# The Potential of TVWS Technology in the Provision of Broadband Internet in Kenya

E.W. Mureu, P.K. Kihato and P.K.Langat

***Abstract***— In Kenya, the data/internet market has maintained an upward trend following increased demand for Internet services and reduced cost of Internet enabled devices. Kenya has a population of about 43 million people, and by the end of last quarter of 2015, there were 31.9 million data/internet users but only 19.9 percent of these had access to broadband internet, marking a penetration level of 14.8 percent. Mobile data/internet subscriptions contributed 99 per cent of the total Internet subscriptions. The term broadband refers to high-speed internet access that is always on and faster than the traditional dial-up access. The main reason for this low penetration of broadband internet is due to the fact that about 67.6 % of Kenyans live in rural areas where most of the current broadband internet service providers have not penetrated due to the low returns on investment considerations. The purpose of this paper is to assess the availability of the Television whitespace (TVWS) spectrum in Kenya which subsequently can be used to provide affordable broadband internet using the TVWS technology to people in areas that would not otherwise be cost effectively served by other technologies. This will be done by carrying out spectrum utilization measurements in some selected areas in Kenya to identify the amount of TV white space spectrum available. The Television White Spaces are frequencies made available for unlicensed use at locations where the spectrum is not being used by licensed services, such as television broadcasting. This spectrum is located in the very high frequency (VHF) and ultra high frequency (UHF) bands. These frequency bands have good propagation and obstacle penetration characteristics. These characteristics make TV white space technology eminently suitable for use in rural areas which are normally vast , scarcely populated and may involve challenging terrain such as hills, foliage, and water. The other reasons that make this technology very attractive are the low costs for building TVWS base stations and the possibility of the TVWS spectrum being offered on license-exempt basis.

***Keywords-*** Broadband Internet, TVWS, UHF, VHF

## I. Introduction

WHITE Space is a label indicating a part of the spectrum, which is available for a Radio communication application (service, system) at a given time in a given geographical area on a non-interfering /non-protected basis with regard to other services with a higher priority on a national basis. Therefore Television White Space (TVWS) refers to frequencies allocated to a TV broadcasting service but not used locally. For the case of Digital Terrestrial Television (DTT) these frequencies are found in the Ultra High Frequency (UHF) band (470 – 790 MHz). These frequencies have better propagation characteristics for use in wireless communications compared to the higher frequencies (2.4 GHz and 3.5 GHz) used by the current Worldwide Interoperability for Microwave Access (WiMAX) systems. Spectrum occupancy measurements [1] carried out in several countries have shown that there is plenty of TV white spaces that could be used for other non-broadcasting services provided no harmful interference is caused to the incumbent services. This constitutes the TVWS spectrum and its amount varies from one country to another and from one region to another of the same country.

Several applications for the TVWS have been proposed and the main one is provision of affordable broadband internet to the un-serviced and hard-to-reach areas like the rural areas. Other proposed applications include: Last mile access to augment city-wide or wide-area data networks; Data offload from mobile networks; Machine-to-machine communications, including smart grid and health-care applications; In-building media distribution; Local government and public safety applications; and broadband internet services to educational and health facilities.

Unlike in developed countries where high occupancy of TV broadcast channels may limit the impact of TVWS applications, situation in the developing countries Kenya is very different. Most of these developing countries have few terrestrial broadcast channels in use, leaving large amounts of television spectrum available for use by TVWS applications. This is even more so in rural areas where TVWS show their greatest potential.

As at 30th November 2015 only 46.4% of the world population had access to the internet of which in Africa only 28.6 % internet penetration had been achieved [2]. In Kenya only 14.8% of the population has access to broadband internet. Mobile data/internet subscriptions contributed 99 per cent of the total Internet subscriptions [3]. The main reason for this low penetration of broadband internet is due to the fact that about 67.6 % of Kenyans live in rural areas where most of the traditional broadband internet service providers have not penetrated due to the low population density which typically results in slower Return on Investment when using licensed spectrum.

