Project Report

On

The Validation of the Draft Regulatory Framework on Spectrum Sharing for Fixed Broadband Services in the UHF Band (TV Band) as a Demonstration of Dynamic Spectrum Access (DSA) methods in Rural Kenya

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The UK Government Prosperity Fund for Digital Inclusion Project supporting Business Models and Enablers for the Digital Inclusion

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Addressing the Digital Divide through Innovative Internet Access Methods

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ACRONYMS

BSD	Broadcast Signal Distributor
CA	Communications Authority of Kenya
CAK	Competition Authority 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 Radiated Power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GDB	Geolocation Database
GPS	Global Positioning System
GSM	Global System for Mobile Telecommunications
GSMA	GSM Alliance
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ITU	International Telecommunications Union
MNO	Mobile Network Operator
NFP	Network Facilities Provider
NLOS	Non-Line-of-Sight
NRA	National Regulatory Authority
PAWS	Protocol to Access White Space Database
RF	Radio Frequency
SNR	Signal to Noise Ratio
TVWS	Television White Spaces
WSD	White Space Device
WRC	ITU World Radiocommunication Conference

Definition of Terms

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
TV White Spaces	White Space in the UHF TV broadcast band 470-694 MHz
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 Authority of Kenya
Geolocation Database	This is an Internet service which responds to TVWS device requests, with white spaces in the device's location
Master WSD	This is a device that is able to communicate with and obtain operational parameters directly from a GDB and also communicates with the client WSDs.
Client WSD	This is a device that is only able to operate in TVWS when under the control of a master WSD.

1. Project Overview

This project aimed at carrying out a validation exercise and stakeholder consultation on the draft framework for Television White Spaces (TVWS) developed by the Communications Authority of Kenya (CA) and Strathmore University (SU). The CA will ratify the draft framework in the coming days to adopt it as the official framework for authorisation of TVWS deployments in Kenya.

The draft framework forms the foundation of Dynamic Spectrum Access (DSA) implementations in Kenya setting the stage for future spectrum sharing initiatives for the country. The studies specifically investigated spectrum sharing for Fixed Broadband services in the UHF Television (TV) band (470-694 MHz) as an enabler of rural wireless Internet access.

Field studies were conducted in Laikipia, Kitui and Kisumu counties; technical demonstrations were done in Nanyuki (Laikipia county) using the new equipment and resources provided by partners from the Dynamic Spectrum Alliance. This work has built on top of previous collaborative research led by the University of Strathclyde (Scotland, UK) in partnership with Strathmore University (Kenya), Copperbelt University (Zambia), University of Ghana (Ghana) and University of Malawi (Malawi). Moreover, it has also been supported by the TVWS journey formulated by the CA back in 2013 when the first trial license for TVWS was issued.

The draft framework inviting public participation was published on the CA website on 3rd March 2020. Stakeholders were also invited to share comments, ideas and inputs on the draft framework. This led to a series of online engagements (due to Covid-19 containment measures) majorly involving discussions with Network Facilities Providers (NFPs), Mobile Network Operators (MNOs), groups such as the GSM Alliance, legal groups on frequency spectrum and data protection and other spectrum innovation-driven members from the Dynamic Spectrum Alliance (DSAL). Technical advisers also participated in the project especially on the simulation of the coexistence calculations.

The overall output of this project will be the official release of the framework in the coming days by the CA. This is meant to leapfrog the commercial deployments of TVWS services in Kenya and embody a template that lays the foundation for the future implementation of technology (hardware & software) and infrastructure testbeds to deliver last mile Internet access for rural communities with an equal inclusivity for the relevant stakeholders in Kenya.

In addition, the project has established a baseline status for partnership between the UK and Kenya on spectrum research and implementations.

2. Project Scope

This project has been implemented in two parts, as initially proposed. Although, the proposition provided a high description of exploring methods of spectrum sharing in enabling Internet access and digital inclusion of the rural communities in Kenya, the specific implementation focused on the rollout inclining to the opportunistic utilisation of UHF TV band for rural Internet access. The two parts outlined in the scope of this work included:

Part I: Assessments and validation of the regulatory framework on spectrum sharing

a) Peer review of the draft framework on Spectrum Sharing for Fixed Broadband services in the UHF band (TV band) as a demonstration of Dynamic Spectrum Access (DSA) informed by the due diligence report and best practices.
b) Analysis of existing spectrum availability gaps for rural Kenya and the previously conducted studies.
c) Assessment of spectrum sharing opportunity for rural Kenya.
d) Establishing the state of knowledge on spectrum sharing by stakeholders.

Part II: Site Surveys at sampled sites in rural Kenya

a) Site survey in three rural counties (Laikipia, Kitui and Kisumu) on viability of spectrum sharing within the TV band.
b) Assessment of opportunity and impact of TVWS utilisation.
c) Stakeholder conference on the validation of the TV White Spaces framework on Spectrum Sharing and dissemination of knowledge and findings.

The entire project has taken six months, with a subsequent request of extension for a period of two months to allow finalisation of the remaining components, assessments and provision of the full report. Therefore, the project will officially be closed on 9th October 2020 covering an extension of developing a capacity-building plan for the stakeholders on TVWS. In the wake of the Covid-19 pandemic, a set of deliverables have been affected such as the stakeholder conference, however a peer review on the draft framework engaging different groups of people through online platforms has been completed successfully. Additionally, a segment that covers development of a framework that can scale up local innovations in the country to help combat the Covid-19 pandemic has also been developed during the extension period alongside the capacity-development plan.

The site surveys took place between January to March 2020. The first site survey took place in Kisumu County, while the final site survey was conducted in Laikipia County after the completion of the Kitui County survey. In Laikipia, a trial network of TVWS was set up in order to extend the effectiveness of the technical studies as the draft framework was being reviewed.

3. Project Team

The team of Strathmore University (SU) together with the team from the Communications Authority of Kenya (CA) have led the implementation of this project. The project also involved a group of technical advisers from Kaiote. Kaiote is a technology company that offers various Internet of Things (IoT) services and technical advisory to organisations working on telecommunications developments. The Dynamic Spectrum Alliance (DSAL) led by its current president, Dr. Martha Suarez, has also been instrumental and deeply involved in the implementation of this project as advisers. They have shared knowledge and experience on TVWS framework as implemented in other countries building on the model rules developed by the alliance for Dynamic Spectrum Access. The project also had a PhD

researcher from the Technical University of Kenya (TUK) who immensely contributed to the project as well. Table 1 lists all the members on the project.

