OPTIMAL INTEGRATED SOLUTION ON THE RURAL DIGITAL: ADAPTATION FROM SOUTH KOREA

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Abstract

Rural Kenya has challenging environment for implementation of communication infrastructure, for data and Internet services, the situation drives network operators to establish network infrastructures in urban areas leaving rural areas as underserve. This paper seeks to identify and recommend an optimal integrated technical solution that utilizes television white space and fiber optic technology, to address the rural digital divide with respect to broadband internet in Kenya. Specifically, for farmers in championing of the Food Security pillar in the Big Four Agenda. With an argument that television white space and optical networks can be integrated and deployed, with the government support to deliver an optimal cost effective solution to reach the digitally unreached and underserved rural populations. The motivation for the study is that despite the potential socioeconomic benefits and growth in demand for broadband internet, rural areas remain isolated digitally.

The study, will appraise various flavors of fiber optic technology, features of television white space before going on to recommend a deployment architecture informed by the results of county situation analyses and lessons learnt from South Korea which is recognized for its quality and technology innovativeness.

The contribution of this study is to encourage researchers and technologists to partner and drive higher education to the next level. Also, to ensure cost effectiveness, the government is encouraged to partner with any operators of technology to provide incentives such as tax rebates and zero rated services to make the big four agenda a reality.

Keywords: *Higher Education, rural digital divide, rural populations (famers), access to free network, TV White Space, fibre optic, integrated.*

Introduction

Broadband internet is gaining more and more demand in rural areas as a means for rural populations to participate in the democratic process, for delivery of remote education, health information and services, social security and other public services (Townsend, Sathiaseelan, Fairhurst, & Wallace, 2013).

Many new technologies such as wideband code division multiple access, high speed downlink packet access, long term evolution (LTE), WiBro, and others have been introduced in an effort to address the increased demand for mobile traffic. As the demand for mobile traffic increases, the demand for frequency also increases. It is not easy to solve this problem because frequency is a finite resource. One of the ways to handle this problem is spectrum reallocation which involves giving up part of the broadcasting spectrum to make room for wireless broadband. While this spectrum reallocation might be considered as an efficient use of the spectrum by wireless mobile service provider, broadcasters argue that spectrum reallocation needs to encompass broader public policy objectives such as universal service local journalism, and public safety (Eggerton, 2009).

It an undeniably way to actualize new agro-business models based on the internet and related technologies thereby opening new opportunities for locals. It's especially important because broadband internet access has a direct positive impact on economics in employment creation and GDP growth in developing countries including sub-Saharan Africa (Itu, 2012). For every 10% increase in internet penetration in developing countries, the GDP grows by 1.38%, an increase that is higher than in developed countries (Kim, Kelly, & Raja, 2010). Therefore, raising the potential of broadband access or the expansion thereof to contribute to socioeconomic development through addressing some of the isolation issues, both socially, and economically in developing countries. In recent times, the demand for broadband internet, be it wireline or wireless, has been on the rise.

This medium has been to access the various services that have now become available online such as mobile banking, agro marketing networking, entertainment, education and much more (Townsend et al., 2013) – some of these services such as remote education and remote healthcare require bandwidth. TV White Space and fiber optics are some of the contemporary technologies that deliver. Due to the limited coverage of WiFi (100m in 802.11ac), WiFi is more suitable for offloading TV White Space traffic in highly subscribed cells. However, this is out of the scope of this paper considering that the journal seeks to recommend a solution to reach digitally isolated sparsely populated rural areas. Therefore, an integration of TV White Space and future-proof fiber optics (CTC, 2015) would ensure stable high-speed internet access to the end user terminal while guaranteeing future viability.

Considering that TV White Space technology has a role to play in bridging the digital divide, (Kim, Choi, and Shin 2011), this paper seeks to identify and recommend an optimal integrated technical solution that utilizes the TV White Space spectrum and fiber optic technology to address the rural digital divide with broadband Internet in Kenya that will lower the cost of internet to famers. With an objectives of Identify TV White Space as the appropriate technology that could be integrated with optical networks and recommend deployment architecture in light of best practice and the prevailing situation on the ground in rural Kenya.

