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DEVELOPMENT OF A WEB BASED GEO-LOCATION DATA BASE FOR THE IDENTIFICATION OF TELEVISION WHITE SPACE IN SOUTH EAST NIGERIA.

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ABSTRACT

Broadband penetration into developing countries such as Nigeria is still very low especially in the rural areas because of the prohibitive costs of laying cable and fiber. The wireless broadband technology has been selected as a better alternative for solving the last mile problem because they are cheaper to implement. Television White Space(TVWS) technology is enjoying a lot of attention from the wireless technology research community because of the fantastic propagation characteristics of the Television spectrum such as wide coverage area and ability to penetrate harsh terrain making it suitable for providing broadband access to rural as well as sparsely populated areas. This work presents a developed web based Geo location data base designed to identify TVWS in a given location and at any given time of the day. The sensing technique was used to investigate the state of the TV spectrum to identify the frequencies that are occupied by licensed users and those frequencies that are vacant for a given region and time. A database was developed using results from the sensing. WSDs can query the database via the internet with the help of a PHP script that handles the logic used to analyze, identify and make predictions on TV white space once the Device has indicated its location and time. The results from the query guide the WSD on its choice of frequency to transmit over. This plays a crucial role in ensuring that the primary (licensed) users are protected from interference which is criteria for TVWS communication technology. Analysis of the results from query also illustrates the inefficiency in the current command-and-control static spectrum allocation to large area regime with over 70% of the TV spectrum left unused at any given time of the day. With the ongoing analogue to digital transition for television broadcast, even more frequencies will be left vacant for opportunistic access by secondary user (WSDs). Hence, the web based Geo location database developed in this paper brings researchers one step closer to solving the last mile problem in South-East Nigeria.

Keywords: *Television White Space, Geo-Location Database, White Space Devices, Sensing Techniques, Television Spectrum.*

1. Introduction

Scientific research has shown that broadband access has been globally acknowledged as the foundation and propeller of the much needed development in a knowledge-driven economy. It has been empirically proven that every 10% increase in broadband penetration in developing countries results in a commensurate increase of 1.3% in GDP (Adebayo 2017). But in semi-urban, suburban and rural areas of Nigeria, where the average cost of deploying and maintaining broadband infrastructure (Such as cables and fiber) coupled with the low income status of occupants, epileptic power supply as well as sparse population distribution, the deployment of top notch broadband technology appears commercially unprofitable to network providers. Wireless technology is seen as a cheaper alternative to the fixed-line or wired infrastructure for the rural regions because very little and relatively cheap infrastructure is required for their implementation. Because of the fantastic propagation characteristics of the

Television spectrum such as wide coverage area and ability to penetrate harsh terrain, it is therefore suitable for providing broadband access to rural and sparsely populated areas. Hence, TVWS technology is gaining a lot of attention from the wireless technology research community as a nudge in the right direction in solving the last mile problem in the rural parts of South-East Nigeria. Two methods have been adopted by the Federal Communications Commission for the identification of white space but the Geo location database technique will be implemented for this work since the sensing technique maybe more expensive to implement in the rural areas (Carlson &Telcordia Company 2015).

The web based Geo Location database developed in this work allows WSD access and query a database system containing the results from sensing after they must have indicated their location and time. Meanwhile, the database responds with a list of predicted vacant frequencies and allowed transmit power for the location. Hence, the WSD selects one of the vacant channels and starts to transmit on it. This in turn plays a crucial role in ensuring that primary (licensed) users are protected from interference which is criteria for TVWS communication technology during opportunistic access in the quest for solving the last mile problem.

2.0 REVIEW OF RELATED WORKS

The use of TVWS for broadband access has been reported on many occasions in literature. But the concept of using a web based Geo location database to identify TVWS within the Television spectrum of the rural parts of Nigeria for broadband access is rarely reported in history. Hence, the need for this current paper which aims at developing a web based Geo Location database capable of analyzing sensing results to make predictions as to what frequencies maybe vacant within the television spectrum at any point in time within a particular region for broadband access in the South-Eastern parts of Nigeria.

In work done in (Tang, Yu & Huang 2017), a consensus-based spectrum sensing scheme for the identification of TVWS was presented. The researchers used Cognitive Radio Networks that operated within the Television Spectrum to provide affordable broadband access in Thailand. They used a fully distributive scheme such that local sensing information obtained by Cognitive Radio Users was sent to the neighboring nodes in the Network. This information was then used by the Cognitive Radio Users to identify TVWS after a consensus algorithm was applied for stimulating new state for consensus variable. This process was continued till the individual states converged to a common value. Spectrum sensing data falsification (SSDF) attacks were also dealt with by the researchers in the work by excluding those nodes from neighboring list that gave greater deviation from mean value.

