Towards Affordable Broadband Communication: A Quantitative Assessment of TV White Space in Tanzania

Jabhera Matogoro(✉), Nerey H. Mvungi, Anatory Justinian, Abhay Karandikar, and Jaspreet Singh

College of Informatics and Virtual Education, The University of Dodoma, P.O Box 490, Dodoma, Tanzania
jaberamatogoro@udom.ac.tz, nhmvungi@udsm.ac.tz, anatory@engineer.com, karandi@ee.iitb.ac.in, jaspreet.singh@iitb.ac.in

Abstract. A quantitative assessment of TV White Space in Tanzania was conducted to assess the level of spectrum utilization as well as a key milestone towards the use of white space for affordable broadband communication. Two approaches have been used; pollution and protection viewpoints and experimental spectrum measurements based on energy detection principle. The study focused on 470–694 MHz UHF spectrum band which is used for digital terrestrial television in Tanzania. It was found that, more than 120 MHz is available as white space in various locations in Tanzania when pollution and protection view point was used and about 184 MHz are available as white space in Dodoma urban using experimental spectrum measurements and almost 100% of the available frequencies are not used in Dodoma rural. Both approaches revealed that there is low spectrum utilization and therefore presents a best case towards development of dynamic spectrum access technologies in Tanzania.

Keywords: White space · Spectrum analyzer · Energy detection principle Dynamic spectrum access

1 Introduction

Tanzania has experienced an exponential increase in the number of voice telephone and Internet users in the last few years. According to Tanzania Communications Regulatory Authority (TCRA) statistics, the number of voice telephone subscribers has increased from 6.3 million users in March, 2007 to 39.9 million users in March, 2017 [1, 2]. Furthermore, the estimated number of Internet users has increased from 5.3 to 19.9 million users in 2011 to 2016 respectively [2]. From 2016 Internet users statistics above, the distribution of Internet users according to technology type is 90.7%, 6.1% and 3.2% for mobile wireless, fixed wireless and fixed wired respectively. The increase of both voice telephone and Internet users in Tanzania has resulted to more demand of spectrum resources to meet the current and future needs.

There is growing recognition across the globe that dynamic spectrum access, especially on the Television White Spaces (TVWS) has significant potential to address

F. Mekuria et al. (Eds.): ICT4DA 2017, LNICST 244, pp. 320–330, 2018.
https://doi.org/10.1007/978-3-319-95153-9_29

challenges associated with the raising importance of radio spectrum and can optimize spectrum utilization. In this paper, an investigation was conducted to quantify the availability of TVWS in 470–694 MHz Ultra High Frequency (UHF) spectrum band in Tanzania. The overarching objectives of this paper is three-fold; firstly, is to guide a range of stakeholders so as to increase the use of the currently underutilized TV UHF spectrum band; secondly, to attract more Research and Development (R&D) investments on dynamic spectrum access using TVWS and thirdly, necessitate the discussion to establish a sound technical and legal framework to embrace the dynamic spectrum access paradigm towards affordable broadband communication in Tanzania.

2 Related Work

An estimation of TV White Space has been regarded as a critical step for the efficient and effective spectrum management scheme. TVWS estimation informs various stakeholders including regulators, researchers, industrial, scientific and medical communities on the current spectrum usage and possible values that can be harvested from using the licensed but under-utilized TV UHF radio spectrum band. The spectrum scarcity experienced by many regulatory authorities can be seen as an artificial problem due to lack of effective technical solutions that make use of the available spectrum band at all times and in all locations. In order to understand how UHF spectrum band is utilized in various locations around the globe, many studies have been carried out and revealed that there is low spectrum utilization especially in TV UHF spectrum band −55.5% to 55.8% in United States [3], 66.58% in Spain [4], 43.06% for urban and only 11.42% for rural in Romania [5], 7.14% in Philippines [6], 13.46% at University of Hull in United Kingdom [7], 56% in Europe [8], 32% in a study conducted in Italy, Spain and Romania [9], 20% in South Africa [10] and approximately 150 MHz and 112 MHz is available as white space in United Kingdom [11] and India [12] respectively. In the literature, it is clearly shown that spectrum utilization differ from one country to another and this is due to the fact that every country is an autonomous regarding local frequency allocation and is also bound by local regulatory bodies [13]. It is therefore important for country specific studies to be conducted to be able to understand local spectrum utilization in various countries around the globe. This is also important when working for technical and legal framework aimed to favor the use of TVWS for broadband communication in a specific self-governing country. It has also observed that spectrum utilization is high in urban area as compared to rural area [5, 14] and hence making rural area the best case to efficiently utilized the unused spectrum band to bridge the digital divide.