The economic and social impact of broadband internet is well researched and documented. An increase in broadband penetration has a greater impact on economic development than a concurrent increase in access to other telecommunications services. The World Bank estimates that

E. W. Mureu, Department of Electrical and Electronic Engineering, JKUAT (+2540724264675; fax: +2546752164; e-mail: emureu@jkuat.ac.ke).
P.K. Kihato, Department of Electrical and Electronic Engineering, JKUAT (e-mail: pkihato@jkuat.ac.ke).
P.K.Langat, Department of Telecommunication Engineering, JKUAT (e-mail:kibetlp@jkuat.ac.ke).

in low and middle-income countries such as Kenya every 10-percentage point increase in broadband penetration accelerates economic growth by 1.38 percentage points [4].The economic impact of broadband is wide – it positively impacts innovation, job creation and employment, as well as the software and manufacturing industries. It promotes access to information – thus promoting transparency and good governance, with related political and social benefits.

It is with all this in mind that this paper explores the potential of the TVWS technology in provision of broadband internet in Kenya in-order to raise the penetration levels as envisaged in the country's vision 2030 [5]. The potential is expressed through determination of the amount of the TVWS spectrum available in different parts of the country. This was done by evaluating the number of unallocated DTT channels from the Communication Authority of Kenya database. This was further qualified by taking UHF spectrum occupancy measurements in four different regions of the country. The availability of substantial amount of TVWS spectrum would be a good indication of the potential of TVWS technology in the country more so in the provision of broadband internet amongst other possible applications. The TVWS technology being a last mile connectivity solution needs to be supported by a backhaul network. It is thus paramount to evaluate existence of such networks in Kenya .The penetration of such networks in many parts of the country also serves as an indicator of the potential of deploying the TVWS technology.

Several other similar measurements have been taken in other countries and under different environments [6]-[11].

From these reviewed publications, it became evident that there is plenty of TVWS spectrum but it is dependent on a country, region, and whether indoor or outdoor. From the literature reviewed there is no work that has been done to establish the amount of TVWS spectrum available in Kenya. This work thus endeavors to fill that gap. The results of this work would be of importance to the policy makers as well as potential investors in the telecommunication industry amongst other stakeholders.

The rest of this paper is organized as follows ; Section two looks at the necessary infrastructure and policy to support TVWS technology, Section three illustrates the superior Propagation characteristics of TVWS, Section four determines the amount of TVWS spectrum available through the use of the Communications Authority of Kenya (CAK) database, Section five analysis the results of UHF spectrum occupancy measurements for four regions in Kenya, section six draws conclusions from the results presented concerning the potential of TVWS technology in Kenya.

## II. POLICY AND INFRASTRUCTURE

### *A. Policy*

The policy frameworks to support the growth of broadband penetration as envisioned in Kenya's vision 2030 are necessary. One the most important framework is the national broadband framework. This has been developed under the National Broadband strategy [12]. The overall objective of this Strategy is to provide quality broadband services to all citizens. The other framework that is important is on the management and regulation of TVWS technology in Kenya. The CAK has not put this in place and hence it is one of the requirements that need to be fast tracked if the country is to benefit from this technology in the near future. There is a pilot project on TVWS technology that is on going in the country [13] and the government has adopted a wait and see approach for it to decide on the way forward[14]. So far the results from these trials have indicated that it possible to use TVWS spectrum for broadband application without causing harmful interference to the DTT receivers. Also it has been found that it could offer data rates of between 6/6 Mbps to 16/6 Mbps [13]. This is within the Kenyan National broadband strategy targets for the rural areas.

### *B. Infrastructure*

The ministry of Information, Communications and Technology conceived and implemented a 4233 km National Optic Fiber Backbone Infrastructure (NOFBI), which was intended to link 80% of the districts and rural towns at the time of implementation. To extend the capacity to all parts of the country, the government is reviewing NOFBI with a view of extending and building additional links to enhance redundancy as shown in Fig.1[12].

