Options for affordable rural broadband connectivity: a focus on TV White Space technology

Kwesi Assan Biney
Ghana Technology University
bineyassankwesi@gmail.com

Abstract

There appears to be a coordinated effort the world over to achieve digital switch over (DSO) from analogue based to digital technology. Ghana signed the Geneva agreement which set 17th June 2015 as the deadline for the DSO. This switch over will create new spectrum opportunities for many wireless technologies due to the abundance of radio spectrum the switch over provides.

This paper focuses on the opportunity for using White Spaces (TV frequencies allocated to a broadcasting service but not used locally) for internet connectivity in the rural and underserved areas of Ghana, using TV White Spaces in Koforidua as a case study. The paper investigates the challenges associated with lack of internet connectivity in rural Ghana and determines if the infrastructure necessary for the implementation of White Space technology in the rural areas was present and adequate. It also documents the user experience of Africa's first commercial TV White Space network services in Koforidua, Ghana. A combination of qualitative and quantitative data collection approaches was used. Purposive and simple random sampling techniques were used in selection and administering of questionnaires.

Lack of internet in the rural areas was found to be mainly due to perceived risk by the commercial network operators because of value for money considerations of existing technology options. Negative incentives for the common ISP to go rural included technical and geographic/landscape challenges. The relevant infrastructure necessary is still undeveloped in Ghana but various infrastructural projects are being undertaken by the Ghana Investment Fund for Electronic Communication (GIFEC) to bridge the infrastructure gap in these areas. Lastly, the user experience of Africa's first commercial service network using TV White Spaces in Koforidua, Ghana were described and documented.

Keywords: TV White Space, Digital switch over (DSO), Internet connectivity and Ghana Investment Fund for Electronic Communication (GIFEC)
JEL classifications: O1, O32, O34, O38, O14, O15

Introduction

Background of study

The importance of internet connectivity in developing countries is immense. Rural areas in Africa have few physical resources such as libraries, and skilled workers tend to migrate to better resourced locations or cities. As Armah (2004) correctly identified several years earlier, the internet had the potential to facilitate growth in different sectors of Africa's economy: health, education, communication and access to markets. Internet connectivity provides access to knowledge and information, which is crucial for social and economic development. Internet broadband services in the 21st century's era of information explosion, has been conceived as the most important resource that contributes greatly towards national development.

Information provides the foundation for innovation, development knowledge and the resource for informed citizenry. As a result information is an essential commodity for the progress of any society. Abdallah (2007) argues that the internet is used in education as it facilitates learning, teaching and communication.

Rural areas, especially those of the developing countries provide a challenging environment to implement communication infrastructure for data and internet based services. The main challenges are the high cost of network implementation and lack of customer base, as rural areas are characterised by low income, highly scattered and low population density. This situation drives network operators to establish network infrastructures in urban centres leaving rural areas as underserved communities. To address this connectivity challenge, this research sought to investigate the challenges associated with lack of internet in the rural areas, availability of infrastructure in rural areas to support this technology and the user experience of the TV White Space network in Koforidua, Ghana.

Problem statement

Access to information has a direct relationship with socio-economic development. Information and communication technologies are important instruments in support of rural development and poverty alleviation. According to the United Nation Statistical Division's data on Ghana, rural population makes up 47 % of the country's population. These rural areas face a high internet connectivity gap. Lack of investment in telecommunication in such areas may be a result of perceived low revenues and steep investment cost. High investment expenditure is typically due either to low population or to geographical characteristics such as thick vegetation and sparsely distributed population and settlements.

The government of Ghana through the National Communication Authority (NCA), the telecom regulator, has been involved in several projects aimed at spreading internet across its rural areas. These projects include the Community Information Centre Initiative which was aimed at facilitating internet to 230 constituencies and the Wiring Ghana Initiative, aimed at constructing an underground fiber optic backbone across the country, spearheaded by Ghana Telecom.