3 Methodology

In order to answer the question on “how much white space is there in Tanzania”, this paper uses two methods. Firstly, a computational tool based on Mat lab simulation to generate a color-coded map of the United Republic of Tanzania showing how many MHz of white-space is available as shown in Figs. 3 and 4. The tool used the pollution

and protection viewpoint that was introduced by [15] to establish the pollution and protection regions and Hata empirical formula [16] was used for propagation loss calculation of the TV UHF transmitters. Among other reasons of choosing this propagation model is due to the fact that it was derived from extensive measurement of data over various situations of irregular terrain and environmental clutter to some extent meeting local environment. Secondly, an experimental spectrum measurement was conducted in Dodoma Region using inexpensive handheld spectrum analyzer [17] to find out how TV UHF spectrum band is utilized in rural and urban areas in Dodoma Region. The measurement was based on energy detection principle where a threshold value was used to determine whether a certain frequency is occupied or not. Furthermore, a Monitoring Software R&S ARGUS [18] was used to validate results obtained from pollution and protection view points as well as that from inexpensive handheld spectrum analyzer. In the literature, two approaches are the commonly used to estimate the white space in a location; pollution and protection viewpoints base on TV transmitters' databases [12, 19, 20] and energy detection principle [10, 14, 21, 22].

3.1 Study Location

This study was designed to estimate TV White Space in Tanzania Mainland. According to 2012 census [23], Tanzania Mainland has a population of 43.6 Million to which 21.2 million are males and 22.4 are female. In addition, Dodoma Region was selected for a measurement campaign in order to assess spectrum utilization in both rural and urban areas. Dodoma Region has a population of 2.08 million in its seven districts councils [23] and is the capital city of Tanzania. The rationale of choosing Dodoma Region for an experimental spectrum measurement is due to the fact that, it is among the fast growing regions of Tanzania presenting high demand for affordable broadband services. Furthermore, the College of Informatics and Virtual Education of the University of Dodoma which is the host institution of this study received an authorization letter from TCRA to conduct a research on dynamic spectrum access using TVWS in Dodoma Region.

3.2 Pollution and Protection Viewpoints

In the literature, the pollution and protection viewpoints approach have been used to estimate white space in United States [20] and India [12]. In pollution viewpoint perspective, the primary user is considered to raise the noise floor at secondary user location and therefore each television tower should have a pollution radius around it in which the secondary user is not allowed to transmit. Whereas, in protection viewpoint, a secondary user is permitted to transmit in a location with the condition that, it is should not cause any harmful interference to the primary receivers in its vicinity [12, 15]. In order to quantify the availability of white space using pollution and protection viewpoints, the researcher of this study received transmitters' information from TCRA. This information included position of the tower (latitude and longitude), transmission power of the TV transmitters, frequency of operation and height of the antenna for all Digital Terrestrial Television (DTT) transmitters in Tanzania. The study used a matlab tool to process the given data in order to quantify the amount of TVWS in Tanzania.

Currently, there are no TV white space regulations in Tanzania. The regulations of FCC (US) are borrowed for the estimation of TV white space in Tanzania. Microphones are ignored in the computation due to lack of available information.