The Rural Digital Divide and Telecom Infrastructure in Kenya.

There has been much growth in the telecommunication industry since the arrival of two undersea fiber optic cables, Teams and Seacom, was a tipping point, and the expansion of Internet services and the growth of local software development were the defining tech moments in line with Vision 2030. The growth of undersea fiber optic cables boosted access to high capacity bandwidth, linking businesses and communities in Kenya with Europe and South Asia. Four undersea cables, including the East African Marine System (Teams), Seacom, Lower Indian Ocean Network (LION2), and East Africa Submarine Cable System (Eassy) servicing Kenya presently. Before the entry of fiber optical cables into the Internet world, service providers had to rely on satellites, whose wholesale prices were high. With the fiber optical cables, the wholesale prices have decreased to about $400 from $3,500 per piece, with a broadband internet 0.13% and internet usage of 36.70%. This study also recognized the application of integrating fiber with TVWS technology in order to breach the glaring digital divides that exist in Kenya. Notably, both the Government and the private sector continue to push for cheapest and most stable technology.

The TVWS coverage and data throughput were determined by:

- The transmission power used by a radio device within a location.
- The height and gain of the base station should be between 30m-40m.
- The use of specific UHF band channels.
- The signal strength varied due to differences between base stations and clients radio (CPE) because of the terrains.
- Interferences from existing terrestrial TV channels, and that need to be protected.
- Geo-location database for providing the frequency bands.
- The time frame within which devices must re-register to receive updated information.

TV White Space trials

The Kenya Communication Authority received an application for the deployment of a trial TV White Space network in December 2012 and authorized the deployment of a trial network by the applicant at two designated rural sites in August 2013 for a period of 12 months. Due to the on-going studies some conditions were prescribed alongside this authorization. These were.

- That the applicant acquires a Network Facilities Providers' (at least NFP Tier 3) operating license in accordance with the existing licensing regime or works in partnership with a licensed operator.

- That the TVWS devices will only operate within the frequency band 470 MHz to 694 MHz on non-protected, noninterference and non-exclusive basis.

- The devices and equipment to be used in the network should be duly type approved by the Commission prior to installation and use.

- Should the deployed trial network cause any interference to a protected radio service, the applicant shall promptly take steps to eliminate the interference and upon notification by the Commission, cease all transmissions until the interference is eliminated.

- The TVWS devices and databases will be installed and operated in consistency with technical rules and/or international standards what will ensure that no harmful interference is caused to any licensed service.

- At the expiry of the trial period, the applicant will present to the Commission a report on the project for review. The satisfactory performance of this, together with the results of the ongoing ITU studies on the matter will determine if the trial will be converted into an operational license.

In 2014 TVWS were carried out in Laikipia County in Nanyuki town. The wireless technology used in the pilot is called dynamic spectrum access, which enables wireless devices to opportunistically tap into unused radio spectrum to establish broadband connections. The project in Kenya uses these new technologies to create broadband connections over the unused portions of wireless spectrum in the television frequency band (so-called "TV white spaces"). The initial installation near Nanyuki currently includes eight customer locations: Male Primary School, Male Secondary School, Gakawa Secondary School, Laikipia County Government Office, Laikipia Public Library, the Red Cross office near Nanyuki, the Burguret Dispensary healthcare clinic (operations to begin soon), and the first Mawingu charging and bandwidth agent. Employees at the Laikipia County Government Office will soon be enjoying Office 365 accounts. The students are taking advantage of Windows Multipoint Server ICT labs. An additional 33 end user locations will be added to the network (early 2014), including several more schools, Mawingu agents, and businesses in the area. The network is featuring white space radios manufactured by Adaptrum and 6 Harmonics.

Providing broadband to rural areas of Kenya is critical to driving prosperity in rural areas, as well as Africa as a whole. It gives students – both children and adults – a new way to experience learning, and rural communities the ability to connect to the world, improving opportunities for economic development via e-commerce and small business growth. where it connected to 13 locations for trial with different results as shown in the table below.