Despite all these efforts by the industry stakeholders, the rural internet access gap has still not been bridged in Ghana. Radio spectrum, a necessity for the propagation of wireless signals and provisioning of innovative wireless services, is a limited resource and hence requires optimal allocation and protection. The switch over from analogue to digital taking place in Ghana will offer a major opportunity to solve this problem of rural internet gap. It will also offer free spectrum formerly used for the transmission of television services in the country.

Research question

This study explores the following research questions:

- what are the challenges associated with lack of internet connectivity in the rural areas?
- is the infrastructure necessary for the implementation of TV White Space technology present in the rural areas?
- what is the user experience of the TV White Space network in Koforidua?

Research objectives

Specifically, this study aims:

- to identify the challenges associated with lack of internet connectivity in the rural areas
- to investigate whether the Infrastructure necessary for the implementation of White Space technology is present in the rural areas
- to describe and document the internet user experience of the TV White Space network in Koforidua.

Literature review

Overview of White Space technology

TV White Space is the portion of the TV bands that is unused by licenced services (Saeed 2011). There are many unused TV channels in the VHF and UHF TV bands. In some geographic regions the utilisation of these TV channels is high, whilst it is very low in other regions. Regulatory agencies permit wireless networks to access unused channels while guaranteeing that these wireless networks do not cause harmful interference to licenced services in the TV bands. These TV White Spaces change, based on geographic location and time. They could provide a much better radio frequency propagation than systems that have been deployed in the industrial, scientific and medical (ISM) bands, allowing for a reliable, cost-effective, and better coverage in rural areas. This is mainly because the TV White Space range exists underneath 1GHz in both the VHF and UHF band (Rashid A. Saeed 2011).

Potential of White Space technology

Zennaro et al (2013) conducted a study to assess the performance of the TV White Spaces (TVWS) network under harsh African environments: intermittent power and constrained internet bandwidth resources. It was observed that unlike other fixed broadband services, TVWS services demonstrated 2.6 times better data rates given the same operating conditions. The tested functional range for the Malawi trial was 7.5 km. This is close to the longest TVWS link known to the authors, which was 10 km in the South African trial (Zennaro, Marco, Pietrosemoli, E 2013).

A similar study conducted by Roberts et al (2014), identified the benefits of using TV broadcast spectrum. Consistent with the results obtained by Microsoft, they found that TVWS signals can easily cover large regions as it transmits in lower frequencies. Comparatively, a typical Wi-Fi signal can cover approximately 100 meters while a TVWS signal at the same power level can easily travel 400 meters and with higher power can cover several kilometers (Roberts et al. n.d.). TVWS signals can easily penetrate common obstructions. A single TVWS base station operating at 20dBm with a 2dBi gain antenna was able to cover all parts of a building spanning a usable area of 222,000 sq ft over 4 floors which had 150 access points to provide high speed access research (Roberts et al. n.d.). Since the TVWS signals travel farther than Wi-Fi, a TVWS deployment would cost less, and would consume less power than Wi-Fi or mesh based topologies to cover sparsely populated communities in Africa. Greater efficiencies can therefore be achieved (Roberts et al. n.d.).

Switch over opportunity

According to the Digital Migration Report (2010), Ghana signed the Geneva (GE06) Agreement in 2006, establishing the Digital Terrestrial Broadcasting Plan in the bands 174 – 230 MHz and 470 – 862 MHz at the Regional Radio Communications Conference (RRC-06). The Geneva Agreement set 17 June 2015 as the deadline for the cessation of international protection for analogue broadcasting transmissions in the said bands.

The migration from analogue to digital was necessary and urgent for the following reasons:

- to comply with and adopt the tenets of the GE-06 Agreement
- to rapidly adopt spectrum efficient methods in the management of the scarce RF spectrum to broaden its utility as a resource in the interest and benefit of stakeholders
- to enhance the quality and experience of TV viewers in Ghana by improving terrestrial TV transmission and reception
- to promote environmental sanity through co-location of broadcast transmission infrastructure.

The switch over from analogue to digital taking place in Ghana and all over the world would lead to a significant amount of free spectrum which could be efficiently used by cognitive radio transceivers which optimise the use of spectra. This switch over would free up a considerable amount of spectrum which will minimise spectrum congestion and facilitate the emergence of new broadband and other innovative services.

