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Modeling TV White Spaces Availability Prediction for White Space Devices Utilization in Delta North Zone of Delta State Nigeria

Wilfred Adigwe[a*], Raphael Obikwelu Okonkwo[b]

[a]*Department of Computer Science Delta State Polytechnic Ozoro, Delta State Nigeria*
[b]*Department of Computer Science Nnamdi Azikiwe University, Awka, Nigeria*
[a]*Email: wilfred7k@yahoo.com*
[b]*Email: oobi2971@yahoo.com*

Abstract

TV white space is the unused TV spectrum which can be used by secondary users to solve the problem of spectrum scarcity and to increase its efficiency. This has become necessary as a result of rapid growth in wireless data traffic, ubiquitous connectivity to the end users which is of high interest in the communication world today. This paper takes a look on analyzing the availability of the TV white spaces in the digital terrestrial television bands in Delta North area of Delta State Nigeria. The frequency span analyzed is between 474-866MHz. The result shows that over 60% of the spectra in this area are underutilized, yet we have high alarming rate of spectrum scarcity by the communication industries. Most of the smart devices competing for these scarce spectra can be deployed to these unutilized spectra at low or no cost thereby freeing most of the spectrum bands. Our analysis shows that we have over 224 MHz frequency bands that are free to be used within this area. The data used for this work was retrieved from a DVB-T2 and Anritsu Ms2711A Spectrum Analyzer. This was connected to Metrodigital mega base station that provides digital terrestrial television services in this area.

Keywords: TV White Space (TVWS); VHF/UHF; Spectrum; Delta North.

1. Introduction

Today we are living through a critical juncture in telecommunications history akin to the advent of the telephone, radio, or television.

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* Corresponding author.

Computers and other digital technologies have enabled an entirely new communications medium, ubiquitous connectivity to the end user has become of higher interest in the communication world. Within these networks, end-user devices are "smart": they are capable of adapting to changing environments and maximizing efficient use of available spectrum to deliver mobile, affordable broadband connectivity. A coalition of consumer and other public interest groups, along with a number of high-tech companies, actively support the widespread adoption of these innovative new technologies [1]. Also the rapid growth in wireless data traffic recently has posed not only unique opportunities but also great challenges for the wireless industry. In order to meet the growing demand without excessive cost or energy consumption, one feasible option for the operators is to acquire more spectra for wireless communication. Unlike the lengthy allocation process for exclusive spectrum licenses, secondary spectrum access is deemed as a flexible alternative to obtain additional spectrum at low cost [2]. In particular, the very high frequency and ultra high frequency television bands (VHF/UHF), which is called "TV White Space", is considered as the most promising candidate for secondary access thanks to its well defined primary usage and favorable propagation characteristic for building penetration and wide area coverage. However, recently several studies have shown that by and large in most frequency bands in almost all areas the spectrum is underutilized [3].

Generally speaking, there have been three main drivers for the increasing capacity and higher data rate in wireless network: the evolution of wireless technology, the densification of base stations and the acquisition of more radio spectrum. Traditionally, the development of wireless technology with higher spectral efficiency has contributed considerably to the improving network capacity. However, the current wireless access technology is already approaching the theoretical bound of the spectrum efficiency performance. Any further improvement would come at great cost of complexity and energy consumption. The deployment of denser network has also been playing a key role in enhancing the system capacity. Nevertheless, the cost for building new transmitter site is increasing rapidly. It would require excessive investment to deploy a network dense enough to accommodate the predicated traffic volume by 2020. Thus, even with better technologies and denser networks, we still need a lot more spectrum than that is available today [4]. However, current static spectrum allocation policy prevents the easy access to wider spectrum due to its lengthy allocation process and high auction price, resulting in a so-called 'spectrum scarcity' phenomenon. It would discourage new entrant to the wireless market and hinders the adaptation to changes in demand, market, and technology. On the contrary, recent measurements have revealed that many of the allocated frequency bands are actually underutilized either spatially or temporarily. Even though a significant chunk of the TV spectrum remains underutilized, the actual unutilized spectrum available varies significantly spatially as well as temporally. This paper is saddled with the intention of how we can utilize the digital terrestrial television bands within Delta north area of Delta State, Nigeria. Delta north is located at South-South region of Nigeria; it is one of the senatorial district out of the three senatorial district in Delta State, Nigeria. It is made up of nine local government areas with a population of over one million two hundred and ninety- three thousand people (1,293,074) in 2006 census [5]. Today this population may have risen to over two million people. With this population an average of over one million has a phone and over 60% of the phones are smart phones. This shows that there will be greater opportunities if the TVWS is properly harnessed.

