.
- A master WSD and the client WSD should conform to the channel usage parameters any time of transmission.
- Two clients are permitted to communicate as long as they adhere to the operational parameters provided by the master WSD.
- The CA will specify the maximum power limits for a particular location and channels to the GDBs. The maximum transmit powers provided by the GDB shall specify the maximum equivalent isotropically radiated power (EIRP) in 8 MHz bands which shall not exceed 40dBm/8 MHz in any 8 MHz channel.
- The maximum EIRP in each 100 KHz band within an 8 MHz band shall be 19 dB below the maximum EIRP in that 8 MHz band
- The CA may instruct a GDB to cease providing services for a specified period of time to any or all WSDs.
- The CA may also remove any GDB from a qualified list for failure of compliance with the rules for the use of TVWS.
- Each WSD will be required to have a unique ID that the GDB uses to identify it. This ID is declared by a manufacturer and consist of a unique serial number of a WSD, the WSD's model number and identifier of the device manufacturer.
- Two device types are defined in the framework – Type A, which is a WSD intended for fixed use only (can have an integral, dedicated or external antenna) and Type B WSD which is not intended for fixed use (and can have integral or dedicated antenna).
- The geolocation capability of the master WSDs based on the antenna location is provided by the latitude and longitude coordinates as well as the altitude (in WGS84 format).
- The level of uncertainty in the accuracy of the WSDs antenna latitude and longitude coordinates as well as the altitude is specified as ±Äx, ±Äy and ±Äz metres respectively
- The unwanted emissions from a WSD outside the nominal channels (out-of-block) within the 470-694 MHz band when the WSD is in transmit mode are referred to as Transmitter unwanted emissions. The out-of-block EIRP spectral density, P_{OOB} spectral density shall satisfy the following limit:

P_{OOB} (dBm / (100 kHz)) ≤ max {P_{IB} (dBm / (8 MHz)) - ACLR (dB) - 84 (dBm / (100 kHz))} where P_{IB} is the measured in-block EIRP spectral density over 8 MHz, and ACLR is the adjacent channel leakage ratio for different emission classes. Table 1 shows the ACLR of the different emission classes adopted by the CA. 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} is to be considered. In this case, the P_{OOB} falls within the n^{th} adjacent DTT channel (based on 8 MHz channels)[13]

Table 1: ACLR for Different Device Emission Classes

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

5. Interference Management

Interference can occur when radio waves are transmitted simultaneously from multiple sources over the same frequency. Frequency/Spectrum management is required to control the transmission of radio waves to avoid interference among wireless users. Traditional spectrum management techniques are based on the command-and-control model. In such a model radio frequency bands are licensed to the authorised users by the government (handled by the Communications CA of Kenya for our case). The common method for allocation is referred to as a "spectrum auction." In a spectrum auction, the government opens a radio frequency band for bidding and specifies a certain type of wireless technology/application for that particular radio frequency band (e.g. cellular or TV service). The government then grants the access to that frequency to the highest bidder alongside stipulating the rules of operation (i.e. etiquette for spectrum usage). Although the command-and-control-based spectrum management framework can guarantee that the RF spectrum will be exclusively licensed to an authorised user, it also gives rise to a spectrum management inefficiency due to the fact that an authorised user may not fully utilise the spectrum at all times in all locations. Moreover, the regulatory requirements put limitations on the wireless technology that can use the licensed spectrum and this may prevent an authorised user from changing their wireless transmission techniques and services according to market demand.

To meet the rising demand of emerging wireless applications and services, the CA model has had to consider the need for the following: (1) flexibility of spectrum usage; (2) the integration of the dimensions and related issues into policy; and (3) support and encouragement of efficient utilisation of spectrum. The entire objectives of the framework is to improve both the technical and economic efficiency of spectrum management. From a technical angle, the new spectrum management model needs to ensure the lowest interference and the highest utilisation of the RF bands. The economic aspects relate to the revenue and satisfaction of the spectrum licensee.

To manage the challenge of interference to the incumbent users of the TV band, the CA has selected to use Geolocation Databases (GDBs). The CA has also proposed that the network operators on TV white spaces be allowed to select their preferred database service provider. The cost of operation will

[13] Devices with better out-of-block emissions are less likely to interfere with existing users and hence can get better TVWS availability. The ETSI Harmonised Standard sets out five classes specified by their ACLR masks. Devices may report their emission class to the database and where they do so this will be taken into account in calculating the operational parameters.

be met by the network facilities providers (NFPs) based on their agreement(s) with the database service provider (s).[14]

The GDB providers in turn, will be required to make available to the CA, information on the WSD operations for purposes of resolving any interference issues. This information includes the frequencies and radiated power of WSDs in a particular location and time. The CA will also be able to instruct the GDB providers to shut down any interfering WSDs. For some GDBs, a portal for the regulator will provide real-time access for monitoring and possible deactivation of rogue WSDs.

6. Qualification of the Geolocation Databases

The CA has also released a separate guideline for the procedure of qualification for the geolocation databases adding on to the framework for TVWS. Qualified geolocation database providers who operate GDBs, in partnership with duly licensed network operators will ensure effective sharing of the radio spectrum with licensed users to match the vision of the CA on dynamic spectrum access (DSA).