Table 1: List of project participants

1. Project Team Members, Task Groups & Stakeholders	
Organization	**Name**
Strathmore	Dr. Joseph Sevilla - Director, iLabAfrica Research Centre
	Dr. Vitalis Ozianyi – Director, Telecommunication Studies
	Dr. Julius Butime – Head of Engineering
	Mr. Leonard Mabele – Research Fellow, Telecommunications
	Mr. Oscar Onyango – Internet of Things (IoT) Researcher
	Mr. Humphrey Owuor – Networks and Communications Researcher
	Mr. Joseph Ridge – IoT Researcher
	Mr. Victor Rop – Networks and Communications Researcher
	Mr. Tiberius Tabulu – Networks and Communications Researcher
	Mr. Titus Tunduny – Networks and Communications Researcher
	Mr. Joseph Shitote – IoT Researcher
	Dr. Kennedy Rono – PhD Researcher (from Technical University of Kenya)
Communications Authority	Mr. Tom Olwero – Director, Frequency Spectrum Management
	Mr. Mohamed Haji - Asst. Director FL&M
	Mr. Peter Ngige - Asst. Director, Frequency Spectrum Management
	Mr. Titus Cheptoo – Manager, Spectrum Monitoring
	Mr. Gababo Wako – Manager, Broadcasting
	Mr. Dennis Sonoiya – Engineer, Frequency Spectrum Management
	Ms. Anne Kinyanjui – Manager, Fixed Networks
	Mr. Nelson Wasilwa – Manager, Mobile Networks
	Ms. Stella Sitati – Engineer, Frequency Monitoring
	Ms. Velma Wandera – Engineer, Broadcasting
	Mr. Reuben Muturi – Research Assistant
	1 Regional Representative
	Communications & Public Affairs Representative
	Multimedia Services Representative
	Competition, Tariffs and Market Analysis Representative
	Network Facility Providers (NFPs)
	County Government Officials
The Dynamic Spectrum Alliance (DSA)	Led by Dr. Martha Suarez, President of the DSA
Stakeholders and Advisers	Local Residents Association
	Kaiote
	Mawingu Networks

	Equipment Vendors
	Department for International Development (DFID)
Donor	Department of International Development Kenyan Representative: Mr. Charles Juma

4. Project Methodology and Outputs

4.1. Site Surveys and Findings

Site surveys took place between 12th January 2020 and 22nd February 2020. The team spent 14 days at each site with the 14th day being the closure day of the survey. The survey exercise involved assessment of the Internet access state for each of the three counties (in select sub-counties) alongside a spectral opportunity based on availability of the unused TV channels. This availability was a determinant that demonstrates an opportunity for provision of Internet to these areas and act as a great thrust of the efforts towards bridging the digital divide.

The findings obtained from the three counties, that is, Kisumu, Kitui and Laikipia are presented here:

12th January – 25th January 2020: Kisumu County

The studies explored viability of spectrum sharing within the TV band in Kisumu County. The field measurements were carried out for two weeks. The areas covered during the site survey include RIAT, the Lake Basin Mall, Akala, Maseno, Mutet, Miwani, Fort Ternan, Ahero, Awach, Sondu, and Miriu Nyakwere. The team made use of the CA's frequency-monitoring vehicle to determine available but unused TV channels. Some of the low altitude areas within Kisumu County, farther away from the city centre had a weak signal strength. Collection of data, hence, had to be done by moving into other neighbouring counties for better reception. The CA's database showed that there are eighteen (18) TV channels assigned for DVB-T transmission sites located in Kisumu County and those within the neighbouring counties (Kericho, Siaya, Kisii, Vihiga, Kakamega and Homa Bay) whose transmission could possibly be received at different locations within Kisumu County. Eight (8) TV channels were assigned for DVB-T transmission from Kiboswa (34° 49' 30" E, 0° 01' 13" S) in Kisumu County while the rest were assigned for DVB-T transmissions from broadcasting sites within 71km radius from Kisumu Town. These eight (8) channels were inactive during the site survey. The findings, hence, demonstrated that there are ten (10) channels that could be used by white space devices (WSDs) to deliver wireless Internet access to Kisumu on the TVWS network.

27th January – 8th February 2020: Kitui County

Kitui studies explored viability of spectrum sharing within the TV band in Kitui sub-counties. The field measurements conducted in the two weeks demonstrated that majority of the assigned channels were off-air. This proved availability of assigned but unused radio frequency (RF) spectrum. A scan of all the twenty-eight (28) DTT channels in Kenya using 8MHz channel separation in the 470-698 MHz band with a measurement time of 3 seconds was also done. The CA's database showed that there are nine (9) TV channels assigned for DVB-T in Kitui. From the field survey, it was noted that only four of the assigned nine TV channels are active. However, in some cases there were areas that were completely out of coverage as indicated in the spectrographs. The terrain is rugged, hence hindering signal penetration leading to poor coverage. There are many available TV channels suitable for deployment of TV white space services in Kitui County.

Figure 1 indicates a signal strength map for each of the DTT channels covering Mwingi, Athi and Kanyonyo Edges of Kitui County.

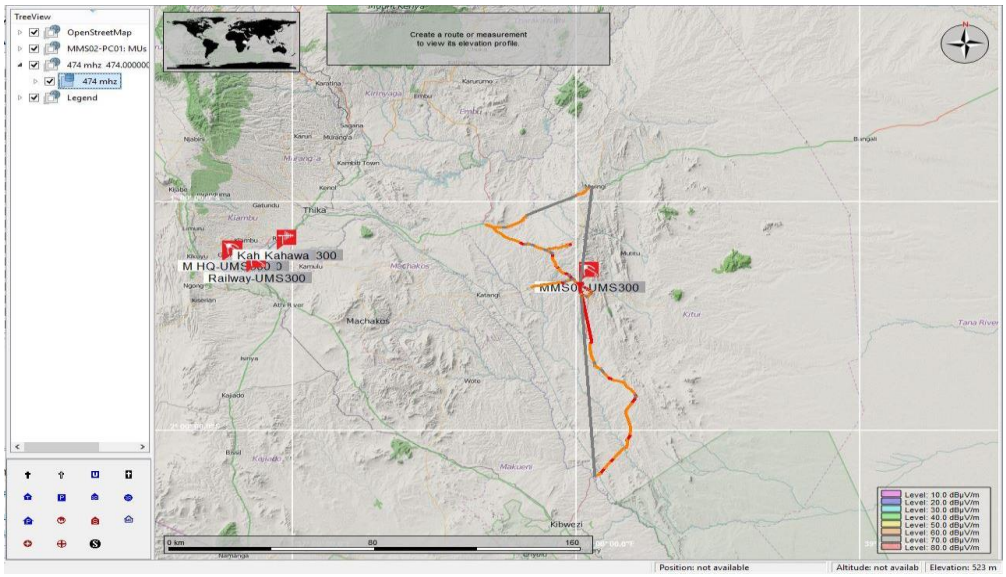


Figure 1: Signal Strength map for each of the DTT channels covering Mwingi, Athi and Kanyonyo in Kitui

Figure 2 gives an example of available TV channels in Kitui Town according to assignments in the CA's spectrum management database. The grey squares in the figure indicate channels, which could potentially accommodate TVWS deployments.