3.3 Measurement Locations and Equipments

A spectrum measurements campaign was conducted in Dodoma Municipal Council, Kondoa, Bahi and Chamwino District Councils to establish spectrum utilization in these locations. Selected locations in Dodoma Municipal Council are categorized as urban area whereas those from Kondoa, Bahi and Chamwino District Councils are rural areas in nature. Figure 1 shows locations considered for measurement campaign in Dodoma Region.

Equipments used for the experimental spectrum measurement consists: RF Explorer WSUB1G Spectrum Analyzer, Toshiba Laptop with Ubuntu Operating System (OS) and Inverter connected to a car battery to power the devices and Nagoya NA-773 wideband telescopic antenna with SMA male connector. RF Explorer spectrum analyzer has the following specifications: Frequency band (240–960 MHz), Frequency span (112 kHz–100 MHz), amplitude resolution (0.5 dBm), dynamic range (−115 dBm to 0 dBm), absolute max input power (+5 dBm) and average noise level (−110 dBm).

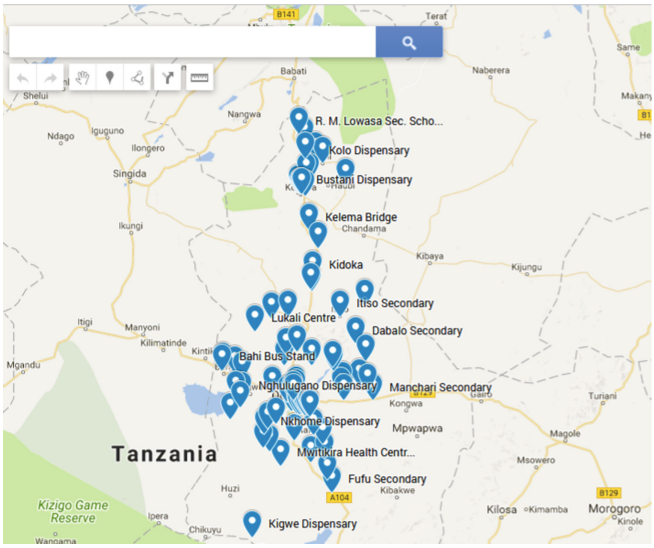

Fig. 1. Locations considered for measurement campaign (Source: Google maps)

For a successful static spectrum measurement, Rfestatic application was installed in Ubuntu OS. To start data acquisitions, a bash script was launched to collect power levels of UHF channels for DTT which ranges from channel 21 to 48 (470–694 MHz). The collected data files were further analyzed to decide if a channel is occupied or not. A threshold value of −85 dBm and 80% of the samples below this threshold value were

used to consider a channel is occupied. In each location, duration of 15 min was configured to collect reading of power levels of TV UHF transmitters in a given location. In addition, spectrum utilization results generated from inexpensive RF Explorer WSUB1G model was further validated using commercial R&S Argus Monitor software, which is the standard software for spectrum monitoring and evaluation in accordance with ITU recommendations [18].

4 Results and Major Observations

In this study, two approaches have been used to estimate white space in Tanzania. The pollution and protection viewpoint was used to generate a color-coded map of Tanzania Mainland showing the amount of spectrum available as white space in MHz as shown in Figs. 2 and 3. This estimate is based on the transmitters' information obtained from TCRA.[1]

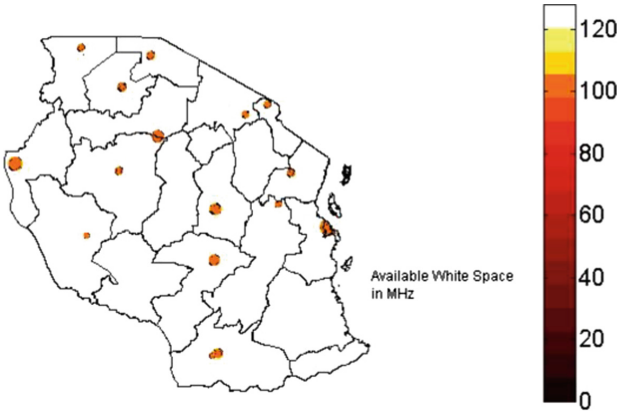

Fig. 2. TV white space availability using pollution viewpoint γ = 15 dB (Color figure online)

