

Overview of Broadband Connectivity for Rural Areas-Tanzania as a Case Study

Mastidia Byanyuma & Zaipuna O. Yonah, *Nelson Mandela African Institution of Science and Technology (NM-AIST) Arusha, Tanzania*

Fatuma Simba
University of Dar es Salaam, Tanzania.

Lena Trojer
Blekinge Institute of Technology, Sweden

Abstract—Broadband connectivity is a necessary service required not only in urban areas but more so in rural areas where most of the basic services are inadequate or do not exist at all. Broadband services 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 communication and other services as in urban areas and be part of the socio-economic development of a given community. Currently, there is a number of technologies and initiatives to connect rural and urban-underserved areas at a reasonable cost but most of the rural users are yet to be connected. This paper gives an overview and a discussion on technologies, broadband connectivity models, infrastructure and policy readiness, and initiatives towards achieving connectivity and bridging the digital divide. The context of this paper is rural areas in Tanzania.

Index Terms—Broadband connectivity, WiMAX, Optic Fibre Cable, rural and urban-underserved, broadband technologies, digital divide.

I. INTRODUCTION

In recent years, broadband connectivity has been a necessity for provision of real-time applications to subsidize the lack of basic services in most areas of developing countries. However, last mile broadband connectivity (i.e. extending the available infrastructure to reach rural users) has been taking a slow speed. Despite its importance to national economies and the personal lives of users, its availability and adoption are not diffusing in rural and urban areas at the same rates [1]. The main reason to this remains the lack of purchasing power to attract investments. This is evident from various governments' initiatives to subsidize the same through Universal Communications Services Access Funds like UCSAF in Tanzania, Universal Service Fund (USF)-Kenya and Universal Service and Access Fund (USAF)-South Africa.

Most of these rural areas are without or have poor basic facilities such as hospitals, schools, road and other social services [2, 3]. In Tanzania, for example, there are many schools in rural areas with very few teachers, with no laboratories, books and other learning tools [4, 5]. These areas are also the ones inhabited by more than 70% [6] of the population despite the lack of basic needs. Reasons

behind the poor or inadequate provision of services in rural areas include among others; perceived business risk attributed to unpredictable revenue streams, high investment cost attributed to infrastructural and cost demands of the current technology, unstable policies in some countries and weak business models [7]. These and other problems have slowed down development in these areas because traditionally investors perceive rural and urban underserved areas as low revenue, high costs, and high-risk areas.

The Tanzania government has embarked on connecting the last mile in rural and urban-underserved areas through various initiatives. The last phase (5th Phase) of the National Information and Communication Technologies (ICT) Broadband Backbone (NICTBB) project is to extend the broadband connectivity to the last mile in rural and urban-underserved areas. Mobile Operators through the UCSAF subsidization initiative and Halotel have collectively covered more than 90% of the geographical area of the country in which case every ward has at least a 2G cellular network coverage.

However, according to the National ICT policy of 2016 (NICTP2016), most citizens still cannot access broadband services [8]. This is in line with Kwigizile *et al* who contends that, the lack of ICTs is a lower barrier than affordability [9]. These facts suggests that, there is more to just bringing broadband connectivity to rural and urban underserved areas and these are discussed in this paper.

Despite the stated inadequacy of broadband services to rural areas, the engagement of rural communities is crucial for economic development and social transformation through e-governance [10] and other programs. Broadband service, in particular, is an important contributor to increased country's Gross Domestic Product (GDP), job creation, broadening of education opportunities, public service delivery, and rural development if the reach, availability, and affordability are guaranteed and the demand and supply side skills to exploit the economic and innovative potential of broadband are developed [11].

This paper gives an overview and a discussion on technologies, broadband connectivity models, infrastructure and policy readiness, and initiatives towards achieving

connectivity and bridging the digital divide. The context of this paper is rural areas in Tanzania.

The paper is organized as follows: Sections II to V discusses broadband and associated services, an overview of broadband technologies, broadband models and initiatives available for providing connectivity in rural areas, respectively; while Sections VI to VII present the infrastructure and policy readiness respectively. Section VIII concludes the paper.

II. WHY BROADBAND?

Broadband is the transmission capacity that is faster than the primary rate Integrated Services Digital Network (ISDN) of at least 2.0 Megabits per second (Mbps). With this capacity, end users can browse the internet, transfer information (multimedia) more freely and possibly on real time speed. In areas with challenging transport and other socio-economic infrastructure, telecommunications infrastructure in terms of both voice, data, and video plays a greater role in balancing the socio-economic activities of such areas. Broadband technology in particular is termed as general purpose technology because adoption of the same results in improved lives in a given area as seen from minimized depopulation caused by poor living conditions in rural areas in the Bavaria State in German; and indicating that an improved broadband coverage makes these municipalities more valuable places to live [12]. Taking an example of mobile money innovation in East Africa [13], through telecoms infrastructure, financial services are everywhere regardless of the geographical situation of an area as long as mobile coverage is there. This is why Donner [14] confirm that a mobile phone is a vehicle that could be utilized efficiently to generate profits and reduce costs in business enterprises [15], a fact any entrepreneur will capitalize on.

