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airjournals@gmail.com; enquiry@airjournal.org

Provisioning of Broadband Connectivity in Rural Areas using Television White Space

[1]Onoh G.N., [2]Arinze S. N., [3]Abonyi D. O. and [4]Okafor P.U.

[1,2,3,&4]Department of Electrical and Electronic Engineering
Enugu State University of Science and Technology (ESUT) Enugu State, Nigeria

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ABSTRACT

The current global move to switch from analog to digital Television has opened up unused channels within the 470MHz to 890MHz called Television White Space. Television White Space radios offer broadband speeds over several kilometers and their signal can travel through obstacles such as buildings, trees and terrains. Television White Space is free to use and affords a good opportunity to supplement the existing licensed spectrum to ease the spectrum scarcity. Unfortunately, rural areas in Nigeria are predominantly unconnected as it is not viable for operators to provide broadband access. This research was aimed at improving the quality of service in a mobile network for the rural areas through the provisioning of broadband connectivity using Television White Space technology. In carrying out this objective, a preliminary measurement within a selected rural community was carried out to ascertain the speed and level of the broadband connectivity available within the community. A spectrum occupancy measurement was done to identify the low occupancy bands suitable for deploying Television White Space technology. The result of the measurement carried out showed that there is an average of 26 unoccupied channels, 5 fully occupied channels and 3 incomplete occupied channels in the TV channel allocated to a TV station. This indicates that there are lots of spectrum utilization opportunities for the provision of broadband internet services. A terrain-based propagation model was developed to select the best sites for both the Television White Space base station and the Client premise equipment for maximum impact. Thereafter, the Capacity and the number of radios required for the deployment of the Television White Space Network were determined.

Keywords: *Television White Space, Broadband Connectivity, Spectrum Occupancy, Propagation model, Capacity Planning*

1. Introduction

Broadband high-speed internet access has become a requirement in today's connected world as it meets the demand for rapid internet connection and integrated data, voice and video services. However, Rural broadband connectivity in Nigeria continues to be a challenge as wireless operators do not provide communication infrastructures due to cost of deployment for low population densities and low return on investment. Rural communities suffer the most without access to the internet. They face social exclusion as they find it difficult to build online social interactions, expand social networks and watch online movies. Rural dwellers are deprived of virtual health care services, remote monitoring of patients and remote radiology. They are deprived of participating in the emerging e-learning technology, research and videoconferencing that can compensate for difficulties associated with distance. Rural businesses are unable to compete in the global economy since the dwellers cannot create an online identity and advertise their products and services. It is possible to build the necessary broadband infrastructure in rural areas with significantly reduced costs using Television White Space (TVWS). TVWS are unused broadcasting frequencies in a wireless spectrum. TVWS allows greater coverage range at low transits power levels. Also, Television White Space is not significantly affected by rain, haze and other natural disturbances owing to its lower frequency. In Nigeria, the TVWS Spectrum allocation and assignment is managed by the National Broadcasting Commission (NBC) and Nigerian Communications Commission (NCC) to promote spectrum discipline, increase efficiency and usage. With proper regulation methods being established by these Government bodies, there will be no harmful interference to television receivers operating within the television broadcaster's frequencies.

An insight into spectrum occupancy in Nigeria was presented by researchers [1]. They conducted an indoor spectrum occupancy measurement within the radio frequency range of 700MHz to 2.5GHz in Gwarinpa district Abuja Nigeria. The measurement lasted for twelve hours and covered between 9am and 9pm. In their work, a threshold of -76dBm based on the noise floor level of the setup was used to decide the presence of primary users. Their results showed that a large portion of the allocated spectrum was underutilized and could be considered for the deployment of TVWS technology. Their investigations however were specifically indoors and the measurements were conducted for twelve hours only. Further analysis for the outdoor investigation at different locations was not carried out which is necessary to actualize the mean peak and off-peak performances.

