PROICT: STRENGTHENING THE CORE CAPABILITIES OF THE LIBERIA TELECOMMUNICATIONS AUTHORITY (LTA)

TELEVISION WHITE SPACE (TVWS) REPORT AND REGULATORY RECOMMENDATIONS

May 2021

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ProICT: Strengthening the Core Capabilities of the Liberian Telecommunications Authority (LTA)

TV White Space (TVWS) Report and Regulatory Recommendations

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CONTENTS

LIST OF TABLES II

LIST OF FIGURES II

ACRONYMS III

EXECUTIVE SUMMARY I

1. INTRODUCTION 3

2. TVWS SHARING: A BRIEF INTRODUCTION 5

3. BENEFITS OF ENABLING SHARED TVWS ACCESS IN LIBERIA 12

4. TVWS REGULATORY EXAMPLES ACROSS AFRICA AND SELECTED OTHER COUNTRIES 22

5. DRAFT TVWS REGULATORY RECOMMENDATIONS 33

6. KEY CONCLUSIONS AND NEXT STEPS 40

ANNEX I. REFERENCES 41

LIST OF TABLES

TABLE 1. TV ASSIGNMENT AND ALLOCATION IN LIBERIA 17

LIST OF FIGURES

FIGURE 1. EXPLAINING GEOGRAPHICALLY INTERLEAVED SPECTRUM 5

FIGURE 2. WHITE SPACES IN BROADCAST BANDS IN CAPE TOWN, SOUTH AFRICA, 2015 6

FIGURE 3. WHITE SPACES IN BROADCAST BANDS 7

FIGURE 4. MOBILE BROADBAND PENETRATION IN AFRICA BY COUNTRY (2018) 10

FIGURE 5. TVWS ENABLES BETTER COVERAGE FOR BROADBAND WIRELESS APPLICATIONS 15

FIGURE 6. ANALOG TV CHANNELS ACROSS AFRICAN COUNTRIES (43 PERCENT ONLY HAVE ONE TO TWO ANALOG TV CHANNELS) 18

FIGURE 7. MAWINGU DATA PRICING IN KENYA (2018) VS. SAFARICOM 20

FIGURE 8. TVWS REGULATIONS ACROSS THE GLOBE 22

FIGURE 9. KEY ROLES FOR GOVERNMENT AND REGULATORS ON TVWS FRAMEWORKS 23

FIGURE 10. TVWS TIMELINE IN SOUTH AFRICA 24

FIGURE 11. TVWS TIMELINE IN KENYA 27

FIGURE 12. COLUMBIA'S MANUAL TVWS ALLOCATION BY THE REGULATOR 32

ACRONYMS

ACE	Africa Coast to Europe
ADSL	Asymmetric Digital Subscriber Line
ARECOM	Autoridade Reguladora das Comunicacoes
ATU	African Telecommunications Union
BWA	Broadband Wireless Access
BS	Broadcasting Service
ACT	Telecommunications Act 2007
CA	Communications Authority
CCL	Cable Consortium of Liberia
CDMA	Code Division Multiple Access
DFID	Department for International Development
DSA	Dynamic Spectrum Access
ECS	Electronic Communications Service
EIRP	Equivalent, Isotopically Radiated Power
ETSI	European Telecommunications Standards Institute
EVD	Ebola Virus Disease
FCC	Federal Communications Commission (USA)
FWA	Fixed Wireless Access
GSM	Global System for Mobile
ICASA	Independent Communications Authority of South Africa
ICT	Information and Communication Technology
IMT	International Mobile Telephony
ISP	Internet Service Provider
ITU	International Telecommunications Union

LibTelCo	Liberia Telecommunications Corporation
LIXP	Liberian Internet eXchange Point
LTA	Liberia Telecommunication Authority
LC-MTN	Lonestar Cell-MTN
MFDB	Ministry of Finance and Development Planning
MIA	Ministry of Internal Affairs
MICAT	Ministry of Information, Culture and Tourism
MNO	Mobile Network Operator
MoPT	Ministry of Post and Telecommunications
MoU	Memorandum of Understanding
NCA	National Communications Authority
NPRM	New Proposed Rulemakings
NREN	National Research and Education Network
OFC	Optic Fiber Cable
OL	Orange Liberia
PMSE	Program Making and Special Events
PSTN	Public Switched Telecommunications Network
QoE	Quality of Experience
QoS	Quality of Service
R-GLSD	Reference Geo-Location Database
RFID	Radio Frequency Identification
S-GLSD	Secondary Geo-Location Spectrum Database
SMS	Short Message Service
SU	Strathmore University

TVWS	Television White Spaces
UAF	Universal Access Fund
UCC	Uganda Communications Commission
UHF	Ultra High Frequency
USF	Universal Service Fund
UHF	Ultra High Frequency
USAID	United States Agency for International Development
VOIP	Voice Over Internet Protocol
VSAT	Very Small Aperture Terminal
WARCIP	West Africa Regional Communications Infrastructure Project
WISP	Wireless Internet Service Provider
WSD	White Space Device

EXECUTIVE SUMMARY

Under the United States Agency for International Development (USAID) Digital Frontiers Project, DAI Global has subcontracted Integra Government Services International LLC ("Integra") in partnership with Atlantic-TM Cameroon to implement the Digital Connectivity and Cybersecurity Partnership's Promoting American Approaches to Information and Communications Technology (ICT) Policy and Regulation (ProICT) Activity and provide consultancy services towards strengthening the core capabilities of the Liberia Telecommunications Authority (LTA) ("ProICT Liberia"). Under this Activity, one of the six workstreams of strengthening is the introduction of TV White Spaces (TVWS) regulations in Liberia.

This TVWS Report presents the benefits of TVWS and provides recommendations to the LTA for enabling its use. It comprises:

1. An overview of the TVWS report and purpose.
2. An introduction to TVWS and its importance to the Government of Liberia (GoL): In addition to enhancing the implementation of the Liberia ICT Policy (2019-2024). TVWS signals can easily cover larger distances, penetrates obstructions such as brick walls, and provide greater cost efficiencies relative to Wi-Fi or mesh-based technologies. TVWS applications are also highly relevant to the Liberian context, including its ability to bridge the digital divide by delivering broadband to rural or hard to serve areas, its ability to provide last mile access, enhance Wi-Fi usage, and enable improved public service delivery (e.g., healthcare, education, and safety), among other uses.
3. The benefits of enabling shared license-exempt TVWS access in Liberia: There are typically three approaches to consider to enable TVWS sharing: a licensed approach, a light licensing approach, or a license exempt approach. It is recommended in this report that not only should shared access to TVWS be enabled in Liberia, but particularly using a license exempt model. As opposed to licensing TVWS spectrum through the regulator (LTA), which would grant rights subject to certain obligations or fees, or using a light-licensed model in which the LTA would record the use of spectrum but not manage it, a license-exempt approach would reduce the administrative burden placed on users and the LTA, while also fostering innovation to deliver more services to citizens and help spur economic growth.
4. TVWS regulatory examples across Africa and select countries across the globe: In particular, the GoL can learn from the examples set by Kenya, Columbia, and other African countries as detailed in Section 4 of this report.
5. Key recommendations to enable TVWS in Liberia: Drawing from the regulatory examples included in Section 4 on TVWS frameworks in other countries, this report provides eight specific recommendations regarding the implementation of spectrum sharing in the broadcast bands for Liberia:

    - Recommendation 1: Enable access to vacant television spectrum in Liberia;
    - Recommendation 2: Allow access on a license-exempt basis to spur innovation and investment in new technology and applications;
    - Recommendation 3: Start with manual TVWS allocation by the LTA and for the proposed TVWS pilot;

- Recommendation 4: Protect primary licensed services by relying on geolocation databases as opposed to spectrum sensing;
- Recommendation 5: Establish classes of devices (i.e., fixed or mobile and master or client) based on transportability and geolocation capabilities;
- Recommendation 6: Use existing type approval procedures to certify devices for operation;
- Recommendation 7: Establish operating parameters that maximize spectrum availability while protecting incumbent services; and
- Recommendation 8: Establish a Liberian pilot involving TVWS in partnership with the Liberian Universal Access Fund.

Overall this report concludes that the LTA enable TVWS regulations in Liberia as soon as possible to bring additional services to Liberian citizens in line with the Liberia ICT Policy. It also recommends shared secondary and opportunistic use of the unused UHF broadcast spectrum in Liberia for mobile broadband and other services through a license-exempt TVWS spectrum sharing framework. This is not only because license-exempt networks carry the majority of the world's data traffic today, but also because of the sheer innovation potential that comes with license-exempt models.

1. INTRODUCTION

Under the United States Agency for International Development (USAID) Digital Frontiers Project, DAI Global subcontracted Integra Government Services International LLC (Integra) in partnership with Atlantic-TM Cameroon to implement the Promoting American Approaches to Information and Communications Technology (ICT) Policy and Regulation (ProICT) Activity and provide consultancy services towards strengthening the core capabilities of the Liberia Telecommunications Authority (LTA) (ProICT Liberia). The core purpose of the engagement is to strengthen the core capabilities of the LTA with regulatory and technical expertise in areas the LTA has identified in consultation with USAID and subsequent conversations with the technical team.

The following workstreams were identified for ProICT Liberia and agreed to in the project work plan:

1. Modernizing regulations governing the deployment of fiber optic cables;
2. Developing regulatory standards for TV Whitespace (TVWS) and related rural access technology;
3. Assisting LTA's administration to optimize, implement, and develop and strategy for the Liberian Universal Access Fund (UAF);
4. Providing advisory and technical assistance to the LTA to help strengthen its role in transitioning the Liberian Internet eXchange Point (LIXP) to an independent and sustainable management structure;
5. Strengthening the Network Type Approval regime at the LTA; and
6. Assisting the reorganization of Liberia's FM Radio spectrum to allow for the highest and best use of these critical radio frequencies.

This report specifically concerns the second workstream above—TVWS and related rural access technology.

PURPOSE OF THIS LIBERIA TVWS REPORT

The primary drivers of this Liberia TVWS Report include:

1. Explaining TVWS and Dynamic Spectrum Access (DSA) including the clear benefits and relevance for Liberia—and hence the LTA;
2. Providing a review of TVWS Activities (and their frameworks) across Africa (and less so the rest of the globe) to help ignite and drive similar momentum in Liberia; and
3. Providing a draft set of TVWS regulatory recommendations for the LTA's consideration for stakeholder consultation, including a recommendation for a TVWS Pilot in partnership with the USF/UAF.

This report also provides the basis for a comprehensive TVWS Regulatory Training of the relevant Liberian stakeholders including the LTA.

TVWS REPORT STRUCTURE

The structure of this TVWS Report is as follows:

- Section 1: Introduction: Provides an introduction and outlines the purpose and of this report;
- Section 2: Explaining TVWS and DSA: Briefly describes the concepts of TVWS and DSA and why the LTA should care about these two regulatory innovations;
- Section 3: Benefits of Enabling Shared and/or License-Exempt Access to TVWS in Liberia - Provides an overview of the expected benefits of license-exempting or providing shared access to TWS in Liberia, emphasizing its potential for fostering innovations and explaining why the ITU would not object to Liberia and the LTA proceeding with such TVWS regulatory frameworks in Liberia;
- Section 4: TVWS Regulatory Examples across Africa and the Globe - Provides a review of TVWS activities (and their regulatory frameworks) across Africa in particular, but also across selected relevant countries across the globe, e.g. Colombia. It commences with the key roles for Regulators and Governments in TVWS regulatory frameworks;
- Section 5: Draft TVWS Regulatory Recommendations for Liberia - Presents the overall simplified Draft TVWS Regulatory recommendations for Liberia including a TVWS Regulatory Pilot Proposal in partnership with the USF/UAF fund of Liberia; and
- Section 6 concludes this report.

This report draws much from the author's work (Nwana, 2014) and from a key Google 2015 Report[1] to which the author was a significant contributor[2] and was submitted to the African Telecommunications Union (ATU).

[1] "AfriSWoG-3 Input Doc 1 – Enabling Use of Television White Spaces Study in Respect of DSA and TVWS Studies from Google." African Telecommunications Union. Accessed May 25, 2021. https://atu-uat.org/download/afriswog-3-input-doc-1-enabling-use-of-television-white-spaces-study-in-respect-of-dsa-and-tvws-studies-from-google/.

[2] At the time, the author of this report was the Founding Executive Director of the Dynamic Spectrum Alliance and worked closely with Google on this 2015 report submitted to the ATU to promote TVWS across Africa. The Alliance is the premier spectrum sharing (including TVWS sharing) advocacy organization in the world, of which Google was a founding member.

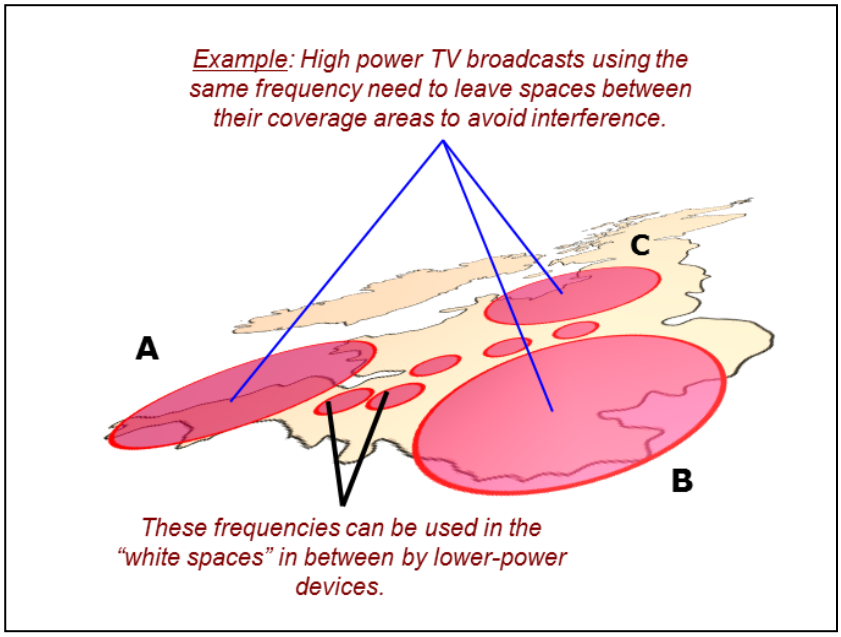
2. TVWS SHARING: A BRIEF INTRODUCTION

As a result of the way spectrum allocations for television broadcasting have typically been done on a nationwide basis, many broadcast channels remain vacant in any given locality.

