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Quantitative estimation of TV white space in Southwest Nigeria

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ABSTRACT

The demand for bandwidth has increased in recent years with the advent of new technologies in the wireless systems which have resulted into spectrum crunch. Utilizing the free ultra high frequency (UHF), television (TV) channels also known as TV white space (TVWS) has been proposed as a strategy for increasing spectral efficiency. Deploying TVWS requires the knowledge of the estimate of the available TVWS. In this paper, a quantitative estimation of the available TVWS in South West, Nigeria is computed using the protection view point approach, the pollution viewpoint approach and the Federal Communication Commission (FCC) rule. Results from the estimation shows that the pollution view point approach will guarantee enough protection from the primary users and hence prevent interference from the secondary users. The findings also reveal that there are abundant TVWS in the considered states for the deployment of TVWS devices.

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1. INTRODUCTION

There is increasing pressure on available spectrum as a result of growing demand for spretrum occupancy for wireless applications especially in the cellular network [1-5]. Spectrum is a finite resource and has been fully allocated as bands for different wireless services. A completely occupied band can only acquire more spectrums if it is released by another band. Several researches have focused on spectrum occupancy measurement in different countries in recent time. Results from recent research shows that most of the allocated spectrums are underutilize [6-10]. Dynamic spectrum access is the permanent viable solution for the problem of spectrum crunch. However, in the interim the the use of currently unoccupied spectrum allocated to TV stations can reduce the problem of the spectrum crunch [11].

Different frequencies are assigned for specific uses by National and International bodies, and in most cases they are granted exclusive rights to operate over these frequencies. A band plan is created by the frequency allocation, which assigns white spaces between licensed radio bands or channels to avoid interference. These spaces have been specifically assigned for a purpose, such as a guard band even though some are utilized. In addition to the assigned spaces for technical reasons, there is also unused radio spectrum which has either never been used, or is becoming free as a result of technical changes. For instance, there is a large areas between 50 MHz and 700 MHz that is freed up by the switchover to digital television [12]. Moreover, most of the TV stations do not transmit to full capacity (reduced coverage area and operation time). These unused or underutilized portions of the TV band are called the TV white spaces (TVWS). TV white space is one of the promising solutions for extending broadband connectivity to underserved areas due to its relatively long wavelength which is able to cover a large area and penetrate buildings, vegetation and terrain with good signal integrity. In order to make use of the available TVWS in any area, a proper estimation of the TVWS needs to be conducted so as not to cause any interference to signals from the surrounding incumbent TV broadcasting stations. Several TVWS measurements and estimation have been conducted by different researchers across the world and the results show that there are sizeable amounts of TVWS available across the globe.

In [13] the available TVWS in Pakistan was analyzedand estimated using energy detection technique for spectrum sensing. The whole TV frequency band (52-862 MHz) was scanned with universal software radio peripheral (USRP2) and a spectrum analyzer was used to validate the results of the USRP2 and the potential of cognitive radios in Pakistan. Comprehensive quantitative assessment and estimate of TVWS in the 470-590 MHz band for four zones of India was also conducted in [14] using the protection view point, pollution view point and the Federal Communication Commission (FCC) [15] requlation approach. A model to estimate the spectral opportunity (SO), otherwise called TV white space (TVWS), in the terrestrial broadcast frequency spectrum was developed in [16]. The model was applied to the latest publicly accessible South African terrestrial broadcast frequency assignments and an estimate of the available SOs in the Guateng province of South Africa was given. Other researches were conducted in [17-30] using different methods to estimate spectrum occupancy with a bid to determine available TVWS for secondary users. Many standards for TV white space devices are being developed all over the world for exploiting the available TVWS [31-38].