The CA is open to have any potential geolocation database(s) provider apply for qualification. The applicants must demonstrate that their database meets requirements defined in the guideline for the procedure of qualification. To be eligible for qualification, the GDB provider must provide a "Regulator Portal" and grant access to the CA's representatives. The key phases to the database approval process include – the application, evaluation and testing of the database then finally qualification.

To be considered for qualification status, the applicant(s) must submit the following – name, physical and postal address as well as appropriate contact names, certificate of incorporation and tax registration certificate from the domicile country and a business plan for the provision of GDB service(s) in Kenya. Anticipated milestone dates for database development (if any) and the expected date of full deployment should form part of the business plan. Furthermore, information about the database such as a test plan and adherence to the IETF's PAWS protocol alongside interoperability needs should also be provided.

Upon acceptance of application and successful evaluation, the GDB provider will sign an agreement with the CA before qualification. Once qualified, the GDB provider together with the GDB will be listed in the Listing server (described in Section 3) and the CA will issue a letter of qualification to the successful GDB provider.

[14] In DSA for TVWS, the rules of entry to ensure a very low probability of interference to the incumbent users of the TV band while at the same time keeping the minimum possible restrictions are based on three broad techniques. These are sensing, beacons and geolocation, which can be used discretely or in combination to effect the desired level of confidence. Majority of the NRAs (including the Communications CA of Kenya) around the world have adopted the geolocation databases. (Wyglinski, Nekovee and Hou, 2009).

To maintain the qualification status, the GDB will be audited from time to time to ensure it still meets the terms and conditions as well as related technical and operational requirements. The CA may revoke the qualification of a GDB and a GDB provider if the GDB/GDB provider do not comply with the terms and conditions outlined in the qualification agreement, related technical or operational requirements.

7. Spectrum Fees

The spectrum fees for TVWS have been left to be consistent with the CA's frequency spectrum fee schedule provided through this link and the Kenya Information and Communications Regulations 2010. The following are the major costs to be incurred in the operation of TV White Spaces:

1. Regulatory administrative cost, which covers the management of the listing server, qualification and regulation of the geolocation databases.
2. Each authorised master WSD is to be subjected to an annual fee of **KES. 10,000.00** (approximately $100). This is consistent with the section 21 of the Frequency Fee Schedule for the Wireless Access Systems (WAS) operating on shared non-protected basis.

The geolocation database(s) providers (GDB providers) will also charge the network operator(s) a fee for utilisation of their database. The CA will determine these fees for accessing the geolocation database(s) in the course of implementation of the framework.

8. Coexistence Considerations

The 470-694 MHz band is primarily allocated to the broadcasting service. Therefore, the usage of the white space devices (WSDs) for TV white spaces has to be implemented in a way that ensures they cause a low probability of harmful interference to the broadcasting services. Moreover, it is also important to ensure that other users adjacent and within the same band are also protected from any interference from the WSDs. This is what forms the basis of coexistence consideration. In general, the WSDs are expected to coexist with other users in the UHF band without hurting their services. Figure 2 illustrates the coexistence of services in the UHF band. It shows the DTT primary band (within which TVWS is included) coexisting with other services such as the future Mobile services in the 450-470 MHz band. [15]

To manage coexistence, the framework proposes to reduce the maximum allowed power at which a WSD can transmit in each frequency in order to minimise the probability of interference. The maximum powers are capped to address interference to – the broadcasting service, broadcasting services (in the neighbouring countries), Mobile services (450-470 MHz) and Mobile Services (in the 700 MHz band).

[15] The coexistence framework computes spectrum allocation parameters for the WSDs taking into account geolocation and category details of the WSDs as well as information on protected DTT services from the CA. Fundamentally, it is the responsibility of the geolocation database(s) to perform these calculations.

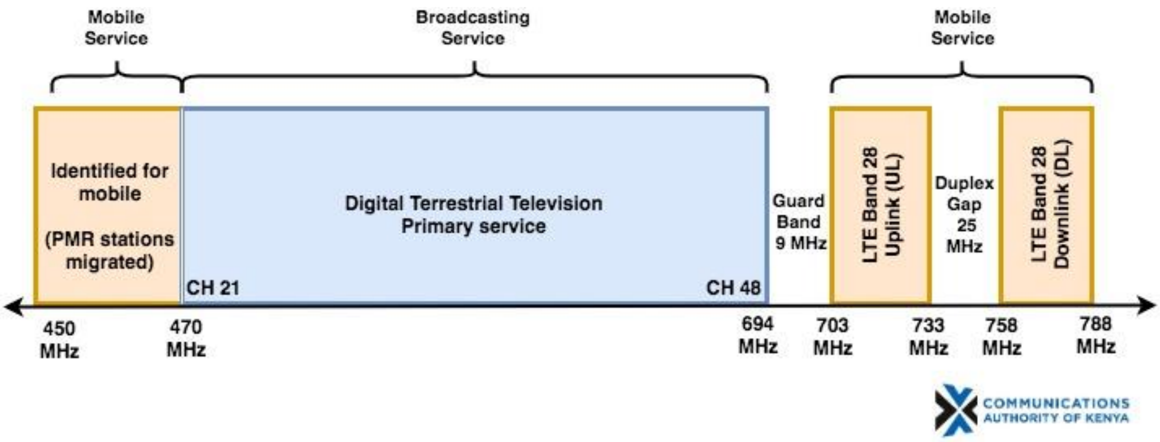

Figure 2: Illustration of UHF band Coexistence of Services

Fortunately, for the 700 MHz mobile services band, there is an existing 9 MHz guard band to ensure no interference from the WSDs.