Geolocation database and spectrum sensing method for the usage of TVWS was proposed by authors [2] to prevent interference to the primary users of the TV spectrum from the secondary users. A spectrum sensing technique identifies the available spectrum holes and detects the transmission by primary users of TVWS. The geolocation database requires primary users to be registered in the database. The secondary users first have to identify their locations and can get information about available free channels and maximum transmit power from the appropriate database. A condition of database consultation and spectrum sensing could provide a more accurate assessment of channel occupancy, leading to a more efficient spectrum usage while protecting incumbents from interference. The establishment of the power level threshold to decide spectrum occupancy is very crucial.

Software Defined Radio Testbed was developed based on Universal Radio Software Peripheral (URSP) with a focus on spectrum probing which is a seemly overlooked component of spectrum sensing [3]. The work expanded theoretical and simulation analysis for comparing different spectrum probing. Different spectrum probing methods were implemented for an independent and cooperative network of the secondary users. The result showed that in independent sensing, periodic probing achieved the smallest delay while in cooperative probing, randomization reduces probing delay. The University of Malawi in partnership with the regulator, MACRA and the International Centre for Theoretical Physics in Trieste launched a white spaces pilot project in the city of Zomba in southern Malawi [4]. Technical results obtained from the Malawi TVWS trial project showed that, unlike other fixed broadband services, TVWS services demonstrated 2.6 times better data rates given the same operating conditions. The testbed functional range at the moment was 7.5km which measures an SNR of 24,7dB, average latency of 118ms and maximum throughput of 420kbps

2. Theory of Work

2.1 Broadband Connection

Broadband Internet service is the most used form of Internet access because of its high access speeds; it is offered in four different forms, DSL Digital Subscriber Line (DSL), cable, fiber-optic and satellite. The DSL internet service makes its connection by utilizing unused telephone wires that cause no interruption to telephone service. The speed experienced with a DSL connection varies with the users distance from the switching station [5]. The broadband cable connection is provided by the local cable TV provider. The cable Internet connection speed varies with the number of users on the service at a specific point in time. Fiber-optic is the fastest Internet connection but its internet service is still in its infancy as its service areas are quite limited because the laying down of the fiber-optic cable takes a while to complete and it is costly [6].The broadband service provided by satellite is the slowest but a good replacement for dial-up. Its greatest strength is its expansive availability. Having a broadband connection line makes it possible for one to obtain be constantly connected to the Internet.

2.2 Television White Space

TV White Space refers to the unused TV channels between the active ones in the VHF and UHF spectrum. TVWS technology makes use of these available channels using an online geolocation database that tells the wireless device which frequency it can use without causing interference to TV broadcasters [7]. TVWS can offer tens of Mbps per channel over several kilometers. TVWS uses lower frequencies and thus allowing the signal to travel much greater distances. It penetrates obstacles such as buildings, terrains and trees. TVWS performs best in rural areas where the spectrum is generally less congested than in urban areas. To transmit on TVWS channels, devices are required to contact a TVWS database to check the availability of channels in their area as shown in figure 1. Devices send their location to the database, and in return, they receive a list of available channels and the power at which they are permitted to transmit and remain clear of TV broadcasts.

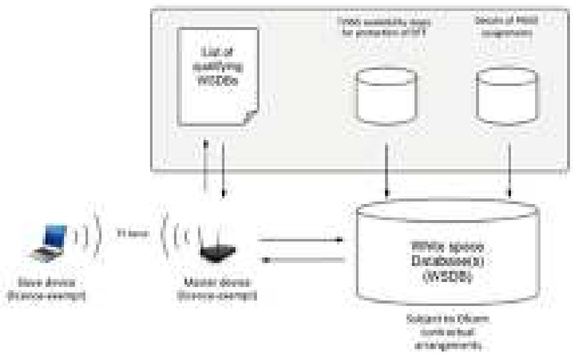

Figure 1 TVWS Technology [8]