Figures 2 and 3 shows that in most places of Tanzania, an average of more than 120 MHz (more than 15 channels of 8 MHz) are available as white space. The color cycles in the map represents various TV transmitters located in Tanzania generated from computer simulation. This result was further validated using physical measurement campaign based on commercial R&S Argus Monitor software in Dodoma Region and it was found that about 184 MHz (23 channels of 8 MHz) is available as white space in urban area. In Dodoma Region, the digital terrestrial television transmitters are located in Imagi Hills with −6.213 and 35.753 coordinates of latitude and longitude respectively.

[1] While TV transmitters' information is publicly available in other countries including US, it is not so in Tanzania. This information is only available upon request to Tanzania Communications Regulatory Authority.

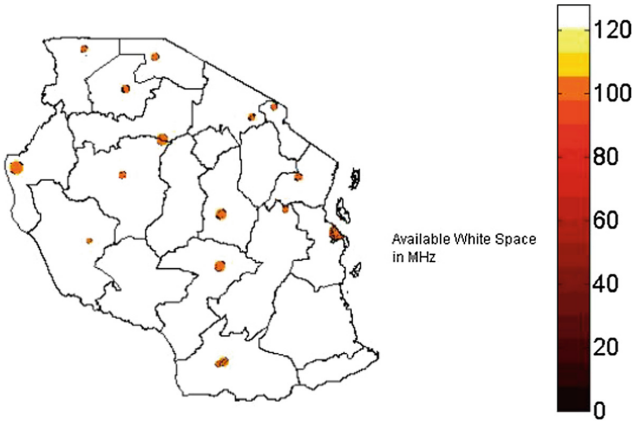

Fig. 3. TV white space availability using protection viewpoint Δ = 1 dB (Color figure online)

The results of the data collected in Nyerere Sqaure (−6.178, 35.748) a location in Dodoma Municipal Council was analyzed using a threshold value of −85, it was found that about 23 channels (82.1%) are free and only 5 channels are occupied (17.9%). Figure 4 shows a heat map graph with Received Signal Strength Indicator (RSSI) in dBm was generated using inexpensive handheld spectrum analyzer at Nyerere Sqaure in Dodoma Region. The color legend represents various power levels, whereby a threshold value of −85 dBm was used to decide if a channel is occupied or not. A result generated in Fig. 4 was validated using commercial R&S Argus Monitor software and found only 40 MHz (5 channels) are available as occupied channels shown in Fig. 5.

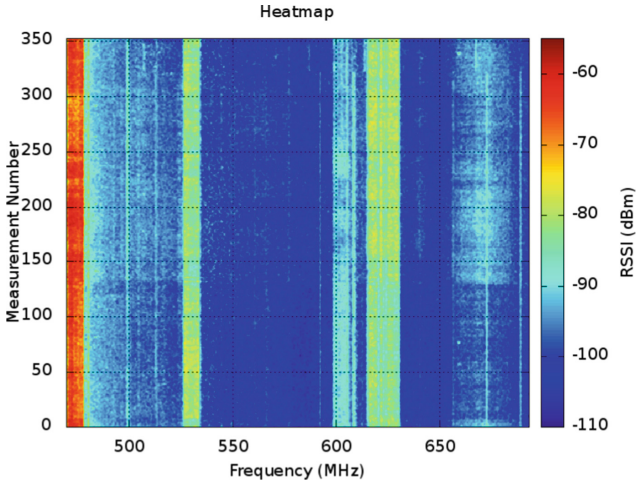

Fig. 4. Spectrum utilization graph for data collected at Nyerere Square (−6.178, 35.748), Dodoma Municipal Council using handheld spectrum analyzer. (Color figure online)

In order to validate results obtained from both computer simulation and measurement campaign using inexpensive handheld spectrum analyzer, commercial R&S Argus Monitor software was used to validate spectrum utilization results in Tanzania, specifically in Nyerere Sqaure as shown in Fig. 5. It was found that only 5 channels were found occupied and 23 channels are available as free channels in this location.