Kenya can embrace the TVWS Technology given that the country has already migrated for the Analogue signal to digital signal thus covering a larger spectrum with great noise immunity and more secure allowing multi-directional transmission simultaneously.

There is an extensive TV coverage throughout the country that is under utilized which can be used for internet transmission. Through the government's one laptop one student project, there is willingness of the government to see that the rural area is served. Moreover, through the devolved government considering that the fibre optic Backbone has been installed to the county level TVWS would be best for the last mile connectivity since there is the need for the connectivity in the Country.

In comparison, there is a lack of proper information in regards to the TVWS technology that needs to be addressed and shared even with the mobile service providers where the technology can even be used as a redundant service even in cities and towns.

There are so many opportunities like free internet since the TV frequency is unlicensed the cost of the web will decrease. Making it cheap and free for the public, also since the highest population resides in the rural area, it's the best area to deploy the technology thus solving a problem of the largest population bridging the digital divide, with this technology in the rural areas and the schools it will enhance education since there will be technology.
The threats are like effects of rural to urban migration leaving some areas undeveloped, the strong competition from the existing operators that Is the mobile service providers with LTE is very high also the political influence where there is no continuity of development a leader after a leader.

South Korea

Korea, has studied the effective use of white television space (TVWS). In particular, a super Wi-Fi service is highlighted as one way of utilizing TVWS (Jahng, 2013). For Example, KT, one of Korea's telecom operators, started a pilot project in a particular region in 2014 as a member of the consortium initiated by the Korean Ministry of Science, ICT and future planning. According to KT, the consortium will use vacant frequencies made available at the location where the spectrum is not being used following the shift from analogue TV to digital TV in 2012, and the bandwidth can be used for low- frequency internet access for up to 10 Kilometers. KT also planned to provide public service such as transportation and weather information at the bus stop for tourists in the service region (shin 2013).

(The Korea communications commission (KCC) conducted a pre-demand survey for applying TVWS in May 2011 and selected the test service consortium in June of the same year (KCC, 2011). In December 2011, KCC confirmed the plan for TVWS utilization and selected two

Consortiums, which were the local information part of Korea Telecom and Jeju Special Self Governing province and the public safety part of National Emergency Management (Jahng, 2013; KCC, 2011).

In 2012, KCC implemented a demand survey of 223 institutions in the government, local government, and industries in order to develop a detailed implementations plan. This Survey estimated the demand for service like Wi-Fi, disasters traffic information, location tracking, and management of public facilities and KCC examined the relevant technical standards (Janng,2013).

On July 31, 2013, the Ministry of Science, ICT and Future Planning (MSIP) selected five consortiums for the test service of TVWS and these consortiums developed the equipment for inspection service for five months. MSIP also held an opening event for TVWS test service. The trial service operations planned to provide several test services such as wireless internet, hybrid ultra – high definition broadcasting, and smart grid in several areas (MSI, 2013).

KT has completed the development of the AP and the appropriate antenna for TVWS and the establishment of wireless and wired infrastructure for TVWS trial service in November 2013(Shin 2013). Also, Jeju Special Self- Government Province and Kisan Telecom have tried to develop the AP for Public Service based on Super through the Project of Government since September 2014 (Song 2015).

Theoretical Framework

Using the Coase Theorem, which is usually used to explain the unprecedented cost advantage that online and digital firms will have in the marketplace (where transaction costs are approaching zero) over traditional firms, in comparing the different technologies and select the best in consideration of different factors, And also the Technology Acceptance Model (TAM) which is a theory that is widely used to explain an individual's acceptance or rejection of information Technology. (Jenk, (2015)

TV White Space

According to ITU discussion paper (ITU. 2013), TVWS is “those currently unoccupied portions of spectrum in the terrestrial television frequency band of the very high frequency (VHF) and Ultra-high frequency (UHF) television spectrum.” This is the gap, which is not used by the licensee territorially or temporally, between two television channels to present interruptions. The TVWS frequency is also usually found in VHF and UHF television broadcasting frequencies which are 470-698 MHZ in the U.S. and 470-790 MHz in Europe.

