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Assessment of Broadband Access Technologies in Tanzanian Rural Areas

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Abstract Broadband technologies are enabling local communities to access many communication services (i.e. voice, Internet, email, video conferencing, etc) for the provision of information related to markets, health, education, public issues and other economic opportunities. Hence, the provision of broadband access technologies is a prerequisite for any developing or third world country to have access to broadband services. The majority of Tanzanians still live in rural areas, which are characterized by primary modes of production, limited social services and poor economic infrastructure. Consequently, broadband access technologies are scarce due to the fact that they require high investment and incur significant running costs, which make their installation and operation unattractive for ISPs to deploy in Tanzanian rural areas. A descriptive survey research has been applied to assess and discuss appropriate broadband access technologies in terms of: accessibility, affordability and reliability for people who live in Tanzanian rural areas. This study has found that 3G/4G Mobile broadband access technologies are a key technology in provision of broadband services due to its extensive nationwide coverage. Therefore it is recommended that Mobile broadband access technologies such as 3G/4G are used for provision of broadband services until optical fibre technology is accessible and affordable in the Tanzania rural areas.

Keywords Internet, Broadband, Wired, Wireless, Mobile

1. Introduction

Currently, almost half of the world's population uses the broadband access technologies for many purposes, including health, education, entertainment, civic engagement, e-government and e-commerce, while nearly a third use social media [1]. The importance of broadband services for sustainable development is clear, as our societies continue to grow and develop. Broadband access technologies are crucial for government services, healthcare, education, library systems, private businesses, and residents. They connect people from a home, business or school to the World-Wide Web and other digital resources. It replaces a traditional "dial-up" or narrow band telephone connection since it is always on and allows you to use multiple services at the same time [1]. For example, you don't need to disconnect from the Internet to make a telephone call. Broadband is available for different technologies (laptops, mobile phones, tablets) and from many different Internet Service Providers (ISPs).

With compatible equipment, broadband connections allow a user to support many different devices at once. You can access the Internet (i.e., surf the world-wide web, listen to music, check your email, visit social media sites, etc.), watch TV, and use your telephone. Often these broadband services (i.e. Internet, phone, and TV) are packaged together or bundled so one ISP provider offers all these options to meet household or small business needs. Broadband service providers can be telephone or cable companies, a wireless network provider (cell phone companies) or satellite service. Thus, broadband access technologies are now vital infrastructure, as essential as water and electricity networks for broadband services, but are also becoming more invisible and integrated into utility networks in 'smart' infrastructure [1].

Broadband access technologies can enable many services to be offered through information and communication technologies (ICTs) to the extent that rural people can get a chance to enjoy quality broadband Internet and other services as in urban areas and be part of the socio-economic development of a given community. Nevertheless rural areas tend to differ from urban areas across the world in terms of their social and economic attainments as well as the available physical infrastructure. This has led to direct impact on the ability to deploy broadband access technologies effectively in rural areas with the assurance that they are commercially viable.

In 2001, the Tanzanian Rural Development Strategy (RDS) supported the introduction of information and

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communication technology (ICT) in rural areas through the creation of tele-centres that offer a wide variety of public and private information-based goods and services, and which support local economic or social development [2]. In addition, National ICT Policy 2003 [3] was developed and revised in 2016 [4] to provide more affordable access to a range of ICT services to as many people as possible in urban and rural areas so as to enhance sustainable socio-economic development and allow the Tanzanian population to participate meaningfully in the globally networked economy. Subsequently, The Tanzanian government in 2010 implemented a National ICT Broadband Backbone (NICTBB) [5, 6] that networked almost all regional headquarters within the country and provided connectivity to six neighboring countries, namely: Kenya, Uganda, Rwanda, Burundi, Zambia, and Malawi. NICTBB investment has catalyzed new interest among telecommunication operators resulting in a willingness to invest in infrastructure to facilitate exploitation of the available long distance terrestrial communication infrastructure. Similarly, the Tanzanian Development Master Plan [7] outlined each village to be provided with ICT services by 2020 (Tanzania Development Vision 2025). Furthermore, The Universal Communications Service Access Act [8] was enacted by the Tanzanian government to ensure the availability of ICT services in under-served rural and urban areas to promote the participation of public and private sectors in the provision of universal services in the under-served rural and urban areas, and to promote the socio-economic development of these rural and urban areas. This was followed by the establishment of the Universal Communication Access Fund (UCAF) [9] by the government of Tanzania to facilitate provision of basic voice communications to rural and under-served areas at an affordable cost in order to bridge the gap between urban and rural areas or under-served areas in Tanzania. Consequently, the Universal Communication Access Fund and five mobile phone operators: Tigo, Zantel, TTCL, Vodacom and Airtel, signed a contract to enable telecommunications companies to construct Microwave towers to facilitate ICT services for Tanzanians who live in rural areas.