WHAT IS TELEVISION WHITE SPACE (TVWS)?

Nwana (2014, Chapters 4 and 6) explains TVWS as "Typically the way TV networks are designed and built in Europe and Africa (mostly using UHF frequencies) will leave what is usually referred to as *geographically interleaved spectrum* in most areas," as articulated in Figure 1 below.

Figure 1. Explaining Geographically Interleaved Spectrum



Source: Ofcom public documents on white spaces[3]

TV networks tend to use very high-power transmitters as compared to mobile networks, but even more importantly, they tend to use the same frequency (i.e., UHF Channel 40 in ITU Region 1, 622–630 MHz) in different geographical parts of the country (i.e. Regions A, B, and C). Using this same channel leaves physical spaces between their coverage areas to avoid interference as shown. This means the frequency (i.e., Channel 40) is geographically interleaved TVWS in between these main Regions A, B, and C, and can be reused. Figure 2 shows how the frequency can be reused (see smaller ovals or circles), particularly if lower power devices are employed, as they will not interfere with the main TV channels in Regions A, B, and C.

TVWS, therefore comprises the unused channels within the television broadcast frequency range at a given location, as shown in Figure 1. The TVWS channels reside within the UHF spectrum in Africa—from 470 MHz to 694 MHz (i.e., band IV channels 21 to 60), or more like 470 MHz to 694 MHz (or

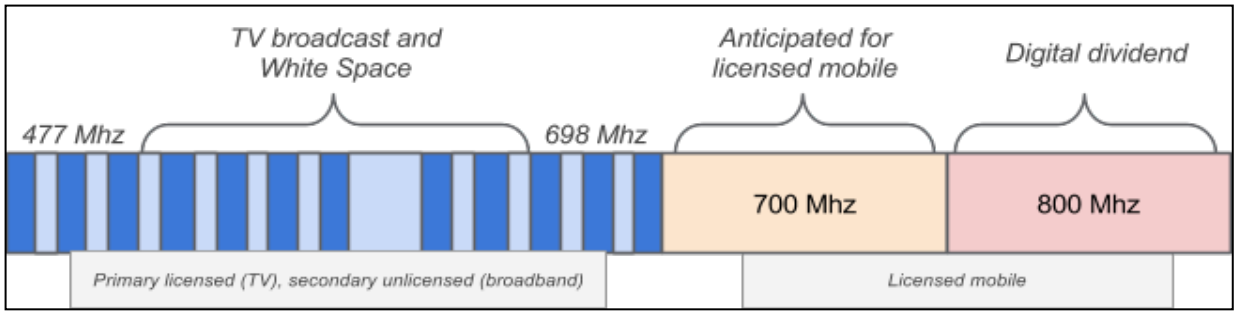
[3] Ofcom, February 14, 2020. https://www.ofcom.org.uk.

channels 21 to 48) if 700 MHz is cleared across Africa for mobile broadband following the World Radio Congress of 2015, as they should be.

The likelihood is that a significant number of UHF channels (each of 8 MHz bandwidth) on the African continent are already "white space" across most countries' national territories. The few channels that are being used for analog TV today will (or should) be cleared out by 2023 and be replaced by probably just a couple to three multiplexes using a UHF channel each to host between twenty and sixty digital channels. This is because each 8 MHz UHF channel can support an entire multiplex of up to 20 television channels, requiring the use of only two to three UHF frequencies to provide up to sixty TV channels. Some of these new digital TV channels may not even be in Band IV UHF (as some may go into Band III) which means in some countries, most of the entire set of UHF channels from 470 MHz to 694 MHz may be mostly white space everywhere. Therefore, a key question is, if technologies like white spaces technology are not employed for UHF in Africa between channels 21 to 48, then how and for what purpose would they be used?

Drawing from the Google (2015) Report, Figure 3 below provides a stylized illustration of the situation in many parts of Africa. The 700 MHz band has been allocated by the ITU in 2015 for mobile use throughout many African countries including Liberia, however, are yet to clear broadcasters off this 700MHz band. The 800MHz band had long been allocated for mobile use by the ITU since 2008.

Figure 2. White Spaces in Broadcast Bands in Cape Town, South Africa, 2015



Source: Google 2015

Figure 2 illustrates a possible scenario where there is ample spectrum available for white space deployments, where the deep blue channels are being used for TV transmissions, but the light blue channels are available white spaces at the locality or area of the country.

From around 2008 to date, numerous countries (including later in Africa) have adopted or are in the process of adopting rules that enable devices to use these vacant (TVWS) channels on a 'no-interference no-protection' basis.[4] Under such frameworks, devices using TVWS must not cause interference to licensed TV broadcasters.

[4] More than two dozen countries have adopted rules authorizing the use of TVWS. Section 4 covers some of these countries and discusses the frameworks, experiences, and rules, as well as TV White Space Regulatory Examples in Africa and around the Globe.

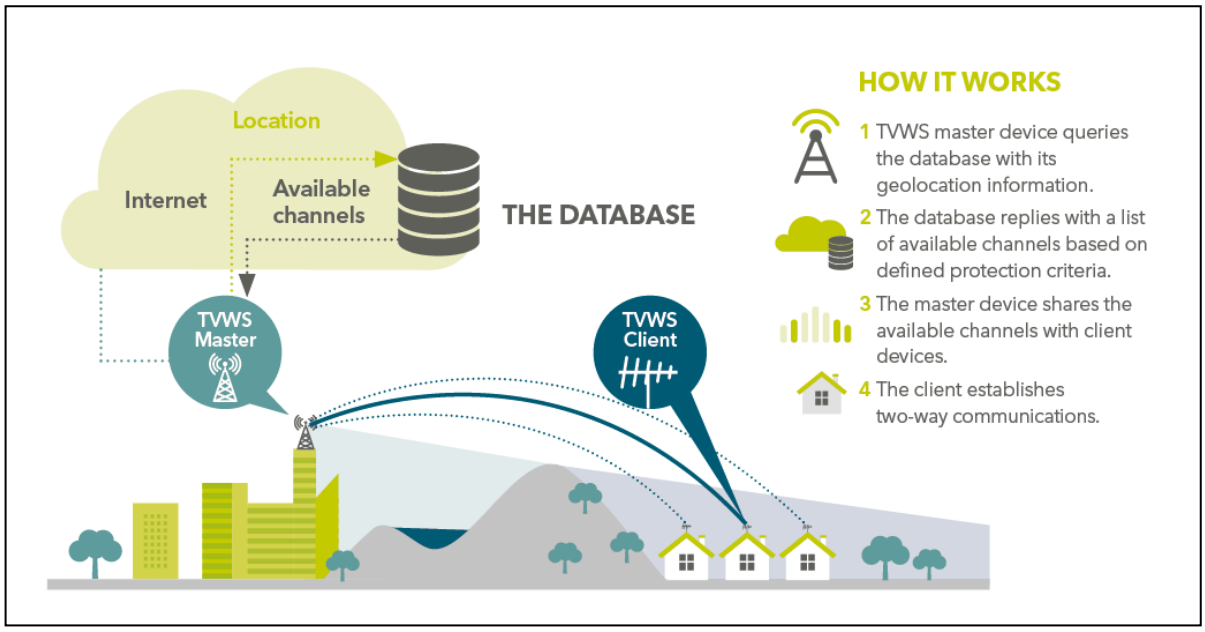
Similarly, users of TVWS will neither receive nor demand any interference protection from either licensed users or each other. Access is typically enabled in conjunction with automated reference to a frequency database, which uses information regarding a device's characteristics and location to determine what channels are available for use by a given device. This 'no-interference no-protection' basis is at the core of most TVWS regulatory frameworks that have been adopted by many countries.

In summary, such TVWS rules and frameworks effectively enable TV broadcast frequencies to be shared with mobile broadband users—thereby increasing the spectrum usage of these TV frequency bands.

DYNAMIC SPECTRUM ACCESS AND TVWS SIMPLIFIED ILLUSTRATION OF ITS WORKING

At its core, DSA is a new approach to spectrum utilization, of which TVWS regulatory frameworks are just one exemplar. DSA techniques enable the "opportunistic" use of otherwise unused spectrum. Opportunistic use enshrines the idea that radio technologies can (and should) identify and use different frequencies within a closely defined band, based on what frequency is available for interference-free operation at a given time and geographic locality.

Figure 3. White Spaces in Broadcast Bands



Source: The Dynamic Spectrum Alliance

This is a revolutionary idea in 100+ year-old spectrum management, which has resulted in large swathes of unutilized spectrum in vast geographical areas most of the time for fear of interference of spectrum services—thereby limiting bands to singular services, such as just broadcast TV, excluding other services. DSA proves opportunistic sharing is not only technically viable (due to recent advances in technology), but also potentially economical, both in terms of increased efficiency of spectrum regulation and in terms of facilitating the delivery of affordable access services.

For example, DSA techniques, when operating in UHF broadcast bands (as is being proposed in this report for Liberia) would enable broadband services in the TVWS spectrum (otherwise reserved for broadcast TV only) without interfering with existing broadcasts and other incumbent services.

Figure 3 depicts a simple DSA illustration for TVWS devices in the UHF TV bands. TVWS radios are typically coordinated by a cloud-based TVWS spectrum database. The database calculates the availability of unused TV channels at a given location. Frequencies are dynamically allocated in real time (hourly, daily, weekly, etc.) based on the usage in a geographic area by incumbent users. The database informs the device about the available TVWS channels and the maximum power level permitted at that location. The device is then able to establish a two-way communication using the unused TV frequency.

For Liberia for example, the TVWS database maintained by the LTA[5] would maintain a list of all protected TV stations and frequencies across the country so the devices would avoid causing interference with TV broadcasts or wireless microphone signals, which also sometimes uses these TV frequencies.

In summary, DSA is a term used to describe a set of radio technologies and regulations that allow devices to opportunistically transmit on unused and available radio spectrum on a secondary basis without interfering with transmissions from primary licensed users like broadcasters in their allocated TV bands. TVWS was and has been the first globally harmonized opportunity to use DSA technologies and regulations in unused TV band frequencies. More details on the workings of DSA are provided later in the report where various rules and frameworks for several countries are described.

THE BENEFITS OF TVWS FOR LIBERIA

This report advocates that the LTA, MoPT, and the Government should consider enacting regulations for TVWS and DSA in Liberia based on the benefits included but not limited to those listed below.

A 2015 USAID STUDY PREVIOUSLY RECOMMENDED TVWS TRIALS IN LIBERIA

In 2014, at the height of the Ebola Crisis, the author of this report, H Nwana (then Executive Director of the Dynamic Spectrum Alliance), visited Monrovia to present and advocate for a TVWS network design and deployment in Monrovia to support the fight against the Ebola Virus Disease (EVD). The project never proceeded, in part because there were no enabling regulations for using TVWS in Liberia. Later, in 2015 and in the immediate aftermath of the EVD crisis, USAID's implementing partner NetHope completed a detailed technical assessment of the then-operative Liberia Broadband Plan/Activities, including its backbone and last mile details[6]. Our technical team's USF Expert, Parvez Iftikhar, was one of that study's international experts. Rural pilots were one of the key recommendations from that team of experts. They encouraged rural rollout through pilots—using

[5] The later recommendations expand on this, but all spectrum regulators who have adopted TVWS regulations start with the regulator maintaining this up-to-date database.

[6] "Liberia Broadband Technical Assessment (Components 2 & 3) Backbone & Last Mile Details (New June 4) & Interim Findings (Updated June 4) NetHope Global Broadband and Innovations Alliance." NetHope, Global Broadband and Innovations Program, June 4, 2015. https://1e8q3q16vyc81g8l3h3md6q5f5e-wpengine.netdna-ssl.com/wp-content/uploads/2015/06/Liberia-Broadband-Technical-Assessment-NetHope.pdf.

mGSM/TVWS/other models, creating a pilot 30kms from the Backbone, requiring only investment in a point-to-point backhaul, and targeting up to 10 towns in Ebola-ravaged areas[7].

Unlike several other African countries where TVWS trials and regulations have materialized, there has been no significant progress along these lines in Liberia. However, in 2020 the LTA revisited TVWS with USAID, resulting in this workstream.

TVWS WOULD ENHANCE THE IMPLEMENTATION OF THE LIBERIA ICT POLICY (2019–2024)

The Liberia ICT Policy (2019–2024) has clear key objectives to which TVWS would be most relevant, particularly Objectives 1, 2, 4, 6, 7, and 9:

- Objective 1. Expand ICT infrastructure and establish a national fiber optic backbone to connect all 15 county capitals and cross-border connectivity with reliable links;
- Objective 2. Address last mile challenges to ensure universal access to voice services and broadband, supported by the adoption of infrastructure sharing and dig-once policies and effective use of the Universal Access Fund to meet the needs of underserved areas;
- Objective 4. Ensure critical ICT infrastructure is well protected and effective response mechanisms are in place to deal with cybersecurity issues and other physical disasters (e.g. epidemics);
- Objective 6. Foster the development of efficient Government E-services and online applications for supporting the growth of Liberia's economy;
- Objective 7. Establish a National Research and Education Network (NREN) for all tertiary and secondary education institutions to provide access to high-speed internet and digital educational services; and
- Objective 9. Use ICT to drive the inclusion of women, marginalized and indigenous groups.

Most TVWS deployments tend to complement Wi-Fi ones too. This is because whilst TVWS would typically provide the backhaul, the last mile would typically be Wi-Fi. Therefore, TVWS is a key emerging low-cost rural broadband *backhaul* solution that could help provide wider-spread Wi-Fi *last mile access* in rural (especially) and urban areas outside Monrovia, particularly as 4G/LTE is unlikely to be rolled out in these areas. Therefore, TVWS is a greenfield area for the LTA, MoPT, and the GoL. We support in this report that the Liberia ICT Policy (2019–2024) could benefit from TVWS policies and regulations enacted in Liberia.