On the other hand, broadband connectivity has made it possible for social networking applications such as WhatsApp, twitter, and Facebook which continue to bring people closer in space such that distance is no longer an issue. Some users have benefited from sharing useful information on farming, health, educational and news on what is happening worldwide. Others have used them to promote their businesses, product, and services close to free of charge. All these have been possible through broadband media in particular mobile broadband through the cellular network, which has comparatively wider coverage in rural areas.

The cellular network coverage is increasing yearly along with improvement in value-added services and applications (mobile apps), which comes with associated benefits to users. From Fig. 1, the mobile cellular penetration rate worldwide is 97% (7 billion mobile cellular subscriptions) which has increased from 738 million subscriptions in 2000 whereas the mobile broadband technology had a penetration of about 47.2% in 2015 that increased about 12 times since 2007. The global internet penetration in terms of individual using the internet was 43.4% in 2015 [16].

On the other hand, Fig. 2 shows the trend of internet use in Tanzania where the mobile wireless has shown an increasing rate from 2011 to 2016. The internet penetration including both wired and wireless (fixed and mobile) were 40% in 2016 which had

increased from 12% in 2011 also indicating a tremendous growth in a very short time. The combination of growth in mobile broadband penetration and the emerging cost-effective technologies are likely to impact communities since currently, mobile technology is the only technology that can reach most of the areas easily, a fact that promises more investment in the sector hence increased associated benefits to the society.

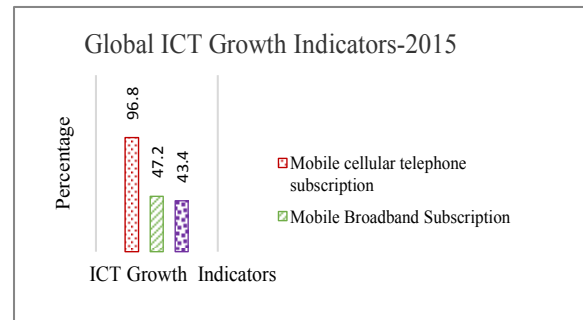


Fig 1: Global ICT Indicators (Source: [17]).

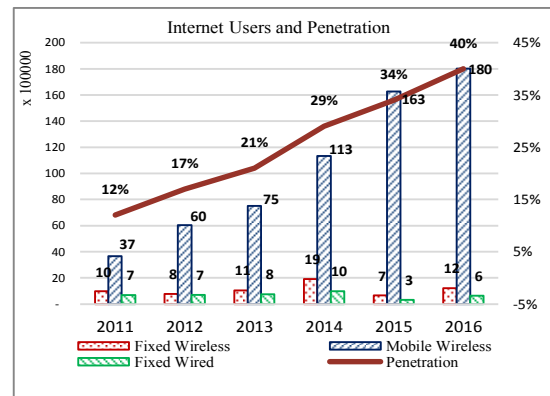


Fig 2: Internet Users by Technology Type and Penetration in Tanzania (Source:[18]).

Users regardless of their geographical area need affordable and reliable broadband access, which is vital for the provision of sophisticated ICT applications [17] such as telemedicine, e-learning and other innovations that may come up in the cause of science and technology advancement to improve livelihood.

In this study, we find that broadband connectivity is currently not an issue to worry about but the issue is adoption, availability, and usage and user experience of broadband services.

III. OVERVIEW OF BROADBAND TECHNOLOGIES

There are many different types of broadband technologies which may be wired or wireless technologies. Most of the wired technologies such as dial-up, Advanced Digital Subscriber line (ADSL), Cable, leased line (T1), Broadband over Powerline (BPL) and fiber optic cable have for a long time been expensive means to reach rural areas where in most cases the population density is very low. On the other hand, wireless technologies such as fixed wireless, Wi-Fi, Satellite, Television White Space (TVWS) [18–20], GPRS/EDGE, (Worldwide Interoperability for Microwave

Access (WiMAX)[21–24] and Long Term Evolution (LTE) are available and can be used to connect the rural users. Other fixed wireless technologies are such as the Local Multipoint Distribution Service (LMDS) and Multichannel Multipoint Distribution Service (MMDS) [26], [27]. Among all these technologies, only a few can be used cost effectively to provide rural and urban-underserved areas broadband connectivity due to various reasons. For instance, the wired technologies need comparatively higher investment cost to reach rural areas making them non-feasible for rural last mile connectivity. The wireless technology in rural and urban-underserved areas of Tanzania are dominated by GPRS, EDGE and VSAT network services which offer limited throughput unsuitable for real-time applications. UMTS, HSPA, and LTE are deployed in urban areas where population density justifies investment leaving rural areas uncovered by these high capacity technologies [28]. The possible reasons for deployment of UMTS, HSPA, and LTE only in city centers are coverage limitation that would require significant investment costs to cover all rural areas.