3. Methodology

The rural community of Agbani in Enugu State was used as an experimental testbed due to its sparsely populated environment. Radio frequency (RF) spectrum measurement on the environment was carried out to determine the number of available TVWS channels and channel usage within the Television UHF. The measurement was done using an RF Explorer spectrum analyzer that has a wideband measurement capability of 240MHz-960MHz. The RF explorer was connected to a laptop with an installed windows PC client. A noise threshold of -110dBm was used to determine the occupancy of the primary users of TV receivers. Frequency sweep was carried out at the testbed focusing mainly on the UHF frequency range of 470MHz-698MHz. A Geo-location database was created using the MYSQL database and data translation technique. The technique imported the frequency scanning results from an excel spreadsheet into the database. The database has the TV received signal strength, the primary and secondary user density, and their locations as well as the number of unoccupied TV channels. Then, the database simulates the maximum permissible transmit power 30dBm for the secondary users. The maximum transmits power is ensured that the location probability is not less than 95%. A query language with the PHP script was used to query the database over the internet for the access and prediction of available TVWS. The propagation path loss model for the experimental testbed was determined using equation 1.

$$P_L(d_i)[dB] = P_L(d_0)[dB] + 10n\log_{10}(\frac{d_i}{d_0}) + S[dB] \quad (1)$$

and

$$n = \frac{\sum_{i=1}^{M} P_L(d_i) - P_L(d_0)}{\sum_{i=1}^{M} [10 \log_{10} \frac{d_i}{d_0}]} \quad (2)$$

Where n is the pathloss exponent, $P_L(d_0)$ is the pathloss at known reference distance(d_0) obtained as the difference between the transmitted power and received power, P_L (d_i) is the pathloss at a transmitter-receiver separation distance (d_i) and S is the shadowing factor and Gaussian random variable obtained as a standard deviation (σ) in equation 3.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{k} (P_L(d_i) - P_L(d_0))^2}{N}} \quad (3)$$

Where N is the number of measurement points in the field measurement
The received signal strength measurement was done for a distance of 1.5Km at 100m intervals using the Enugu state broadcasting service station that is operating at a transmitting power of 62.05dBm. Due to the variations in the measurements, the average received signal strength was used for the determination of the pathloss exponent. The capacity of the TVWS for the experimental testbed was calculated using equation 4.

$$C = \frac{CU \times TH}{OSR} \quad (4)$$

Where CU is the concurrent users, TH is the minimum throughput needed per user and OSR is the oversubscription ratio. Concurrent users were estimated as 330 users per time and doubling of the concurrent users were estimated to be the overloading users of the network. Thus the oversubscription ratio was obtained as the ratio of the number of concurrent users to the number of overloading users. Files were downloaded from a trusted site and the minimum throughput needed per user was obtained using a speed test network analyzer. The number of TVWS radios required for the experimental testbed was calculated using equation 5

$$R = \frac{C}{ATPR} \quad (5)$$

Where C is the capacity of TVWS and ATPR is the average throughput per radio which can be found in the datasheet of Carlson RuralConnect radio. Carlson RuralConnect radio is the equipment designed to support access to vacant television bands and bring wireless broadband to last-mile locations.

Results

The graphical interpretation of the result of the RF occupancy measurements carried out within the testbed is shown in figure 2.

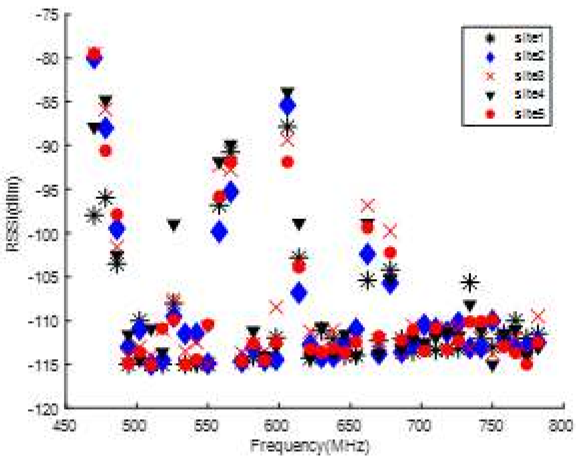

Figure 2: RF Measurement of the Five sites

It was observed that there are more available TVWS in the rural area. The scatter plots showed that there is an average of 26 unoccupied channels as their received signal strength indicator is within the range that is classified as unoccupied using the ambient noise threshold of -110dBm. Also, there are 5 fully occupied channels and 3 not fully occupied channels indicating that there are lots of spectrum utilization opportunities for the provision of broadband internet services.
The average received signal strength used for the determination of the propagation pathloss model is shown in table 1.