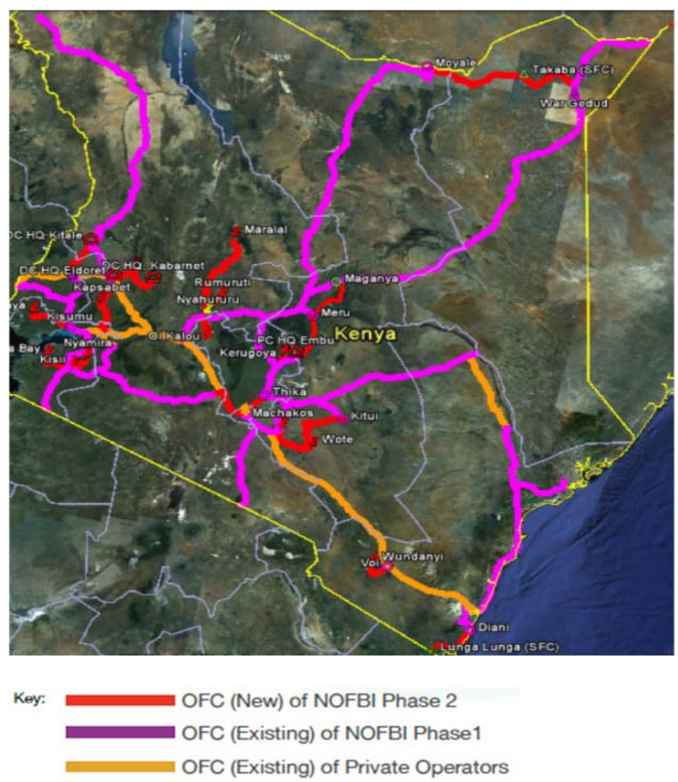


Fig.1 National Optic Fiber Backbone Infrastructure coverage

Fig. 2 shows the service access gaps in Kenya [12].

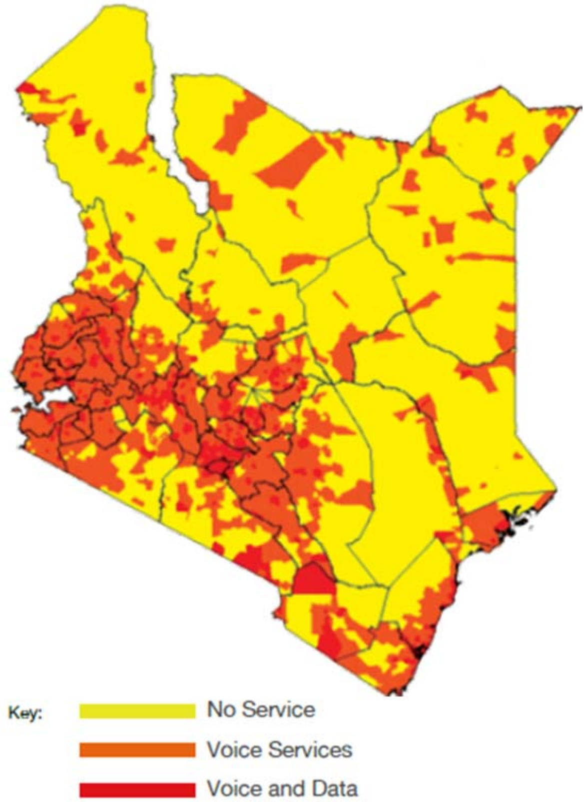


Fig.2: Service Access Gaps

As shown in Fig.2, the voice and data services are concentrated in the major urban areas. Most of the rural areas do not have access to data services.

The TVWS technology being a last mile access solution can leverage on the NOFBI network to provide affordable broadband to the rural areas.

Fig. 3 shows a typical TVWS network setup. The NOFBI or other backhaul network would connect the TVWS base stations to the Internet.