TVWS WOULD ADD BROADBAND INTERNET OPTIONS, DRIVE MORE WI-FI USE, AND ENCOURAGE COMPETITION AND INNOVATION

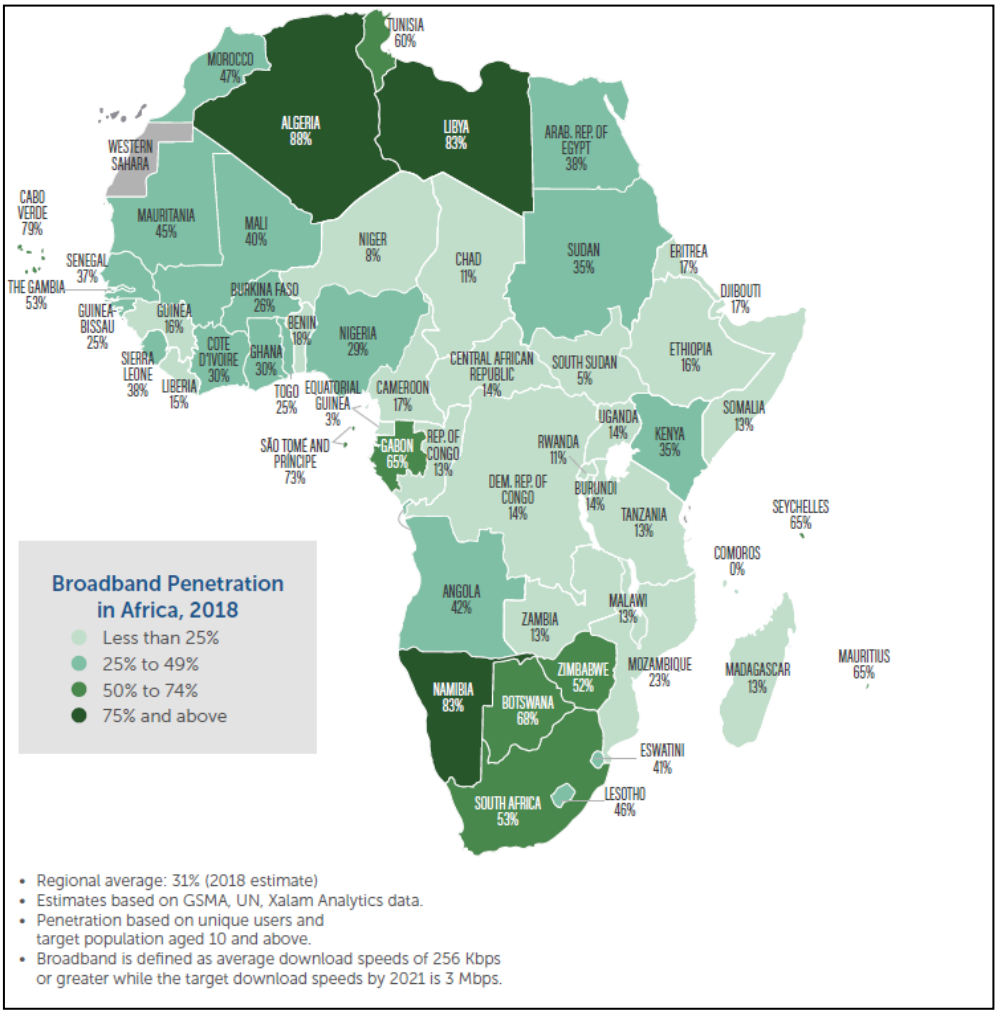
TVWS deployments across the world tend to complement traditional Wi-Fi. As broadband traffic grows exponentially, TVWS devices would greatly expand the utility and help reduce the cost of license-exempt devices for Government operations, promoting the use of more Wi-Fi in rural (and even urban)

[7] Ibid.

areas. The widespread use of license-exempt spectrum would provide great benefits to the Liberian economy as in Western economies via Wi-Fi-powered personal computers, printers, videogame consoles, streaming devices, security cameras, MP3 players, digital cameras, smartphones, tablets, etc. TVWS-enabled backhaul coupled with Wi-Fi-enabled last mile access could add to Liberia's current Internet options of 3G, 4G, and (limited) fiber.

For context, Liberia's civil war destroyed most of its limited fixed telecommunications infrastructure, leaving the country to operate as an almost entirely wireless telecommunications market. It is therefore dominated by two wireless mobile operators: Orange Liberia (OL) and Lonestar Cell-MTN (LC-MTN)

Figure 4. Mobile Broadband Penetration in Africa by Country (2018)



Source: The UN Broadband Commission[8] Moonshot Report.

Internet access is available primarily via the two main mobile operators, but also from the Liberia Telecommunications Corporation (LibTelCo) and several Internet Service Providers (ISPs) including K3

[8] "Connecting Africa through Broadband." 2019. Broadband Commission for Sustainable Development. https://www.broadbandcommission.org/Documents/working-groups/DigitalMoonshotforAfrica_Report.pdf.

Telecom, Electro Shack, PowerNet, and NAS Global. Internet access costs and prices are high and bandwidths/data rates are slow. Despite these several ISPs, a duopoly of the largest ISPs exists by a long margin in the country, and the small ISPs are not yet competitive as the following market shares clearly show.

As of June 2019, the telecoms market shares[9] between the two operators were as follows[10]:

Overall:	OL 66.3 percent, LC-MTN 33.7 percent
3G Market shares:	OL 75.4 percent, LC-MTN 24.6 percent
4G:	OL 100 percent

Therefore, the duopoly has little incentive to innovate and enhance and/or expand mobile data services, as they can continue to make greater margins from voice/SMS services. This in turn means the supply of data services is massively lower than demand, leading to higher prices without the incentive to provide higher quality services. This has led to Liberia trailing behind most African countries on broadband penetration as shown in Figure 5.

Regarding fiber availability, although Liberia is served by the ACE Landing Station that provides much-needed international submarine capacity, much investment in domestic fixed-line backbone infrastructure is still required to make optimal use of the ACE cable landing.

Currently, LibTelCo is the main broadband Internet fixed retail player with an estimated 25km of fiber infrastructure and circa 6,800 broadband customers representing a 1.1 percent household penetration.[11] Generally, the provision of mobile and fixed line services outside Greater Monrovia is poor, requiring the support of infrastructure (e.g., mobile, fiber, FWA, etc.) from the Universal Service Fund (USF) or direct government intervention.

Key Conclusion: Given the current structure of the Liberian wireless market dominated by 2G Voice, 3G/4G LTE internet mainly in Monrovia (at high prices) and minimum fiber, it is recommended that TVWS-enabled Wi-Fi be added to the broadband Internet solutions mix in Liberia, particularly for rural areas, but in urban areas too.

[9] "PSA for LTA New Regulatory Order 0016-02-25-19 on Floor Prices." 2019. Orange Liberia. September 1, 2019. https://www.orange.com.lr/en/psa-lta-floor-prices-orange-liberia.html.

[10] Loda, A, and K Cameron. "Liberia Divestiture Assessment Final Report." United States Agency for International Development (USAID) INVEST Project.

[11] Ibid.

3. BENEFITS OF ENABLING SHARED TVWS ACCESS IN LIBERIA

This section provides an overview of the expected benefits of providing shared access and license-exempting TVWS in Liberia, emphasizing its potential for fostering innovations and explaining that the International Telecommunications Union (ITU) would not object to Liberia and the LTA proceeding with such TVWS regulatory actions.

THE PHYSICS-BASED BENEFITS OF TV WHITE SPACES

The use of TV broadcast spectrum for mobile broadband has three main advantages deriving from sheer physics (Roberts *et al.* 2015).

1. **Greater distances:** Lower frequencies propagate further than higher frequencies. TVWS signals being typically in UHF bands in Africa (and sub-1GHz) can easily cover larger regions than 1800MHz and 2600MHz LTE by a factor of two to four respectively. While a typical Wi-Fi signal at 2400MHz frequency can cover approximately 100 meters, a TVWS signal at the same power level can easily travel 400 meters, and with higher powers can cover several kilometers. The Roberts *et al.* (2015) report on Microsoft TVWS deployments[12] covering 14+ kilometers distances at 10 Mbps user throughputs using conservative U.S./FCC mandated transmission parameters. Such 10 Mbps throughputs exceed expectations outlined in the Liberia ICT Policy (2019–2024). Given the rural nature of the Liberian population, TVWS would support wider-scale broadband internet in Liberia.
2. **Penetrates common obstructions:** While Wi-Fi transmissions do not usually pass through brick walls, TVWS radios, which operate at much lower frequencies, would easily penetrate walls and obstructions. The Roberts *et al.* (2015) report on a Microsoft experiment showed that in one of their buildings (222,000 sq. feet over four floors that has 150 Wi-Fi Access Points to provide high-speed access), they were able to cover *all parts* of the building using just a single TVWS base station operating at 20 dBm (100 MW) with a 2 dBi gain antenna[13]. This suggests the powerful potential of TVWS radios across Liberian university campuses, shopping centers, hotels, and other multi-dwelling units. For example, in Ghana, Microsoft and SpectraLink Wireless launched a commercial TVWS network at Koforidua Polytechnic with over 8,500 students in 2015[14].
3. **Greater efficiencies**: Because the TVWS signals travel farther than Wi-Fi signals—and TVWS base stations and devices are getting cheaper with volumes—a typical TVWS deployment would cost less and consume less power than Wi-Fi or mesh-based topologies to cover sparsely populated areas in Liberia and Africa. TVWS deployments are more economical than LTE deployments in such sparsely populated scenarios in Africa.

TVWS APPLICATIONS TO DATE ARE RELEVANT TO THE LIBERIAN CONTEXT

Wireless broadband operators and other service providers across the globe who have used the TVWS spectrum have covered applications very relevant to Liberia, including:

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[12] Microsoft has been undoubtedly the biggest advocate for TVWS over the past decade. They founded the Dynamic Spectrum Alliance under the Chairmanship of Paul Garnett.

[13] For the more technically inclined, the lowest received signal strength over a 6MHz channel was -79dBm.

[14] "Microsoft, Facebook Launch TV White-Space Pilot in Ghana." FierceWireless. Accessed May 25, 2021. https://www.fiercewireless.com/tech/microsoft-facebook-launch-tv-white-space-pilot-ghana.

- **Bridging the Digital Divide by delivering broadband in rural or hard to serve areas:** Broadband Internet in Liberia today (in Q1/Q2 2021) hardly goes beyond the wider Monrovia Metropolitan Area, the country's capital. In many cases around the world, a combination of TVWS devices and Wi-Fi has been shown to deliver broadband more economically to rural areas like in Kenya and Colombia (see later in this report). Generally, mobile and fixed line services outside the Greater Monrovia area are poor and will require more infrastructure (e.g., TVWS, mobile, fiber, FWA, etc.) support from the USF or direct government intervention. Even in the U.S. (in the Commonwealth of Virginia), TVWS is enabling and closing the rural broadband Internet "homework gap" wherein rural students who have no access to the Internet and computers have been connected through TVWS technologies and regulations[15]. Similarly in Kenya, Mawingu uses TVWS technology and solar-powered base stations to deliver low-cost broadband connectivity in Kenya's rural Laikipia County, including its capital Nanyuki[16]. In general, whitespaces would be used to provide rural locations with broadband Internet services—typically achieved by building a network of Access Points that use TVWS to link remote houses and villages to larger towns that are already connected to the Internet. Figure 4 shows that Liberia is lagging behind most countries in Africa on mobile broadband connectivity at 15 percent in 2018, suggesting any tools to further bridge the digital divide should be encouraged and implemented, including TVWS spectrum sharing;

- **Last mile access to augment citywide or wide-area data networks:** The last mile or last kilometer typically refers to the final leg of a telecommunications network delivering services to end-users. In the developed world like the U.S. or the U.K., physical copper, fiber, or coaxial cable lines connect houses to local exchanges and cable or fiber head-ends. In Liberia (and Africa), such physical connections are not affordable or economical, particularly in rural areas. Furthermore, this last mile/kilometer is also typically a speed bottleneck. Currently, 4G LTE or 3G provide the typical last mile/kilometer connectivity in Liberia. The cost per user of last-mile networks varies based on the density of the population in the locality where the network is built. In areas of low-density localities, where the distance between households is larger, the last mile infrastructure would be shared among fewer users, raising their costs significantly. In short, the network deployment costs in the last mile are inversely proportional to population density. Because Liberia is very rural, TVWS and Wi-Fi would provide an obvious alternative last mile solution in Liberia, particularly outside the Greater Monrovia area. With 15 percent mobile broadband connectivity in Liberia (as shown in Figure 4), last mile access is critical;

- **Enhanced Wi-Fi:** As previously suggested, TVWS is typically used complementarily with Wi-Fi and would therefore drive greater use of Wi-Fi and other unlicensed services such as Zigbee, Radio Frequency Identification (RFIDs), remote car door openers, and more. This greater use of Wi-Fi across rural Liberia in schools and health centers will bolster economic growth;

- **Urban Broadband data offload from mobile networks using Wi-Fi:** As mobile data traffic rises exponentially across cities like Monrovia, Buchanan, and other African capitals or major cities,

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[15] "Mid-Atlantic Broadband Communities and Microsoft Launch New Homework Network to Bring Thousands of Students Online in Rural Virginia." 2017. Stories. https://news.microsoft.com/2017/05/23/mid-atlantic-broadband-communities-and-microsoft-launch-new-homework-network-to-bring-thousands-of-students-online-in-rural-virginia/.

[16] "Affordable Broadband Uses TV White Space to Bridge the Digital Divide in Rural Kenya." n.d. Nethope. Accessed May 27, 2021. https://nethope.org/project/mawingu-tv-white-space/.