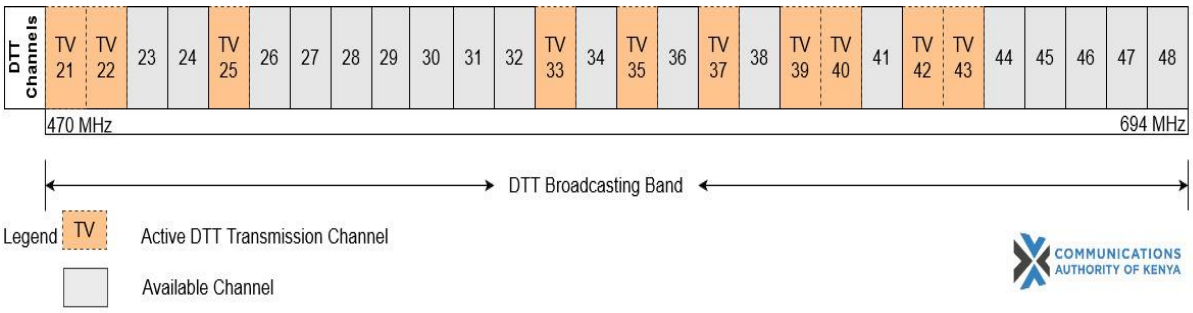


Figure 2: An example of available TV channels in Kitui Town

10th February – 22nd February 2020: Laikipia County

The team visited nine (9) sites in Laikipia County. Built from previous work in Laikipia, the team (SU and CA) working together with Mawingu Networks and members from the Dynamic Spectrum Alliance (DSAL) ran a new trial on the TVWS network in Nanyuki. The team set up one of the new Adaptrum B1000 Base Station and four ACRS2 Client Radios. The client setup had two CPEs at Answer Plaza, 1 at Cape Chestnut and another at Bemwaki Plaza; the Base Station was at Cedar Mall. All of this within Nanyuki town. The network setup with the B1000 base station transmitted in a 120° sector; the four clients each had a directional antenna with an antenna gain of 11dB. The links operated in a Time Division Duplexing (TDD) mode between the master WSD and client WSD in one 8MHz bandwidth channel. The B1000 base station was the master WSD, while the four clients were the client WSDs. The model of radios installed did not allow contiguous channels to be set up. No out-of-band (OOB) emissions were experienced during this experiment. It was also noted that out of the available nine (9) channels, only four (4) were active with DVB-T signals.

4.2. Stakeholder Engagements

On 3rd March 2020, the CA published the draft Regulatory Framework on Spectrum Sharing for Fixed Broadband Services in the UHF Band (TV White Spaces) on its website [1]. This publication was inviting stakeholders and the public to submit comments and views on the framework as the development towards its ratification continued. Various groups submitted comments through the official communication email that had been provided. These groups included the following:

1. GSMA – the global representative of mobile network operators.
2. Article 19 Eastern Africa (Article 19 EA).
3. KICTAnet.
4. Dynamic Spectrum Alliance.
5. Fairspectrum Oy.
6. Microsoft.
7. GoTV Kenya (Multichoice).
8. Kenya Broadcasting Cooperation (KBC).
9. Mawingu Networks.
10. Indigo Telecom PTY.
11. Kenya Power and Lighting Company.
12. Kenya Pipeline Company.
13. Huawei Tech Kenya Limited.
14. Council for Scientific and Industrial Research (CSIR) – South Africa.
15. Red Technologies.

A number of the stakeholders were also assessed through questionnaires which were administered via Google forms. Our previous plan was to host a physical workshop with these stakeholders to present clarifications on the framework and address the various comments that they submitted. Unfortunately, Covid-19 outbreak cut-off the physical interactions. We were hence limited to only online engagements. The online engagements were mostly carried out per each organisation except for some which we managed to team up. The comments shared by the stakeholders ranged from clarification on some of the segments in the draft framework, technical implementations and challenges as well as legal implications. These online engagements took place throughout the month of March 2020 until mid-April 2020.

4.3. Technical Adviser Engagement – Coexistence Calculations

The implementation of this project, as initially structured, also involved engagement with technical advisers. As part of constructing a holistic approach of validating the draft framework, we involved KAIOTE team on the coexistence calculations. KAIOTE is a technology innovation company in the space of Internet of Things (IoT) and Telecommunications. Since the draft framework has been developed as a part of the model rules of the Dynamic Spectrum Alliance (DSAL), it was crucial to validate the computations of coexistence between the incumbent DTT services and the implementation of the WSDs to confirm that, given all scenarios, there will be no interference. The CA provided a set of necessary datasets alongside the equations assimilated from the DSAL rules as well as from the ITU recommendations for coexistence calculations. Furthermore, the technical models were conducted to check for potential interference to Kenya's neighbour countries once TVWS is rolled-out. This was to validate that the implementation of TVWS in Kenya will not interfere with the radio transmissions of neighbour countries in the UHF band and breach the regional agreement signed in Geneva in 2006. This regional agreement is termed as the GE06 Treaty, which adheres to a particular RF transmission threshold at the borders.

4.4. Studies and Developments

This project has largely been driven by research into various secondary technical sources. This is a development following up to the initial due diligence activities that were conducted in the United Kingdom (UK), the United States of America (USA) and South Africa in 2019. These include various regulatory frameworks that have been published by different countries. In this case, some of the countries include, the UK, USA, Canada, Singapore, Colombia, and South Africa. In addition, the draft frameworks from Nigeria and Uganda were studied.

Some of the key references that the project has directly made use of include the following:

i. ETSI EN 301 598: Standard for White Space Devices (WSD); Wireless Access Systems operating in the 470 MHz to 790 MHz frequency band [2].
ii. ETSI TS 102 946: System requirements for Operation in UHF TV Band White Spaces [3].
iii. ETSI TS 103 145: System Architecture and High-Level Procedures for Coordinated & Uncoordinated Use of TV White Spaces [4].
iv. ETSI TS 103 143: System architecture for information Exchange between different Geo-Location databases enabling the operation of White Space Devices [5]
v. Model Rules and Regulations for the use of Television White Spaces v2.0, December 2017 - Dynamic Spectrum Alliance latest TV White Spaces Guidelines [6]
vi. IEEE 802.11af: Standard for Information Technology - Telecommunications & Information Exchange Between Systems [7]
vii. IETF PAWS RFC 7545: IETF Protocol to Access White Space Databases [8]

These diverse sources of knowledge and experience has made the CA adopt the development of a listing server (similar to Ofcom) whose guidelines are provided in the PAWS protocol document. This means that the initial transmission of a WSD will require a check with the regulator's (CA) listing server to select a geolocation database (GDB) of operation. The only usable databases will be the ones qualified by CA and made available on the listing server. The qualification process for the GDB will be conducted as detailed in the framework. Once a GDB is evaluated and confirmed to meet the criteria detailed in the framework, it will be listed on the listing server. The CA's portal for dynamic spectrum access is available for preview at https://gdbs.herokuapp.com

Some of the specific joint deliverables for the team (SU and CA) as submitted to DFID on the project are tabulated in Table 2 as done or not done yet.