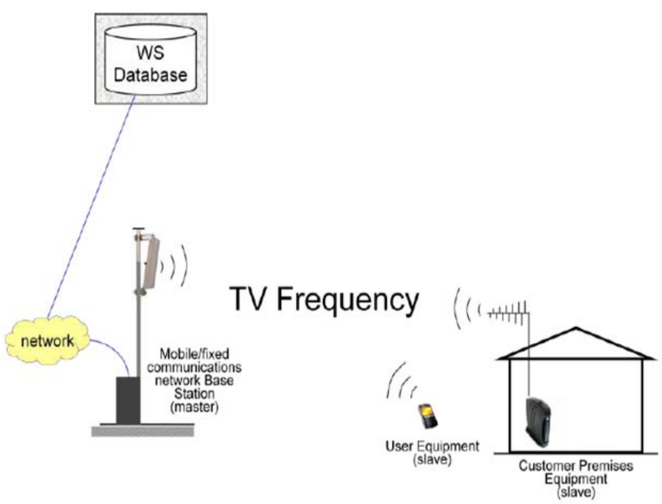


Fig. 3 Typical TVWS network setup

## III. UHF PROPAGATION CHARACTERISTICS

Simulations were carried out to compare the propagation characteristics of the radio signals at UHF frequencies (500 MHz) and at higher frequencies (3000 MHz) normally used by other competing wireless communication technologies like the WiMAX. The simulations were carried out using the Platform IT for an Analysis of Systems in Telecommunications (PIAST) [15], using the ITU-12.P1546-4 propagation prediction model [16].

The ITU-12.P1546-4 is a method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz developed by the Radio communication sector of International Telecommunication Union (ITU-R).

For the TVWS spectrum, a frequency of 500 MHz was chosen and for the WiMAX , a Frequency of 3000 MHz was chosen. All the parameters were kept the same. Fig. 4 and Fig. 5 shows simulation results for the 500 MHz and the 3000 MHz radio signals respectively. In both cases, the transmit power was set at 1KW Effective Radiated Power (ERP) and the radio signal field strength was measured at a distance of 100 Km from the transmitter. From Figures, the field strength of the 500 MHz radio signal is 18 dB (uV/m) and 14.0 dB (uV/m) for the 3000 MHz radio signal.

This shows the 500MHz frequency range used by the TVWS devices suffers less attenuation as distance of propagation increases as compared to the 3000MHz frequency range used by the WiMAX. This therefore shows that the signals of lower frequencies used by the TVWS technology can travel longer distances when compared to signals of higher frequencies used by the WiMAX. The implication of this is that you require fewer Base Transceiver Stations to cover the same region when using TVWS technology than when using WiMAX technology.

The Equation (1) shows how to calculate the radio signal field strength [14]:

$$E = \frac{E_{inf} + \left(E_{sup} + E_{inf}\right)\log\frac{h_1}{h_{inf}}}{\log\left(\frac{h_{sup}}{h_{inf}}\right)} \quad dB\left(\frac{\mu V}{m}\right) \tag{1}$$

$h_{inf}$ : 600 m if $h1$ > 1 200 m, otherwise the nearest nominal effective height below $h1$

$h_{sup}$ : 1 200 m if $h1$ > 1 200 m, otherwise the nearest nominal effective height above $h1$

$E_{inf}$ : field-strength value for *hinf* at the required distance

$E_{su}p$ : field-strength value for *hsup* at the required distance.