Wi-Fi hotspots typically emerge to "offload" this traffic onto Wi-Fi last-mile access networks complemented by TVWS backhaul. TVWS signals, which travel much farther than Wi-Fi signals (as they operate at much lower frequencies) allow for last mile access Wi-Fi hotspots. Therefore, TVWS backhaul equipment would help reduce the number of Wi-Fi access points across an entire business park, university campus, or even central business districts;

- **Machine-to-machine communications (M2M) / Internet of Things (IoT):** Smart grid and health-care applications, traffic sensors, solar sensors, agricultural sensors, weather sensors, etc. are all emerging M2M/IoT applications connected to centralized machine nerve centers. The key benefit is that TVWS could be used to wirelessly transmit using its additional range deep inside buildings (e.g., for wirelessly measuring utility meters in consumers' homes, inventory management, etc.). TVWS would provide more economical wider coverage unmanned networks (e.g., weather networks, monitoring traffic, monitoring electricity networks, etc.) across Liberia and Africa;

- **Distribution of local content and in-building media distribution:** TV whitespaces can be used for distributing local broadcast content, like local TV, for some localities. It could also be used for in-building media/content distribution of content;

- **Local government, education, healthcare, and public safety applications:** In many countries, TVWS is already being used by local governments for connecting schools, health centers, churches, voting centers, and more, as well as providing access to public safety applications such as fire, police, and ambulance services. In general, educational and health services are easily enabled in rural Africa using TVWS devices and traditional Wi-Fi. In the State of Ohio in the U.S., TVWS has enabled broadband access for healthcare providers throughout a local hospital including patient rooms, waiting areas, cafeterias, and meeting rooms[17]. TVWS also enabled outdoor video surveillance to provide additional security for hospital operations;

- **Location-based services:** This use case follows on from the super Wi-Fi use case. If there is a super Wi-Fi hotspot that covers an entire city center, then providing location-based services makes great sense. Content would be provided that is truly local about amenities, restaurants, etc. Restaurant bookings (reservations), route finding, and location information are perhaps services with no fixed world competition. Imagine asking the nearest restaurant or cinema—TVWS would easily enable such location-based services; and

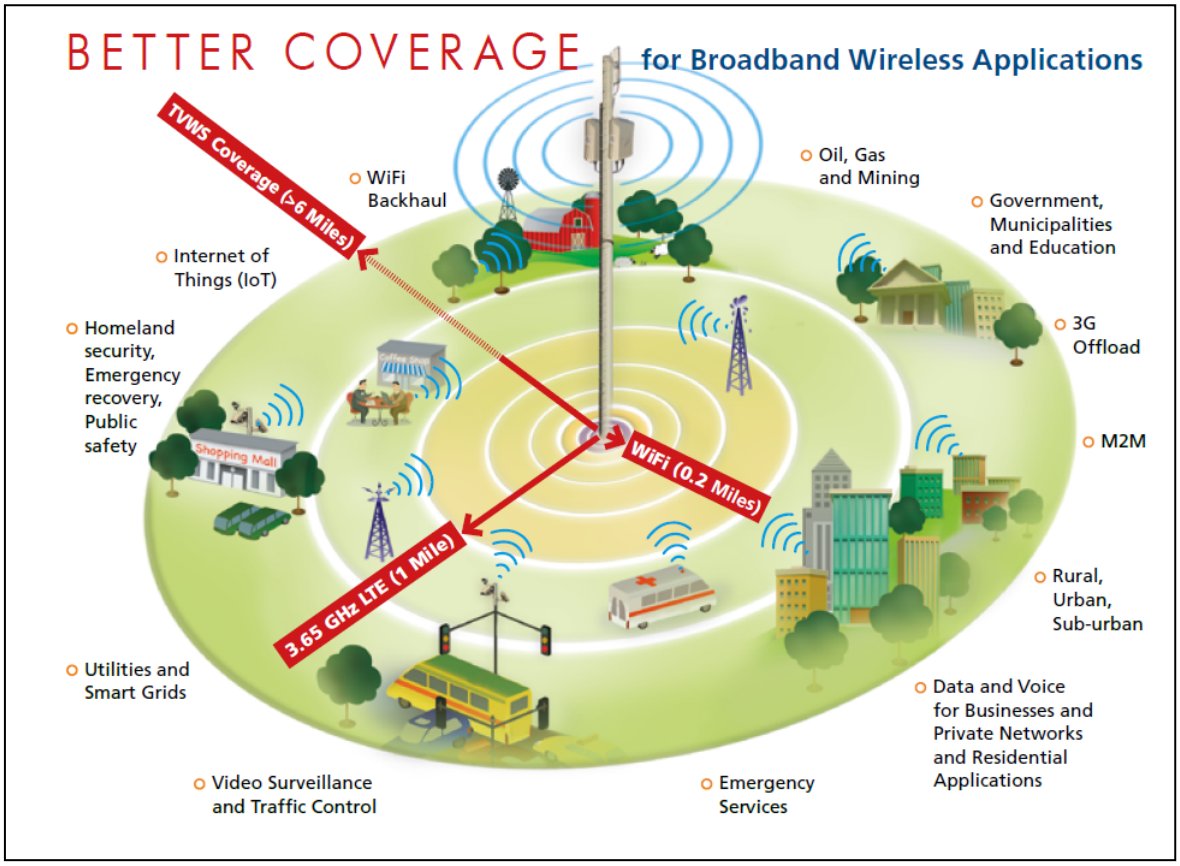
- **Extension of the fiber footprint:** TVWS could be used as an extension of the fiber footprint in Liberia, particularly as fiber backbones are built across the country, but still many kilometers away from village hubs. While it would not make economic sense to run fiber to a population of a hundred poor villagers, TVWS devices would enable traffic from the villagers to a fiber point of presence (PoP) kilometers away, away nurturing use cases that could help rationalize higher capacity fiber buildouts over time.

Figure 5 on the following page provides a visual summary of the likely role and utility of TVWS compared to LTE and Wi-Fi. It shows the wider TVWS coverage into rural and more sparsely

[17] "Ohio Hospital Launches White Space Broadband Trial." 2011. TVTechnology. 2011. https://www.tvtechnology.com/amp/news/ohio-hospital-launches-white-space-broadband-trial.

populated areas, but also where essential and other connectivity services are still required for public safety, utilities/smart grids, video surveillance, data/voice services for business, government, municipalities, education, oil, gas, etc.

Figure 5. TVWS Enables Better Coverage for Broadband Wireless Applications



Source: Runcom 4G TVWS Solutions.[18]

All of these use cases and more are likely applications that Liberian entrepreneurs, in (semi) rural areas in particular, would innovate. These use cases, along with those shown in Figure 4, would promote the Liberia ICT Policy (2019–2024).

THE BENEFITS OF ENABLING TVWS ACCESS ON A LICENSE-EXEMPT MODEL

TVWS unused spectrums abound in Liberia as presented in Table 1 on the following page. Enabling access to the TVWS spectrum that is *primarily* assigned to broadcast TV for other uses on a secondary and opportunistic basis achieves sharing. This leads to the question of how this shared access gets enabled. There are typically three options:

[18] "4G End-To-End Mobile Solutions • 470-698MHz Coverage • Enhanced Capacity Using Channel Aggregation (30Mbps) • 4 Sectors in One Unit • No Self Interference by GPS Synchronization • Affordable User Terminals • Inherent Redundancy Using the Terminals Handoff Feature • Distributed TVWS Server Using Multiple TVWS Data Bases." Accessed May 25, 2021. https://www.winncom.com/pdf/Runcom_RNU4000BS/Runcom_4G_TVWS_Brochure.pdf.

1. **Licensed access to the TVWS spectrum being shared:** For example, the regulator (LTA) would allow other non-broadcast (e.g., mobile broadband) and opportunistic/secondary use of the unused TVWS spectrums at various localities—but on a licensed basis. Licensing would mean secondary use of the TVWS spectrum in Liberia would be subject to rights and obligations from the LTA, with likely obligations including paying license fees (like broadcast TV users), paperwork for applying for the licenses, bureaucracy in dealing with the LTA from rural areas, reporting requirements to the LTA, etc. While there is a rationale for the regulator managing the spectrum—to mitigate against interference—this should be balanced with the relative risks of any such interference into the primary broadcast TV users, which is very low because there are so few TV channels on air.
2. **Light licensing of TVWS:** (see Nwana, 2014, p. 259–260) Light licensing means the regulator (the LTA) keeps records of TVWS spectrum use but does not manage the spectrum per se because incumbents like TV stations can be protected through record keeping and through implementing exclusion zones. Light licensing could also be implemented via a TVWS database.
3. **License-exempt TVWS Spectrum:** Enabling access to TVWS spectrum in Liberia on a licensed-exempt basis that goes beyond database management, to secondary uses of the TVWS spectrum that meet minimal bureaucracy, paperwork, and management practices by the regulator.

Enabling TVWS on a license-exempt basis would have significant consumer and citizen benefits in Liberia as exemplified by Mawingu, Kenya. Nwana (2014) (pp 267-273) provides a comprehensive overview of the Mawingu approach and technology to deliver low-cost, high-speed wireless broadband to locations not even served by electricity, connecting poor, remote or low population areas. Core to the Mawingu approach is the shared secondary and opportunistic use of the unused UHF broadcast spectrum that this Report recommends in Liberia for mobile broadband through a license-exempt TVWS spectrum sharing framework. This is not only because license-exempt networks carry the majority of the world's data traffic today, but also because of the innovation potential that comes with license-exemption, as is also the case with Wi-Fi. The benefits of using shared license-exempt TVWS in Liberia follow.

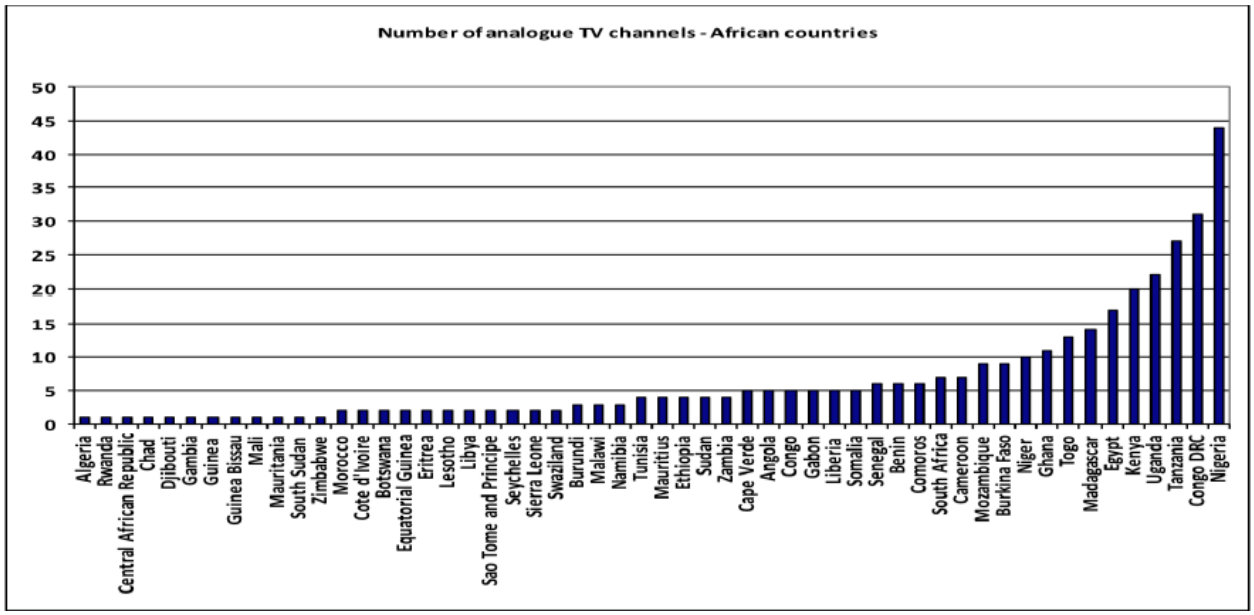
Table 1. TV Assignment and Allocation in Liberia

Television Frequency Allocation and Assignment Details				
CH No.	Frequency	Bandwidth	Status	Comment
21	474	8MHz	Free	
22	482	8MHz		
23	490	8MHz		
24	498	8MHz		
25	506	8MHz		
26	514	8MHz		
27	522	8MHz		
28	530	8MHz		
29	538	8MHz		
30	546	8MHz		
31	554	8MHz	Assigned	
32	562	8MHz		
33	570	8MHz		
34	578	8MHz		
35	586	8MHz		
36	594	8MHz		
37	602	8MHz		
38	610	8MHz		
39	618	8MHz		
40	626	8MHz		
41	634	8MHz		
42	642	8MHz		
43	650	8MHz		
44	658	8MHz		
45	666	8MHz		
46	674	8MHz		
47	682	8MHz		
48	690	8MHz		

Source: Liberian Telecommunications Authority (LTA).

Table 1 depicts that ten 8MHz channels from Channels 21 to Channel 30 (i.e., 474MHz to 546MHz) are completely unused across Liberia, and are essentially white bands. The remaining 17 channels are assigned to TV channels, but recalling from Figure 1, it does not mean that all assigned frequencies are used everywhere in Liberia (i.e., there are lots of TVWS). As shown in Figure 7, Liberia has only five analog channels on air confirming that unused TVWS abound in Channels 31 to 48 confirming the under-utilization of TV channels in Africa.

Figure 6. Analog TV Channels Across African Countries (43 Percent Only Have One to Two Analog TV Channels)



Source: Russell Southwood, Balancing Act.[19]

Given the above, a key recommendation of this report is to enable access to TVWS spectrum in Liberia on a licensed-exempt basis. Most countries that have enabled shared access to TVWS have also taken this approach. Nwana (2014, pp. 253–256) expounds on the approach in more detail but the core reasons are summarized below:

1. First, the license-exempting spectrum has a very good history of generating consumer and citizen value to society from just tiny bits of spectrum. Wi-Fi is the poster child for a license exemption. License exempting TVWS in Liberia minimizes barriers to use and quick access to the spectrum. There would be no quality of service (QoS) guarantees. TVWS devices operate at much lower powers enabling many users and minimizing (to zero in most/all cases with the TVWS database approach) any interference to primary TV broadcasts.
2. Second, a license exemption of TVWS bands will drive more economic growth. To date, most of the more than twelve countries that have adopted rules authorizing the use of TVWS have done so on a license-exempt basis.[20] As Google (2015) notes,

[19] "ITU: Committed to Connecting the World." International Telecommunications Union. Accessed January 2021. http://groups.itu.int/LinkClick.aspx?fileticket=Xs6PiYHrw-w%3Dandtabid=1862.

[20] See Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd. 18661 (2010); Industry Canada, Framework for the Use of Certain Non-Broadcasting Applications in the Television Broadcasting Bands Below 698 MHz (2012), available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10493.html; Press Release, Industry Canada, Enhancing Wi-Fi Services in Rural Communities (Feb. 15, 2015), available at http://news.gc.ca/web/article-en.do?nid=928659; Infocomm Development Authority of Singapore, Regulatory Framework for TV White Space Operations in the VHF/UHF Bands (2014), available at http://www.ida.gov.sg/~/media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf; Ofcom, Implementing TV White Spaces (2015), available at http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/statement/tvws-statement.pdf.

> "Regulators in each of these countries recognized that license-exempt access to spectrum contributes billions to the global economy, and expanding that access will drive further economic growth. For example, technologies like Wi-Fi expand and improve access to broadband, and have saved mobile network operators billions of dollars in network deployment costs."