The distributed network scheme used in (Tang, Yu & Huang 2017), the existing consensus algorithm required each node to have a prior knowledge of the upper bound of the maximum degree of the network which required complex algorithms and expensive infrastructure to achieve. In the research work done in (Ezema, Atimati, Ezeh, Iwuchukwu & Agubor 2016), *a* quantitative approach for TVWS survey was carried out on a spectral range of 470 – 870MHz within the entire campus of the Federal University of Technology Owerri in Imo State and its immediate environs, using an RF spectrum analyzer. The readings were presented using graph plots through the aid of a Touchstone PC spectrum analyzer. In this work, fixed measurement schemes were adopted and two (2) sites were chosen to take measurement. The results revealed that, 64% of the 50 channels surveyed were not in use. The degree of occupancy was found to be very low, thus creating unused spectra spaces within the UHF frequency band which could be used to provide broadband services in sparsely populated rural areas.

Although the results from the research work presented in (Ezema et.al 2016) showed that a large portion of TVWS was available for opportunistic access by Secondary networks with only about 36% of the considered spectral range being occupied by licensed users as of the time the research was carried out. Nonetheless, there was no system put in place to make the results obtained from the measurements readily available for the intended users (WSDs).

Quantitative analysis of the available TV white space in the 470 -590MHz UHF band in India was performed in (NFAP, 2011). It was observed that unlike developed countries, a major portion of the UHF band of the TV spectrum was unutilized in India. The results showed that even while using conservative parameters, at least in 63.43% of the areas within the four zones in India, all the 15 channels (100% of the UHF band) were free.

The average available TV white space was calculated using two methods:

i. The protection and pollution view points
ii. The FCC regulations.

By both methods, the average available TV white space in the UHF band was shown to be more than 100MHz. An algorithm was proposed for reassignment of TV transmitter frequencies to maximize unused spectrum. It was observed that four TV channels (or 32MHz) are sufficient to provide the existing UHF band coverage in India.

The quantitative analysis carried out in (NFAP 2011) does not give an accurate representation of the actual state of the Television Spectrum in India since the data from the Northern part of India was not taken into consideration during the analysis process. Although, the researchers plan to obtain and include the missing north zone data in their work, they also wish to explore suitable regulations in India to enableaffordable broadband coverage using TV white space.

A cooperative (sensor network based) TV spectrum sensing architecture was implemented in (Thanayankizil & Kailas 2016), in the South African sub-orbs of Soweto. The structure was implemented to provide affordable broadband access over the available TVWS in the test bed region. The cooperative TV spectrum sensing technique implemented for this work was divided into two operational networks. One handles cognitive transmissions while the other handles the sensing networks. The latter involved a set of sensors deployed in test bed region, which were used to sense the TV spectrum and relay the process results to a Cognitive Radio Controller (CRC). The CRC further processes the collected data and sends the sensed area of interest's spectrum occupancy information to a Geo-location database, to which it was connected through the Internet. The database centralizes all the sensing information from its attached CRCs and serves as a general register that SUs, who no longer require their own dedicated sensing equipment, can inquire for TVWS availability within the test bed area.

Although the technique implemented in the work done in (Thanayankizil & Kailas 2016) proved to be very efficient in delivering reliable, up to date and accurate information on TVWS availability within the test bed region, but this technique may not be suitable for rural environments since very little activity is recorded in the Television Spectrum (static) for such areas resulting in a waste of resource. Again, the ZigBee sensors used to achieve the sensing networks are quite expensive and they operate in the 2.5GHz frequency, which could be a real source of interference to the incumbent telecommunication networks already in place within the region.

3.0 METHODOLOGY

This paper seeks to achieve the development of a web based geo-location data base that provides White Space Devices (WSDs) with accurate information on which frequencies are occupied and which are not within the UHF band of the Television spectrum (taking Nnobi Community of Anambra State, South-East Nigeria as case study), at any point in time and on any day of the week. A combination of software and hardware components was used as required to achieve this goal.

In this section, the experimental setup for a continuous frequency sweep of the area under observation was critically analyzed taking into consideration the sensing technique being the technique of choice for this work in determining the state of the TV spectrum. TV spectrum sweeps were carried out daily (every fifteen minutes) for a duration of one week i.e. from Monday to Sunday to be able to give an accurate representation of the active Television frequencies within the UHF band at any time of the week. Secondly, the Structured Query Language (SQL) database application and data translation technique that was used to import the scanning results from excel spread sheet format into the database is looked at, also the query language with the PHP script developed for WSDs to query the database over the internet to be able to access, analyze and determine the available TVWS within the research region was also explained.