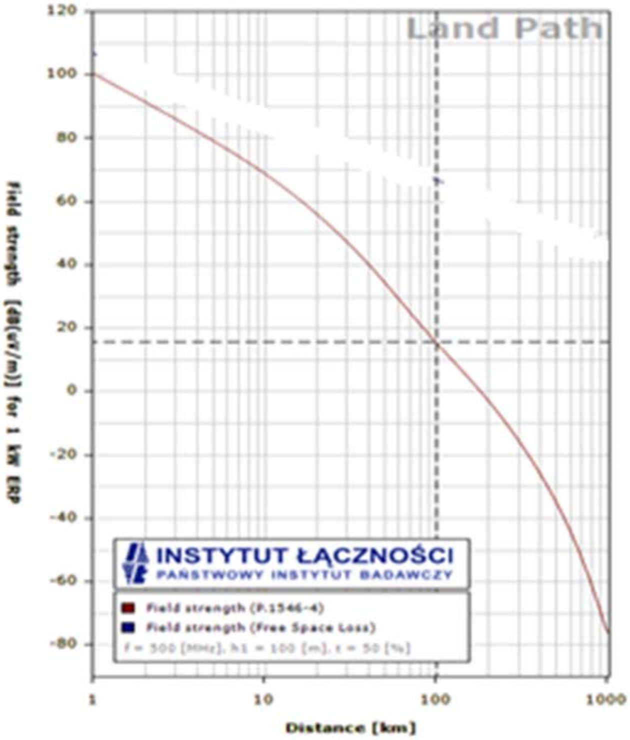


Fig.4 Field Strength for 500 MHz

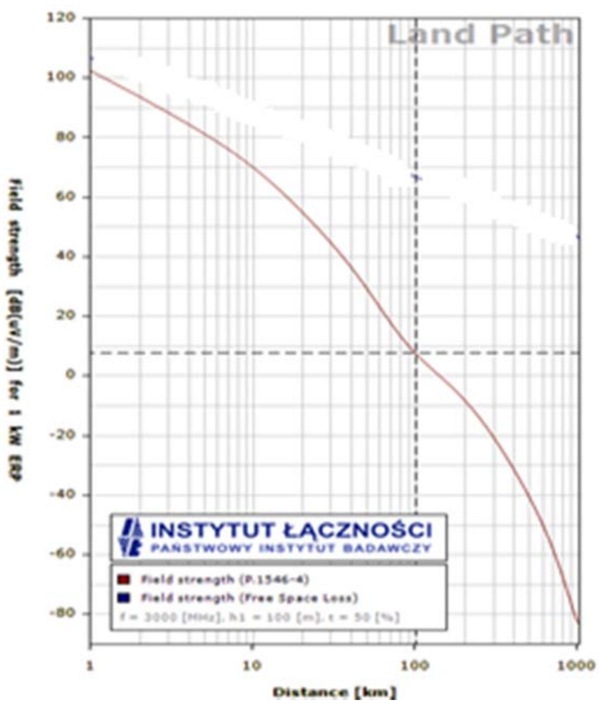


Fig.5 Field Strength for 3000 MHz

## IV. DETERMINATION OF TV WHITE SPACES

### *A. CAK Database*

The CAK has published the list of the Television broadcasting frequencies for the different regions in the country [17]. The DTT channels range from channel 21 (474 MHz) to channel 61 (794 MHz). The channels that have not been allocated for use by TV broadcasting services constitute Television white spaces in that region. Fig.6 is a heat map that shows the amount of Television white spaces in different towns of Kenya. The amount ranges from 23 channels to 40 channels. Since a DTT channel has a bandwidth of 8 MHz, it means the TVWS spectrum ranges from 184 MHz to 320 MHz in different regions of the country. This spectrum can be used for TVWS applications like provision of broadband internet. The amount of television whitespaces for the other areas not indicated can be approximated from the amount of their neighboring towns.