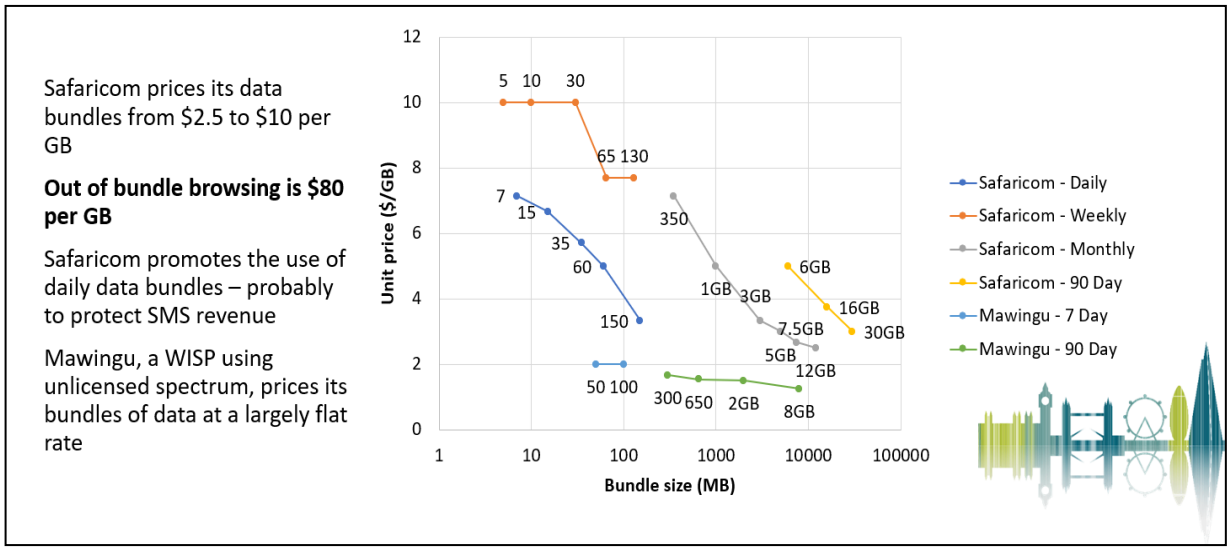
To illustrate the potential impact on economic growth in Liberia, Figure 7 provides real data from competition to 3G/4G LTE in Kenya from a small WISP called Mawingu (described briefly earlier) employing TVWS technology. The dominant and biggest mobile operator in all East Africa Safaricom priced its data bundles from $2.5 to $10 per GB and charged $80 per GB if they strayed outside of their bundles.

In contrast, Mawingu, a WISP, using unlicensed spectrum, prices its bundles at a largely flat rate. Mawingu's reaches 20,000 people in the Laikipia County of Kenya and covers 235 km^2 (square km) including 1,100 K-12 students. The network provides broadband and ICT labs to five schools, a health clinic, county government, restaurants, farms, library services, etc. Along with the flat rate and cheapest pricing (Figure 7), imagine the economic impact of the use of this unlicensed spectrum in this part of Kenya to consumers (i.e., those buying the bundles from Mawingu) and citizens benefiting from libraries, county government services, etc.

These benefits are also possible in Liberia through license-exempting TVWS spectrum. Other studies report on the potential value that can be derived from allowing license-exempt access to broadcast spectrum.[21] Nwana (2014, pp 267–279) details the Mawingu approach, which USAID helped enable along with Microsoft, which is worth replicating in rural or semi-rural Liberia.

[21] Though six to eight years old, these studies are still authoritative e.g., Raul Katz, Assessment of the Economic Value of Unlicensed Spectrum in the United States (2014) (estimating that license-exempt spectrum use contributes over $200 billion per year to the U.S. economy); Raul Katz, Assessment of the Future Economic Value of Unlicensed Spectrum in the United States (2014) (estimating that by 2017, Wi-Fi will contribute $547.22 billion in economic surplus to the U.S. economy on an annual basis), available at http://www.dynamicspectrumalliance.org/assets/Katz-Future-Value-Unlicensed-Spectrum-final-version-1.pdf; Richard Thanki, The Economic Significance of Licence-Exempt Spectrum to the Future of the Internet (2012), available at http://www.wirelessinnovationalliance.org/index.cfm?objectid=DC8708C0-D1D2-11E1-96E9000C296BA163.

Figure 7. Mawingu Data Pricing in Kenya (2018) vs. Safaricom



Source: Dynamic Spectrum Alliance and Richard Thanki.[22]

3. Finally, license-exempting TVWS in Liberia will enable more innovation and experimentation as is evident with the Mawingu WISP in Kenya. As Google (2015) notes "The balance of access to licensed bands, such those used by traditional mobile operators, and license-exempt bands which power many low-power technologies such as Wi-Fi, cordless phones, and baby monitors, have served many countries well. While access to licensed spectrum provides large operators some level of certainty regarding access to spectrum, license-exempt access can accelerate technology development because innovators can introduce products and services without seeking permission from spectrum licensees." Thousands of new license-exempt devices are released to the market and certified each year including Wi-Fi, Bluetooth,[23] Zigbee,[24] and RFID[25] devices, and are all experiencing rapid growth in the last several years.[26] As previously discussed, there is also increasing demand for machine-to-machine and IoT technologies, smart grids, wireless payments devices, wireless healthcare, inventory management, using sensors in farms, and more. Such innovations would be possible in Liberia during the current decade.

The Kenya case study above illustrates that shared access to TVWS spectrum in Liberia, if prioritized, could benefit both consumers and citizens. A licensed, a light licensed, or a licensed-exempt framework approach could be used, although the recommendation is a license-exempt approach for reasons provided in the prior subsection. In all three approaches, a database would be necessary to enable DSA access to the unused TV frequencies at any locality. Africa, Ghana, and South Africa, for example, have

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[22] "Resources." Dynamic Spectrum Alliance. Accessed February 1, 2021. http://dynamicspectrumalliance.org/resources/#Economic_Social.

[23] Bluetooth is a standard facilitating hands-free operation of music players, mobile phones, and other devices.

[24] Zigbee powers technologies that benefit from ad hoc and mesh networking solutions, such as home automation.

[25] Radio Frequency Identification (RFID) technologies are used in a variety of industries to track inventory or other objects.

[26] Four years ago, Mark Cooper assessed the state of innovation in the wireless ecosystem and concluded that hundreds of companies serve the license-exempt market, while the market for licensed devices is more concentrated. See Mark Cooper, Efficiency Gains and Consumer Benefits of Unlicensed Access to the Shared Public Airwaves 26 (2011), available at http://consumerfed.org/pdfs/EFFICIENCYGAINS-1-31.pdf.

opted for license-exempt TVWS frameworks while Kenya has opted for a light-license TVWS framework. All three countries' frameworks require TVWS databases.

Notably, a sharing framework could begin without a database. The regulator would use a starting framework where TVWS channels are allocated and assigned to Internet Service Providers (ISPs) manually and tracked in the Regulator's spectrum management software (SM4DC). This approach is strongly recommended because TVWS sharing could benefit consumers and citizens while the details of the TVWS database frameworks and logistics are explored and decided.

In conclusion, expediting shared access to unused TVWS spectrum is not only feasible from a technical and regulatory perspective, but could also have an important economic impact in Liberia, as observed in Kenya.

4. TVWS REGULATORY EXAMPLES ACROSS AFRICA AND SELECTED OTHER COUNTRIES

This section provides an overview of TVWS activities (and their regulatory frameworks) across Africa in particular, but also across selected relevant countries across the globe (e.g., Colombia).

Many countries across the globe have already adopted fully-fledged frameworks and rules (or are in the process of doing so) for the use of TVWS as shown in Figure 8.

Figure 8. TVWS Regulations Across the Globe

Source: Dynamic Spectrum Alliance,[27] current as of May 2020. As noted earlier, the author of this report was the Founding Executive Director of the Dynamic Spectrum Alliance where he helped pioneer the key roles for Regulators and Governments.

In Africa (as of May 2020), Ghana, Uganda, Mozambique, and South Africa have already adopted TVWS frameworks and rules as shown in Figure 9, while similar rules and frameworks were in progress in Nigeria, Kenya, Botswana, and Guinea Bissau. As of February 2021, TVWS frameworks and guidelines in Nigeria and Kenya are being finalized for adoption following consultation exercises.

KEY ROLES FOR GOVERNMENTS AND REGULATORS ON TVWS REGULATIONS

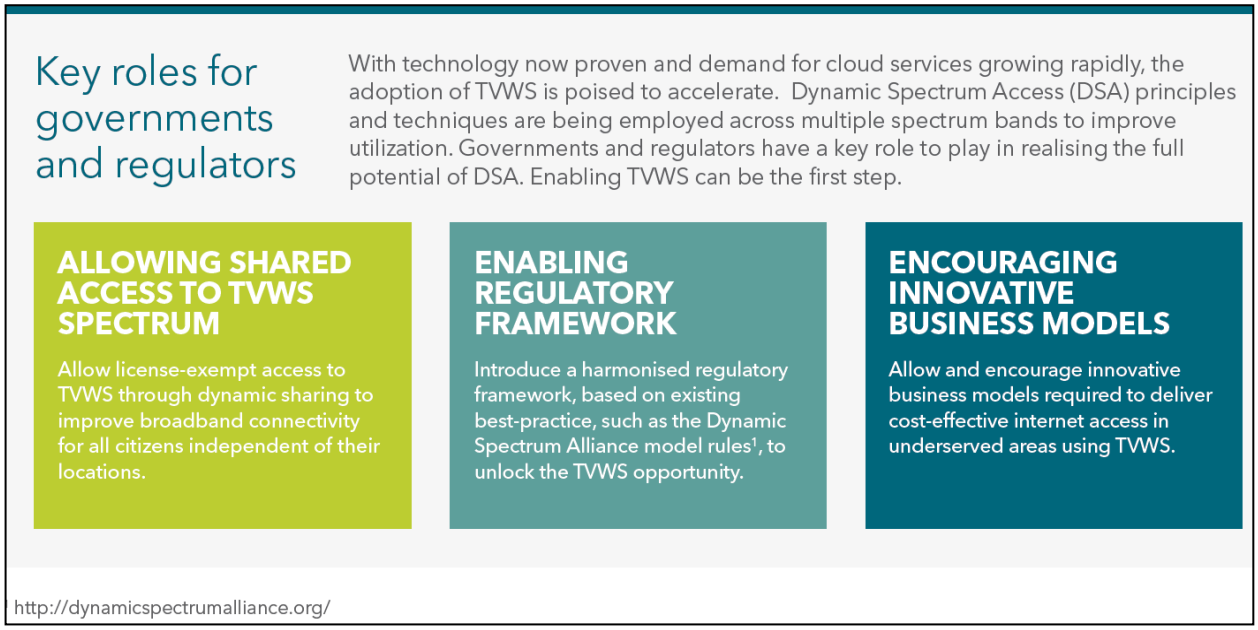
Figure 9 on the following page speaks outlines the roles for Governments and Regulators: 1) allowing shared access to the TVWS spectrum as recommended in Section 3, 2) enabling the Regulatory Framework, and 3) encouraging innovative business models.

[27] Ibid.

The previous sections outlined the case for allowing shared access to the TVWS spectrum in Liberia. This section examines some TVWS regulatory frameworks that have been adopted in Africa and elsewhere across the globe. The ITU recognizes that no international action is required for Regulators to Proceed with Authorizing Access to TVWS

Practically all countries in Africa are signatories to the Constitution and Convention of the ITU, as well as the ITU's Radio Regulations. Radio Regulations try to harmonize the international spectrum across all countries to maximize economies of scale of the use of similar equipment worldwide. However, the ITU's rules make clear that no ITU action is necessary to enable the use of TVWS on an opportunistic basis.[28] Therefore, Member States can pursue such TVWS policies without concern of being contrary to radio regulations and without waiting for further international guidance or studies. Indeed, the former Director of the ITU's Radiocommunication Bureau, Francois Rancy, observed that authorizing dynamic spectrum access, including access to white spaces is "Essentially in the hands of national regulators in each country."[29]

Figure 9. Key Roles for Government and Regulators on TVWS Frameworks



Source: Dynamic Spectrum Alliance.[30]

AFRICA TVWS REGULATORY FRAMEWORKS AND RULES

[28] See Radio Regulations Art. 4.4 (2012) (recognizing that secondary and opportunistic use is permitted so long as such uses do not cause harmful interference to the primary user), available at https://www.itu.int/pub/R-REG-RR.

[29] François Rancy, Director, ITU Radiocommunication Bureau, Remarks at the ITU Radiocommunication Seminar for Arab Countries (Dec. 13, 2013). At the same meeting, Rancy also noted that regulators can take advantage of best practices and are currently being considered by ITU-R Study Groups 1, 5, and 6. See id.

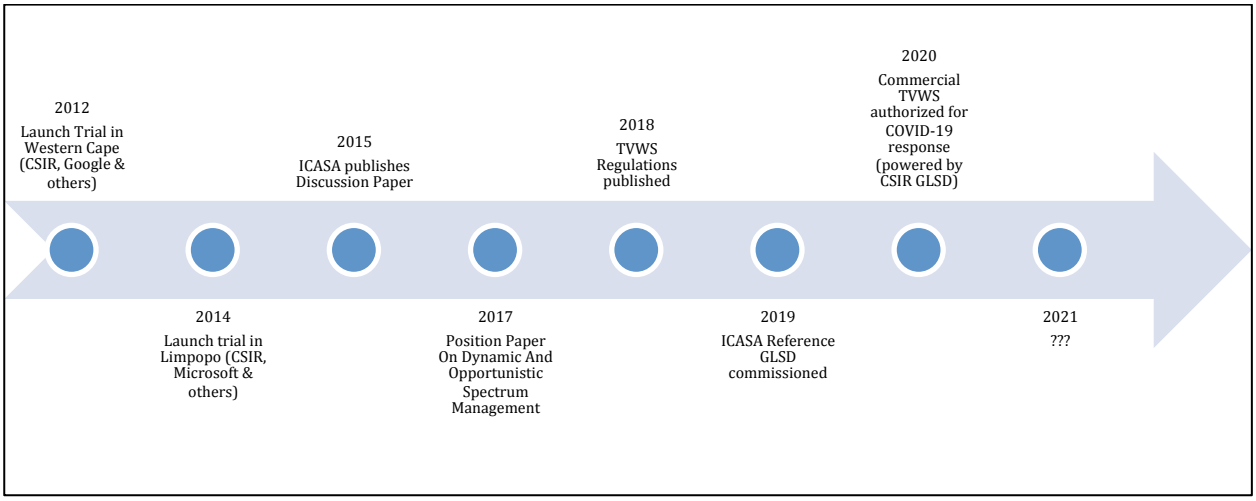
[30] Ibid.