Table 2: List of Specific objectives with their status

Specific Objectives	Status
Provision of the approved due diligent reports	Completed
Provision of the reviewed and approved draft framework	Completed. Pending Approval by CA
Incorporation of the stakeholders' comments in the draft framework	Completed
Publication of the rules and the final version of the framework	CA to publish the rules after approval of the

	draft framework
Conductibility of the Stakeholder Consultations and Engagements conducted	Completed
Collection of stakeholder feedback	Completed
Dissemination of the Knowledge and Validation of the obtained results	Physical Interaction affected by Covid-19. Online Engagements carried out.
Identification of existing spectrum opportunities, barriers and gaps	Completed
Provision of a guide list of potential Partners and Partnerships to advance DSA work	Completed
Identification of the Technical gaps and Capacity Development strategy in the identified gaps for future interventions in line with DSA (Key players including CA and other Government Agencies).	Completed
Recommendation of the next phases of the project identified and clearly linked to the successful implementation of phase 1. This would include practical implementation of spectrum sharing models with network operators in multiple spectrum bands. An implementation work plan shall be delivered as part of this project	Provided as Annex to this Report
Provision of the guiding report for the implementation of the regulatory framework on TVWS by the Communications Authority of Kenya under Dynamic Spectrum Access (DSA) structure	Provided in this document

Some of the specific objectives are discussed separately under this section.

4.4.1. Identification of Existing Spectrum Opportunities, Barriers and Gaps

The studies conducted in this project demonstrate a huge spectral opportunity through the usage of TVWS. They illustrate new spectrum management methods that national regulatory authorities (NRAs) can adopt in ensuring optimal spectrum use. Spectrum innovation through dynamic spectrum access techniques seems to be paving way for efficient utilisation of the radio frequency (RF) on shared access. The approach that CA has taken for TVWS in the draft framework, anchored in a "Use it or Share it" architecture, is a potential opportunity of delivering wireless Internet access alongside DTT services. Rural populations stand to benefit from affordable access to the Internet as observed during the site surveys to Kisumu, Kitui and Laikipia. As an opportunity, rural areas can be able to access e-government services; have connected rural schools that can equitably compete with their urban counterparts as well as connected hospitals and health centres. Rural Entrepreneurship and Startup ecosystem is also a noteworthy pillar that can spin off from TVWS deployments contributing to creation of more jobs and services for the country. The ratification of the draft framework potentially also draws Kenya closer to its bigger vision of a digital economy and enable more innovative initiatives. For instance, Internet of Things (IoT) deployments will be extended to the rural areas through TVWS backhaul networks.

The opportunity of scaling dynamic spectrum access techniques to other spectrum bands is also notable. Larger economies such as the United States of America (USA) and the United Kingdom (UK) are already leading projects in the mobile network bands including the fifth generation technology for cellular networks (5G) on spectrum sharing paradigms. Most recently, the USA, the UK and South Korea have launched initiatives to support Wi-Fi demand on the 6 GHz band [9]. This is to be done on a shared basis. These type of spectrum models are opportunities worth exploring by our NRA, the Communications Authority of Kenya (CA) as it embarks on the journey of dynamic spectrum access to bring more Kenyans online extending the work done for TVWS and its potential commercial deployments.

Business models, maturity and availability of the technology requirements such as hardware and software as well as the global state of TVWS deployments might be the major barriers to be dealt with for commercial TVWS rollout in Kenya. The subject of business models has been in the realm of research since the initial global trials of TVWS especially with the fact that, apart from paying a nominal fee for TVWS installation, the service providers will also be required to incur a cost of using a geolocation database. The latter two barriers also tie to the business models that will sustain the commercial activities for TVWS. On the other hand, the gaps are largely inclined to the lack of the knowledge on TVWS as a wireless Internet provision technology; the regulatory approach as well the technical expertise for rollout. A gap on utilisation of technology for the rural communities was identified during the site surveys. In such a case, capacity development and awareness to the rural communities is significant in ensuring that the rural populations optimally exploit the TVWS technology and the services provided through it.

4.4.2. Potential Partners to Advance DSA Work

This project has led to conversations with various stakeholders stretching from the legal space to global alliance bodies such as GSMA. Based on the background of this study, which is driven by an academic-regulator (SU-CA) collaboration, it is prudent that new spectrum usage techniques, studies and innovation include an academic institution and a regulator. Moreover, the lessons learnt throughout the study especially on coexistence calculations and geolocation databases also depict that industry involvement must not be left out. Presumably, dynamic spectrum access (DSA) is a novel approach that is becoming ''dynamic" in its context of implementation which might be driven by spectrum sensing, beacon reception or geolocation databases in spectrum bands that have not been exploited on shared access yet. Therefore, the following list outlines a number of partners that can potentially work with SU and CA in driving forward more DSA work for Kenya:

Table 3: List of Potential Partners based on the Achieved work

Category	Institution / Company/ Group
Spectrum Alliance bodies	DSAL, GSMA
Industry	Fairspectrum Oy, KAIOTE, Indigo Telecom, Multichoice, Mawingu Networks
Research Institutions	Universities (Strathmore University, University of Strathclyde, TUK)
Government	CA, KiCTANET, ICTA
Policy and Legal	Microsoft, Article 19 East Africa
Funding Organisations	DFID

The categories listed in the table above are only based on the roles the different institutions or groups have played throughout this study and can definitely change based on future DSA work. Some institutions might position themselves as policy champions in future DSA work as opposed to technical

or vice versa. Only research institutions will continually hold their roles, although based on project requirements, their roles can also be altered. It is also worth noting that, in future dynamic spectrum access developments work, these partners could potentially form a consortium with various shared or separated roles to drive spectrum sharing initiatives forward. Other partners might also be included in the network in future work.

4.4.3. Identification of the Technical gaps and Capacity Development strategy in the identified gaps for future interventions in line with DSA (Key players including CA and other Government Agencies)

TVWS rollout will definitely require sufficient capacity to guarantee fruitful delivery of novel wireless services to the country once CA releases the regulatory framework. The deployment models will also need a great understanding by Network Facilities Providers (NFPs) and Internet Service Providers (ISPs) to provide clarity on operational costs, business models and sustainability. Notably, Kenya has only had one consistent NFP running trials on TVWS. That is Mawingu Networks. The potential number of NFPs to utilise TVWS is gradually growing coming from the stakeholder engagements that this project has had. Primarily, this is potentially the first ever rollout of spectrum on shared access in Kenya. Therefore, it is inevitable that a capacity development strategy is drafted aligning to the gaps that have been discussed in section 4.4.1. The capacity development strategy proposed according to this study include segmentation of the stakeholders, assessment of the knowledge on TVWS, assessment on capital requirements, scrutiny of the market potential, rollout and sustainability. Table 4 shows the various pillars and their deliverable elements as part of the capacity strategy.

Table 4: Pillars and Deliverable elements for Capacity Strategy

No.	Pillars	Deliverable Elements
1.	Segmentation/Grouping of the Stakeholders	Identification of the network facilities providers (NFPs) and Internet service providers (ISPs) potentially ready on deployment of TVWS to offer broadband Internet access.
2.	Assessment of the knowledge on Kenya's TVWS framework, TVWS Technology, Implementation and Deployments	Assessments of the overall knowledge on TVWS by NFPs and ISPs. The understanding of the framework, the technical model and professional skills to be provided.
3.	Capital requirements assessment framework	Procedures for determining the CAPEX requirements for deployment of TVWS for broadband services to be covered. Costs of the hardware, regulatory fees as well as the geolocation database utilisation to be examined.
4.	Scrutiny of the Market and Market potential for TVWS	Assessment of the TVWS market and its local potential to be covered in this segment. Discussions to be carried out on development of a guideline to stakeholders in assessing the commercial potential of TVWS deployment for provision of broadband services.
5.	Service implementation process framework	This to look at business models in comparison to other models in other countries. Discussions based on experience by the network operators (NOs), NFPs and ISPs to lead to the development of some guidelines for determining a suitable business model and approach for provision of broadband services through TVWS roll-out.

