Spectrum Sharing in Kenya: Progress, Opportunities, Challenges and Way Forward

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***Abstract*—Spectrum Sharing (SS) is gradually turning into the *de facto* method that can be adopted to address the growing radio frequency (RF) spectrum demand across the world. This is due to the rapidly increasing number of wireless devices and new bandwidth hungry Internet-based services. Amidst this tremendous appetite for Internet access, however, a significant population on the planet is still underserved owing to the fact that they have limited Internet access options. SS can therefore be adopted as an opportunistic technique to deliver more Internet access options. The experience of both TV White Spaces (TVWS) and Wi-Fi 6E provide great SS examples. Notwithstanding, SS also faces a set of challenges which seem to impede its adoption. In this paper, we share our findings on a Gap Analysis study conducted in Kenya on SS between October 2021 and September 2022. The study examined the opportunities and challenges with a special focus on the pillars of regulations, economics and technology, relevant to the implementation of SS in Kenya.**

Keywords—Spectrum Sharing, Dynamic Spectrum Access, Opportunistic Spectrum Access, TV White Spaces, Wi-Fi 6E

I. INTRODUCTION

The rapid progress of connected environments and wireless communication generations has increased the number of wireless connected devices exponentially in the recent years [1]. While this is commendable in terms of growth of Internet users and devices, the 2022 *Global Connectivity Report* published by the International Telecommunication Union (ITU) shows that one-third of humanity (2.9 billion people) is still offline and many users still lack meaningful connectivity [2]. This presents a conundrum that requires a proper balance of the needs of the radio frequency (RF) spectrum - the lifeblood of wireless communications. One end requires consideration of enhanced quality of Internet access while the other enunciates on the provision of affordable and meaningful Internet access as presented by authors in [3].

Traditionally, however, the approach of allocating the RF spectrum has been premised on a “command-and-control” model, which guarantees that the RF spectrum will be exclusively licensed to an authorised user (i.e., licensee) who wins the RF bidding and can use the RF spectrum without any interference. Further, this sort of authorisation sometimes means allocation of the RF spectrum across the entire country [3]. Recent studies such as the work in [4] show that such an approach leads to inefficiency in spectrum usage. The inefficiency arises due to the fact that an authorised user may not fully exploit the RF spectrum at all times and in all locations. Moreover, regulatory requirements put restrictions on the wireless technologies that can flexibly use the licensed RF spectrum to deliver connectivity services based on market demand [5]. Hence, the dawn of the concept of Spectrum Sharing (SS).

Authors in [6] describe SS as a wireless network with two types of users; one with a higher priority (known as primary users or PUs) and another with a lower priority (known as secondary users or SUs) sharing the same RF band. A demonstration of coexistence between these two users has been shown in various studies such as the work in [7] and [8] with the requirement that SUs’ transmission must not exceed a certain threshold in order to protect the PUs’ licensed transmission from interference. A practical implementation of this approach to deliver the needed SS for spectral efficiency is said to need technology and regulatory implementation that supports dynamic access to the licensed RF spectrum [9]. Such an implementation is what is termed Dynamic Spectrum Access (DSA). Most often DSA is used synonymously with SS [5]. In the context of our study, DSA is considered to implement cognitive-driven detection of frequency availability for the SU access by evaluating parameters such as signal waveform, emission power, antenna beamforming, network protocol and topology among other SS operational factors [10].

Similar to many regimes around the world, the concept of SS in Kenya was introduced through the authorisation of access to Television White Spaces (TVWS) in the Ultra-High Frequency (UHF) band of 470-694 MHz. Conducted trials as well as validation studies in the country postulated that Digital Terrestrial Television (DTT) as PUs could coexist with new SU entrants in the band. The SUs, hence, were authorised to provide broadband access while operating within the required Equivalent Isotropic Radiated Power (EIRP) limit of 42 dBm [11]. This foundation has enabled newer SS studies within the country such as the coexistence of the incumbents in the 6 GHz band (5.925-7.125 GHz) and the opportunistic implementation of Wi-Fi 6E similar to studies by the European Conference of Postal and Telecommunications Administrations (CEPT) [12].