Beginning with high-level summaries of the TVWS frameworks and rules in the four African countries that have adopted TVWS rules (plus Kenya), this section also briefly reviews other TVWS efforts across other African countries.

SOUTH AFRICA

South Africa was the first African country to fully adopt a TVWS framework and set of rules in 2018 after a long process, as shown in Figure 10.

Figure 10. TVWS Timeline in South Africa



Source: CSIR[31]

The 2018 TVWS framework and regulations allow for the operation of TVWS devices on a licensed-exempt basis[32]. Devices rely on TVWS database to avoid interference with protected primary TV broadcast services. The South African TVWS regulatory framework allows for TVWS use in the 470 MHz to 694 MHz (excluding the Radio Astronomy sub-band of 606MHz to 614MHz) on a secondary basis by White Space Devices (WSDs).

The TVWS framework and rules adopted by the Independent Communications Authority of South Africa (ICASA)[33] prescribes that all operations of WSD networks be controlled by Secondary Geo-Location Spectrum Database (S-GLSD) providers. Essentially, the rules authorize private and public secondary database operations using the ICASA Reference GLSD without placing a limit on the number of database providers offering services. ICASA will remain responsible for monitoring the activities of S-GLSD providers enforcing compliance with the TVWS regulations through the Reference Geo-Location Database (R-GLSD). The latter tool is, therefore, key to enabling ICASA to implement the TVWS regulatory framework in South Africa.

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[31] "Television Whitespaces - a New and Innovative Way to Connect People | CSIR." www.csir.co.za. Accessed February 1, 2021. https://www.csir.co.za/television-whitespaces-connect-people.

[32] Icasa.org.za, 2021. https://www.icasa.org.za/legislation-and-regulations/regulations-on-the-use-of-television-white-spaces-2018.

[33] Independent Communications Authority of South Africa. Accessed May 25, 20121. https://www.icsas.org.za.

ICASA has not only imposed security and certification qualification requirements of databases via the R-GLSD, but the WSDs must also be type-approved as compliant with the TVWS framework and regulations. The rules establish varying maximum power levels based on the presence of primary incumbents, and the WSDs must comply with the European Telecommunications Standards Institute (ETSI) emissions masks limits/standards. This is because ETSI has developed a harmonized European standard for white space devices, and this standard could easily be extended to Region 1.[34]

The ICASA rules authorize two classes of devices: Fixed WSD or a Nomadic WSD, and only a fixed WSD can be a Master WSD while Nomadic WSDs must be clients to a Master WSD.

WSDs are also allowed to operate adjacent to occupied TV channels while complying with out-of-band emissions masks in the latest ETSI EN 301 598 standard or successor directives[35].

GHANA

Ghana followed South Africa and adopted its version of a TVWS framework and set of rules in May 2019, following a period of six years. The regulator, the National Communications Authority (NCA)[36] collaborated with Google to map the available TVWS spectrum in the country in July 2013. Microsoft and Spectra Wireless later collaborated to run a six-month trial in Ghana that was successful. The network was used to undertake the following: 1) provide internet services during the DSA Global Summit held in Accra in 2014, and 2) provide internet services for some institutions. The NCA subsequently authorized Spectra Wireless to commercially operate TVWS in the UHF band (470MHz–694MHz) even before the eventual TVWS regulations of 2019.

Ghana's TVWS framework and regulations[37] allow for the operations of TVWS devices on a licensed-exempt basis[38]. Devices rely on geo-location capability and TVWS database access to avoid interference with protected primary TV broadcast services. The Ghanaian TVWS regulatory framework allows for TVWS use in both UHF Band IV (470–528 MHz) and UHF Band V (528–694MHz).

Like with the U.S. TVWS rules (see later), TVWS devices in Ghana may rely on either databases or sensing to avoid interference with primary incumbent services. The NCA must approve any TVWS database in Ghana as compliant with the TVWS framework and rules. The rules establish four classes of TVWS devices: Fixed, Mode I fixed, Mode I portable (no internal geo-location) and Mode II portable (with internal geo-location). A Master Device that controls Client Mode I devices may either be a Fixed or a Mode II portable. Client TVWS Mode I devices can only operate on available frequencies determined by its Master Fixed or Mode II device. Fixed devices must limit their power to no more than 4W EIRP (36 dBm) within the six metropolitan districts and up to 10W (40 dBm) ERP elsewhere. Personal/portable devices are limited to 100mW (20 dBm) equivalent, isotopic radiated power (EIRP).

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[34] ETSI, ETSI EN 301 598 V1.0.0 (2013) available at http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.00.00_20/en_301598v010000a.pdf

[35] "ETSI - Welcome to the World of Standards!" ETSI. Accessed May 25, 2021. http://www.etsi.org/technologies-clusters/technologies/regulation-legislation/red.

[36] National Communications Authority

[37] "National Communications Authority Guidelines for the Operation of Data Services Using TVWS in Ghana V1.0." 2019. https://www.nca.org.gh/assets/Uploads/Guidelines-for-TVWS-Data-Services.pdf.

[38] Icasa.org.za, 2021. https://www.icasa.org.za/legislation-and-regulations/regulations-on-the-use-of-television-white-spaces-2018.

TVWS Devices must be type-approved as compliant with the TVWS framework and regulations. The rules establish out-of-band emissions masks must comply with the out-of-band emissions masks in Section 4.2 ETSI EN 301 598 standard or successor directives[39]. Unlike in South Africa, TVWS devices are not allowed to operate adjacent to occupied TV channels.

UGANDA

Uganda followed Ghana in Africa and adopted its TVWS framework and set of rules[40] in November 2019 by the regulator, the Uganda Communications Commission (UCC)[41].

Uganda's TVWS framework and regulations allow for the operation of TVWS devices on a license-exempt basis and also allow for TVWS use in 470 MHz to 694 MHz.

TVWS Devices in Uganda may rely on either databases or sensing to avoid interference with primary incumbent services. UCC must approve any TVWS Geo-Location Databases (GLDB) in Uganda as compliant with the TVWS framework and rules. There could be several such compliant databases in Uganda operated by eligible persons, operators, a consortium of operators, or a Ugandan statutory organization.

The rules establish two classes of TVWS devices: Fixed white space devices (WSDs) and Portable WSDs—and both classes may be Master or Client. However, a Master WSD, which controls Client WSD, must be able to communicate with an approved GLDB. Fixed devices must limit their power to no more than 4W EIRP (36 dBm) and must comply with out-of-band emissions of no more than -56.8dBm/100KHz. Client WSDs are limited to 100mW (20 dBm) EIRP.

WSDs must be type-approved as compliant with the TVWS framework and regulations and abiding by the ETSI EN 301 598 standard or successor directives[42]. Like in South Africa, TVWS devices are allowed to operate adjacent to occupied TV channels as long as they abide by out-of-band limits.

MOZAMBIQUE

Mozambique adopted its TVWS Framework and Rules[43] in August 2019 by the regulator, Autoridade Reguladora das Comunicacoes (ARECOM).[44] Mozambique's Communications Regulatory Authority has approved a new TV-White Space (TVWS) technical standard to regulate the use of frequencies in the 470MHz-694MHz band. ARECOM noted that the measure would enable it to share these UHF frequencies to wireless broadband services without impacting TV broadcasters, which utilize the spectrum.

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[39] ETSI.

[40] "Standard for Television White Spaces Access and Use in Ghana." Uganda Communications Commission, November 2019. https://www.ucc.co.ug/wp-content/uploads/2017/09/UCC-TVWS-standards.pdf.

[41] Ibid.

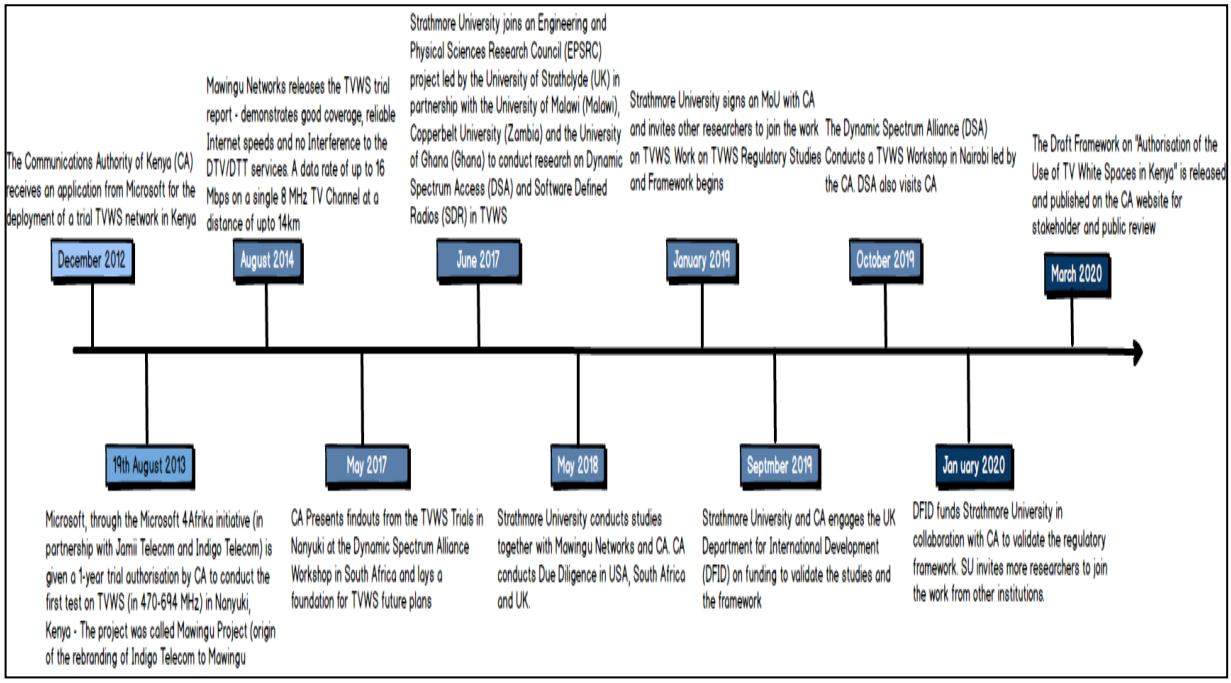
[42] ETSI.

[43] "Resolucão Que Aprova a Norma Técnica TV-White Space (TVWS)." Accessed May 25, 2021. https://www.arecom.gov.mz/index.php/mercado/documentos-telecomunicacoes/190-resolucao-que-aprova-a-norma-tecnica-tv-white-space-tvws.

[44] Autoridade Reguladora das Comunicacoes.

Mozambique has largely adopted the recommended Dynamic Spectrum Alliance's TVWS model rules.[45]

Figure 11. TVWS Timeline in Kenya



Source: Strathmore University, Kenya.[46]

KENYA

AS we started writing this report, Kenya was close to adopting a TVWS framework and set of rules[47] after a long process as shown in Figure 11. Then, as this Report was being finalized, Kenya finally approved and gazetted its TVWS Regulations[48].

The history of TVWS in Kenya began in 2013 with a Microsoft 4Afrika Trial Authorization from the regulator in the vicinity of Nanyuki and Kalema – yet again the Mawingu project (see Nwana, 2014, pp. 267) – a project that also involved both Microsoft and USAID. The results demonstrated:

- No interference to the incumbent DTV services;
- Point-to-multipoint coverage of up to 14km;
- TVWS operated at 2.5W (EIRP Measurement);

[45] Dynamic Spectrum Alliance.

[46] Strathmore University, personal communication.

[47] "Authorisation on the Use of TV White Space." Communications Authority of Kenya. February 2020. https://ca.go.ke/wp-content/uploads/2020/03/Authorisation-of-the-use-of-TV-White-Spaces.pdf.

[48] Pai, Shailaja. "Kenya Approves TVWS Framework." Developing Telecoms. Accessed May 25, 2021. https://www.developingtelecoms.com/telecom-business/telecom-regulation/11175-kenya-approves-tvws-framework.html.

- Approximately 235km^2 covered using multiple 90-degree base station sector antennas;
- Approximately 16 Mbps of speeds have been achieved on a single eight MHz TV channel;
- Base station powered by solar energy; and
- Video streaming, emails, video conferencing, and high-speed VPN services supported seamlessly.

Strathmore University (SU) and the Communications Authority of Kenya (CA) signed a memorandum of understanding (MoU) in January 2019 (stretching to 2022) to establish a framework of collaboration on spectrum management research. The research covers DSA techniques, TVWS, 5G, software-defined radio and cognitive radio techniques, as well as cybersecurity.

In December 2019, the U.K. Department for International Development (DFID) provided a grant to SU in collaboration with CA to complete the validation exercise for the TVWS draft framework whose work had begun earlier. The project officially began in January 2020 and was expected to end in August 2020, however, Covid-19 has impacted delivery.

One of the results is the TVWS framework and set of rules,[49] which is being reviewed. Kenya's draft TVWS framework and regulations allow for the operation of TVWS devices on a lightly licensed regulatory model basis and allows for TVWS use in 470 MHz to 694 MHz.

TVWS Devices in Kenya must rely on databases to geolocation databases to avoid interference with primary incumbent broadcast TV services. The regulator (CA) must qualify, approve, and control any TVWS geolocation database as compliant with the TVWS framework and rules. There could be several such compliant databases in Kenya.

The draft rules establish two classes of TVWS devices: Master WSD and Client WSD. A Master WSD, which controls client WSDs, must be able to communicate with an approved geolocation database. Other details will be finalized at the end of the consultation on the draft framework and rules.

NIGERIA, BOTSWANA, GUINEA BISSAU, AND FRANCOPHONE AFRICA

Nigeria, Kenya, Botswana, and Guinea Bissau have all had TVWS trials and are expected—like Kenya—to finalize their TVWS frameworks and rules by the end of the calendar year 2021.

Several other countries in Francophone Africa are also working on TVWS sharing regulations, including those that have carried out TVWS trials like Senegal, Ivory Coast, and others.

TANZANIA, MALAWI, AND NAMIBIA

Three other African countries that have carried out significant TVWS trials in the past, which are yet to yield TVWS Frameworks and Regulations, include Tanzania, Malawi, and Namibia.

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[49] "Authorisation on the Use of TV White Space." Communications Authority of Kenya. February 2020. https://ca.go.ke/wp-content/uploads/2020/03/Authorisation-of-the-use-of-TV-White-Spaces.pdf.