Due to the opportunity that global digital switch over presents, Deshmukhl et al (2013) conducted a study in India to assess the availability of geographically interleaved spectrum, also known as Television Spectrum White Spaces and proposed a wireless network (Deshmukhl et al. 2013). A Wi-Fi-like network for broadband services backhauled by fiber optic network for administration, education, medical services and other executive services of the government was proposed.

From their assessment it was noticed that only three channels were currently being used by the national broadcaster so they proposed an interweaved type of spectrum sharing since the larger parts of the Digital Terrestrial Television (DTTV) spectrum remains unutilised or underutilised. This sharing would ensure the consistent availability of the secondary spectrum opportunity. The collaborative spectrum sensing was considered for detection of spectrum opportunity. Finally, secondary exclusive licensing or secondary shared licensing was proposed for this network. It was assumed that the Quality of Service (QoS) requirements in the rural areas are not high, since the higher requirements on QoS imposes stringent demands due to sensitivity to variance in the achievable data rate (Deshmukhl et al. 2013).

Rural connectivity

Simba et al (2011) researched the available connectivity technologies with potentials to offer broadband access network to rural areas. They stated that rural areas, especially those of the developing countries, provide a challenging environment to implement communication infrastructure for data and internet based services. The main challenges are the high cost of network implementation and lack of customer base, as rural areas are characterised by low income, highly scattered and low population density. Their survey was on wireless access technologies, due to the fact that they are efficient in terms of cost, time of deployment and network management for rural environments (Simba et al. 2011).

The Ghana Investment Fund for Electronic Communication (GIFEC), formerly known as Ghana Investment Fund for Telecommunications, was created as an implementing agency of the Ministry of Communications in the year 2004 to facilitate the provision of ICT, internet connectivity and infrastructure. GIFEC has initiated numerous projects with the aim of bridging the gap in the underserved and unserved areas of Ghana. These projects are under the Universal Access to Electronic Communications Program. This nine-year program, seeks to bridge the digital-gap between the underserved, unserved and the served communities in the electronic communications sector.

Some of these projects include: the Rural Telephony Project, the Common Telecommunication Facility Project, the Last Mile Initiative Project and the Community Information Centers Project among others.

Benefits of rural connectivity
Igboaka (2010) conducted a study to explore internet use for economic development in Ihiala, a village in southeastern Nigeria. The researcher examined how the inhabitants of this rural area used the internet to get information and the type of activities crucial for personal and community-wide economic progress. The study concluded that, for economic activities, two categories of use were identified: use of the internet for financial transactions and use of the internet for business activities. Additionally there were perspectives on internet use for education (Igboaka 2010).

Uses of the internet for financial purposes
The results showed that Ihiala internet users used the internet for information searches on stocks and trading shares as the most common use for financial purposes. However, there was also moderate use of the internet for e-banking and other banking activities (Igboaka 2010).

- *Uses of the internet for business purposes:* results from the frequency distribution of users of the internet for business showed that 81.7 % of the respondents search for information on goods and services, 78.7% of the respondents used the internet to check for goods and commodity prices, about 74.3% of the respondents used the internet to do business (Igboaka 2010).

- *Perspectives on internet use for education purposes:* internet use for educational purposes was the most common economic development activity among respondents. The study showed that 94.6% of respondents used the internet for that purpose (Igboaka 2010).

- *Challenges of rural connectivity:* Kenny (2000) examined the importance of reducing costs associated with internet connectivity and increasing the number of rural access points to increase rural internet access. He emphasised on how the internet has the potential to play a significant role in reducing poverty and promoting sustainable development, especially in rural areas. From the findings of the research, Kenny stated that active competition between providers will become important in reducing cost and also the introduction of low-cost rural access options. He also suggested that countries could auction subsidies toward the initial provision of internet services in a rural area using the Chilean experience as a model (Kenny 2000).