5. Highlights from the Draft Framework

5.1. TV White Spaces Journey in Kenya

Figure 1

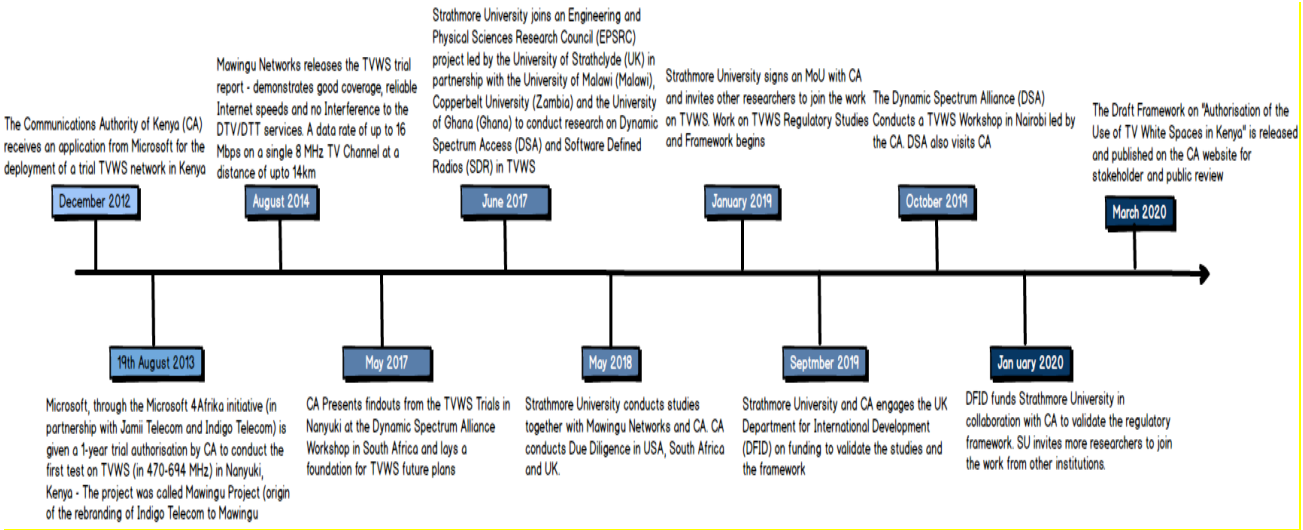


Figure 3: TVWS Journey in Kenya

Figure 3 shows the TVWS journey in Kenya from December 2012. The CA first permitted TV White Space trials in September 2013, when Microsoft East Africa was authorised to jointly test the technology with Indigo Telecom for one year. In December 2014, Mawingu Networks were issued a similar trial Authorisation for one year [10]. The Authority declined to issue commercial operation since the eco-system was still under development, there was no harmonised approach to dynamic spectrum access at international level and the use of UHF spectrum was frictional because of the digital switchover. The CA, however, continued to receive requests for trials for the deployment of TVWS networks within the DTT band. In November 2016, the Authority granted authorisation for the deployment of TVWS networks through the Broadcast Signal Distributors.

Following the initial trials, Signet Signal distributors requested authorisation to carry out TVWS trials using a different model. This new model would entail Signet applying for assignment of unused/unassigned UHF TV spectrum in a given area and partnering with a Network Facility Provider (NFP) operator to provide fixed wireless broadband services on a revenue share model on a secondary basis. Pan Africa Networks Group (PANG) were also issued authorisation to trial the same concept. Table 5 illustrates a summary of TVWS trials in Kenya.

Table 5: Summary of TV White Space Trials in Kenya

	Start (& Duration)	Operator	Affiliated Network Facilities Providers	Authorized Locations	Database Provider & Equipment Vendors	Outcome
1.	September 2013 (1 year)	Microsoft East Africa	Indigo Telecom	Kajiado & Laikipia	6Harmonics & Adaptrum (No database)	Trial Completed
2.	December 2014 (1 year)	Mawingu Networks	-	Laikipia	6Harmonics Adaptrum & Nominet	Trial Completed

	Start (& Duration)	Operator	Affiliated Network Facilities Providers	Authorized Locations	Database Provider & Equipment Vendors	Outcome
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 (5 Months)	Mawingu Networks	-	Embu	Adaptrum Redline & Fairspectrum	Trial Completed

5.2. Framework Guidelines from the Communications Authority of Kenya

The draft framework, which will be ratified in the coming days by the CA shall authorise the lightly licensed model for TVWS implementation in Kenya. The operation of WSDs in the UHF TV band will be on a secondary basis. In the draft framework, CA proposes to adopt a light-licensing model, where every master white space device (WSD) is registered and fully managed by a geolocation database (GDB). The operation of Type Approved WSDs on a lightly licensed basis is unlikely to lead to harmful interference to DTT services if the WSDs are controlled by a geolocation database (GDB) approved by CA and comply with the technical and operational requirements. Master WSDs shall only use operational parameters that have been generated by an authorised database.

The authority will also release the procedure for qualification of a geolocation database (GDB) to accompany the framework once deliberations are completed. The GDB shall hold information about licensed DTT Transmissions and calculate channels and power levels that are available at a location required by a white space device (WSD). The GDB shall perform calculations for the specific location and technical characteristics provided by the device and communicate available channels and power levels to the requesting device.

On spectrum usage, CA has proposed to authorise dynamic spectrum access in the UHF band 470-694 MHz on a non-protected, non-interference basis by the white space devices (WSDs). The UHF band 470 – 694 MHz is primarily allocated to the broadcasting service, specifically for DTT transmission. In establishing the regulatory requirements for TVWS applications in Kenya, the CA sets limits that will offer the protection required to prevent harmful interference to DTT broadcasting service. The adopted Dynamic Spectrum Access implements the geolocation databases (GDBs). This requires the use of geolocation databases that receive periodic updates from the CA's Spectrum Management database and provide cloud services to the TVWS operators and the WSDs. The WSDs must meet the minimum technical specification set by the CA and be Type Approved before installation and use. The WSDs, just like the GDBs, shall be authorised by CA to operate at specific locations and times. This will be determined by the GDBs. Figure 4 shows the UHF TV band spectrum and the adjacent bands.