The Nigerian Communication Commission in the year 2020 constituted a committee to draft the TVWS guideline in Nigeria in preparation for the deployment of TVWS. To do this appropriately, it is needful to have an estimate of the TVWS across the licensed TV bands. In this paper, a quantitative estimation of the available TVWS in the UHF band in South West, Nigeria is carried out using the protection view point approach, the pollution viewpoint approach and the FCC rule. To do the quantitative estimation of the available TVWS using the the three methods, an empirical model for path loss must be adopted for the region that best predict the path loss in the region. Investigations conducted in [39-43] shows that Hata-Davison is the most appropriate path loss models for describing the propagation profile in the region and is henced adopted for the estimation of the TVWS in the adopted region.

2. RESEARCH METHOD

2.1. TV broadcasting systems in Nigeria

The TV broadcasting designation bands according to Nigerian Broadcasting Commission (NBC) include band III and band IV/V. Band III is a Very High Frequency band (30-300 MHz) and it frequency ranges from 174 MHz to 230 MHz. This band corresponds to channels 5 to 12 of Nigeria TV broadcasting system. Bands IV and V are in the UHF (300MHz–3GHz) band. The frequency of band IV is between 470 MHz and 582 MHz which correspond to channels 21-34. The frequencies of band V is between 582 MHz and 790 MHz which correspond to channels 35-60 [42].

2.2. Study area

The Southwest zone of Nigeria consists of six states which are Ekiti, Lagos, Ogun, Ondo, Osun and Oyo states. These states are made up of urban, sub-urban and rural settlements, hence the reason for the selection. In this work, we defined TVWS from the perspective of the coverage area of the TV broadcasting sstation. This is considered as the geographic area within the TV noise limited grade B contour. The coverage area is the area where the received signal strength for channels 14 to 69 exceeds 64 dBu and 41 dBu for analog and DTV systems respectively [41]. The parameters required to estimate the available TVWS are the location of the tower, transmission power of the TV transmitter, frequency of operation and height of the antenna. The government owned TV stations operating in the UHF band is adopted for this investigation and their operational parameters are shown in Table 1.

Table 1. Transmission parameters of the adopted UHF TV stations in Southwest, Nigeria

TV Stations	Ekiti TV	Lagos TV	Ogun TV	Ondo TV	Osun TV	Oyo TV
Channel	41	35	25	23	22	28
(mid frequency MHz)	(631.25)	(583.25)	(503.25)	(487.25)	(479.25)	(527.25)
Transmitter antenna height (m)	200	396.24	45.72	304	304.80	198.20
Transmitter Power (kW)	1.76	40	35	40	30	30
Latitude	7.67576	6.61591	7.14255	7.29347	7.77670	7.41217
Longitude	5.24660	3.35501	3.42131	5.16084	4.58961	3.93165

Using the TV transmitter information and a suitable propagation model, quantifying available TV white space in the UHF TV band were done by three different methods which are:

a. Protection viewpoint

The protection viewpoint ensure that the primary users are immunued from interference from the secondary devicesThe protection area is defined as [14];

$$P_t + P_L(r_p) - N_0 = \Delta \tag{1}$$

where is the power of the primary transmitter in dB, $P_L(r_p)$ is the path-loss in dB at a radial distance from the transmitter, N_o is the thermal noise in dBm and Δ is the threshold SINR in dBm. in (1) is modified as:

$$P_t + P_L(r_p) - N_0 = \Delta + \psi \tag{2}$$

where Ψ is for the fade margin added. For adjacent channels an additional 27dB fade margin was provided. The distance from the transmitter up to which no secondary user can transmit is the existing no-talk radius r_n. The difference $r_n - r_p$ is calculated such that if a secondary user transmits at a distance $r_n - r_p$ from a TV band receiver located at r_p, then the SINR at the receiver within a radius r_n does not fall below Δ. $r_n - r_p$ is then calculated as follows [14];

$$P_s - P_L(r_n - r_p) = \psi \tag{3}$$

where P_s is the secondary transmitter power in dBm.