As stated in the Roberts *et al.* (2015) report, the Namibia TVWS pilot called Citizen Connect (a partnership between Microsoft and MyDigitalBridge Foundation), "consists of a network of TVWS sites deployed over a 62km by 152km (9,424 km2) area. It uses radios from Adaptrum and covers three regional councils: Oshana, Ohangwena, and Omusati in northern Namibia. The network delivers connectivity at three regional offices, 28 rural schools, and seven education circuit offices, with a link range of 8km to 12km and typical speeds from 5 Mbps to 10 Mbps, which is sufficient for a host of user applications, including voice, video, and data. Usage from the Oshana cluster for the first week in February 2015 was a total of 8.13 GB of traffic, with 7.6 GB attributed to the downlink and 537.5 MB on the uplink."

The Namibia Pilot shows the opportunities for using TVWS technologies in Liberia. It is also likely TVWS regulations would also emerge from Tanzania, Malawi, and Namibia in 2022-23, or possibly sooner.

OTHER NON-AFRICAN TVWS REGULATORY FRAMEWORKS AND RULES

The TVWS frameworks and rules from some other non-African countries were reviewed including the United States (U.S.), the United Kingdom (U.K), Canada, and Colombia. This section draws from Google (2015).

UNITED STATES OF AMERICA

The Federal Communications Commission (FCC) pioneered the first-ever adopted rules for the use of TVWS in 2008.[50] Since then, it has amended its rules several times, and as recently as the 2020 New Proposed Rulemakings (NPRMs) on TVWS.[51] The rules allow the operation of devices on a license-exempt basis.[52]

TVWS devices rely on either databases or sensing to avoid interference with protected services.[53] The rules authorize private sector database operations without placing a limit on the number of database providers offering service.[54] They also impose certain security and certification requirements on databases.[55] They established three classes of devices: fixed, mode I portable, and mode II portable.[56] Fixed devices must limit their power to no more than four W EIRP, and personal portable devices are limited to 100 mW.[57] Devices must also comply with strict out-of-band emissions masks.[58] The most

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[50] Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd. 16807 (2008).

[51] Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd. 18661 (2010); Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Third Memorandum Opinion and Order, 27 FCC Rcd. 3692 (2012). Also Part 15 rules; 2015 Report and Order; 2019 Report and Order; 2020 Proposed NPRM

[52] 47 C.F.R. § 15.701.

[53] 47 C.F.R. §§ 15.711, 15.717.

[54] 47 C.F.R. § 15.715.

[55] Ibid.

[56] 47 C.F.R. § 15.703(c), (e), (f).

[57] 47 C.F.R. § 15.709.

recent amended rules, approved in October 2020, allow for expanded use of this spectrum for the delivery of broadband internet services in rural and underserved communities while protecting broadcast TV stations (and other licensed services) from harmful interference.

The new order amends the FCC's Part 15 rules, which govern how unlicensed TVWS devices operate over spectrum not being used by incumbents. Wireless Internet Service Providers (WISPs) currently use fixed white space devices to provide internet connectivity to schools, libraries, and rural households. The FCC says its order will strengthen these efforts by allowing for more flexibility in how wireless services are provided within white spaces, better reflecting technological and geographic realities. The FCC is particularly increasing the maximum permissible power and antenna height for fixed white space devices operating in less congested areas (generally rural and unserved) in the TV bands. The amended rules also increase the minimum required separation distances between protected services and entities operating in the band and white space devices operating at the new higher power levels, as well as higher heights above average terrain to ensure that broadcast television stations are protected from harmful interference. Also, the FCC is permitting higher power mobile operations using white space devices in less congested areas within defined geo-fenced areas, such as school bus routes or farm boundaries. The rule changes also provide flexibility for new and innovative narrowband white space devices so that users can more fully benefit from the Internet of Things applications. Finally, the Commission adopted a Further Notice of Proposed Rulemaking to explore whether to modify its rules to permit the use of terrain-based models to determine available TV channels for white space devices.

UNITED KINGDOM

The U.K. telecommunications and media regulator, Ofcom, adopted rules for the use of TVWS in early 2015.[59] They allow the operation of devices on a license-exempt basis.[60] They also authorize private sector database operations by one or more database providers.[61] Ofcom's rules impose qualification requirements on databases.[62] They established four classes of devices: fixed master, fixed slave, portable master, and portable slave.[63] They also established varying maximum power levels based on the presence of incumbents and assume that devices will comply with the European Telecommunications Standards Institute (ETSI) emissions mask classifications.[64] However, Ofcom's rules do not allow the use of sensing-only devices.[65]

CANADA

Telecommunications regulator, Industry Canada, released its framework (October 2012) for the use of certain non-broadcasting applications in the television broadcasting bands below 698 MHz.[66] In 2015, it

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58 Ibid.

59 See generally Ofcom Framework Statement.

60 Id. at 1.

61 Id. at 14-15.

62 Ibid.

63 Id. at 37.

64 Id. at 35, 44.

65 See generally id.

66 See Canadian Framework.

released detailed database specifications and a document specifying application procedures for database providers,[67] as well as detailed technical requirements for white space devices.[68] Overall, the Canadian rules have largely tracked those of the U.S. to harmonize devices across their long border. The Canadian TVWS rules allow the operation of devices on a license-exempt basis.[69] However, like the U.K., they do not allow the use of sensing-only devices.[70] They authorize private sector database operations without placing a limit on the number of database providers offering service.[71] They impose certain security and certification requirements on databases.[72] They establish three classes of devices: fixed, mode I portable, and mode II portable.[73] The maximum transmit powers, interference protection calculations, and out-of-band emissions restrictions broadly track the U.S. rules.[74]

COLOMBIA – TVWS SHARING STARTED WITH MANUAL ALLOCATION BY THE REGULATOR

Colombia was the first country in Latin America to adopt its TVWS Framework and Regulations in 2018 and updated in 2020.[75]. The spectrum regulator ANE carried out a study in which it realized that 99 percent of Colombian municipalities use just 10 of the available 48 channels assigned for broadcasting. This was a key driver for introducing TVWS sharing regulations in Colombia. Colombia has since adopted a TVWS geo-location framework like Ghana, South Africa, Uganda, Kenya, U.S., U.K., etc. However, interestingly, Colombia did not wait for a geo-location TVWS database regime to be in place before they started TVWS sharing. They commenced as soon as they could with manual TVWS allocation by the regulator, ANE.

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[67] See Application Procedures; Database Specifications.

[68] "White Space Devices (WSDs)", RSS-222, Issue 1. February 2015. https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/RSS-222-Issue1.pdf/$file/RSS-222-Issue1.pdf.

[69] Canadian Framework at 5.

[70] Canadian Framework at 6.

[71] Id. at 7.

[72] Id. at 9-10.

[73] Id. at 10-11.

[74] Id. at 18; White Spaces Devices at 10-11.

[75] Resolución 105 de 2020 ANE Colombia (2020). http://www.ane.gov.co/Documentos compartidos/ArchivosDescargables/noticias/RESOLUCI%C3%93N No 000105 DE 27-03-2020(1).pdf.

Figure 12. Columbia's Manual TVWS Allocation by the Regulator

	Manual TVWS allocation by Regulator	TVWS Database as Custom Solution to Regulator
Description	Channels allocated/assigned to ISPs are manually tracked in Regulator spectrum management software	Database is developed as a custom solution either in-house or under agreement with a 3rd party software developer, a University or a Research institution that adapts the database to the TVWS rules of the country and then possibly manages it
Example deployments	Colombia at start, while the database was being deployed	Colombia, South Africa
Funding & Payment	Regulator (negligible)	A. Regulator pays (or arranges a public grant) for software development and potentially operation/maintenance. B. Regulator issues a beauty contest where prospective database operators present their assets, operating plan and also their business model. Regulator awards which one will be the most appropriate to run the service.
Development	Regulator in-house (negligible)	Regulator, University/Research institution or Commercial database developer
Management	Regulator (requires personnel)	Regulator, University/Research institution or Commercial database developer
Pros	✓ Simple ✓ Instant ✓ Low cost ✓ Good for a small number of TVWS radios (e.g. less than 100) ✓ Interim solution before moving to one of the other two approaches	✓ Rules can be implemented that are highly customizable ✓ Commercial motive can motivate quality of solution ✓ Might promote expertise from universities and research centers. ✓ Regulator can choose to make the service free or very low cost to operators (and more affordable to final users). ✓ Cost could be lower compared to a commercial solution, but it might not always be the case.
Cons	☒ Does not scale ☒ Will require changes when upgrading to database ☒ Spectrum usage information is not automatically available to regulator. ☒ Power limits are not enforced automatically	☒ Long duration to build and deploy, with potentially high costs if the regulations are too specific or if additional features are included (like for example the radio-database integration or the user interface) . ☒ No benefit from global scale in the development and the cloud infrastructure.. ☒ Regulator has to staff to maintain ☒ IT infrastructure / cloud capacity to be provided by regulator ☒ Typically not as easy to use ☒ Changes/Updates to software require ongoing maintenance agreements

Source: Dynamic Spectrum Alliance

SUMMARY OF THE ABOVE TVWS REGULATIONS

Key Recommendation: As shown in Figure 12, Colombia commenced TVWS sharing by manual TVWS allocation by Regulator ANE where unused TVWS channels were allocated or assigned manually and tracked in ANE's spectrum management software. The advantages of this approach are clear: it is simple, instant, low costs, good for a small number of TVWS radios, and a good interim approach. There are also drawbacks, however, and it is recommended that the LTA begin similarly to Colombia, and later progress to an eventual TVWS geolocation-based approach like the other African countries reviewed.

Key Conclusion: Liberia has every incentive to proceed with its TVWS Framework and Rules as there are no less than twelve to fifteen other African countries that have already adopted TVWS rules, carried out TVWS pilots, and are in the process of adopting TVWS frameworks and rules. Liberia can learn the lessons from these countries and proceed to TVWS regulations more quickly and will be of great benefit to the Liberia ICT Policy (2019–2024) and Liberian consumers and citizens, as has been seen in other African countries through the pilots and commercial rollouts.

5. DRAFT TVWS REGULATORY RECOMMENDATIONS

This section provides the overall simplified draft TVWS regulatory recommendations for Liberia, including a TVWS Regulatory Pilot Proposal in partnership with the USF/UAF fund of Liberia. It draws from all of the previous sections of this report.

Drawing from the regulations overviewed in the previous section on TVWS Frameworks and Rules across Africa and Colombia, this report makes specific recommendations regarding implementing spectrum sharing of the broadcast bands for Liberia. These recommendations are broadly based on existing rules for enabling access to white spaces, and the experiences of early adopters across Africa, the U.S., the U.K., and Colombia. The recommendations also draw from the recommendations of Google (2015), which was an effort by the Dynamic Spectrum Alliance.

RECOMMENDATION 1: ENABLE ACCESS TO VACANT TELEVISION SPECTRUM IN LIBERIA

TVWS technology has the potential to close the digital divide and expand economic growth in Liberia. By allowing such access, the LTA would not only meet its mandate to ensure efficient use of radio frequency spectrum but also help achieve the goals of the Liberia ICT Policy (2019–2024).

RECOMMENDATION 2: ALLOW ACCESS ON A LICENSE-EXEMPT BASIS

As outlined in Section 3, based on the experiences of other license-exempt bands in countries like Kenya, allowing TVWS devices to operate on a license-exempt basis in Liberia will drive both consumer and citizen benefits, and spur innovation and investment in new technologies and applications. Allowing access to the TVWS spectrum in Liberia will be especially impactful because there are very few license-exempt allocations sub 1 GHz.[76] A licensed model, by contrast, is likely to take longer to implement—as it would likely require clearing and auctioning—and does not foster opportunistic, rapid innovation in the same way that a license-exempt model would. Alternatively, a lightly licensed model could be used in Liberia, although the recommendation is to employ a license-exempt framework.

RECOMMENDATION 3: START WITH MANUAL TVWS ALLOCATION BY THE LTA AND FOR THE PROPOSED TVWS PILOT

As discussed earlier, Colombia (in Latin America) commenced TVWS sharing by manual TVWS allocation by Regulator ANE where unused TVWS channels were allocated and assigned manually and tracked in ANE's spectrum management software. The recommendation is that the LTA also commence TVWS spectrum sharing in Liberia via manual sharing as described in Figure 12. The Liberian TVWS Pilot should also proceed with manual allocation by the LTA.

RECOMMENDATION 4: PROTECT PRIMARY LICENSED SERVICES BY RELYING ON DATABASES

When enabling access to TVWS, it is recommended that the Liberia TVWS framework protect incumbent television broadcasters from harmful interference. To date, African regulators have authorized two permissible methods: 1) geolocation databases, and 2) spectrum sensing. However, this

[76] Ibid Thanki.

report recommends only the geolocation databases approach. Spectrum sensing is arguably too complicated for Liberia.

Using a database-based approach, TVWS availability is calculated using propagation models for TV signal strength and other incumbent operations. WSDs report their location to the database, and the database responds with channel availability and other technical parameters. Channel availability rules are determined by the regulator (LTA) and implemented by the geolocation database.

In addition to determining channel availability, the geolocation databases offer several advantages in ensuring protection against harmful interference. First, the database allows operating parameters to be changed—whether because of changes in incumbent operations, temporary requirements to limit access (for example, to accommodate program-making and special events (PMSE) equipment on a limited-time basis), or improvements in broadcast or other incumbent technologies—without upgrading devices in the field. This approach ensures real-time compliance with regulatory changes and allows regulators to adjust parameters based on experiences in the field. Second, because Master WSDs (and hence Client WSDs) report their location to the database, any interference complaints can be investigated quickly, and the LTA can require databases to shut off interfering devices. Third, several regulatory regimes require fixed device operators to provide their contact information to the regulator so that they can be reached easily if interference is detected.

To date, database providers have relied partially or entirely on information collected by the regulator to determine incumbent operations' locations and characteristics. Therefore, the success of the Liberian databases necessarily depends on the LTA receiving sufficient and accurate information regarding the entities to be protected.

To support competition and innovation in the provision of database services, the LTA should allow multiple TVWS databases to operate in any Liberia, so long as the databases can exchange data with each other. Allowing multiple databases will take advantage of industry and individual company expertise in developing and maintaining resilient infrastructure, managing device queries, providing customer service, and developing value-added services.