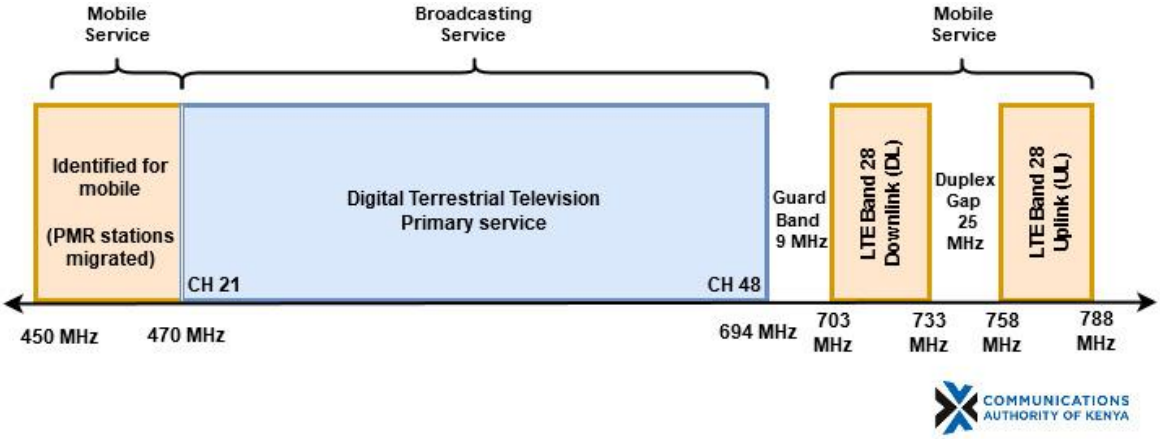


Figure 4: The UHF TV band spectrum and the adjacent bands in Kenya

The network operators will require annual authorisation to operate and will be required to pay for the service of a geo-location database (GDB) provider, of their choice, qualified by the Authority. The DSA framework for TV white spaces in Kenya takes on the following key components as shown in Figure 5.

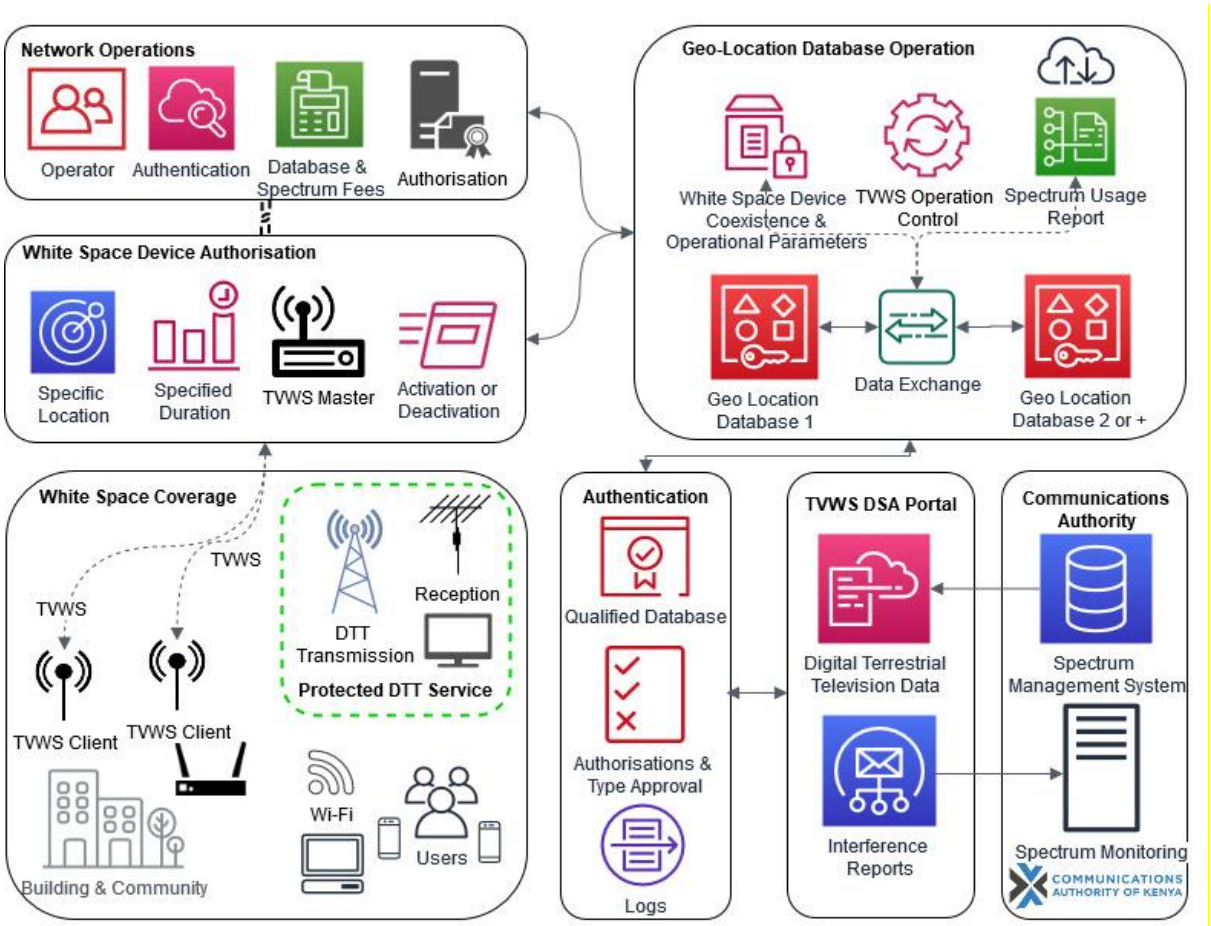


Figure 5: Illustration of the key components for DSA in the UHF TV band in Kenya

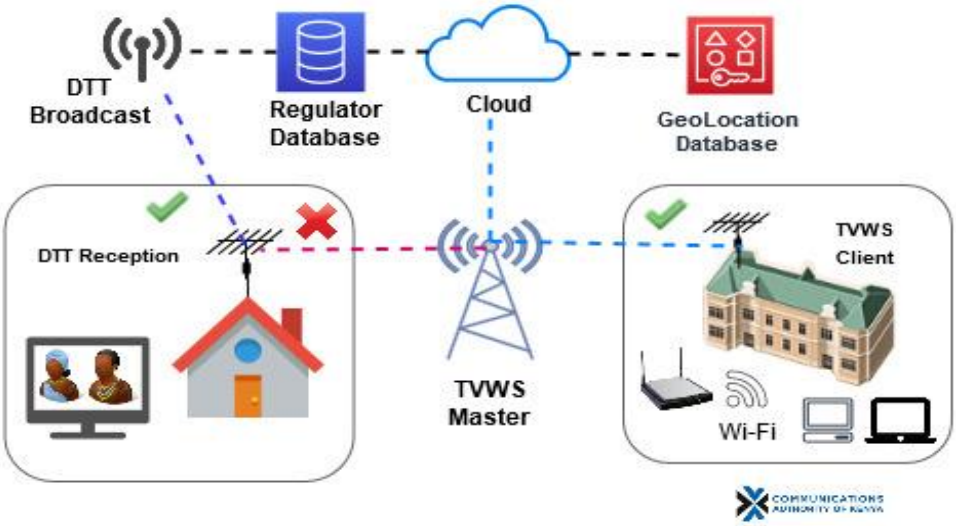


Figure 6: A simple Illustration of Coexistence between TVWS and DTT

A simple illustration of how a TV White Space Deployment would coexist with DTT service is shown in Figure 6. The master WSD transmissions shall not interfere with DTT reception, as signified by the red "X" mark.