Accordingly, the ITU Secretary General called for equitable and affordable ICT services for African rural areas to increase knowledge and development among Africans living in rural areas [10]. Reliable broadband access technologies are still scarce in Tanzanian rural areas due the fact that high investment and operational costs make the operations unattractive for ISPs to deploy [11]. This has led to inaccessible and unaffordable broadband services in rural areas. Thus, in order to be aligned with National ICT Policy 2016 and accelerate the socio-economic development in the rural areas, it is imperative to deploy affordable broadband access technologies so that majority of users so that they can afford to subscribe and be able to access various ICT services. In other countries in the world, for example USA, [12, 13] suggested various access technologies that could be used to extend broadband coverage to American rural communities. Similarly, in Albania [14] and Srilanka [15] outlined their Strategies for the promotion of broadband infrastructure to ensure that everyone – wherever they live, and whatever their circumstances – has access to the benefits of broadband services. The Federal Government of Nigeria also proposed to upgrade mobile networks to a 3G wireless coverage across the country so that every Nigerian who lives in urban or rural areas can subscribe to access broadband internet using their mobile devices [16]. In addition, The Federal Government of Nigeria explored opportunities for use of TV White Spaces / unlicensed spectrum to achieve last mile connectivity especially in rural areas [16]. In the same way, [17] assessed and proposed TV white space implementation for rural broadband in Bangladesh. Furthermore, [18] provided a comparison of various broadband access technologies in terms of their capacity (data rates) and coverage for rural areas of the developing countries in Africa. In case of Tanzania, [19] provided an overview and a discussion on technologies, broadband connectivity models, infrastructure and policy readiness, and initiatives towards achieving connectivity and bridging the digital divide in Tanzania.

With the above perspectives, this article discusses, assesses and recommends on appropriate broadband access technologies that would be affordable and reliable for people who live in Tanzania rural areas. In additional, it provides in depth analysis of various broadband access technologies to rural areas, and assesses their accessibility, affordability and reliability.

2. Literature Review

Broadband infrastructure refers to a physical medium over which broadband services can be transmitted (e.g. a twisted pair of copper wires, coaxial cables, optical fibres or antenna towers and sites if transmission is done wirelessly) [20, 21]. Broadband infrastructures are split into three major sections. These are the broadband backbone networks, the Regional (Metropolitan) broadband networks and the Broadband Access Network.

The broadband backbone network is an element of the network infrastructure that provides high-speed, high-capacity connections among the network's physical points of presence. The broadband backbone network carries high traffic from the landing point of the international communications infrastructure or from the nearest point of the border in a landlocked country to the different regions of the country. The Metropolitan is accountable for interfacing between the backbone network and the access network. Subsequently, the broadband access network is for providing broadband services to the households and residential or business units.

The two main groups of "Broadband Access Network" are fixed line and wireless broadband access. The fixed line broadband access provides broadband service through a direct "wired" connection from the end user to the ISP. While, the Wireless broadband access uses radio or

microwave frequencies to provides a broadband connection between the customer and the operator's network.

In addition, the wireless broadband access networks provides Internet access to customers without the need for underground copper, fiber, or other forms of commercial network cabling. Compared to more established wired access network like Optical fibre networks, DSL, etc; wireless broadband access technologies brings added convenience and mobility to rural areas. The wired and wireless broadband access technologies that can provide the bandwidth required to deliver broadband services are described below:

2.1. Asymmetrical Digital Subscriber Line (ADSL)

ADSL provides a broadband service that is a fast, stable and reliable connection to the internet for web-surfing, software downloads, news, entertainment and other internet based applications and content services. ADSL splits the landline into two; one for telephone and other for internet or data services. The subscriber e exchange, whereby the line terminates into a multiplexer is called a Digital Subscriber Line Access Multiplexer (DSLAM); this is where a frequency splitter generally separates the voice signal for the voice calls and the data is sent over to the IP network.

The ADSL system is asymmetrical because the data rate from the telephone exchange to the end user is much greater than in the opposite direction. This means that the end user receives more bandwidth (downstream data rates) than transmit (upstream data rates). ADSL provides maximum downstream data rates of 1.544 Mb/s for shared users and up to a maximum of 8 Mb/s downstream for dedicated users within a distance of 3 km.

2.2. Very Small Aperture Terminal (VSATs) Satellite

A (VSAT) is a device - known as a small earth station - that is used to transmit & receive data signals through a satellite in geostationary orbit. The satellites in geostationary orbit that provide voice and data communications to various local ISP are Gilat, Intelsat, etc. VSAT countrywide operates in the C-band (4/6 GHz) or Ku-band (11/14.5 GHz). For communications between satellite and VSAT to take place, a very small portion of a satellite transponder is used for each VSAT return path channel. Each VSAT terminal is assigned a frequency for the return path, which it shares with other VSAT terminals using digital communication techniques such as TDMA and CDMA.