b. Pollution viewpoint

In the pollution view point approach, the fact that the interference caused by the primary user on a secondary receiver might be higher than the tolerable interference level of the secondary receiver is considered. The pollution radius r_{pol} is therefore given thus (4) [14], where ϒ is the tolerable interference of the secondary receiver.

$$P_t + P_L(r_p) = N_0 + \gamma \tag{4}$$

c. FCC rule

The FCC rule was developed in the USA by spectrum regulator in a bid to determine the no-talk radius around a TV tower. In the FCC rule, the protected radius is assumed to be the same as the Grade B contour and the interference level at the protected radius (r_p) should be 23 dB lower than the signal level. In the UHF band, r_p is the distance from the TV tower where the field strength of the primary signal falls to 41 dBu [14]. The parameters used for the calculation of the TVWS according to protection and pollution viewpoints are given in Tables 2 and 3 respectively. There are a few assumptions made in this work which should be pointed out. Firstly, there are no TVWS regulations in Nigeria, so the regulations of FCC (USA) are made use of for the TVWS estimation. Secondly, microphones and other wireless devices using the TV band are not put into consideration due to lack of available information about their operations.

Table 2. Parameters for calculating TVWS using protection [14]

Parameter	Specification
Maximum tolerable interference (ϒ) by secondary user	15 dB (specified for 802.11g systems)
Maximum tolerable interference (ϒ) by secondary user (adjacent channel)	45 dB
Noise in a 8 MHz band (N_0)	-104.97 dBm

Table 3. Parameters for calculating TVWS using pollution viewpoint [14]

Parameter	Specification
Target fading margin (Ψ)	1 dB (Specified by FCC)
Additional fading margin in adjacent channel	27 dB (Specified by FCC)
Required SINR for primary receiver	45 dB
Transmission power of secondary device	36 dBm
Height above average terrain (HAAT) of secondary device	30 m

3. RESULTS AND ANALYSIS

Figures 1 to 6 shows the results of the estimation of TVWS for Government-owned UHF TV channels in each of the Southwestern States using the protection viewpoint, pollution viewpoint, and the FCC rule. The coverage area of the TV stations and the available TVWS is displayed on the administrative maps of the states. Figure 1 shows the TVWS estimation for Ekiti State displayed on its administrative map. The circles represent the coverage area of the TV station as predicted by the protection viewpoint, pollution viewpoint and the FCC rule. Areas outside these circles are regarded to as TVWS. The TVWS shown in white in the map are areas outside the radius of 40.90 km from the transmitter with reference to the pollution viewpoint.

Figure 2 shows the coverage area of the Lagos TV broadcastion station and the available TVWS from this TV ststaion. The TVWS are area outside the radius of 59.48 km from the transmitter. The result shows that the huge part of Lekki, Epe and Badagry are available for deployment of TVWS devices. For Ogun State, the TVWS is shown in Figure 3. The TVWS in Ogun State are areas outside the radius of 28.47 km from the transmitter from the perpective of the poulltion view point. The result shows whole lots of land mass as TVWS available for the deployment of TVWS technology. A closer look shows that about nine local government areas are free for usage by secondary users as TVWS. For Ondo State, the TVWS is shown in Figure 4. The TVWS in Ondo State are areas outside the radius of 58.59 km from the transmitter from the perpective of the poulltion view point. The result shows a huge land mass as TVWS available for the deployment of TVWS technology. A closer look shows that about ten local government areas is free for usage by secondary users.