Despite these initiatives to enable SS in Kenya, a number of challenges have emerged ranging from regulatory, technology and economic factors as noted in [13]- [14]. Hence, this paper aims to provide context in terms of progress, opportunities and challenges of spectrum sharing (SS) that are equally affecting Kenya. This is based on a Gap Analysis

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study conducted in the country for a period of one year until September 2022 [15]. The paper shares recommendations based on the implementation of spectrum sharing in various regimes and other studies as a way forward for successful implementation of SS in Kenya.

The rest of the paper is organised as follows. Section II presents a summary background of SS developments in Kenya. Section III highlights the objectives and methodology used in the study. Section IV shares a summary of the findings on the understanding and opportunities of SS. Section V presents the challenges while section VI features the recommendations as a way forward. Section VII concludes the paper.

II. A Summary Status of Spectrum Sharing in Kenya

Kenya's publication of the framework on the *Authorisation of the Use of Television White Spaces* (TVWS) [11] and the *Licensing and Shared Spectrum Framework for Community Networks* (CNs) [16] in 2021 posit the pioneer steps of adopting SS as an opportunity to enhance broadband access to the millions of underserved Kenyans. Prior to this milestone, a technical assessment of prospects for Dynamic Spectrum Access (DSA) had been carried out in the UHF TV band (470-694 MHz) for TVWS as presented by authors in [17]. Subsequent documentation such as the paper by authors in [11] further substantiated the opportunity of SS through TVWS since the first trial in September 2013 when Microsoft East Africa was authorised to test TVWS technology for a period of one year under the moniker "Mawingu Project."

The "Mawingu Project" as detailed in the report titled "Rural Broadband Trials" submitted to the Communications Authority of Kenya (CA) [18] as the debutant SS network, demonstrated the technical viability of secondary access in the UHF TV band, forming a foundation to which the TVWS framework would eventually be developed [11]. Speeds of up to 16 Mbps on a single 8 MHz TV channel at distances of up to 14km were achieved with TVWS stations operating at 2.5 watts (approx. 34 dBm) EIRP. Notably, "Mawingu Project" had been deployed without implementation of any of the three techniques that can be used to manage opportunistic access to licensed spectrum i.e. spectrum sensing, beacons or geolocation databases [19].

The progress of TVWS, as outlined in the TVWS regulatory framework [20], postulated the country's strategy to adopting DSA to deliver on efficient utilisation of spectrum and enhance Internet access. However, the regulations [20] and other publications [11]- [18] heavily focused on the technology approach of managing the opportunistic access of the UHF band with the aspects of economics and market considerations not given as much attention. Even so, the adopted technology approach of implementing geolocation databases as the effective tool of protecting the DTT services posed challenges such as reliability of the database(s) to determine available frequency and effectively manage interference aggregation, the establishment of connection among the SU TVWS devices [21] and the overall understanding of the architecture to the stakeholders.

Notwithstanding the economics and market gaps as well as the identified novelty of geolocation databases, the publication of the framework on Community Networks [16] further cemented the trajectory of the country towards inclusive broadband access driven by SS. Traditionally, CNs have utilised Wi-Fi technologies for both backhaul and Wi-Fi hotspots on license-exempt spectrum across the globe [22]. However, with the challenges of congestion and signal interference in the 2.4 GHz and 5 GHz bands, the quality of connectivity is always affected [23]. Therefore, in the Kenya's CNs framework, opportunity of addressing such issues included looking into other RF bands such as license-exempt access in the 6 GHz, 24 GHz and 60 GHz. The proposition to expand shared spectrum access to the International Mobile Telephony (IMT) bands such as the 1700 MHz, 3300 MHz and 3500 MHz is also enunciated.

Recently, momentum has gathered to study the 6 GHz band further to enable full access to the 1200 MHz (5.925 – 7.125 GHz) for Wi-Fi 6E coexisting with the Fixed Services (FS) and Fixed Satellite Services (FSS) [24]. Although Kenya has allowed access to the lower part of the band (5.925-6.425 MHz) under the *Guidelines for Short-range devices* [25], the findings of the 6 GHz study by authors in [26] propose a compelling consideration of allowing access to the 1200 MHz spectrum. Based on their assessment of Wi-Fi 6E applications and use cases for both enterprises and consumer market including development of Internet of Things (IoT) innovation [26], a cumulative economic value of US $20.29 billion can be realised for the country between 2022 and 2030 as shown in Fig. 1, furthering the opportunity of SS.