Therefore for the end user to access the Internet through satellite technology they must own a VSAT dish that comprises an antenna and receiver for transmitting and receiving satellite signals respectively, as well as a satellite modem and computer. VSAT transmit data rates that range from narrowband up to a maximum of 16 Mb/s; hence it has a higher bandwidth than 3G mobile technology. Therefore the broad coverage area and higher bandwidth of VSAT makes them be suitable for many forms of communication, for example, point-to-multipoint Internet services, voice and video conferencing.

However due to the high installation cost of VSAT equipment and Satellite Internet bandwidth this technology is more suitable for corporate users than home users. In additional, transmission of signals in satellite communications is affected by moisture and rain, it also has high latency due to the signal having to travel 35,000km (22,000miles) into space to a satellite in a geostationary orbit and back to earth again. The signal delay can be as much as 500 to 900 milliseconds, which makes the satellites communication ineffectual for real time applications, such as online games, VOIP, video conferencing etc.

2.3. Optical Fibre Network

An optical network is a data communication network built with optical fiber technology [22-26]. It utilizes optical fiber cables as the primary communication medium by converting data into modulated light and passing data as light pulses between sender and receiver nodes. Optical networks use an optical transmitter device to convert an electrical signal received from a network node into light pulses, which are then injected into a fiber optic cable for transport to a receiving device. The light pulses of an optical network are transported a fixed distance until the pulses are regenerated through an optical repeater or amplifier device. Once a signal is delivered to a destination network, it is converted back into an electrical signal through an optical receiver device and sent to a recipient node.

An optical network is less prone to external inference and attenuation and can achieve substantially higher bandwidth speeds than copper networks. Optical fibre networks provides almost unlimited bandwidth capabilities and offers today's fastest high-speed data connectivity. In 2006, The Fiber Technology councils from Europe, Asia and North America standardized the definitions for fiber to the home (FTTH) and fiber to the building (also called fiber to the basement) (FTTB) as follows [22-26]: FTTB is an Optical fibre network that extends from an operator's switching equipment to at least the boundary of a private property enclosing homes or businesses. The optical fiber terminates before reaching home living spaces or business office spaces. The access path then continues over another access medium – such as copper or wireless – to subscribers. FTTH extends from an operator's switching equipment to at least the boundary of a home living space or business office space. The definition excludes architectures in which the optical fiber terminates before reaching either a home living space or business office space and the access path continues over a physical medium other than optical fiber.

Optical Fibre Network and wireless communication systems are becoming a necessity in many residential and commercial projects across the globe. Today, several initiatives promise to make Optical network more economical to deploy and better positioned to meet even the most aggressive bandwidth demand forecasts. Demands for bandwidth are constantly rising. Very soon the required

bandwidth on copper pairs will only be applicable on short distances for new and enhanced Internet applications. Optical fibers and their ability to transmit high bandwidths over long distances are a solution.

Investments in distributing optical fibers to single flats can be reduced by using the already installed infrastructure in multi-tenant buildings. A network operator can install a Digital Subscriber Line Access Multiplexer (DSLAM) in order to terminate the optical fiber inside the building (FTTB). The DSLAM then connects the subscribers via DSL using the existing telephone cabling. Each subscriber gets more than 100 Mbps on these short telephone lines using VDSL2 transmission. Thus, the network operator can offer the full spectrum of services like broadband Internet, VoIP, Video-on-Demand and Internet television (IPTV) at minimal costs.

2.4. WiMAX

WiMax, the Worldwide Interoperability for Microwave Access is a wireless broadband access technology dealing with provision of data over long distances using the wireless communication method in many different ways [27]. Based on IEEE 802.16, WiMax is claimed as an alternative broadband rather than cable and DSL. WiMax consists of a tower, similar to a cell phone tower, and a receiver often built into a laptop or computer system. WiMAX can be differentiated/grouped into two basic standard types, fixed and portable/mobile [28]. The WiMAX standards are continuously evolving to keep up with other standards in various advances that are being made with unique protocols.

2.4.1. Fixed WiMAX

WiMAX can be used for point to point communication. Fixed wireless access protocols are designed in IEEE 802.16 Standard 2004 Release [28]. The Standard 802.16d is referred as Fixed WiMAX. Mounted antennas used at the subscriber's site for data reception/transmission, often referred to as "Fixed Wireless" antennas are mounted on a roof/mast similar to a satellite television dish. The IEEE 802.16 2004 Release addresses indoor installations for safety purposes. It connects businesses and homes to high speed Internet. Orthogonal Frequency Division Multiplexing (OFDM) modulation is used in Fixed WiMAX, which supports sub-channelization in the Uplink.