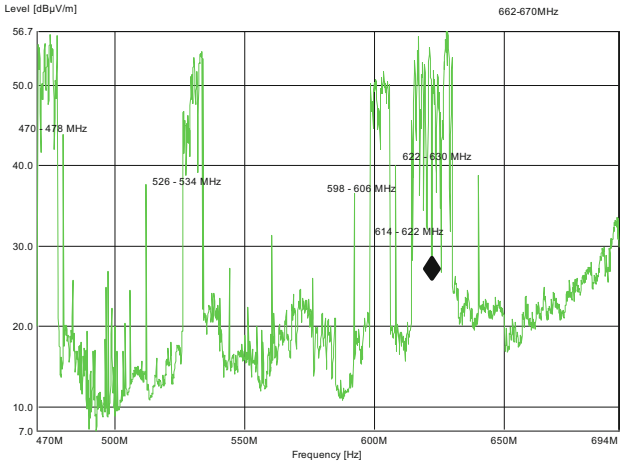

Fig. 5. Spectrum utilization graph for data collected at Nyerere Square, Dodoma Municipal Council from R&S Argus Monitoring Software.

Table 1 shows the results of free and occupied channels in Dodoma Municipal Councils. It is clearly shown that in most of locations, 23 channels out of 28 channels (82.1%) of the spectrum are unused in Dodoma Municipal Council. This is an indication that there is a high possibility of using the identified unused UHF spectrum for other services such as broadband communication without affecting broadcasting services.

Table 1. Free and occupied channels in various locations in Dodoma Municipal Council.

Location name	Coordinates (Lat & Long)	Free channels	Occupied channel
Kikuyu Secondary	−6.201, 35.729	23	5
The University of Dodoma	−6.216, 35.789	23	5
Miyuji Secondary	−6.132, 35.740	27	1
Nyerere Square	−6.178, 35.748	23	5
College of Business Education	−6.177, 35.758	25	3

The study further revealed that almost all 28 channels (100%) of TV UHF spectrum is unused in Kondoa District Council as shown in Table 2. Kondoa District Council is

located about 140 km from Dodoma Municipal Council where all digital terrestrial transmitters are located.

Table 2. Free and occupied channels in various locations in Kondoa District Council.

Location name	Coordinates (Lat & Long)	Free channels	Occupied channel
Masange Secondary	−4.606, 35.804	28	0
Busi Health Centre	−4.850, 36.051	28	0
ULA Secondary School	−4.900, 35.765	28	0
Kondoa Girls High School	−4.888, 35.769	28	0
Bustani Teacher's College	−4.898, 35.789	28	0
Pahi Centre	−4.716, 35.917	28	0

Figure 6 heat map graph for spectrum utilization at Ibihwa Dispensary in Bahi District Councils and Table 3 shows the number of free and occupied channels in various locations in Chamwino District Council. The blue color indicates that all channels have power level below −85 dBm. Similarly, the study revealed that almost all 28 channels (100%) of TV UHF spectrum band are unused in these locations. Bahi and Chamwino District Councils are located about 60 km and 40 km from Dodoma Municipal Council respectively.

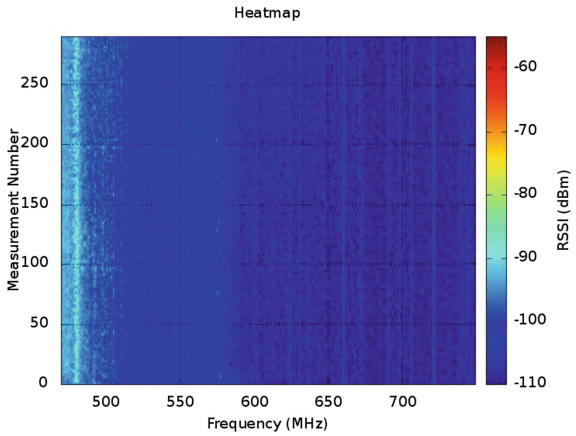

Fig. 6. Spectrum utilization graph for data collected at Ibihwa Dispensary (−6.005, 35.432), Bahi District Council using handheld spectrum analyzer. (Color figure online)

Table 3. Free and occupied channels in various locations in Chamwino District Council.