Table 1: Received Signal Strength Indicator (RSSI) of the experimental Testbed

Distance(m)	Measured RSSI (dBm)	Transmitted Power(dBm)	pathloss $P_L(d_0)$ dB
100	-42	62.05	104.05
200	-43	62.05	105.05
300	-47	62.05	109.05
400	-51	62.05	113.05
500	-53	62.05	115.05
600	-57	62.05	119.05
700	-59	62.05	121.05
800	-62	62.05	124.05
900	-65	62.05	127.05
1000	-71	62.05	133.05
1100	-73	62.05	135.05
1200	-75	62.05	137.05
1300	-81	62.05	143.05
1400	-83	62.05	145.05
1500	-86	62.05	148.05

The measured pathloss for the experimental testbed is shown in figure 3.

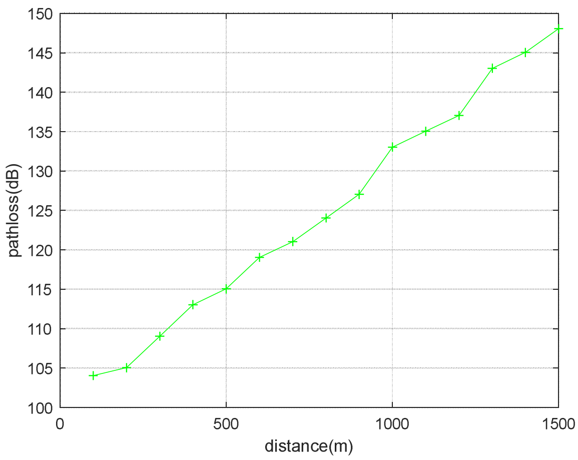

Figure 3: Pathloss for the Experimental Testbed

It was observed that pathloss increases as distance increases. It is also a result of environmental factors on the transmitted signal. With the minimum throughput of 1.02Mbps obtained for a user and average throughput of 72Mbps per radio, the capacity was found to be 673.2Mbps and the number of TVWS radios required for the experimental testbed is 9.

4. Conclusion

The future of every nation's economic growth is dependent on the internet as it is the crucial technology of the information age. Expanding access to affordable broadband and dependable high-speed internet in rural areas unlocks access to robust economic growth educational opportunities and health care. The availability of the TVWS in the rural areas conducted from this research presents a great opportunity for better coverage and substantial bandwidth for broadband communications. Hence, TVWS can be effectively deployed and utilized to provide low-cost broadband internet access in rural areas rather than left unused in the broadcasting sector.

References

Najashi, B.G., Wenjiang F., and Kadri C. (2018). An Insight into Spectrum Occupancy in Nigeria. *International Journal of Computer Science* 10(1), 394-399.

Brew M., Darbari C., Bolton G., Weiss S., and Stewart R.W. (2019). A low cost and power efficient TV white space technology solution for future rural broadband access networks. *IEE GLOBECOM Workshops*, 1024-1028.

David, A. (2017). A Software Defined Radio Testbed for Research in Dynamic Spectrum Access, https://api.semanticscholar.org/Corpus1D:36407996

Mikeka, C., Thodi, M., Mlatho, J. S.P., Pininfolo, J., Kondwani, D., Momba, L., Zennaro, M., Moret A. (2018). Malawi Television White Spaces (TVWS) Pilot Network Performance Analysis *Journal of Wireless Networking and Communications,* 4(1), 26-32.

Parker, C. (2020). What is Broadband? https://whatismyipaddress.com/broadband.

Oaks, R. (2019). What is the difference between satellite, DSL, cable and Fiber Internet? https://www.highspeedinternet.com/resources/what-is-the-difference-between-sattelit-dsl-cable-and-fiber-internet

Nominet. (2020). What is TV White Space? https://www.nominet.uk/what-is-tv-white-space/

The Office of Communications (2018). TV White Spaces: approach to coexistence, https://www.ofcom.org.uk/_data/assets/pdf_file/0023/69305/white-spaces.pdf