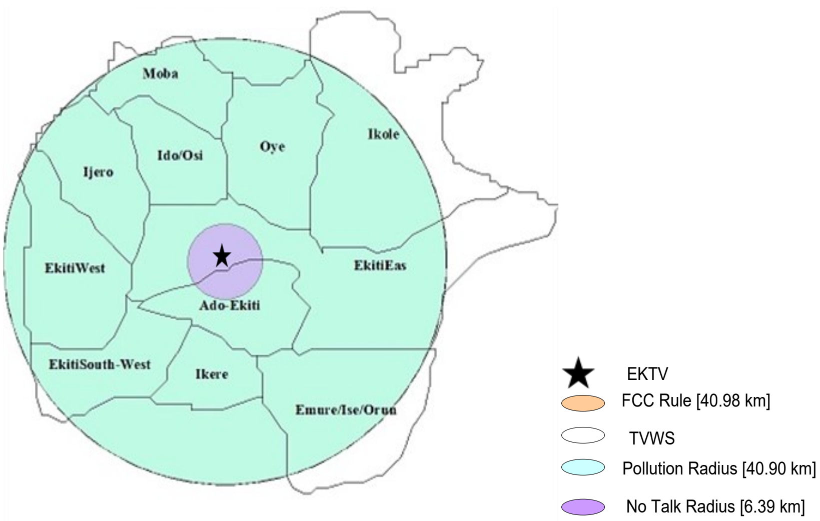

Figure 1. TVWS for Ekiti State

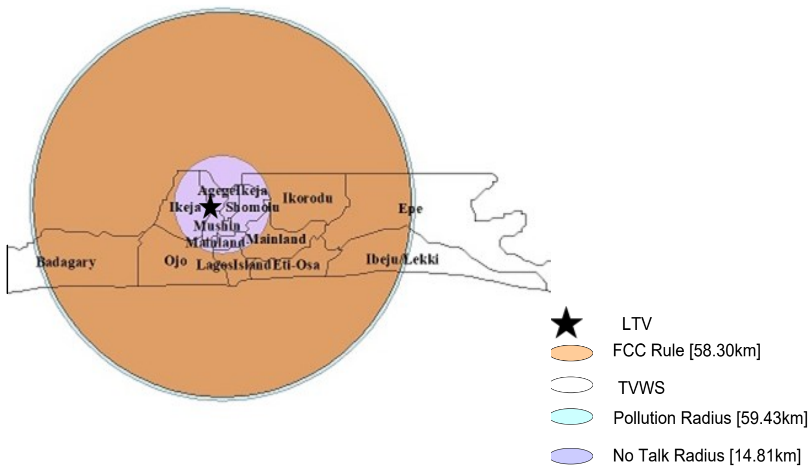

Figure 2. TVWS for Lagos State

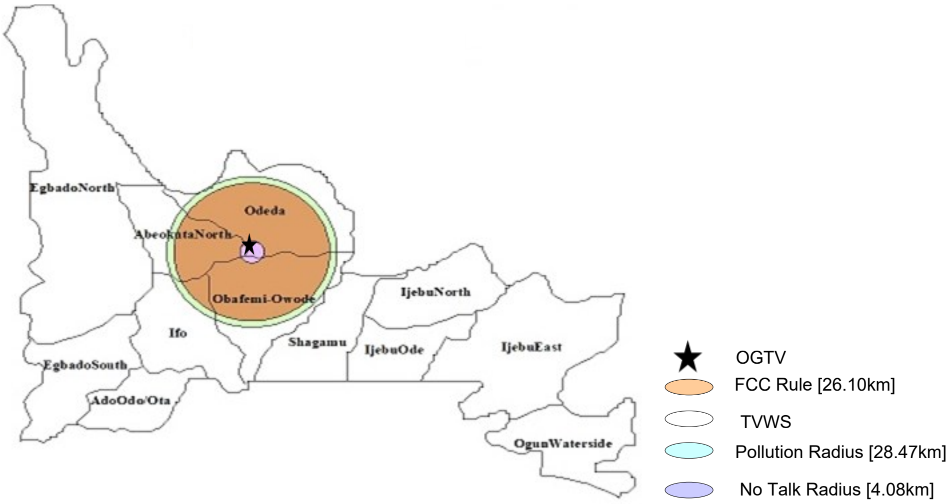

Figure 3. TVWS for Ogun State

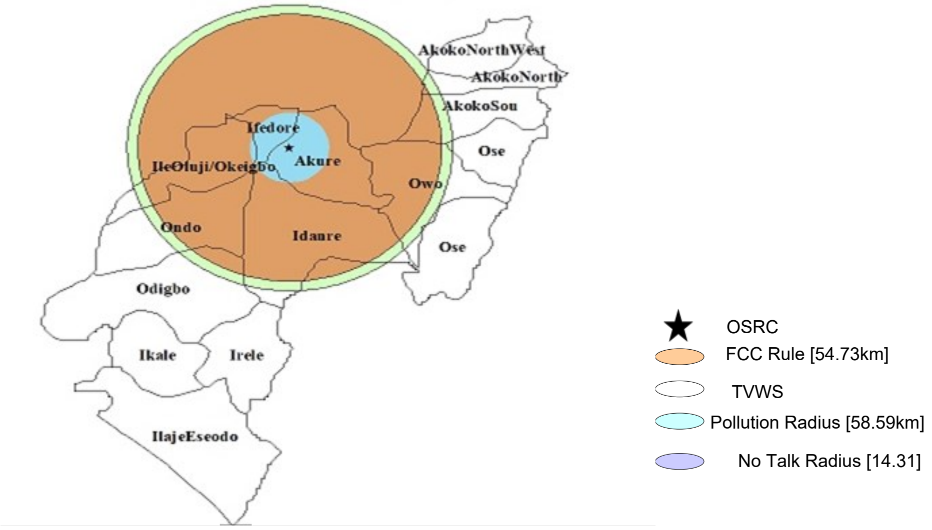

Figure 4. TVWS for Ondo state

Figure 5 shows the coverage area of the Osun TV broadcastion station and the available TVWS from this TV ststaion. The TVWS are area outside the radius of 52.70 km from the transmitter. The result shows that the huge part of about four local government areas namely Irewole, Ayedaade, Ife South and Ife North are available for deployment of TVWS devices. For Oyo State, the TV coverage area and also the available TVWS is shown in Figure 6 using the three adopted approaches. The TVWS in Oyo State are areas outside the radius of 47.84 km from the transmitter from the perpective of the poulltion view point. The result shows a massive land mass as TVWS available for the deployment of TVWS technology. A closer look shows that about eleven local government areas is free for usage by secondary users.

To quantify the result further, the estimation of TVWS is given in Figure 7 in terms of the number of free unoccupied channels per State, that is, UHF channels that have never been occupied by any licensee. It is assumed here that all the occupied channels in each state are being received in every part of the state. From Figure 7, it can be seen that there is an abundance of TVWS (free channels) in each state as the percentage of free channels in Ekiti, Lagos, Ondo, Osun, Oyo and Ogun States is 97.96%, 81.63%, 95.92%, 95.92%, 95.92% and 97.96% respectively.