2.4.2. Portable/Mobile WiMAX

The IEEE 802.16 Standard 2004 Release also provides goals for portability [28]. The Standards 802.16e and 802.16m supports the mobility. WiMAX has the ability to support both 3G and 4G technology. The WiMAX standard 802.16e comes under the 3G classification (IMT-2000) while 802.16m is classified as a 4G technology (IMT-2000Advanced). Orthogonal Frequency Division Multiple Access (OFDMA) modulation is used in mobile WiMAX. OFDMA is similar to that of OFDM but an enhanced version. In this, multiple subcarriers are grouped into subchannels. OFDMA improves multipath performance. There are several advantages that can be derived from the deployment of WiMAX [29].

Firstly, it supports higher throughput rates, higher data speeds, and a wider operating range. This makes the technology very useful for deployment in difficult terrain areas or in environments with limited wired infrastructure. Moreover, WiMax supports and interfaces easily to other wired and wireless technologies such as Ethernet, ATM, VLANs, and Wi-Fi. The main drawback to the deployment of WiMax is proprietary equipment. WiMax equipment must be able to utilize power efficiently in order to deliver optimum functionality. For WiMax, the output power usage is based on a ranging process that determines the correct timing offset and power settings. Therefore, the transmissions for each subscriber station are supposed to be such that they arrive at the base station at the proper time and at the same power level. When WiMax is deployed outdoors, in non-line of sight environments it may encounter delay, which can cause potential inter-symbol interference.

2.4.3. Mobile Technologies

The mobile wireless industry started its technology creation, revolution and evolution since early 1970. From the Mid 1990's the cellular communication industry has witnessed explosive growth. Wireless communication networks have become much more pervasive than anyone could have imagined when the cellular concept was first deployed in 1960's and 1970's. Mobile cellular subscribers are increasing by 40% per year, and by the end of 2010 there were 4 times more mobile cellular subscription than fixed telephone lines.

The rapid worldwide growth in cellular telephone subscribers has demonstrated conclusively that wireless communications is a robust, viable voice and data transport mechanism. The wide spread success of cellular has led to the development of newer wireless systems and standards for many other types of telecommunication traffic besides mobile voice telephone calls. After the development of the cellular concept numerous mobile technologies have evolved [30, 31].

First generation (1G) was the first mobile technology, this delivered the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The 1G network relies on analog systems whereas the 2G network relies on digital systems. The first generation cellular systems relied exclusively on FDMA/FDD and analogy FM.

The 2G (second generation) standard is the most popular and commonly used cellular standard. Second generation standards use digital modulation formats: TDMA/FDD and CDMA/FDD multiple access technique. The second generation standard includes 3 TDMA standard and 1 CDMA standard, namely: 1) Global system for mobile (GSM) 2) Interim standard 136 (IS-136) 3) pacific digital cellular (PDC) 4) Interim standard 95 (IS-95).

The 3G (Third generation) wireless systems concentrates on multimedia services and internet data rates. This is a set of standards used for mobile devices and mobile telecommunication services and networks that comply with the International Mobile Telecommunications-2000 (IMT2000) specifications by the International Telecommunication Union. 3G finds application in wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV.

4G is the fourth generation of mobile phone mobile communications standards. It is a successor of the third generation (3G) standards. A 4G system provides mobile ultra broadband Internet access, for example to laptops with USB wireless modems, to smart phones, and to other mobile devices. Conceivable applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing and 3D television.

Over 95% of the World's population lives within the footprint of a 2G network while the reach of 3G mobile broadband capable networks is around 70% [32]. The mobile broadband coverage gaps exist primarily in developing world markets (especially in Africa and Asia) where the technical and commercial challenges to network expansion are significant. Areas without mobile coverage often lack basic infrastructure such as roads and electricity meaning it is significantly more expensive for mobile operators to deploy, power and maintain base stations and to install the backhaul capacity needed to provide end users with fast data connections.

In addition to higher operating and capital costs, the revenue generating opportunity from base stations in rural areas is often greatly reduced compared to urban areas. Population densities are typically much lower (meaning a smaller market opportunity) as are income levels (meaning lower levels of per user spend on mobile services).

3. Research Methodology

A descriptive survey method was chosen in order to provide in depth understanding of broadband access technologies that are available in Tanzanian rural areas.

With this approach, structured questionnaires were used in order to obtain basics understanding of the broadband access technologies in Tanzania from several respondents who were selected purposively according to the cluster of their rural areas. Subsequently, the primary data obtained from structured questionnaires were quantitatively analyzed to extract statistical indicators of broadband access technologies.

Also semi-structured interviews were used during face-to-face meetings with a senior officers from leading Mobile Operators and Data Telecommunications companies in Tanzania such as Vodacom, Tigo Airtel, Zantel, Tanzania Telecommunications Company Limited (TTCL), Satcom Network Africa, Simbanet, UCSAF, and Tanzania Communication Regulatory Authority (TCRA) in order to draw out primary data for broadband access technologies in the respectively companies.