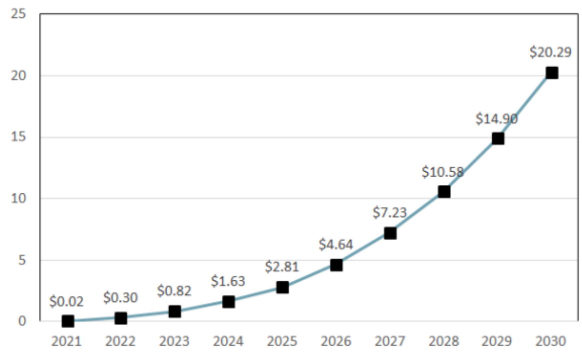

Fig. 1: Cumulative Economic Value of Wi-Fi 6E in Kenya

Source: Telecom Advisory Services

III. Objectives and Methodology

The objective of this paper is to expound on the findings of the Gap Analysis study on Spectrum Sharing (SS) for Kenya. The research on the Gap Analysis study was conducted between September 2021 and September 2022 [15]. While the aim of the study was to evaluate the existing state of spectrum sharing in Kenya, this paper extends its findings by highlighting further opportunity and the potential way forward on SS for the country based on comparative studies such as ones presented in [1] and [27]. The study made use of desk research methodology and engagement of stakeholders by use of questionnaires and discussions through focus groups. Through the desk research, ongoing initiatives in the country on SS including planned pilot deployments of DSA networks alongside regulatory strategies supporting SS were evaluated. This was done through the access to various secondary sources such as documents published within the country on SS, enacted regulatory frameworks by CA and in-country blueprints such as the National Broadband Strategy

[28]. Further reports and publications such as the work by authors in [2], [10], [21] and [27] on spectrum sharing around the world also contributed significantly to the desk research.

The stakeholder engagements involved sending a questionnaire to the stakeholders through the use of a Google Form and conducting a workshop (physical and virtual) to obtain their views which formed part of the qualitative assessment of the study. The stakeholder groups included a set of Wireless Internet Service Providers (WISPs) and the public institutions, policy and spectrum lobby groups. The WISPs were grouped further based on their license categories in the country and the locations within which they operate. An analysis was then evaluated based on their level of familiarity on the concept of SS or DSA and the enacted frameworks by the country on SS. Their technical understanding on the requirements of coexistence for SS, particularly on TVWS and the 6 GHz Wi-Fi was also assessed. For the engagement with public institutions, spectrum advocacy and lobby groups, a virtual workshop was held through the Microsoft Teams platform investigating the policy initiatives, regulatory understanding of SS and any existing or planned activities on SS developments.

IV. Findings: Status, Progress and Opportunities

In this section, we share the findings of the Gap Analysis study based on the desk research and stakeholder engagements. The findings shared in this paper include our interpretation of the secondary sources in terms of the journey of SS in Kenya [18], the various developments through TVWS [11] as the pioneer technology of SS, the regulatory framework of CNs [16] and the newer developments in the country on the 6 GHz band [26]- [29].

A. Findings Based on the Desk Research

Noting the recent tremendous growth of Internet access in the country, spectrum sharing is underscored as one of the innovations that can help circumvent the challenges of RF spectrum scarcity and interference to foster the growth of ubiquitous, high-speed, affordable and low-latency connectivity [28]. CA highlights that the country ought to promote DSA for flexible utilisation of the RF spectrum. Previous experience as noted by the Global Alliance of Mobile Network Operators (GSMA) in [30] during the digital migration in Kenya, has shown that the cost of clearing and re-allocating spectrum is very high. Mobile Network Operators (MNOs), for instance, cited challenges of cost and unfair assignment to the 800 MHz band. This was described to delay the efforts of the digital dividend due to the push for exclusive access to spectrum [30].