ICASA (South Africa), NCA (Ghana), UCC (Uganda), and Ofcom (U.K.) have developed processes for certifying geolocation databases. Although individual requirements vary, the rules for database provision often include the following basic features:

- Liberian TVWS databases should demonstrate that they can protect incumbents from harmful interference according to the protection criteria established by the regulator;
- Liberian TVWS databases should offer their services to all TVWS devices on a non-discriminatory basis, although they may charge reasonable fees for such services;
- Liberian TVWS databases should share information necessary for effective interference protection with each other;
- Liberian TVWS databases should maintain and exchange information in a secure manner; and

- In response to a formal request from the regulator, Liberian TVWS databases should be able to restrict operations of a registered device that causes harmful interference to licensed services.

RECOMMENDATION 5: ESTABLISH CLASSES OF DEVICES BASED ON TRANSPORTABILITY AND GEOLOCATION CAPABILITIES

Liberia TVWS regulations need to continue to enhance the worldwide TVWS ecosystem by adopting similar WSD standards in other countries. As gleaned from the regulatory examples across Africa from the previous section, most regulators have adopted two sets of regulatory categories for TVWS devices: fixed or mobile/portable; and master or client. This provides manufacturers flexibility in designing devices for miscellaneous use cases. Establishing these categories will also allow regulators to tailor their rules by device type:

- Fixed devices transmit and receive communications at a specified fixed location and obtain information on available white space channels from a white space database.[77] Database-enabled fixed devices may have the option to manually report their location, rather than relying on an automated geolocation capability;[78]

- Mobile devices, which include nomadic or transportable devices, that transmit and receive communications while in motion or at various locations that may change;[79]

- Master devices, also sometimes called Mode II devices, use an automated geolocation capability to access a white space database, either directly or through another master device;[80] and

- Client devices, also sometimes called Mode I or slave devices, do not use an internal geolocation capability and do not directly access a white space database to obtain a list of available white space channels.[81]

RECOMMENDATION 6: USE EXISTING TYPE APPROVAL PROCEDURES TO CERTIFY DEVICES FOR OPERATION

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[77] See, e.g., 47 C.F.R. § 15.703(c); Infocomm Development Authority of Singapore, Regulatory Framework For TV White Space Operations In The VHF/UHF Bands (2014) (Singapore Explanatory Statement), available at http://www.ida.gov.sg/~/media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf; Ofcom, Implementing TV White Spaces 37 (2015) (Ofcom Framework Statement), available at http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/statement/tvws-statement.pdf; Industry Canada, Framework for the Use of Certain Non-broadcasting Applications in the Television Broadcasting Bands Below 698 MHz 10 (2012) (Canadian Framework), available at https://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/TVWhiteSpace-October2012.pdf/$file/TVWhiteSpace-October2012.pdf.

[78] 47 C.F.R. § 15.711(b)(1); Singapore Explanatory Statement at 20; Ofcom, Manually Configurable White Space Devices (2015) (calling for consultation responses on this question), available at http://stakeholders.ofcom.org.uk/binaries/consultations/manually-configurable-wsds/summary/manually-configurable-wsds.pdf.

[79] 47 C.F.R. § 15.703(i); Ofcom Framework Statement at 37; Singapore Explanatory Statement; Canadian Framework at 11.

[80] See, e.g., 47 C.F.R. § 15.703(f); Singapore Explanatory Statement; Canadian Framework at 11; Ofcom Framework Statement at 36.

[81] See, e.g., 47 C.F.R. § 15.703(e); Singapore Explanatory Statement at 7; Canadian Framework at 11; Ofcom Framework Statement at 36.

LTA already has a network-type approval regime (like TVWS), which is part of the workstreams of the LTA Strengthening program. Just as the LTA has adopted type approval for other license-exempt devices, such as Wi-Fi devices, these procedures can accommodate white space devices as well. As noted earlier, ETSI has developed a harmonized European standard for white space devices. This standard is being largely extended to the rest of ITU Region 1 more broadly and has been adopted in Ghana, South Africa, Kenya, Uganda, and Mozambique.[82] These countries are taking advantage of devices being developed for the European market and so should Liberia.

RECOMMENDATION 7: ESTABLISH OPERATING PARAMETERS THAT MAXIMIZE SPECTRUM AVAILABILITY WHILE PROTECTING INCUMBENT SERVICES

All the rules for TVWS devices adopted by regulators establish several technical guidelines for use of the spectrum, including maximum transmit powers, out-of-band emissions limits, and whether to permit operation on adjacent channels. LTA's rules should do the same. The LTA TVWS rules should maximize spectrum availability while protecting incumbent broadcast TV services from harmful interference, without being overly cautious. For example, it may be too cautious for the LTA not to allow the use of adjacent channels by used TV channels in Ghana, although South Africa's rules do allow this practice.

POWER LIMITS

Like in Ghana and Uganda rules, a good start for Liberian TVWS rules would be that fixed devices must limit their power to no more than 4W EIRP (36 dBm) within the Greater Monrovia area and up to 10W (40 dBm) ERP elsewhere. Personal portable devices should be limited to 100mW (20 dBm) EIRP. This is consistent with the DSA's model rules for the use of TVWS, which recommends capping device power at 10W EIRP in any given channel.[83]

OUT-OF-BAND EMISSIONS

There are several approaches to out-of-band emissions regulation rules. One approach is that the Liberian TVWS rules take advantage of the ETSI standard, which specifies five classes of devices, each of which has a minimum emissions mask like some African countries have done, including South Africa. The general best practice principle is that WSDs with a cleaner emissions mask will have greater access to spectrum than devices that cannot meet a strict mask. Another approach is to establish fixed out-of-band emissions requirements, as Uganda rules have done.

On balance, it is recommended the Liberian rules take advantage of the WSD ETSI standards. The LTA rules should establish out-of-band emissions masks that comply with the out-of-band emissions masks in Section 4.2 of the ETSI EN 301 598 standard or successor directives. This would simplify the type approval process for WSD devices coming into Liberia.

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[82] ETSI, ETSI EN 301 598 V1.0.0. 2013. http://www.etsi.org/deliver/etsi_en/301500_301599/301598/01.00.00_20/en_301598v010000a.pdf.

[83] Dynamic Spectrum Alliance, Suggested Technical Rules and Regulations for the Use of Television White Spaces § 7(a)(1)(i) & n.5. (DSA Model Rules), available at http://www.dynamicspectrumalliance.org/assets/submissions/Suggested%20Technical%20Rules%20and%20Regulations%20for%20the%20use%20of%20TVWS.pdf.

ADJACENT CHANNEL OPERATION

Some African countries (South Africa and Uganda) have adopted TVWS rules for access to white spaces allowing operation in vacant channels adjacent to existing broadcast channels. Ghana's TVWS rules, on the other hand, do not allow for this.

The South African Cape Town TVWS Pilot results, where fixed devices operated at 4W EIRP adjacent to channels used by TV broadcasters, and in some cases, between two channels used by TV transmitters (adjacent on either side to the TVWS channel) were closely reviewed.[84] No interference was detected, and the trial participants received no complaints from neighboring broadcasters.[85] Therefore it was concluded that adjacent channel operations at power levels up to 4W do not pose a significant risk, and can provide substantial benefits. Therefore, it is recommended the Liberia LTA rules allow for adjacent channel operations like the rules in South Africa and Uganda allow.

PROPAGATION MODEL

There are two propagation models typically used: 1) terrain-based, point-to-point modeling to protect incumbent broadcasters like was used in the South African TVWS Pilot (e.g., the Longley-Rice propagation model[86]), or 2) the ITU-R Recommended P-1812-3 model, often used to calculate broadcaster-to-broadcaster interference protection.[87]

On balance, it would be easier for the LTA to adopt the ITU-R Recommendation P-1812-3, a path-specific propagation prediction method for point-to-area terrestrial services in the VHF and UHF bands for computation of propagation loss, which they already use.

Therefore, it is recommended the LTA-approved TVWS Geo-location databases implement propagation algorithms and interference parameters, under Article 5, to calculate operating parameters for WSDs at a given location, considering the variability in terrain and calculating propagation and spectrum availability using ITU-R P-1812. Database operators would update the algorithms or parameter values provided by the LTA. As recommended earlier, the LTA should start with manual TVWS allocation using their in-house P-1812 model.

GEOLOCATION CAPABILITY OF DEVICES

Recall that the coexistence framework computes spectrum allocation parameters for WSD taking into account geolocation and category details of the WSD, and information on protected DTT service from the Authority. Ofcom (U.K.) has adopted a best practice approach where location is one of the device

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[84] James Carlson *et al*., Studies on the Use of Television White Spaces in South Africa: Recommendations and Learnings from the Cape Town Television White Spaces Trial 38-39 (Cape Town Trial Recommendations), available at http://www.tenet.ac.za/tvws/recommendations-and-learnings-from-the-cape-town-tv-white-spaces-trial; see also Part 15 NPRM at ¶ 37, n.59 (reconsidering earlier precedent based on the Cape Town experience and other similar results).

[85] Id.

[86] Carlson, *et al*., supra note 60, at 40.

[87] See Office of Engineering and Technology Releases and Seeks Comment on Updated OET-69 Software, Public Notice, ET Docket No. 13-26; GN Docket No. 12-268, 28 FCC Rcd. 950 (2013); ITU-R Recommendation P.1812-3 (2013), available at http://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1812-3-201309-I!!PDF-E.pdf.

parameters that devices may report to the database.[88] The database uses that information as an input when calculating spectrum availability at the device's reported location.

It is therefore the responsibility of the geolocation database to perform such calculations. The LTA will specify which channels are available for TVWS use in Liberia with 8 MHz channels. It is recommended that WSDs (both master and client) should be required to have geolocation functionality. It is also recommended that manually configurable devices should not be granted Type Approval (just limited approval during the trial and perhaps slightly beyond), to limit the risk of harmful interference by transmissions from unauthorized devices. It may be too cautious to insist on Client WSDs to have geolocation functionality, but such caution is arguably justified for the market conditions in Liberia.

Furthermore, master devices should communicate their device parameters to the parent geolocation database and obtain operational parameters for their transmissions. This communication should not be performed over a white space channel.

RECOMMENDATION 8: ESTABLISH A LIBERIAN PILOT INVOLVING TVWS IN PARTNERSHIP WITH THE LIBERIAN UNIVERSAL ACCESS FUND

As reported earlier, in 2015, USAID's NetHope, carried out a detailed technical assessment of the then Liberia Broadband Plan/Activities, including its backbone and last mile details.[89] One of the key recommendations from the team of experts was for rural pilots, including TVWS devices.

In Liberia also, it is recommended that such a pilot, in partnership with the USF/UAF, be conducted.

The goals of the pilot would include:

- Demonstrating to Government and other stakeholders including MoPT, State House, MFDB, MiCAT, UAF, LTA, ISPs, CCL, universities, etc. that TVWS has a potentially significant role in achieving the aims of the Liberia ICT Policy (2019–2024);
- Demonstrate and validate the proposed Liberian TVWS Framework and Rules emanating from the ProICT Liberia Activity to strengthen the LTA including:
  - Testing end to end processes including device operations;
  - Outlining database operations;
  - The LTA calculating data and spectrum availability from white space calculations; and
  - Proving no harmful interference into broadcast TV services even when operating in adjacent channels in Liberia;

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[88] Id. at 40.

[89] "Liberia Broadband Technical Assessment (Components 2 & 3) Backbone & Last Mile Details (New June 4) & Interim Findings (Updated June 4) NetHope Global Broadband and Innovations Alliance.". June 4, 2015. https://1e8q3q16vyc81g8l3h3md6q5f5e-wpengine.netdna-ssl.com/wp-content/uploads/2015/06/Liberia-Broadband-Technical-Assessment-NetHope.pdf.

- Attract Liberian entrepreneurs, new ISPs, etc. To consider using the proposed license-exempt TVWS framework along with Wi-Fi to innovate in more rural Liberia to start bridging more of the broadband digital divide. The WISP Mawingu in Kenya should act as an incentive;

- Potentially attract and involve at least one Liberian University to build capacity into TVWS and retaining such capacity in Liberia. Recall Objective 7 of the Liberia ICT Policy (2019–2024): Establish a National Education and Research Network (NREN) for all tertiary and secondary education institutions to provide access to high-speed internet and digital educational services. Also, recall the Namibian pilot accomplishments earlier; and

- Promote TVWS as an approach to drive demand-side traffic generation for the Liberia fiber backbone project led by LibTelco.

6. KEY CONCLUSIONS AND NEXT STEPS

Several conclusions that have already been highlighted in this report are worth reinforcing in the conclusion of this report to strengthen the LTA:

1. Given the current structure of the Liberian Wireless Market dominated by 2G Voice, 3G/4G LTE Internet mainly in Monrovia (at high prices), and minimum fiber, it is strongly recommended that TVWS-enabled Wi-Fi be added to the Broadband Internet solutions mix in Liberia, particularly for rural areas, but in urban areas too.
2. Liberia has every incentive to proceed with its TVWS Framework and Rules, as there are no less than twelve to fifteen other African countries that already have adopted TVWS rules, carried out TVWS pilots, and are in the process of adopting TVWS frameworks and rules. Liberia can learn the lessons from these countries and proceed to TVWS regulations more quickly with more benefits to both the Liberia ICT Policy (2019–2024) and Liberian consumers and citizens, as is seen in other African countries through the pilots and commercial rollouts.
3. Enable access to the TVWS spectrum in Liberia on a licensed-exempt basis using geolocation databases like other African countries have already done.
4. Start the Liberian TVWS sharing framework without a database. This means the regulator would use a starting framework where TVWS channels are allocated and assigned to Internet Service Providers (ISPs) manually and tracked in the Regulator's spectrum management software—as done in Colombia.
5. Conduct a Pilot with the UAF involving TVWS devices. This concurs with one of the recommendations of the 2015 USAID-funded NetHope key recommendations for rural pilots for TVWS devices. A key role of the TVWS Pilot in partnership with the UAF (along with the enabling regulatory framework) is to encourage innovative business models in Liberia towards broadband Internet and promoting the implementation of the Liberia ICT Policy (2019–2024).
6. Implement the key eight recommendations in Section 5, which should be captured in a Draft Set of LTA Regulations and Standards for TVWS Access and Use in Liberia. Once drafted and adopted, revise them as needed. Then the LTA and the UAF should promote them in Liberia to drive innovation and consumer and citizen benefits, as seen in other countries like Kenya.
7. Lastly, as the Dynamic Spectrum Alliance advocates, the key roles for Governments and Regulators with TVWS are threefold: 1) allow shared access to the TVWS spectrum, 2) provide the enabling regulatory framework, and 3) encourage innovative business models.

ANNEX I. REFERENCES

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