3.1 HARDWARE COMPONENTS USED

The RF Exploreris the principal hardware component used for in this work.It is essentially a handheld digital spectrum analyzer. Its operation is based on a highly integrated frequency synthesizer which offers high performance. For this work, we used RF Explorer model 3G combo.This model comes with a Nagoya NA-773 wideband telescopic and whip dipole antenna. The unit serves as the spectrum sensing equipment in this setup and is used to detect the active frequencies within the television spectrum of the area under observation.



Figure1: RF Explorer Spectrum Analyzer

V SOFTWARE TOOL SET

WAMP Server (MySQL Database): The WAMP Server is a Web development platform on Windows that allows you to create dynamic Web applications with Apache2, PHP, and MySQL. WAMP Server automatically installs everything you need to intuitively develop Web applications. You will be able to tune your server without even touching its setting files. Best of all, WAMP Server is available for free (under GPML license) in both 32 and 64 bit versions. Alongside, PHPMYADMIN allows you to manage easily your databases. WAMP server is not compatible with Windows XP, SP3, or Windows Server 2003.

PHPMYADMIN: this is a tool set or function contained in the WAMP server, this interface holds information on all the data bases contained in the array.

Features provided by the PHPMYADMIN include:

1. Web interface
2. MySQL and MariaDB database management
3. Import data from CSV and SQL
4. Export data to various formats: CSV, SQL, XML, PDF (via the TCPDF library), ISO/IEC 26300 – Open Document Text and Spreadsheet, Word, Excel, LaTeX among others

In this work, the PHPMYADMIN application was used in the administration of query on the developed database as duly required.

Adobe Dreamweaver: This is a development application that combines a visual design surface known as Live View and a code editor with standard features such as syntax highlighting, code completion, and code collapsing as well as more sophisticated features such as real-time syntax checking and code introspection for generating code hints to assist the user in writing code.
Combined with an array of site management tools, Dreamweaver lets its users design, code and manage websites as well as mobile content. Dreamweaver is positioned as a versatile web design and development tool that enables visualization of web content while coding. Dreamweaver, like other HTML editors, edits files locally then uploads them to the remote web server using FTP, SFTP, or WebDAV.

Google Maps: Google Mapis a web mapping service developed by Google. It offers satellite imagery, street maps, 360° panoramic views of streets (Street View), real-time traffic conditions (Google Traffic), and route planning for traveling by foot, car, bicycle (in beta), or public transportation. It also offers longitude and latitude positioning services with GPs positioning.