Therefore, SS is seen as an opportunity to free up more unoccupied or partly occupied RF spectrum to enable both fixed and mobile Internet access [10]. The country's experience during the COVID-19 pandemic [18] when the regulatory framework for TVWS was being validated, appreciated the flexibility of allowing access to unused spectrum [11] due to the identification of over ten channels that had been assigned to DTT services but remained heavily unused. On the other hand, the developments on Community Networks (CNs) identifies a tremendous opportunity of Point-to-Point (PtP) and Point-to-Multipoint (PtMP) connections that can leverage various IMT bands. This is marked as the future to deliver localised and affordable broadband access in [16] and [22] even as the 24 GHz and 60 GHz bands are made available on license-exempt basis. Similarly, the 6 GHz band is seen as an essential driver that can deliver better speeds and capacity and enable the country achieve the predicted economic value shown in figure 1 [26]. Moreover, this seems to align with the Wi-Fi Alliance's (WFAs) forecast of USD $4.9 trillion in economic value for Wi-Fi across the globe [31] given that Wi-Fi carries more Internet traffic than any other wireless technology despite only having 300 MHz of unrestricted spectrum in the 2.4 GHz and the 5 GHz bands [32].

B. Findings Based on Stakeholder Engagements

Out of the 30 groups of Wireless Internet Service Providers (WISPs) surveyed through the Google Form, the four main ones who provided comprehensive feedback include: *Dimension Data (DD), Kenya Electricity Transmission Company (KETRACO)*, *Telkom Kenya (TK)* and *Dunia Moja (DM) Community Network*. *DD*, *KETRCO* and *TK* provide services in all locations – urban, semi-urban and in the rural areas. DM operates in a rural area. Fig. 2., shows the distribution of the stakeholders in terms of the areas of operation.

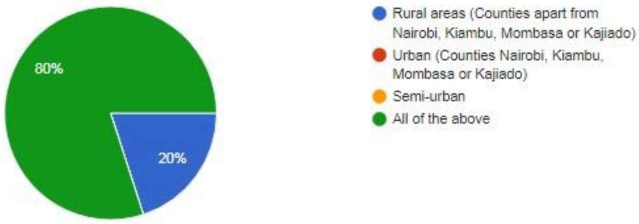

Fig. 2: Distribution by percentage by area of operation by the Stakeholders engaged

Of the surveyed stakeholders, only 60% were familiar with the concept of SS with 20% having never heard of it as shown in Fig. 3. In Fig. 4, 60% had no developments or initiatives on DSA deployments. However, 80% identified an opportunity of deploying TVWS as a shared spectrum network to enhance rural broadband access as shown in Fig. 5. Through TVWS, stakeholders also note that such a shared spectrum network can be leveraged to provide backhaul support and IoT innovations. In regards to Wi-Fi 6E, stakeholders expressed familiarity as shown in Fig. 6 and identified it as an opportunity to leapfrog Wi-Fi capacity in the country. The opportunity of SS in other bands was hailed by CNs just as noted in [16].

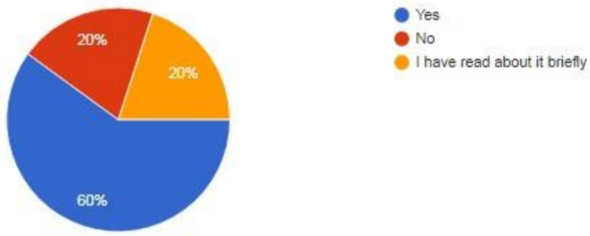

Fig. 3: Familiarity with the concept of SS

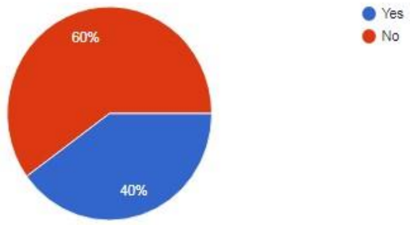

Fig. 4: Status of initiatives on DSA

Fig. 5: Potential of TVWS usage

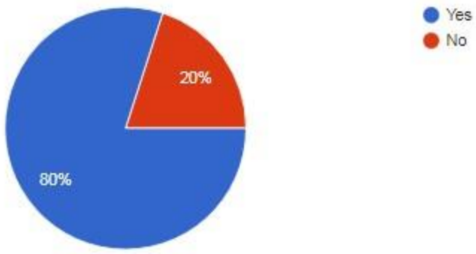

Fig. 6: Level of familiarity by stakeholders on Wi-Fi 6E

V. CHALLENGES OF ADOPTING SPECTRUM SHARING

This section presents the economic and market, regulatory and technology challenges studied in adopting SS in Kenya. Here, we underscore the different experiences posed by the economic approach of adopting SS as presented in [21], technical limitations as noted by authors in [14] and the regulatory challenges that are highlighted by CA in [20] among other references that align to the Kenyan context.