In addition, the primary data from semi-structured interviews were analyzed by using a qualitative approach with the aim of assessing in depth, the broadband access technologies in Tanzanian rural areas. Furthermore, a document review was applied to analyze secondary data from the selected public and private companies and other sources, for example: newspapers, ICT journals, letters, minutes, meetings or websites in order to supplement information collected from primary data.

4. Findings and Discussions

ADSL is used by various Internet service providers (ISP) in Tanzania to provide broadband services to rural and urban areas. Accordingly to the research conducted, ADSL technology has penetrated to all districts in Tanzania. However, the end users need their own landline, ADSL Modem, Computer i.e. (desktop, laptop, etc) to be able to subscribe into the ADSL service. As a result, the majority of the people have not subscribed to this service due to the high cost of installation charges, monthly landline rental, and internet tariff charges.

For VSAT technology, there are three major data telecommunications companies known as SatCom Networks Africa Ltd (SCNA), iWay Africa, and Simbanet that provide broadband services to urban and rural areas in Tanzania via VSAT satellite technology. This technology is installed only in few places especially remote areas, as the Mobile /Optical Fiber Technology has replaced it especially for Broadband access technologies in most areas in Tanzania.

On the other hand, although Wi-Max is embedded in many devices including USB dongles, WiFi devices, laptops, and cellular phones and are a contender for "broadband access technology in rural and emerging markets where fiber to copper and ADSL is not cost effective technology. Wi-Max is still not deployed at large in Tanzania because of the high cost of implementation due to the fact that it must be run on its own network; it cannot utilize GSM or CDMA networks as Mobile technology such as EDGE and EVDO do. Several Internet Service Providers and leading Mobile companies in Tanzania for example SimbaNET [34], Raha [35], Cats-NET [36], TTCL [37], Vodacom [38], Tigo [39] and Zantel [40] have WiMAX systems operating in the 3.3GHz and 3.5GHz bands offering broadband services to customers in urban areas.

Accordingly to [41], WiMAX has a simplified network connection amongst local government in Tanzania (TAMISEMI), however the number of WiMAX users remain relatively very low (14.9%) compared to other African countries such as Kenya (69.6%), Morocco (60.6%), Egypt (54.6%), South Africa (49%) and Senegal (51.1%). For the case of Mobile Technology, we found that in some urban and rural areas of Tanzania mainland cities like Dar es Salaam, Arusha, Mwanza, Dodoma, Coastal, Morogoro,

Mara, Bukoba, Songea, Lindi, Mtwara, Kigoma, Njombe, Kilimanjaro, Iringa, Pemba, Mbeya, Tanga as well as in Zanzibar islands there is wide coverage of broadband access technologies (i.e 2/3G mobile technology) such as Evolution-Data Optimized (EV-DO), Enhanced Data Rates for GSM Evolution (EDGE), and High-Speed Downlink Packet Access (HSPA).

For example, most wireless towers owned by a large public telecommunication incumbent (TTCL) [38] are installed by EV-DO Wireless Technology. EVDO provides broadband Internet to end users by using mobile handsets, tablets or a USB dongle. To access the Internet via a USB dongle a customer needs to plug it into the laptop USB port. EV-DO Wireless service is relatively low cost with high capacity; allows rich web browsing and application usage. The EV-DO technology is a 3G CDMA 2000 family type that uses asymmetric communication, allocating more bandwidth for downloads than for uploads. With this notion, EVDO provides broadband speeds up to 3.1 Mbps as download speeds and uploads up to 0.8 Mbps (800 Kbps).

However, end users especially in rural areas find it difficult to access broadband Internet due to the signal strength, which deteriorates when the users access the internet far away from the wireless towers. On the other hand, Mobile technology EDGE is provided by three leading mobile operators in Tanzania who are: Airtel, Tigo, and Zantel. EDGE enables end users to access broadband Internet service through: mobile handsets, tablets or computers similarly to other mobile/wireless services.

EDGE technology is a 3G GSM standard and supports peak theoretical network data rates of 474 kbps, with average throughput of 70 to 130 kbps on both the downlink and the uplink. The average rates are fast enough to support a wide range of broadband services, including streaming audio and video, fast Internet access and large file downloads. Most wireless towers owned by the above companies have been upgraded with EDGE technology. Therefore end users can access broadband services where there are nearby wireless towers deployed. EVDO is 3G mobile technology that is a relatively straightforward and cost-effective for most end users. However, the signal strength deteriorates when the user is far away from the wireless tower as in EDGE mobile technology.