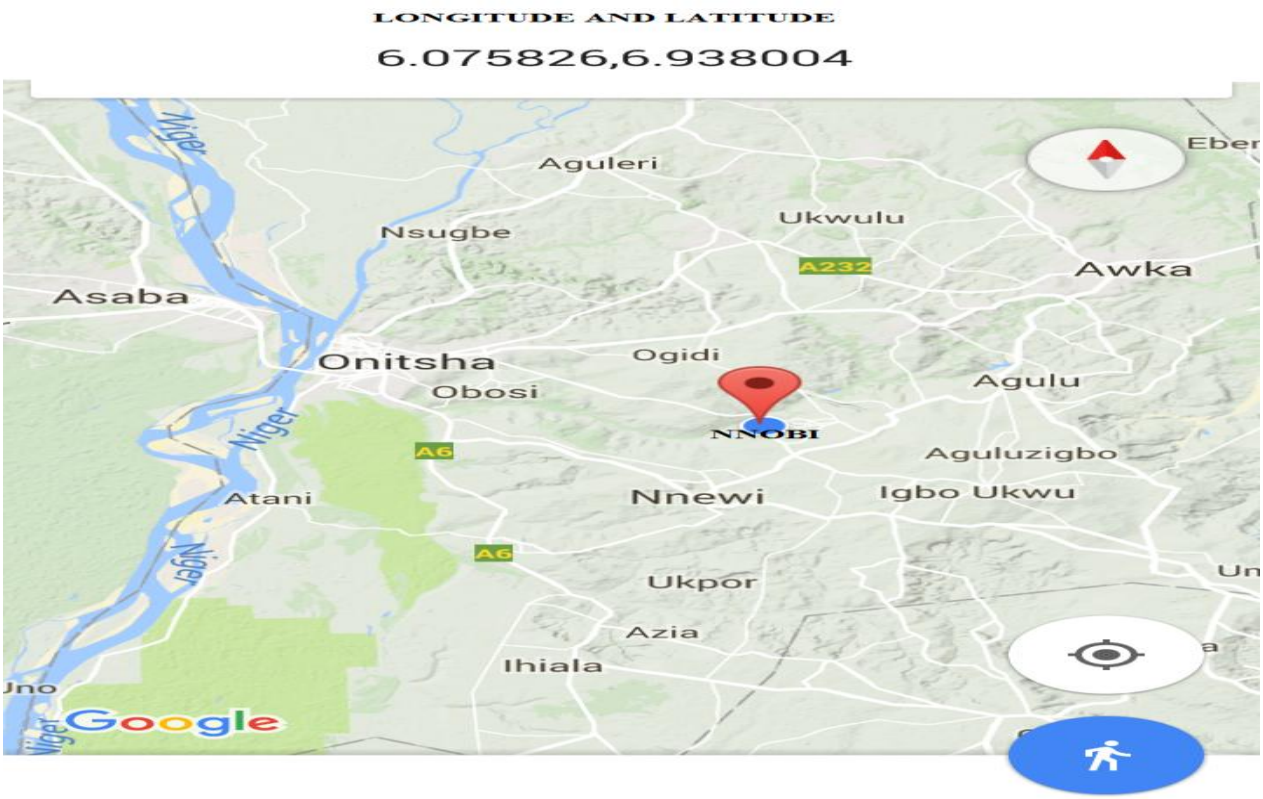


Figure2: Google Maps Showing Longitude & Latitude of Measurement Location

RF Explorer Windows Client: This is the main tool for communication between RF Explorer device and PC. It displays high resolution graphics of monitored RF signals in real time, it trouble shoot RF issues, and detect sources of RF interference. The main screen includes all the functionality to make Spectrum Analyzer measurements in a PC. The results from its operation can be saved and viewed in the following format; graphics, print, zoom in/out in CSV log files as a waterfall – heat map or in Microsoft excel for better interpretation.

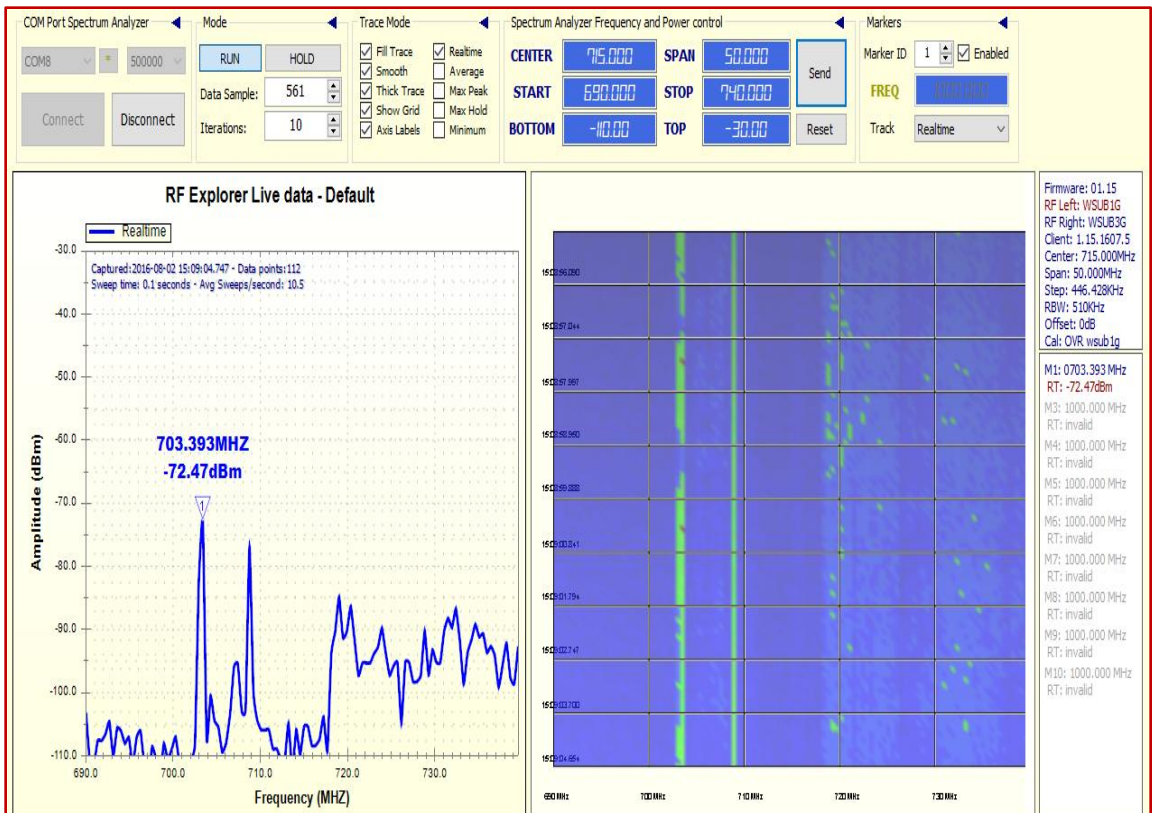


Figure 3:RF Explorer Client Interface.