6. Challenges and Next Steps

Covid-19 has come with its fair share of challenges even as we push efforts to officially launch the regulatory framework for TVWS and enable the commercial deployments for rural connectivity through dynamic spectrum access. The initially planned stakeholder conference did not take place as planned (previously planned to be a physical workshop). Plans on knowledge sharing have been developed as an extension of this project to deliver the first next steps of capacity building for the stakeholders on TVWS technology. The extension period has also covered a collaborative development of a framework for identification and scale-up of local innovations helping the Kenyan government combat the Covid-19 pandemic. These two spin-off projects have been covered in separate documents but are summarised in section 7 of this report.

7. Extension Projects

7.1. Capacity Building Plan for Network Operators to use TV White Spaces Technology for Broadband Provision in Underserved Areas under a Dynamic Spectrum Access (DSA) Framework

This extension project focused on the development of a capacity-building plan that could be adopted by CA in training stakeholders (network facility providers, broadcasters, Internet service providers and other potential TVWS service providers) on the various identified aspects that are directly relevant in driving the commercial deployments on TV white spaces (TVWS). The aspects identified included the regulatory, technology, economic and market requirements.

Figure 7 shows an iterative and incremental approach that was proposed in conducting an exercise that can equip the various stakeholders with more knowledge on TVWS.

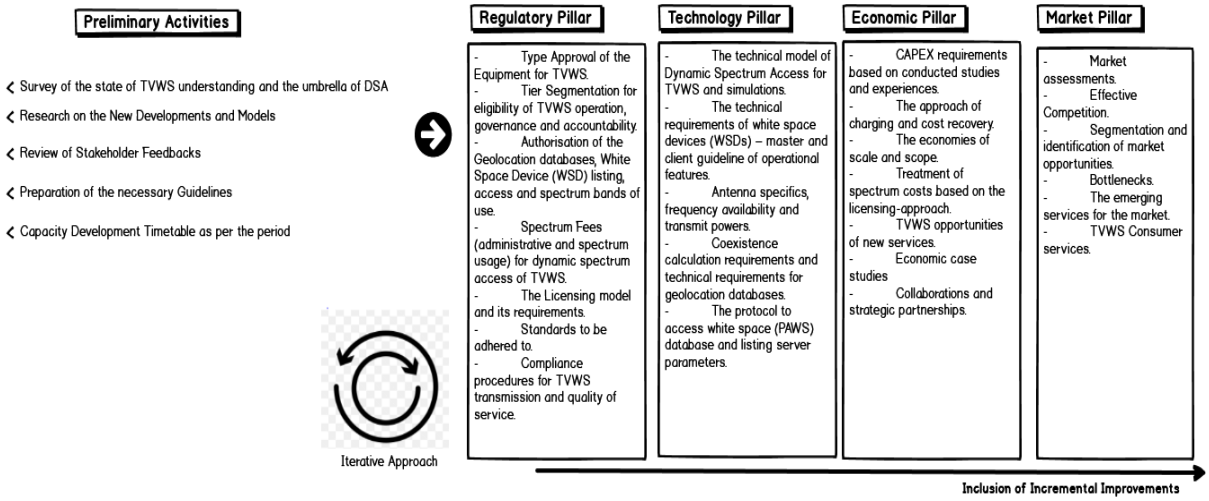


Figure 7: Proposed Capacity Building Structure for TVWS

7.2. Collaborative Development of the Framework for Identification and Scale-up of Local Innovations that can help Kenya combat Covid-19

This project focused on the development of frameworks aimed at addressing the structural challenges that hinder growth of local innovations and to provide a pathway for a successful innovation ecosystem in Kenya. The developed frameworks proposed a multi-stakeholder approach that promotes mechanisms for building an ecosystem that will enable innovators identify their challenges and to exploit existing opportunities. They also provide innovators with a means of identifying the pathways that will accelerate the innovation process. Moreover, the frameworks have proposed a mechanism of identifying and supporting the local innovations. The frameworks are also build to provide other stakeholders like the government institutions identify, support and promote scaling of the innovation product. The project involved the study of the local innovation ecosystem and utilisation of existing data and documents to construct/develop the proposed system. The proposed frameworks have already been presented to the client at a plenary meeting and have adopted the proposed document with minor amendments to the proposed framework. The proposed amendments have since been incorporated.

8. Conclusions

This project has been extremely beneficial in helping us, as a country, to embrace spectrum innovation as a bridge to reduce the gap of the digital divide. Within the East African (E.A.) region, we become the first country to comprehensively cover studies and critically review the regulatory framework for the first implementation of dynamic spectrum access (DSA) in Kenya through TV White Spaces as a potential technology to enhance rural broadband access. Strathmore University in collaboration with the Communications Authority of Kenya sincerely appreciate the financial support accorded by the UK department for International development (DFID) to successfully carry out the validation studies. The challenges faced in the execution of this project have provided a baseline of lessons to improve the approach of studies to be carried in the future implementation of DSA in other bands and to also note down local and global potential collaborations to continue work on last mile Internet access. Emanating from our experience, we envision more regulatory and academic collaborations taking place not only within the E.A. region but also in Africa and other continents in achieving fruitful outcomes focused on spectrum studies.

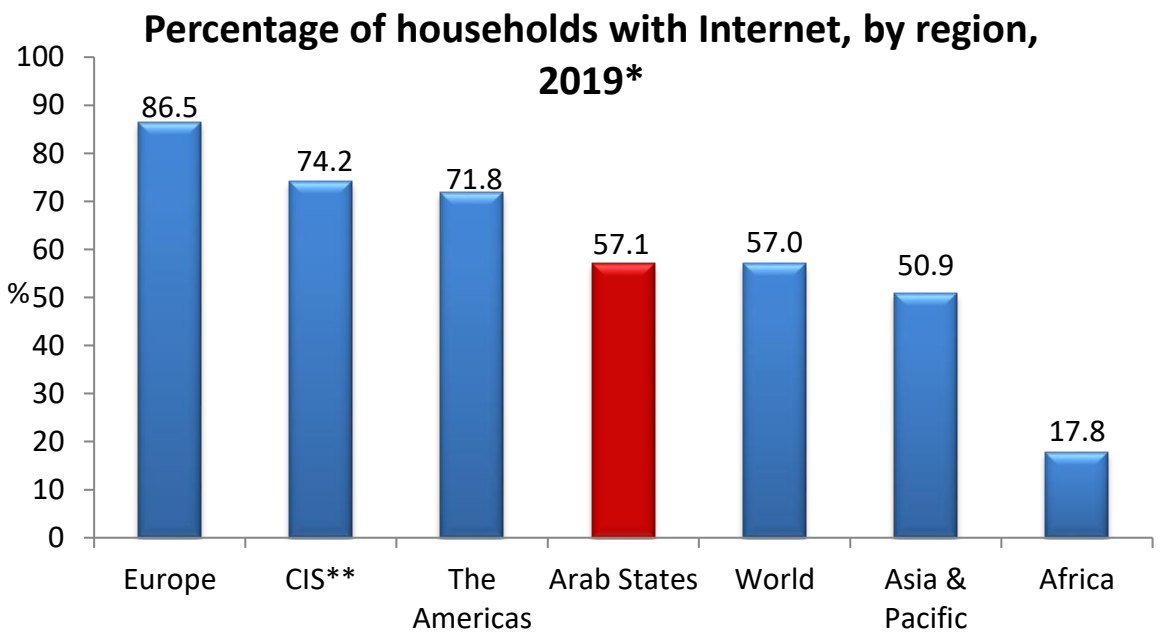
Annex 1: Summary and Recommendations of the Next Phase

The demand for wireless Internet access is rapidly growing everyday especially with the emerging use cases driven by the Internet of Things (IoT). The 2019 ITU statistics estimated that 53.6% or 4.1 billion of the global population are using the Internet [11]. This percentage has tremendously grown due to the growth in the provision of broadband to the developing economies from 2008 to 2019. Table 6 compares Internet users by level of development in 2008 and 2019.