Another 3G technology HSDPA is deployed in urban and rural areas via wireless towers by one of the major Mobile operators in Tanzania, Vodacom. HSDPA is a packet-based mobile telephony protocol used in 3G GSM mobile networks to increase data capacity and speed up transfer rates. HSDPA provides download speeds at least five times faster than GPRS and EDGE, allowing users of HSDPA networks a broader selection of video and music downloads. HSPDA specifies data transfer speeds of up to 14.4 Mbps per cell for downloads and 2 Mbps per cell for uploads. In practice, users are more likely to experience throughput speeds of 400-700 Kbps, with bursts of up to 1 Mbps. It is a cost-effective Broadband infrastructure that can be afforded by anyone who owns a mobile handset, tablet or computer. For the reasons outlined above the majority of Tanzanians use 3G Mobile Technologies for Voice and Internet access.

Mobile broadband technology has improved in rural areas due to the Government of Tanzania subsidising the mobile operators, namely: Airtel, Tigo, TTCL and Vodacom through the Universal Communication Services Access Fund (UCSAF) for building Communication Towers for providing wireless access in rural areas. With this initiative, as of December 30, 2016, a total of 347 wards out of 244 wards were able to access Internet/Voice services while the rest were completed by June 2017. On the other hand, wired broadband access by the use of Optical Fibre Technology has also improved in Tanzania after the Government implemented a National ICT broadband backbone (NICTBB).

The NICTBB is implemented by the use of Optical Fibre Technologies, using Dense wavelength division multiplexing (DWDM) and Synchronous digital hierarchy (SDH) to supports 40 wavelengths per fibre and each wavelength carries 10 Gbps [5]; thus enabling a single fibre to carry four hundred gigabits/s of information. Dense wavelength division multiplexing (DWDM) forms the network backbone whilst SDHs are mostly deployed for Metropolitan or Lastmile access in urban areas of various cities in Tanzania (i.e. Dar es Salaam, Coast region, Mwanza, Arusha, Dodoma, Mbeya and Moshi, which brings optical fibre closer to the building.

Fibre to the Building (FTTB) has enabled each home or business unit to be directly connected to the NICTBB local exchange. The FTTB dedicated connection lines of a point to point (P2P) network facilitate subscriber specific service supply, higher subscriber bandwidth with improved traffic security, and simple provision of symmetric broadband services. FTTB operates at up to 1 Gbps over distances of up to 20 km, which is 40 times greater bandwidth delivery than ADSL technology that can only achieve delivery at 1km.

The government is also collaborating with private sectors to implement Metro Optical rings to extend the NICTBB infrastructure nationwide particularly in the urban areas of the country. The implementation of metro networks started since 2011 whereby 300 km of optical fibre cable was completed and operationalized in 2016. In addition, the Metro network was implemented from 2014 to 2016 in Arusha and Mwanza with coverage of a total distance of 94 km of optical fibre cable. Optical fibre Metro Networks are also being deployed in other cities/regions such as Dodoma, Morogoro, Tanga, Moshi, Mbeya, Shinyanga, Musoma, and Biharamulo.

Furthermore, the Government signed a memorandum with a Thailand Company called VIETTEL to jointly invest in the broadband access technologies in rural and underserved areas by construction of 20,000 km of the Optical fiber network to cover 150 District Councils in the country [42]. With all that said, Mobile (wireless) subscriptions for voice have risen from 2.76 million in 2013 to 4.36 million in Dec

2018 (see figure 1), which is equivalent to 81% of voice penetration rate (see Mobile versus Fixed wired (voice) penetration trend in figure 3); while wired (fixed) subscription for voice has declined from 164,999 in 2013 to 124, 238 (see figure 2) in Dec 2018, which is equivalent to 0.2% of voice penetration rate (see figure 3) [43].

On the other hand, Internet subscription by the use of Mobile (Wireless) has increased from 7.4 million in 2013 to 22.3 millions in 2018 (see figure 4); this is equivalent to 41% of Internet penetration rate (figure 5) . On the contrary, wired (fixed) subscription for Internet has declined from 761,508 in 2013 to 164,017 (see figure 6) in Dec 2018, which is equivalent to 0.3% of Internet penetration rate (see Fig 5) [43]. Figure 7 & 8 respectively shows the Mobile vs Fixed wire for both voice and Internet trends from the year 2013 to 2018.

Nonetheless, in terms of broadband Internet penetration especially for fixed wired Technologies, Tanzania still lags behind other countries in the region with similar GDP per capita and literacy levels due to sparse penetration of broadband access technologies (Wired network) in rural and urban underserved areas. Thus there are calls for the extension of cost effective broadband access technologies (Fixed wired network) in the said areas, to enable local communities to afford to access broadband services for the provision of information related to markets, health, and education, their rights, public issues and other economic opportunities.