Location name	Coordinates (Lat & Long)	Free channels	Occupied channel
Dabalo Secondary	−4.606, 35.804	28	0
Itiso Secondary	−4.850, 36.051	28	0
Chilonwa Secondary	−4.900, 35.765	28	0
Fufu Secondary	−4.888, 35.769	28	0
Makwawa Secondary	−4.898, 35.789	28	0
Mvumi Mission Secondary	−4.716, 35.917	28	0

5 Conclusion and Recommendation

In this paper, a quantitative assessment of TV White Space in Tanzania was conducted. In Tanzania, digital terrestrial television is allocated to use spectrum band in the range of 470–694 MHz with about 28 channels of 8 MHz. When the pollution and protection view point approach was used, it was found that more than 120 MHz of TV UHF spectrum band is available as free channel in most of locations in Tanzania. In addition, the study found that almost 82.1% of TV UHF spectrum is unused in most of urban areas of Dodoma Region when energy detection principle was used. Experimental measurements that were conducted in Kondoa, Bahi and Chamwino District Councils also revealed that 100% of TV UHF spectrum band is not used in most of these locations. This study is an important milestone towards development of dynamic spectrum access technologies in Tanzania. The College of Informatics and Virtual Education of the University of Dodoma has received an authorization letter from TCRA to transmit in TV UHF spectrum band for dynamic spectrum access researches. In future, a test bed network will be deployed in Dodoma Region to make use of the identified white space for wireless broadband communication. The test bed network will also be a critical step to help various stakeholders in the development of legal and technical framework that favors the use of dynamic spectrum access in Tanzania. For efficient spectrum utilization in Tanzania, a geo-location database is currently under development at the University of Dodoma, the results of this work will further be published for public access.

Acknowledgments. Mr. Jabhera Matogoro, a first author of this study would like to extend his thanks to NAM S&T Centre of New Delhi and Indian Institute of Technology Bombay, India for the award of Six Months Research Training Fellowship for Developing Country Scientists (RTF-DCS) where he participated in TV White Space Research Project in India. This work was also supported by various stakeholders in different capacity, including; The University of Dodoma, Higher Education Students' Loans Board, International Centre for Theoretical Physics, Internet Society, Council for Scientific and Industrial Research and Tanzania Communications Regulatory Authority.