ADOPTED STRUCTURE FOR WEB BASED GEOLOCATION DATABASE

The SQL database structure adopted for this research work was simplified for easy operation by the administrator to enable an effortless manipulation of the table data and helping with quick and effective analysis of query results. The flowchart below shows the query flow structure of the designed database for this work.

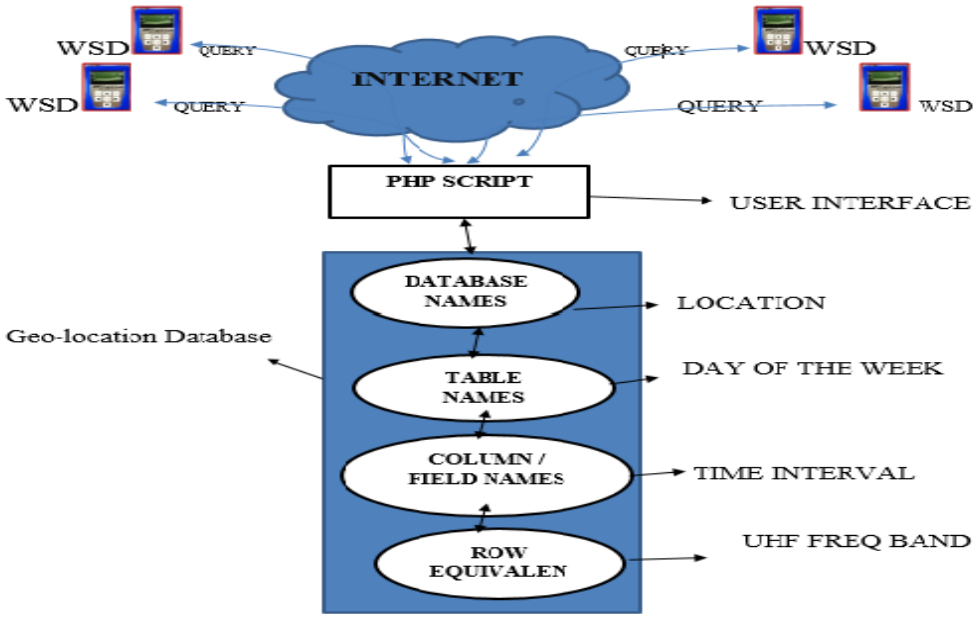


Figure 4: Structure for Web based Geo-location data base

THEORY OF OPERATION

After the scanning of the UHF band of the television spectrum scheduled every fifteen minutes for one week (Monday – Sunday) had been completed successfully using the RF Explorer, the results were carefully imported into the WAMP server. This process required that a series of conversions was to be carried out on the scanning results which was in excel (XLSX) sheet format before it could be successfully imported into the WAMP server environment. A Span of 20MHz was used to enhance sensitivity of the spectrum measured, and the frequency resolution for the experiments was set to 178.6 KHz on the RF Explorer window client with an omnidirectional antenna fixed on top of a car and the laptop inside the car as shown in figure 5. The antenna height is 1.5m above the ground at the site under observation where frequency sweeps were carried out.

Table 1: Measured GPS Location for NNOBI

SITE NAME	LATITUDE	LONGITUDE
Nnobi	6.075826	6.938004

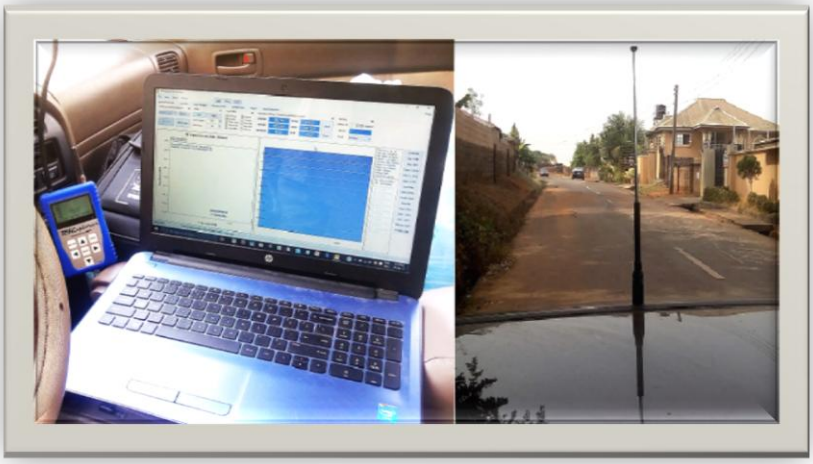


Figure 5: RF Explorer Scanning Setup

In the WAMP server environment, the imported scanning results are grouped categorically and this grouping or structuring is the backbone of this entire Geo-location database design. The database structure for this work is described below.