TVWS has several characteristics. First, its non-protection/ noninterference nature is available depending on time and location. It can be used when this spectrum is not used for broadcasting, and is also dependent on the local and regional usage of the band (ITU, 2012). This spectrum therefore needs technology and connects the empty spectrum territorially or temporally like the cognitive low radio frequency. Third, because of its capability of high transmission, it is excellent in building penetration. Due to these characteristics, this spectrum can be usefully applied in many ways (Koo et al., 2011).

TVWS has been used in many ways ancillary to broadcasting such as the wireless microphone, smart grid/telemetry, video surveillance, broadband and enhanced location services (ITU 2012). This spectrum can be used in other ways, including rural broadband, WI-FI like access with an extended range, and machine to machine communications. One of the suggested applications is using TVWS to provide fixed wireless broadband communications in rural areas. TVWS can also be used to provide fixed or mobile indoor/outdoor Communications in hotspots and Wireless Communications and multi-media distribution at home. This application is similar to wireless communication in homes where multi-media content or other data are transferred from one device to another. Another application is using this spectrum for Machine to Machine communications. This is used to control consumer devices in homes, control and monitor the equipment in factories and control the remote sensing of the environment (Ofcom, 2013).

Optical Network Technologies

It is highly advantageous to deploy optical technologies because, in the long run, they provide cost-effective investment because they are future proof (CTC, 2013); it is believed that Next Generation Networks (NGN) shall be based on optical and wireless technologies. According to KANG (2014), the main advantages of using fiber optics are:

1. Low attenuation and low error rate estimated at 10^-12

2. Optical fiber installations are not susceptible to Electromagnetic interference (EMI), or Radio Frequency Interference(RFI).
3. Not prone to weather problems such as lightning, a major issue in copper installations
4. Fiber has high fault tolerance and reliability ensuring high survivability for the network
5. Optical systems are highly secure with the highest privacy of all available transmission media
6. Optical fiber has the longest wireline medium lifespan ranging from 20 to 50 years.

Although there are two main categories of optical technologies in the access network: Passive Optical Networks (PONs) and Active Optical Networks (AONs), there are several Flavors of Passive optical network technologies that can be integrated with TV White Space as opposed to AONs. AONs have electrically active components between the optical line termination (OLT) and optical network termination ONU while PONs only have passive ones such as couplers and splitters. For this and other reasons, PONs have been identified as the most competent and cost-effective solution for high bandwidth and fault-tolerant connections making them the technology of choice for backhauling and integrating with mobile wireless technologies such as TV White Space. (Gaur, 2014).

Though built on the same core technology, PON implementations in the access network differ widely regarding capabilities, security, scalability, data rates ranging from 1.244 to more than 10 Gbps, and so on. The major implementations (flavors or versions) are broadband PON (BPON), Ethernet PON (EPON), Gigabit PON (GPON), 10 Gigabit PON (10G PON or XGPON) and wavelength division multiplexing PON (WDM-PON).

Proposed Adapted Protected PON-TVWS Integrated Architecture

This paper proposes the adaptation of the architectural model proposed by Gaur (2014) to ensure adequate survivability and reliability at low cost. The main features of the proposal are:

1. The addition of protection mechanism from OLT to ONU-eNB. Proposing to use 1:1 protection to provide the highest durability considering that the redundant line would only be used when the active line goes down for one reason or another.
2. The OLT-ONU segment shall use long reach PON with a separation distance of up to 100km. It is cardinal because the architecture is to be deployed in rural areas where long separation distances are the norm.

3. Installation over power-lines is proposed to lower construction costs. Civil works account for 80% CapEx in fiber optic installations (Erricson, 2010). Although the on the power-lines fibers are installed, EMI would not be a problem because optical fiber is not susceptible to it.

4. Where villages are located very far away, and longer separation distances are required, inline optical amplifiers can be installed at 80 to 120 km intervals. These amps need to be powered; nonetheless, since the fibers are being installed along the power grid, power is available all the way if needed.

5. WDM-PON could be used to provide value-added services. WDM-PON also has the advantage of being protocol independent requiring no specialized equipment to connect ONU and BS. However, in this architecture, the integrated ONU-eNB is used.

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