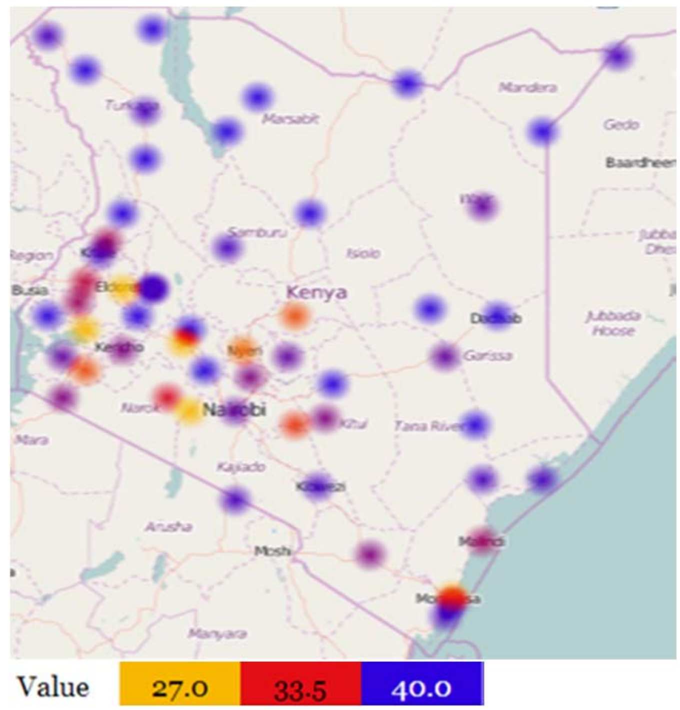


Fig.6 Amount of Television whitespaces in Kenya

### *B. Spectrum occupancy measurements*

Since the TVWS technology is envisaged to work opportunistically there could be channels that have been allocated to a TV broadcaster by the CAK but currently not in use. Such channels also constitute television white spaces. These channels can be identified through spectrum occupancy measurements. We undertook to make spectrum occupancy measurements in four regions of Kenya to establish whether there are DTT channels that have been allocated by CAK but not currently in use.

The measurement involved scanning all the DTT UHF channels and noting the channels where signal was detected and where no signal was detected. The channels where signal was not detected are taken to constitute the TVWS. This was done using a TV set-top box connected to a TV set and a UHF yagi antenna. The measurements were taken out-door in elevated areas with the antenna mounted at a raised position to ensure maximum reception. The measurements were repeated at several sites in the same region to ensure credibility of the results.

The results of these UHF spectrum occupancy measurements are as shown in TABLE 1togeteher with the corresponding information from the CAK frequency allocation database.

TABLE 1
UHF SPECTRUM OCCUPANCY MEASUREMENT RESULTS

| **TOWN** | **No. of channels allocated by CAK** | **No. of free channels according to CAK database** | **No. of channels found to be in use** | **No. of channels found to be free** |
|---|---|---|---|---|
| Nairobi | 19 | 23 | 15 | 27 |
| Nyeri | 12 | 30 | 8 | 34 |
| Machakos | 10 | 32 | 8 | 34 |
| Nakuru | 14 | 28 | 10 | 32 |

The spectrum occupancy measurements found that there are channels allocated for DTT broadcasting services by the CAK in various regions but which were not in use in the respective regions.

This therefore mean there is actually more TVWS spectrum than the amount that could be obtained from CAK database. The spectrum occupancy measurement is therefore more reliable in quantifying the amount of TVWS available in a region as it gives real-time information.

## V.CONCLUSION

The amount of the TVWS spectrum was found to be in plenty in all areas of Kenya both in rural and in urban areas. It means that the TVWS technology can be used both in urban and rural areas of Kenya. The discovery of some allocated but otherwise idle channels means that dynamic spectrum access methods are better placed to implement the TVWS technology than the static spectrum access methods. This is in order to improve on the spectrum use efficiency. The infrastructure to support the TVWS technology is found to be in place in most parts of the country. This is through the initiative of the National Optic Fiber Backbone Infrastructure. Some of the necessary policy frameworks were found to be in place and this includes the National Broadband and Vision 2030 strategies. What was found to be missing and need to be put in place is the management and regulation framework for the TVWS technology. The superior propagation characteristics of the UHF frequencies would give TVWS technology an advantage over other competing wireless technologies because it would be cheaper to implement by requiring fewer number of Base Transceiver Stations. The implementation cost can further be reduced if the government decides to offer TVWS spectrum on license-exempt basis. With a national broadband penetration of 14.8% only, it means there is enough market for the TVWS technology. This is more so in rural areas where such services are largely unavailable. In conclusion, we can therefore say that there is a huge potential of the TVWS technology in Kenya, for the provision of the much needed broadband internet. Future works in this area could be to undertake more exhaustive UHF spectrum occupancy measurements in all regions of the country to determine the actual amount of TVWS spectrum in the country.

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