A. Economic and Market Challenges

The economic study of the opportunity of Wi-Fi 6E in the 6 GHz band for Kenya [26] as shown in Fig. 1 is associated with allocating the full 1200 MHz of the 6 GHz band. However, the recommendations of the African Telecommunications Union (ATU) [33] as well as the CA's guidelines [25] propose adoption of licence-exempt access only in the lower part of the band (5925 – 6425 MHz). This allows only 500 MHz of spectrum to be available for the Radio Local Area Networks (RLANs) to support Wi-Fi 6E. Authors in [34], note that such an allocation will be unable to support advanced use cases or support even routine consumer and enterprise networking needs. As such, an economic study in the 5925-6425 MHz would be necessary.

Notably, an identified opportunity for larger channels (from 160 to 320 MHz) and the increase in the number of spatial streams to 16 is envisaged to boost peak data rates to 30 Gbps for Wi-Fi 6E in the full band. Moreover, multi-band aggregation to further enhance access of Wi-Fi in the 6 GHz band is already in the pipeline for Wi-Fi 7 [35]. This, in retrospect, presents a different market opinion that should have been considered by both CA and ATU in allowing full access in the 6 GHz band. Such developments elucidate a challenging SS reality for Kenya. That is, a regulatory approach failing to consider the long-term market opportunity or a market study not being carried out for the envisioned regulatory approach.

Similar challenges were experienced in the TVWS [10] where the lack of assessment of the market opportunity and the long-term economic impact failed to be studied or were not studied in context. Later on, the regulations struggled to be embraced for commercial deployment. The TVWS regulations in Kenya were enacted in support of rural broadband deployments [20] where a significant fraction of the underserved live [11]. Unfortunately, the approach of the technology (as enshrined in the regulations) appeared expensive to guarantee return on investment to the ISPs deploying the network in the rural areas. This has led to very little commercial deployments.

B. Regulatory

The successful adoption of SS for Kenya, just like everywhere else across the world, primarily depends on the establishment of the regulations [19]. Given the nature of regulations, particularly with the novel approach of dynamic spectrum access (DSA), a longer period of time is bound to be taken [36]. However, a comparative study of TVWS regulations across the world presented by authors in [37] demonstrate that Kenya took longer than anticipated to develop the regulations given the templates that existed in other countries such as Canada, Singapore, United Kingdom (UK), United States (US) among others. The first TVWS trial in Kenya was in 2013 [11] while the regulations were implemented in 2021 [20]. Our engagement with the stakeholders showed that the seven-year period took away the enthusiasm that existed during the trials to rapidly allow commercial deployments to take place. Other regulatory challenges noted during the study and as also highlighted by authors in [38] include:

a) The Challenge of the Geolocation Databases (or Automated Frequency Coordination): Although this approach of regulations was adopted across the world [37], the CA highlights it as one of the most challenging components for the TVWS SS-based regulations [20]. The use of the geolocation database warrants that a secondary radio has to first learn its geolocation based on global positioning system (GPS) technology to determine the existing "white spaces" before initiating transmission. Aspects of fairness in regards to who should operate the geolocation database, who should pay for it and how it should be deployed operationally as pointed out by authors in [39] are also challenging for Kenya. A potential limitation seems to exist for future developments on SS based on this regulatory approach under the new name - Automated Frequency Coordination (AFC) - for the standard power devices in the 6 GHz band alongside SS opportunity in other shareable bands [40].

b) *Lack of harmonisation of TVWS Regulations within the East African Region:* Presently, only Kenya and Uganda have developed TVWS regulations within East Africa [11]. The challenge of cross-border interference is noted in the Kenyan regulations [20] albeit the GE06 agreement is cited as a guiding template for cross-border interference mitigation plan. However, as identified in [19],a regional approach to TVWS can significantly lower the costs of deploying the infrastructure, allow the least-resourced regulators to enjoy the same benefits as the best-resourced as well as rapidly address any potential cross-border interference. At the moment, this is not the case.