Television White Spaces (TVWS) refers to unused portions of spectrum in the television (TV) bands, such as guard bands between broadcasting channels and channels freed up by the transition from analogue to digital TV broadcasting [6].

TVWS signals have longer range, better speeds and robust non-line-of-sight performance. This coupled with abundant bandwidth allow these channels to be used for delivering broadband internet access in areas that aren't easily accessible by cable at much lower costs than optical fiber or conventional wireless networks. In addition, TVWS can be used for machine to machine communication and to cheaply provide wireless fidelity (Wi-Fi) access in university campuses and public spaces. TV bands are harmonized worldwide, and this raises the expectation that TVWS will be available globally.

2. Related Works

There are several papers which study TVWS and its availability.

Masonta and his colleagues [7] proposed a TVWS access framework to provide a harmonized platform and guidelines suitable for developing regions, such as the SADC member states, that will ensure maximum social and economical benefits offered by the TVWS are realized within the region. The proposed framework is based on co-evolution process (by Lyytinen and King [8] and Bauer and his colleagues [9], which focuses on three key domains of change in the wireless communications environment: Policy or regulation, technology or innovation, and business or market. Co-evolution process can be viewed as a large systemic innovation that demands coordination of many independent and heterogeneous players to ensure compatibility and interoperability across different systems. Naik et. al., [10] took a milestone in analyzing the TVWS availability in India their result shows that over 75% of the channels in the area analyzed are unutilized. Alemu [11] did spectrum availability assessment tool for TV White Space. His spectrum availability assessment was done as a back-end computation for Spectrum Availability Assessment Tool. He claimed that in simulation environments, the process of estimating the amount of spectrum involves modeling the radio environment, considering the primary system network coverage and radio characteristics, devising measurement metrics and using appropriate secondary system scenarios for studying the feasibility of the assessment. The common denominator of all the previous works is assumptions about network characteristics.

3. Motivation

The main contributions of this paper are the following:

1) For the first time, the empirical quantification of the available TV white space in the 474-866MHz in Delta North, Nigeria is presented. The quantification utilizes existing methods in the literature, namely spectrum availability assessment tool for TV White Space [11], Television White Space (TVWS) Access Framework for Developing Regions and the technical specifications of Nigerian National Broadband Plan 2013 – 2018 [12]. It is found that UHF TV band spectrum is heavily underutilized in Nigeria.

2) Motivated by underutilization of UHF TV band spectrum, an analysis of the availability of the TVWS for TV transmitters operating in the 474-866 MHz band has been presented. It is observed that at least 80% UHF TV band channels are underutilized from our analysis. The importance of the above results must be understood in

the context of Nigeria digital switch over which is ongoing. Besides, based on above results, the TV band in Delta North of Nigeria is underutilized and this situation is quite different from other developed countries. The optimal mechanism(s) for the use of TV white spaces in this area can be different and it should be studied by further research

4. Methodology

The method for the assessment of TVWS availability in Delta North of Nigeria involves the following steps:

DVB-T2 System Setup Analysis: This includes collecting the primary system transmitters across Delta North which will have direct impact (or may be victimized) to secondary system scenarios. This step identifies the location; transmiter power and transmission patterns of primary transmitters.

Primary Coverage Area Computation: Using appropriate propagation and terrain models, the approximate coverage areas for DVB-T2 transmitters can be estimated. The coverage is calculated for each pixel (the smallest unit of geographical coverage for the assessment) across the whole area.

Computation Of Received Signal: Based on the parameters of the transmitter, the received signal at different points were determined to ascertain the quality of service of the operating devices.

Table 1: Summary of 474 – 570MHz Spectrum Occupancy Description in Asaba and Evrons

Frequency Span	Channel No	Status
474 – 482MHz	21	Occupied/in use
482 – 490MHz	22	Occupied/in use
490 – 498MHz	23	Occupied/in use
498 – 506MHz	24	Occupied/in use
506 – 514MHz	25	Free
514 – 522MHz	26	Free
522 – 530MHz	27	Free
530 – 538MHz	28	Free
538 – 546MHz	29	Free
546 – 554MHz	30	Free
554 – 562MHz	31	Free
562 – 570MHz	32	Occupied/in use
570 – 578MHz	33	Free

The above is the analysis form Asaba and environs for frequencies within the range of 474 to 570MHz, we have a total of 13 channels. Total number of occupied channels = 5; Total number of unoccupied (white space) channels = 8. This shows that in this area 38% are occupied while 62% are free to be used by white space devices in this area.