- **The Database Name:** it holds the information about the LOCATION or area where the scanning results were obtained, in this case NNOBI community.
- **Table Name:** this identifies uniquely which day of the week the scanning results represent. For this research paper, the results for Monday's scan are represented as Monday same goes for every other day of the week.
- **Column or Field Name:** this is a time representation of the individual scanning carried out every fifteen minute interval starting from 12 mid night.

Row Equivalent: these represent the corresponding row values for the frequency and its corresponding or measured energy level at that particular time of the day.

- **PHP Script**

The PHP script is a web development tool that is responsible for the logic aspect of the entire system. It also serves as the brain of the entire setup as it handles all calculations, approximations, data manipulations and even oversees the activities of the data base querying process. The MYSQL query codes are embedded within the PHP scripts using codes to call up any necessary data variable during the sequence of execution.

The PHP snippets are embedded within the HTML elements. The HTML elements are responsible for the look and feel of the interactive interface via which the White Space Devices (WSDs) are expected to access the database. In other words, HTML elements (Hyper Text Markup Language) are responsible for the user interface which is to be interacted with by the WSDs.
The PHP scripts are also essentially responsible for initializing connections with the database, while the SQL codesare responsible for querying the data base. Results from the query are then displayed to the screen using the HTML elements.

- **White Space Devices**

These are the intended users of the television white spaces lodged within the UHF band of the Television Spectrum

- **Internet**

For this research paper, the PHP script is uploaded to a remote C-PANEL alongside the geo-location data base that has already been properly structured. This setup enables the web page to be readily accessible to WSDs over the internet. For this purpose the internet can be viewed as an access channel to the geo-location data base which holds all the results from the frequency scan carried out.

4.0 RESULT AND ANALYSIS

The development of the web based Geo Location database in this work was segmented into stages. The first stage that was carried out was the TV spectrum sweep achieved with the help of the RF Explorer device taken at fifteen minutes intervals for one week.

In the next stage, results from the sweep were imported into the Wamp Server and given the appropriate structure best suited for the required database to be developed.

A web page interface was developed next using HTML tags and the PHP code snippets to handle the logic flow of the entire system. This stage is essentially the brain of the entire setup as it handles the querying of the database by the WSDs, identification of TVWS from amongst the sweep results and TV spectrum predictions deduced from sweep history. This stage is also responsible for facilitating the connection between the WSD, Web Page and the data base. For this work, the web page is subdivided into three essential pages. The first page or home page displays an interactive interface. Here, the WSD fills the required fields displayed on the interface before it is allowed to query the database successfully. Once completed and sent, the webpage automatically uses the imputed information to query the data base and displays the results in the result page in a matter of seconds.

Table2: RF Explorer Scan Result

1	RF Explorer CSV data file: RFExplorer PC Client - Format v002										
2	Start Frequency: 470MHZ										
3	Step Frequency: 178.571KHZ										
4	Total data entries: 96										
5	Steps per entry: 112										
6											
7	Time	470	470.179	470.357	470.536	470.714	470.893	471.071	471.25	471.429	471.607
8	0:00:00	-97.5	-86	-86.5	-91	-86	-80.5	-88.5	-85.5	-89	-94
9	0:15:00	-99	-90.5	-85.5	-83	-87	-91.5	-85.5	-88.5	-87	-88
10	0:30:00	-101	-88.5	-91	-93.5	-88.5	-90	-81.5	-86	-87.5	-89.5
11	0:45:00	-101	-92.5	-89.5	-82	-83	-88.5	-85.5	-83.5	-97.5	-92
12	1:00:00	-87.5	-86	-84.5	-92.5	-86	-94.5	-89.5	-85	-84	-90.5
13	1:15:00	-98.5	-90.5	-89	-90	-89.5	-84	-92	-91	-85	-86
14	1:30:00	-97	-85.5	-89	-86	-86.5	-88	-86.5	-87.5	-90.5	-88.5
15	1:45:00	-92.5	-87	-91.5	-84	-87.5	-88.5	-93.5	-90.5	-83.5	-90.5
16	2:00:00	-92	-83	-84.5	-86.5	-86.5	-83.5	-86.5	-88	-86.5	-89
17	2:15:00	-92.5	-92.5	-82	-85.5	-84	-91	-94	-80.5	-87.5	-88.5
18	2:30:00	-103.5	-88	-89.5	-79	-90	-86	-90.5	-88	-84.5	-93.5
19	2:45:00	-92.5	-89.5	-85.5	-96	-93	-85	-86.5	-90	-90.5	-84.5
20	3:00:00	-106.5	-89.5	-89.5	-87.5	-89.5	-86.5	-87.5	-88.5	-89	-85.5
21	3:15:00	-96	-95.5	-85.5	-94	-85.5	-88	-85.5	-89	-86.5	-83.5
22	3:30:00	93	93	90.5	91	88	95	84	81.5	83.5	89.5