C. Technology

The technology challenges identified during the study include:

a) Backhaul Challenges: Deployment of shared spectrum networks depends on the availability and affordability of the backhaul network in order to deliver meaningful Internet access [2]. The approach of CNs as well as TVWS, therefore requires reliable backhaul. Both SS-based frameworks have been earmarked for providing Internet to the underserved. As such, reliable backhaul for last-mile is key. Issues of dark fibre as well as costly backhaul network alternatives are noted as challenges [22].

b) Local Development of the Radio Technologies: During stakeholder engagements, the lack of local capacity and active participation in the development of the radio technologies for spectrum sharing was listed as a key challenge to SS. It was partly attributed to for the delay in enabling regulations as well as limiting local understanding of SS. Compared to South Africa [11], where efforts of implementing the geolocation databases were locally led for TVWS, the situation in Kenya was not the same.

D. Other Challenges

Challenges such as lack of awareness and capacity, lack of sufficient regulatory engagement by the ISPs and lack of Research and Development (R&D) within the ISP ecosystem are cited as other challenges by the stakeholders. This is also highlighted in the Kenya's National Broadband Strategy [28].

VI. Way Forward: Recommendations

In this section, we present our recommendations as a way forward to addressing the identified challenges in Section V.

A. On Regulations

a) Transparency in Provision of Information – Although we note that there exist processes to doing this and policies to which CA is bound, stakeholders observed that the subject of spectrum sharing will only thrive in the country if more research, information engagement sessions and collaborations are fostered.

b) Authorisation of New Entrants – To promote more developments on spectrum innovation, a new level of license can be unlocked to allow new entrants into the market just as the US did with the Citizens Broadband Radio Service (CBRS) band [40].

c) Implementation of Capacity Awareness Programs –Stakeholders pointed out a need to develop awareness and enhance capacity for the adoption of SS in Kenya.

d) Development of a Spectrum Sharing Blueprint for Kenya – This may be significant in defining the strategic adoption for SS for the country to complement the efforts of the National Broadband Strategy [28].

e) On the present state of the use of Geolocation Databases (Automated Frequency Coordination (AFC)): As a key pillar to sustaining SS while guaranteeing the desired protection to the incumbents [21], a research study that looks at all the aspects of AFC in the various designated bands for SS in the country ought to be conducted.

f) Authorisation of the Manual Configuration for TVWS Devices in "Less Congested" Areas – With the revisions of the FCC to increase the maximum permissible radiated power from 10 to 16 watts EIRP for fixed WSDs in the "less congested areas", [37], we propose that an evaluation be conducted to develop similar steps in the near future for Kenya. A similar evaluation can also be carried out in various RF bands that can be opportunistically exploited.

B. On Technology

a) Notification of Errors in Predicting the Availability of White Spaces – As part of a technology ecosystem and reliability on a propagation model, the database may have errors in predicting the white spaces and sometimes may fail to distinguish the quality of white space channels [38]. A notification system can be developed to report such scenarios.

b) Backhaul Studies and Mapping – Given the existing backhaul challenges, mapping needs to be done to help determine the footprint of the backhaul networks such as one through fiber and satellite. This would help resolve issues of dark fiber and help provide routes across the country for deployment of last-mile networks based on spectrum sharing [17].

C. On Economics and Market

In this segment, we recommend that financing options such as grants, debt financing and the Universal Service Fund (USF) methodologies be implemented for initial deployments of shared spectrum networks. Such financing approaches have been implemented in other initiatives such as climate financing for the newer technologies by Global Centre for Climate Adaptation [41]. Other approaches such as tax exemption and incentives on network equipment can also be implemented to leapfrog the establishment of new entrants into the telecommunications space.

VII. Conclusions

In this paper, status, progress, opportunities and challenges of adopting of spectrum sharing (SS) in Kenya have been presented. A set of recommendations have also been shared on how to combat the challenges and realise the opportunity of SS for the country. Although there is significant progress on SS in Kenya, a number of challenges still abound across regulations, technology and economics. Such challenges, as noted, can also be addressed through further contextual research of SS in Kenya.

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