Table 2: Summary of 578 – 666 MHz Spectrum Occupancy Description in Asaba and Evrons

Frequency Span	**Channel No**	**Status**
578 – 586MHz	34	Free
586 – 594MHz	35	Free
594 – 602MHz	36	Free
602 – 610MHz	37	Occupied/in use
610 – 618MHz	38	Free
618 – 626MHz	39	Occupied/in use
626 – 634MHz	40	Free
634 – 642MHz	41	Free
642 – 650MHz	42	Free
650 – 658MHz	43	Free
658 – 666MHz	44	Free
666 – 674MHz	45	Occupied/in use
674 – 682MHz	46	Occupied/in use

When the spectrum occupancy of 578 to 674MHz was analyzed in that same area, the total number of channels here is 13; Total number of occupied channel was 4 and free channels within this range are 9. This shows that only 69% of the channels are free to be used by white space devices in this area.

Table 3: Summary of 682 – 770 MHz Spectrum Occupancy Description in Asaba and Evrons

Frequency Span	**Channel No**	**Status**
682 – 690MHz	47	Occupied/in use
690 – 698MHz	48	Occupied/in use
698 – 706MHz	49	Occupied/in use
706 – 714MHz	50	Free
714 – 722MHz	51	Occupied/in use
722 – 730MHz	52	Reserved
730 – 738MHz	53	Reserved
738 – 748MHz	54	Occupied/in use
746 – 754MHz	55	Occupied/in use
754 – 762MHz	56	Occupied/in use
762 – 770MHz	57	Occupied/in use
770 – 778MHz	58	Occupied/in use

In the frequency of 682 to 770MHz in Asaba and environs, it shows that total number of 12 channels was analyzed and total of 11 out of the 12 were occupied. This shows that 92% of the channels are occupied, it also shows that white space devices may not be deployed to this frequency range in this area to avoid interference. Hence it can be termed red zone or "no go area" zone.

Table 4: Summary of 778 – 866 MHz Spectrum Occupancy Description in Asaba and Evrons

Frequency Span	Channel No	Status
778 – 786MHz	59	Reserved
786 – 794MHz	60	Reserved
794 – 802MHz	61	Free
802 – 810MHz	62	Free
810 – 818MHz	63	Free
818 – 826MHz	64	Free
826 – 834MHz	65	Free
834 – 842MHz	66	Free
842 – 850MHz	67	Free
850 – 858MHz	68	Free
858 – 866MHz	69	Free
866 – 874MHz	70	free

In table 4 above, a total of 12 channels were analyzed and it shows that only 2 channels was occupied and a total of 10 channels representing 83% are unoccupied that can be used for white space devices in that zone. From the analysis made we can comfortable say in frequencies 474 to 866 MHz we have a total number of fifty (50) channels.

The number of occupied channels is 22 representing 44% and unoccupied channels are 28 representing 56%. Therefore the total free spectrum (white space) is 28 X 8 representing 224MHz. This can be made available for white space devices to use. We also made analysis from another area in the same Delta north, below are the results.

In table 5, spectrum occupancy in Ubulu-Uku and environs was analyzed the number of channels within 474 to 570MHz range was 13; Total number of occupied channels = 7; Total number of unoccupied (white space) channels = 6; it also reveals that some of the licensed channels are occupied by their owners. This shows that in this area 54% are occupied while only 46% are free to be used by white space devices.

When the spectrum occupancy of 578 to 674MHz was analyzed, the total number of channels here is 13; Total number of occupied channel was 7 and free channels within this range are 6. This shows that 46% of the channels are free to be used by white space devices in that zone.