Pejovic et al (2012) conducted a thorough examination of internet usage at three locations in rural Africa consisting of network traffic analysis and internet use. Interviews revealed several major obstacles to efficient broadband usage. These obstacles included restrictions on the locality of access, a lack of locally relevant content, unfamiliarity with new concepts, shortage of trained personnel, high cost of internet access, and limited connection capacity with respect to the internet structure and content. Internet usage analysis points out that a metric employed for measuring broadband in rural Africa has to describe the state of connectivity with respect to all the obstacles (Pejovic et al. 2012).

White space and rural connectivity
Ramoroka (2014) examined the benefits and challenges of using TV White Spaces for internet connection in rural and township schools. The University of Limpopo TV White Spaces trial project was used as a case study (Ramoroka 2014).

The challenges of using ICT for teaching and learning included lack of teachers' and learners' knowledge and skills, limited infrastructure and the use of internet connection for personal communications. From the study it was concluded that the TV White Spaces can be used effectively and efficiently to connect previously disadvantaged townships and rural areas to wireless internet which can then be used to develop teaching and learning within these areas. Also the use of ICT has the ability to positively improve teaching and learning in South Africa's rural and township schools (Ramoroka 2014).

Microsoft 4Afrika initiative
Over the past five years, Microsoft has been working to demonstrate the viability and potential of Dynamic Spectrum and TV White Spaces with industry and government partners around the world. A core goal of the 4Afrika Initiative is to facilitate access to technology for the masses and to empower African students, entrepreneurs, developers and others to become active global citizens. The viability of the technology has been proven in multiple trials and commercial deployments around the world (Microsoft Research 2015).

Case of Ghana
In May 2014, Microsoft announced a commercial pilot in Ghana at the Dynamic Spectrum Alliance Global Summit held in Accra. Microsoft intended to work with public and private sector partners to deploy networks using low-cost

wireless technologies, including TV White Space radios, to better enable the next generation of cloud-connected experiences. The networks used TV White Space-enabled radios and other wireless technologies to connect campus buildings as well as off-campus hostels where students live to ensure they have access to fast broadband. The pilot in Ghana was a commercial partnership with Spectra Wireless and a research partnership with Facebook. This pilot is part of Microsoft 4Afrika Initiative (Microsoft Research 2015).

The pilot made use of TVWS under a test licence from the National Communication Authority (NCA) to enable students and faculty members at Koforidua Polytechnic to enjoy always-on and fast internet access. The network was coupled with a productivity and communications application solution from Microsoft, as well as a device funding model enabling students to purchase a new internet-enabled device. Facebook signed on as a partner to this project to better understand how TV White Space spectrum and equipment can support wireless internet users (Garnett, 2014).

After the successful end to the trail in 2014, Spectra wireless and Microsoft 4Afrika launched Africa's first commercial service network utilising TV White Spaces on the 26th of January 2015 in Ghana. This service allowed students to buy affordable, high speed internet bundles and devices.

Research methodology

Research design

For this study the researcher adopted the descriptive method of research. Descriptive research design was chosen to give the researcher a vivid picture of the phenomena being investigated. The descriptive research method is typically used "to portray an accurate profile of persons, events or situation" (Robson, 2002).

Research scope

The research scope is a composition of the study area and the study population. The study area for the research was the telecommunication sector in Ghana as well as Koforidua Polytechnic. The total population was 6,075.

Sampling techniques

A mix of sampling techniques was adopted by the researcher for the study. The choice of sampling techniques was based on the research objectives and the type of data to be collected.

The sample comprised of employees of three network operators, the regulatory body National Communication Authority (NCA), students of Koforidua Polytechnic, and staff of Spectra Wireless. NCA, the Network Operators and Spectra Wireless were stratified into departments/units and specific employees were selected for interviewing while others were randomly selected as respondents to questionnaires.

The total sample size was 227.148 responded and five participants were interviewed while the remaining 143 responded to the questionnaires. The major prerequisite for participation was knowledge, experience and involvement in the subject area.