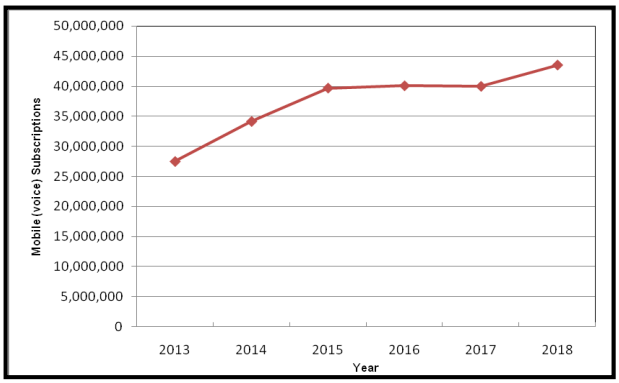

Figure 1. Mobile (voice) Subscriptions

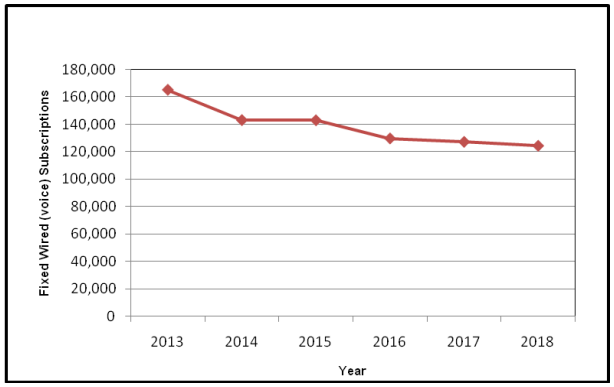

Figure 2. Fixed (voice) wireless Subscriptions

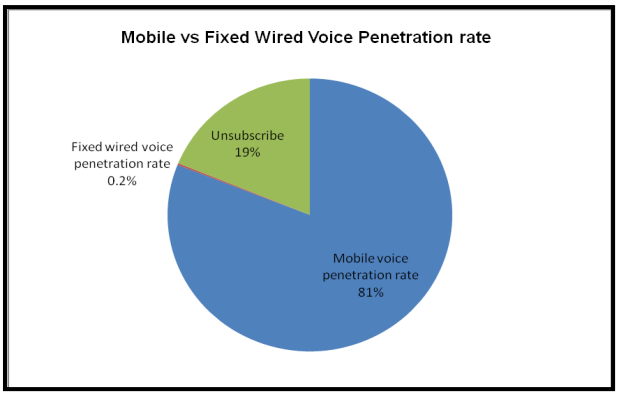

Figure 3. Mobile vs.Fixed Wired (voice) Penetration rate

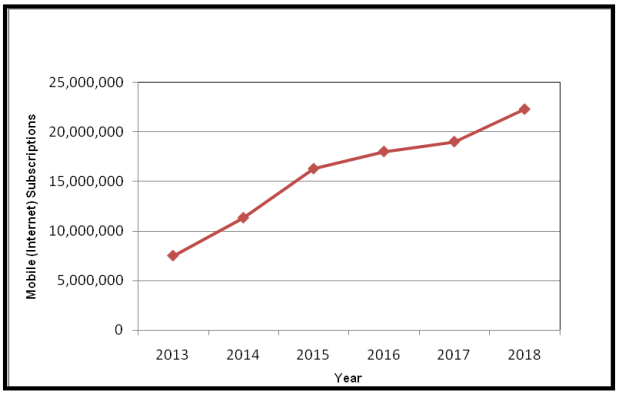

Figure 4. Mobile (Internet) Wireless Penetration rate

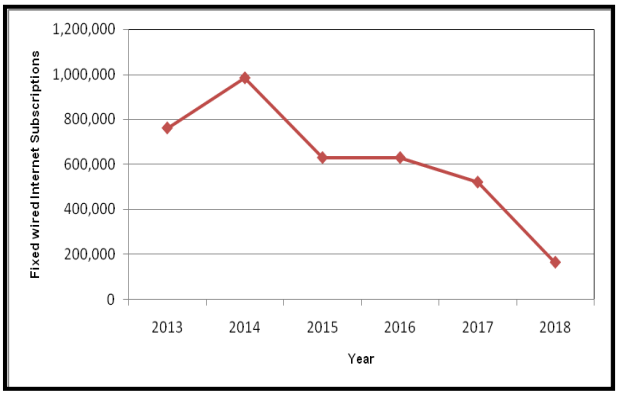

Figure 5. Fixed wired (Internet) penetration rate

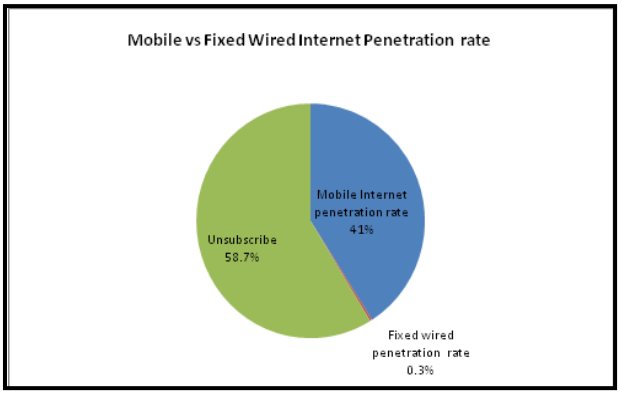

Figure 6. Mobile vs.Fixed Wired (Internet) Penetration rate

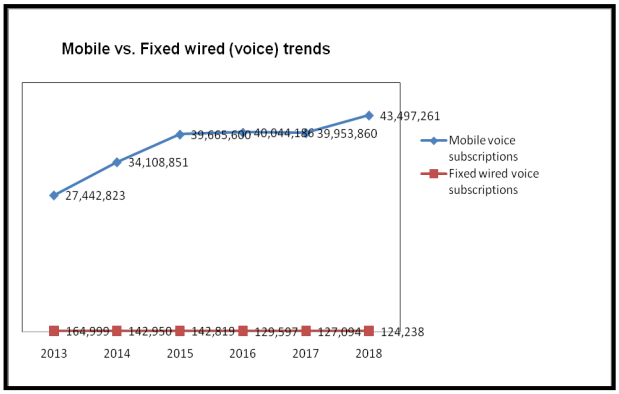

Figure 7. Mobile vs. Fixed wired (voice) trends from 2013 to 2018

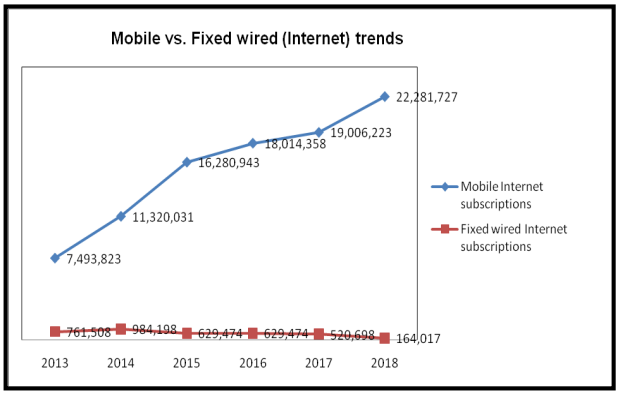

Figure 8. Mobile vs. Fixed wired (Internet) trends from 2013 to 2018

5. Conclusions

Optical fibre no doubt is the perfect medium for high capacity backhaul, but it takes time to install and the cost of deploying it can only be justified in densely populated areas. It has also been observed that the current cost for accessing broadband services in the rural areas by the use of Optical fibre is too high. However, despite the extension of optical technology to most urban areas in the country and a than thirty percent reduction in price [11], optical fibre technology is still expensive in comparison with other technologies; for example Mobile, WiMax, ADSL or VSAT technologies. Only large public or private organizations can afford to deploy it for broadband access technology. The biggest challenges have been the high and uneconomic cost of acquisition of right of ways (ROW) and installation that impact the deployment of optical fibre.

On the contrary, Mobile technologies especially 3G/4G are picking up the slack and are key technologies in broadband service provision with their extensive nationwide coverage including rural areas. 2G Mobile technology has a larger coverage than 3G/4G but it allows voice and low speed data access; this provides a low quality of service for accessing broadband services. Therefore we are recommending Mobile technology such as 3G/4G, which has very high speed to be used for provision of broadband services until optical fibre is accessible and affordable in the rural areas.