Table 5: Summary of 474 – 570MHz Spectrum Occupancy Description in Ubulu-Uku and Evrons

Frequency Span	**Channel No**	**Status**
474 – 482MHz	21	Occupied/in use
482 – 490MHz	22	Occupied/in use
490 – 498MHz	23	Occupied/in use
498 – 506MHz	24	Occupied/in use
506 – 514MHz	25	Free
514 – 522MHz	26	Free
522 – 530MHz	27	Free
530 – 538MHz	28	Free
538 – 546MHz	29	Free
546 – 554MHz	30	Free
554 – 562MHz	31	Occupied/in use
562 – 570MHz	32	Occupied/in use
570 – 578MHz	33	Occupied/in use

Table 6: Summary of 578 – 674MHz Spectrum Occupancy Description in Ubulu-Uku and Evrons

Frequency Span	**Channel No**	**Status**
578 – 586MHz	34	Free
586 – 594MHz	35	Occupied/in use
594 – 602MHz	36	Free
602 – 610MHz	37	Occupied/in use
610 – 618MHz	38	Free
618 – 626MHz	39	Occupied/in use
626 – 634MHz	40	Free
634 – 642MHz	41	Free
642 – 650MHz	42	Occupied/in use
650 – 658MHz	43	Free
658 – 666MHz	44	Occupied/in use
666 – 674MHz	45	Occupied/in use
674 – 682MHz	46	Occupied/in use

In the frequency of 682 to 770MHz in Ubulu-Uku area, it shows that total number of 12 channels was analyzed and total of 9 were occupied while a total of 3 was unoccupied. This shows that only 25% of the channel can be used by white space devices in this area while 75% are occupied.

Table 7: Summary of 682 – 770MHz Spectrum Occupancy Description in Ubulu-Uku and Evrons

Frequency Span	**Channel No**	**Status**
682 – 690MHz	47	Occupied/in use
690 – 698MHz	48	Occupied/in use
698 – 706MHz	49	Occupied/in use
706 – 714MHz	50	Free
714 – 722MHz	51	Occupied/in use
722 – 730MHz	52	Occupied/in use
730 – 738MHz	53	Reserved
738 – 748MHz	54	Free
746 – 754MHz	55	Occupied/in use
754 – 762MHz	56	Free
762 – 770MHz	57	Occupied/in use
770 – 778MHz	58	Occupied/in use

Table 8: Summary of 778 – 866MHz Spectrum Occupancy Description in Ubulu-Uku and Evrons

Frequency Span	**Channel No**	**Status**
778 – 786MHz	59	Reserved
786 – 794MHz	60	Reserved
794 – 802MHz	61	Free
802 – 810MHz	62	Free
810 – 818MHz	63	Free
818 – 826MHz	64	Free
826 – 834MHz	65	Free
834 – 842MHz	66	Free
842 – 850MHz	67	Free
850 – 858MHz	68	Free
858 – 866MHz	69	Free
866 – 874MHz	70	free

In table 8 above, a total of 12 channels were analyzed and it shows that only 2 channels was occupied and a total of 10 channels representing 83% are unoccupied that can be used for white space devices in this area while 17% are occupied. From the analysis made we can comfortable say in frequencies 474 to 874 MHz we have a total number of fifty (50) channels. The number of occupied channels is 25 representing 50% and unoccupied channels are 25 representing 50%. Therefore the total free spectrum (white space) is 25 X 8 given us 200MHz.

We want further to model the received signal strength at some selected distances from the transmitter using Friis free space equation, considering that wireless devices can be at different points with the zone.

$$P_r = P_t G_t G_r \frac{\lambda^2}{(4\pi d)^2} \quad (1)$$

where

G_t and G_r are the transmit and receive antenna gains

λ is the wavelength

d is the T – R separation

P_t is the transmitted power

Pr is the received power

Equation (1) can be modified in relation to a reference point, d_0

$$P_r = P_t K \left(\frac{d_0}{d}\right)^{\gamma} \quad (2)$$

Where

K is a unitless constant that depends on the antenna characteristics and free-space path loss up to distance $\boldsymbol{d_0}$

K can be obtained as

$$K = G_t G_r \frac{\lambda^2}{4\pi d_0^2} \quad (3)$$

$$\lambda = \frac{\text{Speed of light}}{\text{Frequency}} \quad (4)$$

Where $\boldsymbol{\gamma}$ is the path loss exponent whose value is a function of the environment.

Using the transmitter parameters and also receiving antenna gain G_r being equal to transmitting antenna gain which is 12dB. We can obtain the received devices signal strength at different locations as shown in table 9.

Table 9: Received signal strength at different distances from the transmitter.