A mix of cluster, simple random and purposive sampling was used in soliciting data. The cluster sampling allowed the main telecom industries to be grouped into six clusters each representing the main telecommunication companies in Ghana: MTN, Vodafone, Tigo, Airtel, Expresso and Glo. Simple random sampling was used in selecting three clusters from the sample frame, namely Tigo, MTN and Expresso. Purposive or judgmental sampling was then employed to enable the researcher select department and units that will best enable the researcher to meet his objectives. The researcher used purposive sampling in selecting an engineer from the Engineering Department of the NCA, Network Operators and Spectra Wireless. Simple random sampling was used in the distribution of the questionnaires to the students. In addition to the primary data, the study captured secondary data from annual reports and publications from GIFEC.

Analysis of results

Objective 1 – to identify the challenges associated with lack of internet connectivity in rural areas

Table 1: Challenges of Rural internet Penetration

	frequency	*percent*	*cumulative percent*
Low Return on investment	**17**	51.5%	51.5%
Technical challenges	**10**	30.3%	81.8%
Geographical/ Landscape Challenges	**6**	18.2%	100%
Total	**33**	100%	

Source: researchers field data (2015) technical departments of Expresso, TIGO and MTN

Table 1 shows that out of the 33 respondents, 17 (51.5%) agreed that the main challenge associated with the lack of internet in rural and underserved areas was due to the fact that return on investment in those areas are very low. Ten respondents (30.3%) chose technical challenges and six respondents (18.2%) agreed that the geographical features were the main challenge.

The respondents were asked to state whether there were other challenges associated with the lack of internet in the rural and underserved areas. Some respondents (30.3%) admitted that there were other challenges apart from the ones stated above. The main challenges included the steep bandwidth cost and lack of knowledge and expertise. Other challenges were low patronage, customer base, no computers and illiteracy.

Objective 2 – to investigate whether the infrastructure necessary for the implementation of White Space technology is present in the rural areas

Table 2: Can current infrastructure support TV White Space technology?

	frequency	*percent*	*cumulative percent*
Yes	**9**	28.1%	28.1%
No	**23**	71.9%	100%
Total	**32**	100%	

Source: researchers field data (2015) technical departments of Expresso, TIGO and MTN

From the Table 2 above, out of 33 respondents, 23 respondents (71.9%) disagreed that the current infrastructure can support the TV White Space technology in the rural areas. From the responses received from the question above, there was a lot of skepticism that current infrastructure could support TV White Space technology.

Response from the interview sections

The following section presents responses from interviews conducted on selected respondents. Four respondents were selected for the interview. Out of the respondents, two were selected from the Technical Departments of the Network Operators; one was selected from the Engineering Department of the National Communication Authority and the fourth respondent, an engineer from Spectra Wireless, the company that conducted the first TV White Space trial in Ghana. All the respondents had experience in the telecommunication industry and also had extensive knowledge of TV White Space technology.

One of the questions posed to the chosen sample of respondents concerned the challenges associated with internet connectivity in the rural areas. According to the respondents, the lack of internet connectivity in these areas was due to the lack of commercial interest of the Network operators. These network operators, like most other companies are profit making organisations, and as such there is always the need to make good returns on their investments. The rural areas are usually characterised by a sparse population and very few industries and institutions, thus leading to a low customer base for internet connectivity. Even more daunting is the cost involved in constructing buildings and other technological infrastructure and the purchase of licences. Low profits and return on investment does not justify setting up in these areas.

The respondents were then asked whether the infrastructure necessary for the implementation of this technology was present in the rural areas. Mention was made of a current lag in the infrastructure necessary for the TV White Space technology.

Due to the above reasons, the Ghana Investment Fund for Electronic Communication (GIFEC) has undertaken several initiatives to provide this infrastructure for these areas to allow network operators access. Some of these initiatives include the Rural Telephony Project and the Common Telecommunication Facility Project. The main objective of the Rural Telephony Project is to motivate telecommunication operators to extend their services to such locations and areas that are less commercially viable. This is also encouraged by the Ghana Investment Fund for Electronic Communication (GIFEC). The latter funds the cost of erecting the towers. In addition, the Common Telecommunication Facility Project is also aimed at providing towers and masts at unserved and underserved communities for the provision of telecommunication access.