The Tanzanian Government should continue to collaborate with Private Institutions in implementing both Mobile broadband (i.e. 3G and 4G) and optical fibre technologies in rural and underserved urban areas as well as ensuring the cost of providing broadband access is reduced and affordable by the majority of Tanzanians. There is a strong correlation between high spectrum prices and poorer coverage, as well as more expensive and lower quality mobile broadband services; reducing or entirely waiving the fees for acquiring spectrum licenses would be a beneficial strategy to reduce funding requirements for deploying wireless towers in rural areas; this would enable Mobile broadband access technologies to be affordable and accessible to the majority of people who live in rural areas. Also, Government should also undertake a reallocation and reassignment strategy to ensure a more effective utilisation of spectra available for mobile broadband access technologies.

In addition, the Government should be looking at new spectrum sources to harness for Mobile technology rollout and TV white spaces spectra for accessibility of broadband services in rural areas. Lastly, In addition to the above recommendations, Government should encourage and put in place the law that will enforce Mobile operators to share Wireless towers especially in rural areas so as to reduce investment cost (CAPEX) and operational cost.

This would result in a decline of the cost of accessing broadband services, particularly internet services. Hence, the majority of population living in rural areas would be able to access broadband services for a low cost at speeds exceeding 20 Mbit/s.

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