S/N	**Tx Coverage Radius (KM)**	**Received Devices Radius (KM)**	**P_t (W)**	**Signal strength P_r (W)**
1	60	10	27.78dB	–32.77dB
2	60	20	27.78dB	–44.82dB
3	60	23	27.78dB	–47.24dB
4	60	30	27.78dB	–51.86dB
5	60	40	27.78dB	–56.84dB
6	60	50	27.78dB	–60.73dB
7	60	60	27.78dB	–63.89dB
8	60	70	27.78dB	–66.58dB

5. Implementation

The aim of this paper is to evaluate the TVWS availability in Delta North of Delta State Nigeria and to see how these underutilized channels can be used for other wireless devices at low or no cost. The experimental testbed for this work is one of the Metrodigital mega base station situated on hills of Ubulu-Uku in Delta north area of Delta State Nigeria for digital terrestrial transmission. The base station is covering over 60KM radius with a transmitting power of 600W. All the data used for this research was generated from the Metrodigital Communication company.

The research instruments used are as follows:

(i) Laptop

(ii) DVB-T2

(iii) Anritsu Ms2711A Spectrum Analyzer

5.1 Procedure for Data Collection

This research was carryout at Metrodigital communication base station situated at Ubulu-Uku Delta State and their main office at Asaba Delta State Nigeria. With the help of DVB-T2 and spectrum analyzer, the data for this work was retrieved.

The following procedures were adopted for the collection of data for this work:

(i) **Connection**– The laptop used for retrieving the data was switch on, setup and made ready

(ii) **Connection to DVB-T2 –** This decoder was used to scan through the frequency span of 474 – 866MHz. It showed all the terrestrial operators with the area and the frequencies for which they are operating on. It also shows the unoccupied frequencies.

(iii) **Connection to spectrum analyzer –** To further confirm the authenticity of the occupied and the availability of the frequencies, we connected the spectrum analyzer to the base station and also made scan of the frequency span.

(iv) **Retrieval of Data –** From the option chosen above, we then key in the details required for this work such as frequency span, channel, status e.t.c.

All the data for the spectrum availability was displayed and opened with Microsoft excel. It was tabulated, presented and analyzed as can be seen above.

6. Result

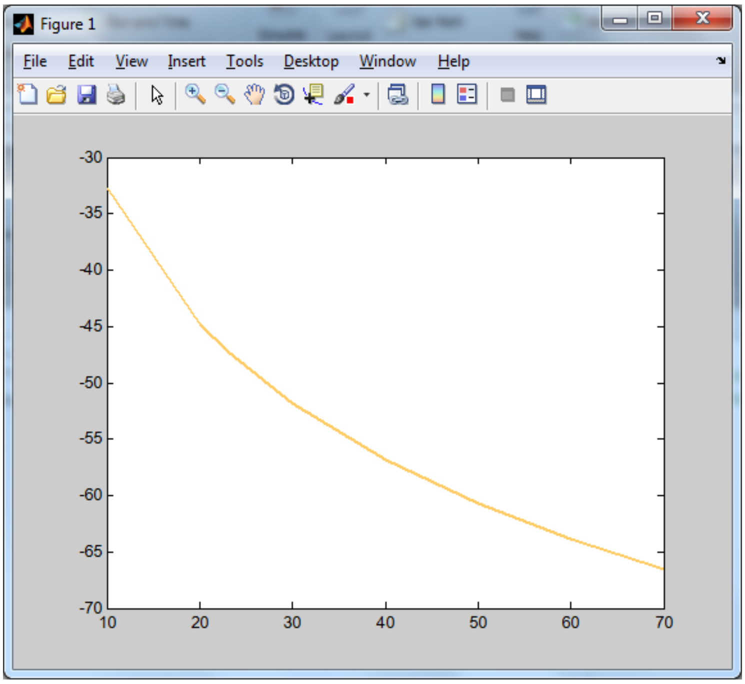

Figure 1: Received signal strength at varying distances

Table 1 to 8 shows that there are numerous channels underutilized; these channels are just there whereas communication industries are faced with spectrum scarcity and many wireless devices are competing for the limited spectrum resources when they can conveniently utilize these TV white spaces without causing any harmful obstruction to the broadcasting stations. Table 9 shows the received signal strength for the worst scenario.