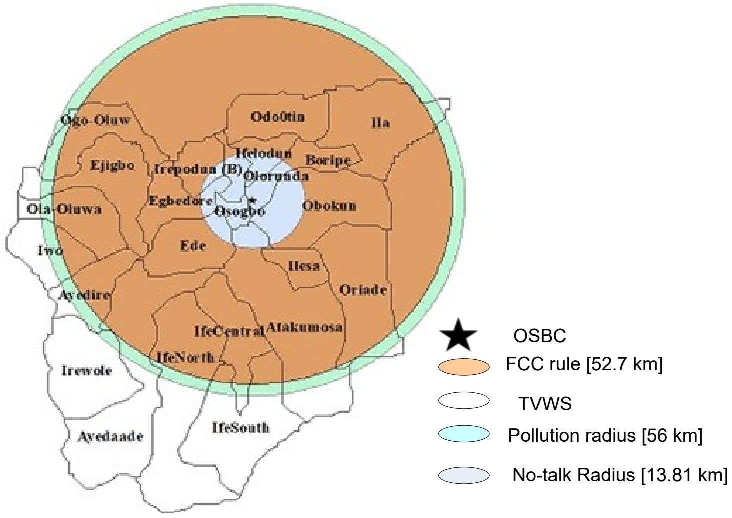

Figure 5: TVWS for Osun State

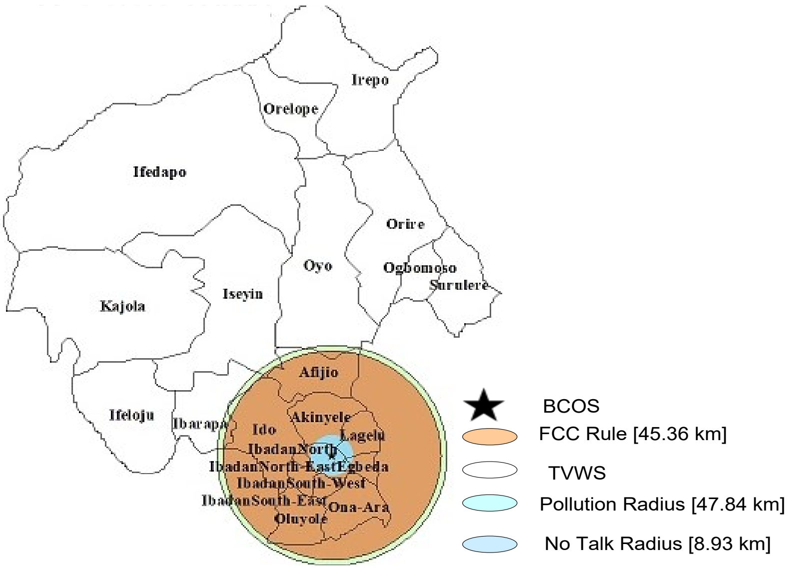

Figure 6. TVWS for Oyo state

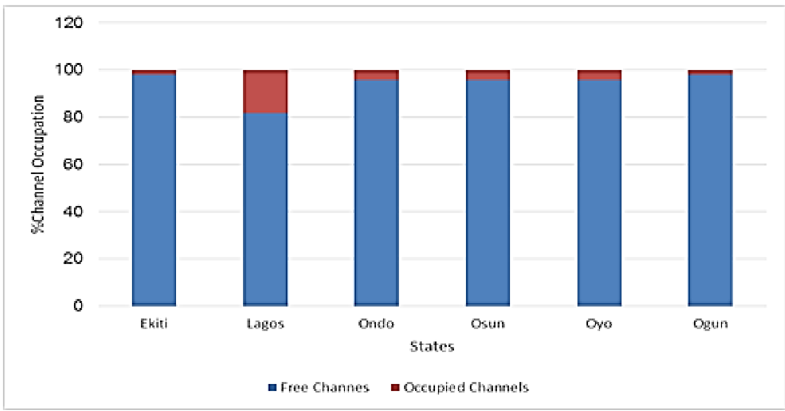

Figure 7. TVWS without adjacent channel consideration

4. CONCLUSION

TVWS was estimated for Southwest, Nigeria using the protection viewpoint approach, the pollution viewpoint approach and FCC rule and the result were displayed on the administrative maps of each state using the ArcGis application software. TVWS was also estimated according to the number of unoccupied channels in each state. It was assumed that all the occupied channels in each state are being received in every part of the state.Findings from the research shows that adopting pollution view point for TVWS estimation will guarantee enough protection for primary users and prevent interference for secondary users. It was discovered that an abundance of TVWS exist in Southwest, Nigeria, with Ekiti State having 97.96% TVWS, Lagos State 81.63%, Ondo State 95.92%, Ogun State 97.96%, Osun State 95.92% and Oyo State 95.92%. It is therefore recommended that the pollution view point be adopted for the deployment of TVWS space in Nigeria. The report from the research will be valuable for the NCC in the development of guidelines for TVWS deployment and operation in Nigeria. Area of intended futher research include interference suppression, spectrum management and dynamic spectrum access.

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