When asked whether they would suggest TV White Space connectivity to the rural areas, all the respondents gave an affirmative answer. The respondents also made mention of the fact that the rural areas are characterised by free channels as compared to the cities but also lack access and need a lower cost deployment alternative. TVWS technology should be considered as another alternative for addressing connectivity needs in these rural areas.

Objective 3 – to investigate the internet user experience of the TV White Space network in Koforidua Polytechnic

Description of network set up at Koforidua Polytechnic

The researcher gathered that the connection to the campus was from a leased line from Accra to the Vodafone towers at the Koforidua mountain top. This connection serves as the main backhaul link. A technical survey was carried out to find out possible locations to mount the radio devices. After the points were located, GPS coordinates were taken to perform a simulation to determine whether the locations will be appropriate.

A scan was done using a spectrum analyser after the successful completion of the simulation to identify the occupied and free channels within the area. This scan was done between the 470 MHz and 689 MHz. An appropriate channel was then selected and configured into the radio equipment. The radios used were 6Harmonics products. Various point-to-point and point-to-multipoint were installed on building tops on campus using the TV White Spaces after the scan. A cable was then dropped from the radio to the various Wi-Fi access points on the campus and hostels nearby where the students are able to connect their devices.

Table 3: Experience in internet use (years)

	frequency	*percent*	*cumulative percent*
Below 3 years	**30**	27.3%	27.3%
3-4 years	**22**	20%	47.3%
5-6 years	**14**	12.7%	60%
Above 7 years	**44**	40%	100%
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

From the research findings, the majority of users (40%) had over seven years of experience using the internet. This was closely followed by 47% of users who had only used the internet for less than five years.

Table 4: Hours of internet use per week.

	frequency	*percent*	*cumulative percent*
0 to 1 hour/week	**4**	3.6%	3.6%
2 to 4 hours/week	**52**	47.3%	50.9%
5 to 6 hours/week	**22**	20%	70.9%
7 to 9 hours/week	**6**	5.5%	76.4%
10 to 20 hours/week	**16**	14.5%	90.9%
Over 21 hours/week	**10**	9.1%	100%
Total	**110**	100.00%	

Source: researchers field data (2015) students of Koforidua Polytechnic

The group of survey respondents spending two to four hours per week on the internet constitutes close to 50% of the total responses. This is closely followed by students who spend five to six hours per week on the internet. These students constitute 20% of the survey population. From the submissions it can be concluded that most of the student spend two to six hours on the internet per week.

Table 5: Primary use of the internet

	frequency	*percent*	*cumulative percent*
Education (school work)	**46**	41.8%	41.8%
Entertainment	**16**	14.5%	56.3%
Communication with others (excl. email)	**10**	9.1%	65.4%
Gathering information for personal needs	**24**	21.8%	87.2%
Social media	**14**	12.8%	100%
Other	**0**	0%	
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

By far the biggest use of the internet by student sampled from Koforidua Polytechnic is for educational purposes and school work. This contributed close to 42% of the students surveyed. The next greater use is for searching information for personal use which contributed approximately 22% of the internet use.

Table 6: Medium/means in connecting to the internet before network deployed over TV White Space

	frequency	*percent*	*cumulative percent*
Modem	**42**	38.9%	38.9%
School Wi-Fi	**32**	29.6%	68.5%
Mobile phone	**32**	29.6%	98.1%
None	**0**	0%	98.1%
Other	**2**	1.9%	100%
Total	**108**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

From the research findings most of the students are connecting using modem making about 42% of internet traffic. School Wi-Fi and mobile phone constitute 32% of internet traffic. In effect the three ways of connecting are contributing a total of 98% of internet connectivity.