Table 3: Table Structure and Structural Properties



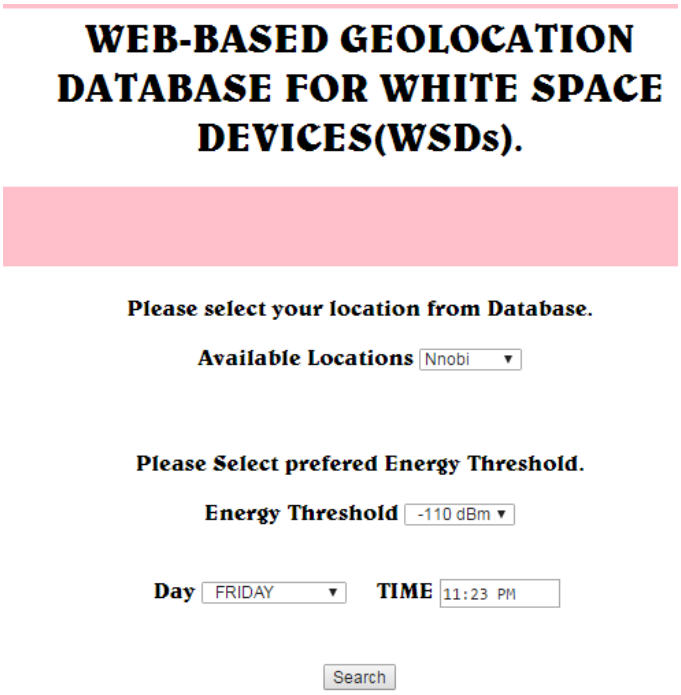
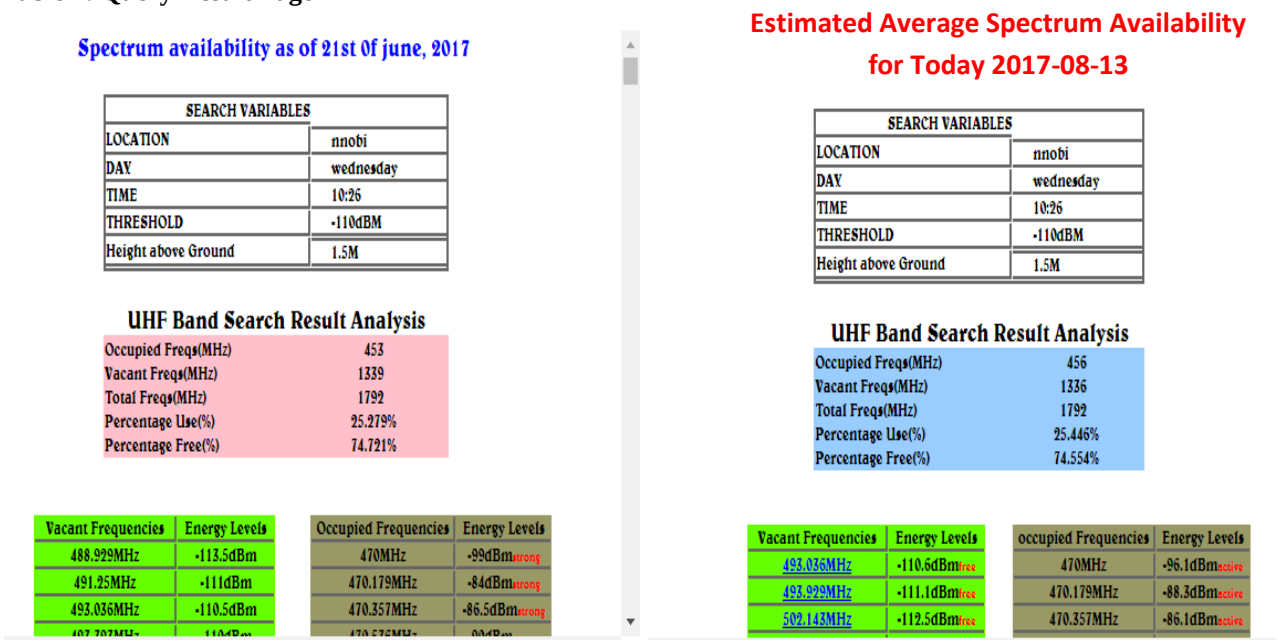