References

1. TCRA: Telecommunication Statistics as at March 2007 (2007). https://www.tcra.go.tz/index.php/2007/March-2007. Accessed 29 June 2017
2. TCRA: Quarterly Communications Statistics Report: January–March 2017 Quarter. Dar es Salaam (2017)
3. McHenry, M.A., Tenhula, P.A., McCloskey, D., Roberson, D.A., Hood, C.S.: Chicago spectrum occupancy measurements & analysis and a long-term studies proposal. In: TAPAS' 2006, Proceedings of the First International Workshop on Technology and Policy for Accessing Spectrum, Article No. 1 (2006)
4. López-Benítez, M., Umbert, A., Casadevall, F.: Evaluation of spectrum occupancy in Spain for cognitive radio applications. In: VTC Spring 2009 - IEEE 69th Vehicular Technology Conference, Barcelona, pp. 1–5 (2009)
5. Martian, A.: Evaluation of spectrum occupancy in urban and rural environments of Romania. Rev. Roum. des Sci. Tech. - Ser. Electrotech. Energ. **59**(1), 87–96 (2014)
6. Pintor, A.L.C., To, M.R.S., Salenga, J.S., Geslani, G.M., Agpawa, D.P., Cabatuan, M.K.: Spectrum survey of VHF and UHF bands in the Philippines. In: TENCON 2012, IEEE Region 10 Conference, Cebu, pp. 1–6 (2012)
7. Mehdawi, M., Riley, N., Paulson, K., Fanan, A., Ammar, M.: Spectrum occupancy survey in HULL-UK for cognitive radio applications: measurement & analysis. Int. J. Sci. Technol. Res. **2**(4), 231–236 (2013)
8. Van de Beek, J., Riihijarvi, J., Achtzehn, A., Mahonen, P.: TV white space in Europe. IEEE Trans. Mob. Comput. **11**(2), 178–188 (2012)
9. Fadda, M., Popescu, V., Murroni, M., Angueira, P., Morgade, J.: On the feasibility of unlicensed communications in the TV white space: field measurements in the UHF band. Int. J. Digit. Multimed. Broadcast. **2015** (2015)
10. Barnes, S.D., Jansen Van Vuuren, P.A., Maharaj, B.T.: Spectrum occupancy investigation: measurements in South Africa. Meas. J. Int. Meas. Confed. **46**(9), 3098–3112 (2013)
11. Nekovee, M.: Quantifying the availability of TV white spaces for cognitive radio operation in the UK. In: 2009 IEEE International Conference on Communications Workshops, Dresden, pp. 1–5 (2009)
12. Naik, G., Singhal, S., Kumar, A., Karandikar, A.: Quantitative assessment of TV white space in India. In: 2014 Twentieth National Conference on Communications (NCC), pp. 1–6 (2014)
13. Brown, T.X., Pietrosemoli, E., Zennaro, M., Bagula, A., Mauwa, H., Nleya, S.M.: A survey of TV white space measurements. In: International Conference on E-Infrastructure and E-Services for Developing Countries, pp. 164–172 (2014)
14. Kumar, P., Rakheja, N., Sarswat, A., Varshney, H., Bhatia, P., Goli, S.R., Ribeiro, V.J., Sharma, M.: White space detection and spectrum characterization in urban and rural India. In: 2013 IEEE 14th International Symposium on "A World Wireless, Mobile and Multimedia Networks" (WoWMoM), Madrid, pp. 1–6 (2013)
15. Mishra, S.M.: Maximizing Available Spectrum for Cognitive Radios. University of California at Berkeley, Berkeley (2010)
16. Hata, M.: Empirical formula for propagation loss in land mobile radio services. IEEE Trans. Veh. Technol. **29**(3), 317–325 (1980)
17. RF Explorer: RF Explorer User Manual. http://j3.rf-explorer.com/download/docs/RFExplorerSpectrumAnalyzerUserManual.pdf. Accessed 27 June 2017
18. Rohde-Schwarz: Monitoring Software R&S ARGUS. http://www.rohde-schwarz-ad.com/docs/specmon/TI_ARGUS.pdf. Accessed 17 May 2017

19. Makris, D., Gardikis, G., Kourtis, A.: Quantifying TV white space capacity: a geolocation-based approach. IEEE Commun. Mag. **50**(9), 145–152 (2012)
20. Harrison, K., Mishra, S.M., Sahai, A.: How much white-space capacity is there? In: 2010 IEEE Symposium on New Frontiers in Dynamic Spectrum Access Network (DySPAN), Singapore, pp. 1–10 (2010)
21. Zennaro, M., Pietrosemoli, E., Mlatho, J., Thodi, M., Mikeka, C.: An assessment study on white spaces in Malawi using affordable tools. In: 2013 IEEE Global Humanitarian Technology Conference (GHTC), San Jose, CA, pp. 265–269 (2013)
22. Dinh, C.H., Van Tien, P.: Assessment of TV white space in Vietnam. In: 2014 International Conference on Advanced Technologies for Communications (ATC 2014), Hanoi, pp. 637–640 (2014)
23. United Repubic of Tanzania (URT): 2012 Population and Housing Census Population Distribution by Administrative Areas. National Bureau of Statistics, Dar es Salaam (2013)