Table 7: Challenges faced with previous means of connecting to the internet

	frequency	percent	cumulative percent
Slow connection	**52**	47.3%	47.3%
Unstable connection	**40**	36.4%	83.7%
Limited connectivity	**16**	14.5%	98.2%
Other	**2**	1.8%	100%
	110	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

With the question of what challenges the students faced with internet connections, most responded to slow and unstable connection and this accounted for as much as 47% and 36% respectively. Limited connectivity was 14.5% and only sixteen respondents alluded to that.

Table 8: Has the TV White Space network solved your challenges?

	frequency	percent	cumulative percent
Yes	**84**	76.4%	76.4%
No	**26**	23.6%	100%
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

With the introduction of the TV White Space network the students agreed that it was a big improvement on their previous connectivity. 76% of the respondents agreed that most of their previous challenges had been resolved. Some issues did remain, however, including periodic instability, slow connectivity and limited access.

Table 9: Speed rating of the TV White Space network

	frequency	percent	cumulative percent
Very Fast	**18**	16.4%	16.4%
Fast	**48**	43.6%	60%
Manageable	**32**	29.1%	89.1%
Slow	**12**	10.9%	100%
Very Slow	**0**	0%	100%
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

With regards to the speed rating of the connectivity, as much as 43% of the respondent agreed that it was fast whilst 29% felt the speed was not the best but was manageable. However, 16% were of the view that connectivity was very fast. Only twelve respondents representing about 11% thought it was slow. No respondent commented that it was very slow.

Table 10: Satisfaction of the TV White Space network in terms of stability

	frequency	percent	cumulative percent
Very satisfied	**18**	16.4%	16.4%
Satisfied	**48**	43.6%	60%
Okay	**38**	34.5%	94.5%
Dissatisfied	**6**	5.5%	100%
Very dissatisfied	**0**	0%	100%
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

On the whole 43% of the respondents were satisfied, 38 people out of the 110 who responded were satisfied with the service and 16% were very satisfied. The respondents who were dissatisfied accounted for only 5%. The overall percentage of respondents who were satisfied was a high 94%.

Table 11: Do you have challenges with TV White Space network?

	frequency	percent	cumulative percent
Yes	**22**	20%	20%
No	**88**	80%	100%
Total	**110**	100%	

Source: researchers field data (2015) students of Koforidua Polytechnic

Table 11 above shows that out of 110 respondents, 88 respondents had no challenges with the TV White Space network, twenty two respondents however had challenges with the network.

Speed test

Download speeds of about 4Mbps and upload speed of 7Mbps were achieved when a speed test was conducted on the network. However, these results are dependent on the number of devices connected when the test was taken.

Conclusion and recommendation

Conclusion

The network operators face many challenges in relation to transmitting internet to the rural areas. Some of these challenges include geographical and landscape challenges, technical challenges, low return on investment and high bandwidth cost.

However, the main challenge identified by the researcher was low return on investment in the rural and underserved areas. Low return on investment does not make transmitting to these rural and underserved areas attractive to the network operators, hence the lack of connectivity in these areas.

The researcher also investigated whether the infrastructure necessary for the adoption of TV White Space technology in these rural areas were present. From the finding, it was concluded that the digital switch over will create a big opportunity for the use of this technology in these areas. Mainly due to the abundance of free channels after the switch over. The catch at this moment, however, is that the technological infrastructure necessary for this to happen is lagging. As a result, the Ghana Investment Fund for Electronic Communication (GIFEC) in collaboration with other companies are setting up infrastructure in these underserved areas to make these areas attractive to operators. Over 67 towers and masts have already been built in these areas.

The researcher also investigated the internet user experience of the first TV White Space network in Koforidua. From the survey over 80% of the student were very satisfied with the network. These students were very impressed about the speed and were able to achieve their primary aim of internet usage. Most of the student did not have any challenges with the network, the introduction of the network has solved most of the challenges they were experiencing with other means of internet connection.

Recommendation

In the government's quest to bridge the connectivity gap in the rural and underserved areas, TVWS technology should be considered and incorporated in the numerous projects being undertaken by GIFEC to solve the connectivity needs of rural areas.

TVWS technology should be considered as an alternative for connectivity needs in the rural these areas.

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