Figure 6: Query Page (TVWS Finder Web Page)

The query result page displays the results generated by the query page simply by securing a connection to the database where the sweep results were structured and stored. The related information is selected and automatically analyzed by the PHP codes before displaying results as shown in Table 4

Table 4: Query Result Page



The display on the left illustrates the spectrum occupancy of the TV spectrum obtained from the last sweep results updated to the database. It shows the query or search variables imputed by the WSD, which was used to generate the

displayed results. It also shows the result analysis frame where the amounts of occupied frequencies, vacant frequencies, percentage of used and vacant frequencies respectively are displayed.Finally, a bar chart is generated to further illustrate the disparity between amount of occupied frequencies and the amount of vacant frequencies as at the time the sweep was carried out.

The display to the right of the screen is a generated Average of what the TV spectrum occupancy would be as at the current day and time of the query based on the TV spectrum history gathered over the one week TV spectrum sweep exercise.

The vacant frequencies generated in the frame on the right were enabled to be clickable such that the WSD can select one of the predicted vacant frequencies displayed in the bar chart. Once a vacant frequency is selected by the WSD, the frequency history page is initiated and a frequency history or timeline is generated showing the sensed energy levels of the selected frequency at that particular reference time for the entire week. It also pulls up from the database the energy levels recorded fifteen minutes before and after the reference time for the same frequency under observation. This gives the WSD a better understanding of the occupancy history of the selected frequency. Finally, the Estimated Average energy level is displayed along with the allowable transmission power for that frequency.

Table 5: Frequency History Page

FREQUENCY HISTORY FOR (502.143 MHz)

ReferenceTime	MON (19/5/17)	TUE (20/5/17)	WED (21/5/17)	THR (22/5/17)	FRI (23/5/17)	SAT (24/5/17)	SUN (25/5/17)
15min Before	-113.5dBM	-115dBM	-115dBM	-114.5dBM	-115dBM	-115dBM	-115dBM
10:26	-112dBM	-115dBM	-115dBM	-115dBM	-115dBM	-110.5dBM	-112dBM
15min After	-113.5dBM	-115dBM	-115dBM	-114.5dBM	-115dBM	-115dBM	-115dBM

Predicted Energy Level For Today 2017-08-13 (-112.5 dBM)
Allowable Tx Power (4W)

5.0. Conclusion

The frequency sweep of the UHF band of the television spectrum was carried out (i.e. from 470MHz to 789MHz) using the spectrum sensing technique and was taken at intervals of 15 minutes for one week while the results were structured into a database. A webpage user interface was developed and hosted over the internet. White space devices can access this web page via the unique web address and using the query options on the homepage/query page, they are able to query the database. The result page in turn automatically generates an analysis based on the query options sent to the database by the WSD.

The analysis generated by the query page helped to identify which frequencies were occupied by primary use and which frequencies were vacant for secondary use.The analysis displayed showed the amount of used and unused frequencies as well as the percentage of used frequencies to the unused frequencies at any point in time of the week per selected location. Finally from the analysis, a prediction is made on TVWS availability at that reference time

based on spectrum records stored in the Geo location database. The analysis generated is uniquely different and greatly depends on the Location, day of the week, energy threshold and time selected by the WSD from the query page or home page.

From result analysis generated, it was gathered that for a standard energy threshold of -110dBM specified by (FCC,2008)], more than 70% of the frequencies in the UHF band of the television spectrum is left unused at any time of the day and on any day of the week in Nnobi community of Anambra State, South East Nigeria.
This result goes to show how the current fixed spectrum assignment to large geographic area policy has proved to be an uneconomical and inefficient use of the rather limited radio resource especially with the current explosion in the demand for spectrum due to the evolution of broadband hungry applications such as Facebook, twitter and their likes. Furthermore, the Geo-location database developed in this work also promises to totally eradicate the probability of interference between primary and secondary users within the UHF band if only the fidelity of the database is not compromised hence, TV spectrum sweep or scan should be carried out as frequently as possible to ensure that the information represented in the data base is as up to date and as accurate as possible reflecting the current state of occupancy of the TV spectrum.

Finally, from the generated results obtained from the result page, it can be concluded that there is a great potential to provide broadband internet access over TV white space frequencies in Nnobi community of Anambra State as well as the entire south east since there's an excess of more than 70% of TV white space available at any time of the day/week. In general, the TVWS technology proves to be a step in the right direction in solving the last mile problem in rural areas. .

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