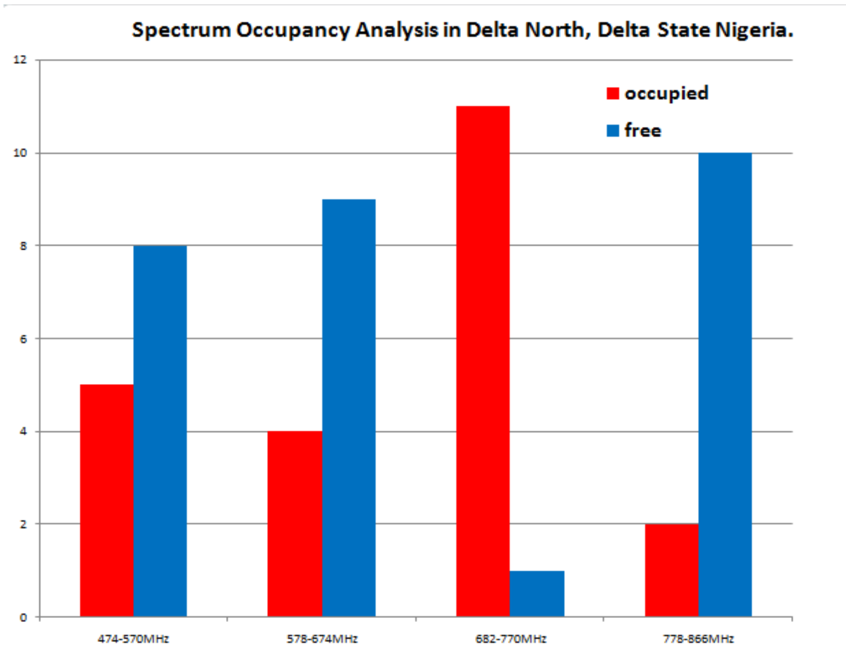

Figure 2: Spectrum occupancy in Asaba and Environs, Delta State

Figure 1 above shows the signal strength at different positions of the wireless devices. It shows that the wireless devices can conveniently communicate with good quality of service obtained with distances closer to the transmitter. In the spectrum occupancy analyzed as shown in figure 2, it shows that there are substantive channels that are really not used at all for all year round

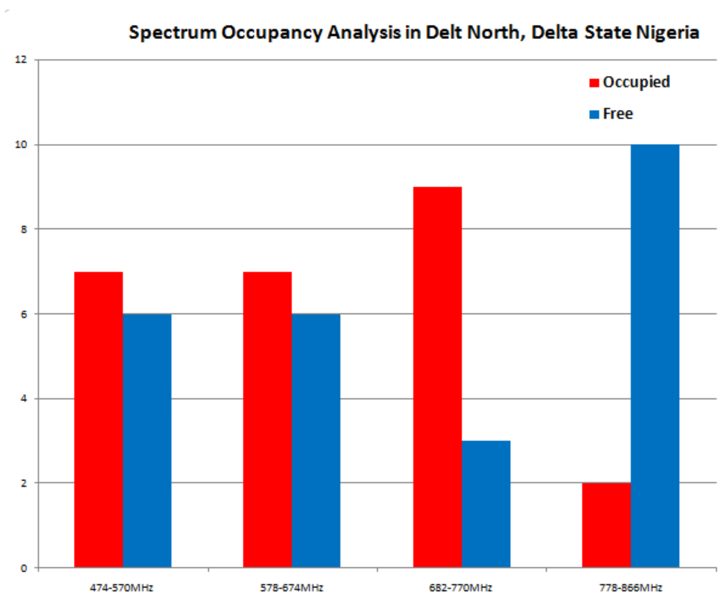

Figure 3: Spectrum occupancy in Ubulu-Uku and Environs, Delta State

Figure 3 shows the spectrum occupancy in another area of Delta North called Ubulu-Uku, the analysis shows that we have the presence of TVWS that are really not used.

7. Conclusion and Recommendation

Nowadays, the lack of access to frequency bands for wireless data traffic has created the so called "spectrum scarcity" phenomenon. It is regarded as a major barrier for providing sufficient capacity to meet the growing demand for wireless data services. This paper was able to analyze the availability of TVWS in Delta North of Delta State, Nigeria as an alternative way to meet the growing demands of our wireless devices. In the course of our findings it was discovered reasonable percentage of digital terrestrial television bands within this zone are grossly underutilized. The received signal strength was also computed to determine if wireless device can enjoy good quality of service if deployed. The results show that with good channel allocation algorithm implemented, our competing wireless devices can enjoy this aspect of spectrum at low or no cost implication.

8. Recommendation

Considering the findings from this work, we recommend that

(i) The Federal government of Nigeria should hasten the digital switch over (DSO) processes to open up more channels in the digital terrestrial television band for wireless devices usage.

(ii) Wireless communication providers should put more of their resources in these areas to harness the potentials in the area.

(iii) Proper implementation algorithm should be created that will monitor the interference of wireless devices in relation to the incumbent users.

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