Table 6: ITU 2019 Statistics on Individuals Using the Internet

Individuals using the Internet (in millions)	2008	2019*
Developed	754	1,107
Developing	811	3,020
Total	1,570	4,131

Despite this growth, ITU statistics also show that Africa as a continent is performing dismally in terms of percentage of households with Internet. Figure 7 shows the percentage of the households with Internet by region and Africa posted 17.8% in 2019. Notably, the African region also posted the least percentage of the individuals using the Internet per 100 inhabitants in 2019 as shown in figure 8.



Regions are based on the ITU BDT Regions, see: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx

Figure 8: Percentage of households with Internet by region

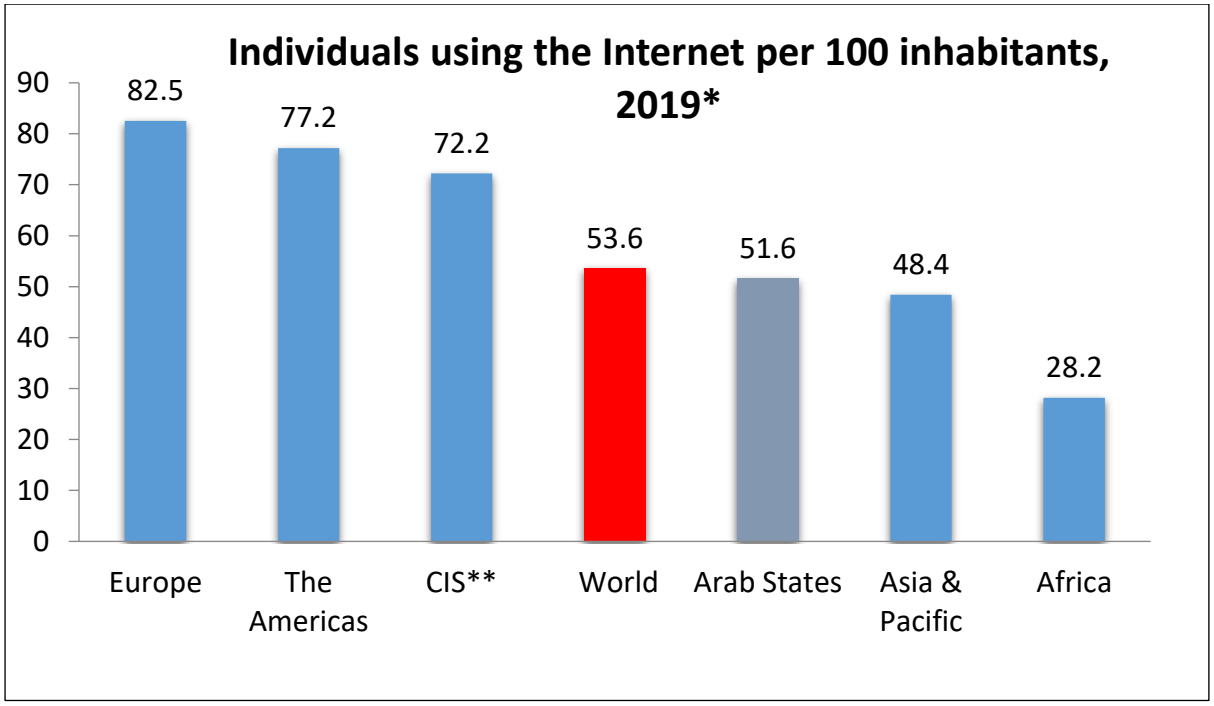


Figure 9: A Graphical representation of the individuals using the Internet per 100 inhabitants per region

The discussion report released in April-May 2019 by the Kenya ICT Action Network (KiCTAnet) on "Social-economic Impact of Broadband in Kenya" elucidates that a big percentage of the Kenyan population is still unconnected with unavailable broadband being an impediment [12]. The cellular network coverage is also cited to be missing in a number of places, particularly the rural counties. This largely creates inequality and immensely widens the gap of the digital divide. Services such as tax filing, obtainment of the driving license, passports among other government services are currently delivered through a digital platform. Therefore, a lack of broadband access limits a greater percentage of the population (especially the rural populations) in accessing these services based on need.

In the wake of the Covid-19 pandemic, it is inevitable that efforts to provide broadband access needs to be stepped up in addressing the digital divide. Spectrum, as a driver of provision of the broadband, is a scarce resource that requires new usage models to address the rapidly growing demand. Spectrum sharing is hence gaining traction to eliminate the traditional challenge caused by static licensing of the radio frequency. The work presented in this report on TVWS creates a first approach of dynamic spectrum sharing in Kenya to demonstrate effective and efficient ways of utilising spectrum.

The recommendations provided here are inclined to more advanced studies on dynamic spectrum access implementation in other bands and draw inspiration from the Memorandum of Understanding (MoU) between Strathmore University (SU) and the Communications Authority of Kenya (CA). The studies will majorly expound on the technical, business and policy model of the Television White Spaces (TVWS) and other shareable bands. Research work on software defined radios and cognitive radios will also form a baseline for future technical trials as the NRA moves towards adoption of DSA techniques. The specific recommendations for the next phase of this project include:

1. Investigation of spectrum sharing initiatives and models in the fifth generation technology of the cellular standard (5G) covering the sub-6 GHz band. Specific focus is to be given to technical trials in the rural areas drawing from lessons in other countries such as the UK through the 5G RuralFirst Project. Model of spectrum sharing on 5G non-stand alone (NSA) to also be investigated.

2. Studies on Software Defined Radio and Cognitive Radio techniques for dynamic spectrum sharing to be carried out as well. This will include advanced work on the use of geolocation databases (GDB) and implementation of spectrum sensing. Comparative models will be derived here spelling the next future approach on policy for DSA implementations.
3. More studies on Spectrum standards (ITU, DSA, IEEE etc) even as CA unlocks the dynamic spectrum access (DSA) opportunities for spectrum utilisation for last mile Internet access.
4. Next Generation Wi-Fi studies – Shared usage of the 6 GHz band allowing Wi-Fi access.

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