For the desired coexistence requirements, the geolocation databases will apply coexistence rules determined by coexistence calculations defined by the ITU.R P-1812 model[16], which is the one adopted for Kenya. The ITU.R P-1812 model is a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands. It is used for predicting the propagation loss of UHF radio signals while computing the field strength of a TV signal at particular geographic location. While implementing the model, the GDBs calculations will ingest the following datasets:

1. DTT transmitter data – actual and simulated information on DTT transmitters and their locations. These data is often referred to as the incumbents data.
2. WSDs location information (provided by the Master WSDs that must be GPS-enabled). For client WSDs that do not have GPS, the master WSDs will report their location.
3. Cross-border related data informed by the agreed emission levels under the GE06[17] Agreement. The objective of the GE06 agreement is to protect DTT services in signatory countries by ensuring cross-border emissions do not exceed certain levels.

[16] The ITU.R P-1812 model is one of the two propagation models proposed by the model rules and regulations of the dynamic spectrum alliance (DSAL) which the CA has adopted for database coexistence calculations. The other one is the Longley-Rice. ITU.R P-1812 is a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands (30 MHz to 3 GHz). It predicts signal levels at the median of the multipath exceeded for a given percentage of time, p% in the range 1% ≤ p ≤ 50% and a given percentage of locations, p_L, in the range 1% ≤ p_L ≤ 99%. The method provides detailed analysis based on the terrain profile and is suitable for predictions for radiocommunications systems utilising terrestrial circuits having path lengths from 0.25 km up to about 3000 km distance with both terminals within approximately 3km height above ground. https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1812-5-201908-I!!PDF-E.pdf. (ITU-R, 2007)

[17] The Regional Radio Conference 2006 (GE06) was an ITU conference that replaced parts of the Stockholm Agreement of 1961 for the European Broadcasting Area and parts of the Geneva Agreement of 1989 for the African Broadcasting Area. GE06 focused entirely on minimising cross-border interference of digital television and potential future benefits of designating a significant portion of the unutilised spectrum for broadband access (mobile broadband at the time). GE06 established frequency plans for analogue and digital broadcasting in Band III (174-230 MHz) and Band (470-862 MHz). It also established the timeline of the transition period for the phasing out of the analogue television. https://www.gsma.com/spectrum/wp-content/uploads/DigitalDividend/DDtoolkit/geneva-06.html

Notably, the WSDs have no official internationally recognised frequency plan or treaty to govern registration, deployment, potential interference and coordination requirements. Hence, the CA has adopted the GE06 guideline to ensure the neighbouring countries' DTT services are not hampered by harmful interference from the WSDs. Furthermore, the CA has also assimilated the trigger field strength levels from the GE06 treaty to serve as a baseline for determining power levels for the WSDs at any location and channel in order to protect our neighbouring countries and also limit the same thresholds from being exceeded in those countries.

9. Conclusions

The implementation of TVWS comes with quite a number of new requirements such as the use of geolocation databases that calls for the various stakeholders to stay abreast with all the documents cited by the CA in the framework. This is due to the fact TVWS forms the first step towards opening up spectrum for sharing and dynamic utilisation. In the quest to achieve efficient spectrum usage and deliver on affordable Internet access, stakeholders must continuously contribute to the dynamic developments that the CA will be developing time to time to effectively evolve DSA in Kenya.

This document just provides a summary of the framework for TVWS and it has been developed with the objective of providing simplicity in understanding the Kenyan rules for TVWS and opening up the ecosystem for an informed spectrum innovation journey as developments on dynamic spectrum access begin for the country. All the major blocks of the regulations outlined in the have been included here that operators and new entrants can quickly check although it is highly recommended that they look at the comprehensive document of the framework.

Dynamic spectrum access (DSA) is presenting an alternative method to manage the underutilised spectrum and spur broadband access, particularly beneficial to the rural underserved areas. Spectrum sharing techniques are currently going through in-depth research and development and will predominantly feature in the new wireless Internet access networks that includes International Mobile Telecommunications (IMT) bands such as LTE and 5G, new Wi-Fi networks such as 6 GHz Wi-Fi /Wi-Fi 6E as well as a number of ISM bands. In regards to TVWS - the worldwide baseline for DSA implementations, the CA notes its immense potential to bridging the digital divide and considers more studies as well as continuous engagement with stakeholders to deliver long-term contributions that will evolve the framework to fit the country's strategic broadband initiatives. Besides, they will also aid in fitting our contextual spectral needs in a proper place.

10. References

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