However, some of these technologies can be used as first or middle mile in combination with other wireless technologies. Various initiatives have proposed or implemented a combination of the above technologies to achieve reach, capacity, and quality of service. In some of these, both wired and wireless technologies have been recommended to be used together to achieve the required throughput and convenience. Example, in some areas fiber optic technology [28] has been proposed to be combined with MMDS as the access network to reach rural and urban-underserved areas. Alternatively, UMTS operating at 900MHz is used to extend the capacity and coverage of UMTS at 2100MHz to rural areas where the available technology is GSM/EDGE with low data rate [29].

Various technologies are available to date to achieve broadband connectivity and these are either implemented in different areas or are proposed to be implemented. Most of these are a combination of one or two technologies with the aim of lowering capital expenditure (CAPEX) and operational expenditure (OPEX) while achieving the desired goal in terms of quality of service, reach, sustainability and affordability. In this section, both used and proposed technology set-ups for broadband connectivity for rural areas are presented.

A combination of different technologies has been recommended to be a good option to reach rural areas cost effectively with required throughput. This is because some of the technologies despite their high capacity and QoS are not viable to use to extend the same as the access network. For instance, combining Optic Fibre technology with WiMAX (FiWi) is one of the hybrid technology where WiMAX is used to extend the reach of Fibre Optic connectivity to the users [29]. Such set up are Passive Optical Network (PON) with WiMAX integration and Optical Fibre with WiMAX integration as shown in Figs. 3 and 4, respectively:

IV. BROADBAND CONNECTIVITY MODEL TRENDS FOR RURAL AREAS

Various models are proposed by various researchers for Tanzania environment taking into consideration of technology, network set up, management and other factors

to achieve the desired service. Examples of rural and urban underserved areas models are Mesh networks, Broadband Island, Nokia Siemens Networks and Rural Netco shared broadband model. These are presented in the next paragraphs. These models aim at connecting the rural areas in its totality. While these models are prospective general technology especially proposed for the rural areas, currently Tanzania has a cellular coverage of about 90% as stated previously and fiber optic network coverage of almost 25600 km (government 7600 km and Halotel 18,000km).

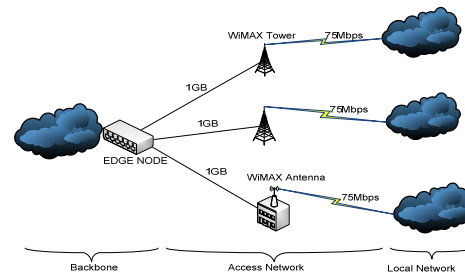


Fig 3: PON and WiMAX Integration [29].

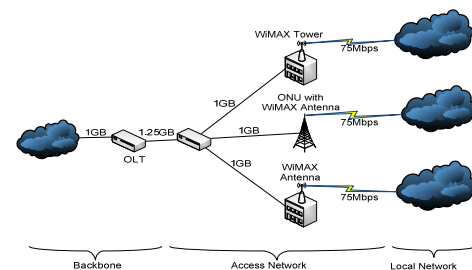


Fig 4: Optical Fibre with WiMAX [29].

A. Mesh Networks

A WiMAX mesh network that lowers the subscriber's cost and helps to bridge the digital divide through the elimination of the middleman (i.e. ISPs) is proposed in [30]. WiMAX mesh network is based on Wireless Mesh Network (WMN), a special kind of Mobile Ad Hoc Network (MANET) with the WiMAX technology as a wireless part of the network.

WMNs have special characteristics such as dynamic self-organization, self-configuring, self-healing, high scalability and reliable services and are able to balance traffic and provide support to drop connections to fixed or mobile clients [31]. These are convenient characteristics for a network in rural areas where constant network management may make the business unprofitable. The basic topology of an IEEE 802.16 mesh network consists of two parts namely; Base Station (BS), a coordinating node and Subscriber Station (SS).

B. Broadband Island

As a move to address further the access gap, Nungu *et al* [32] developed an Island model to make use of unutilized TANESCO fiber optic network that existed between Bunda and Serengeti districts in Mara Region, Tanzania. In this model, only local communication among government offices, education, healthcare, and other entrepreneurs were considered. This broadband island had a narrowband VSAT connection to the Internet but the main focus was local connectivity. In similar set ups, unutilized networks can be used to provide not only voice but also broadband services

to users around that network. Promotion and mainstreaming the broadband island model can benefit many at a reasonable cost.

C. Nokia Siemens Village Network

The Nokia Siemens Village Connection (NSVC) system is PC based, using IP (Internet Protocol), with backhauling delivered mainly by satellite. Each Access Point is supported by a regional Access Centre which can support up to 200 Access Points with each Access Centre providing network coverage for up to 14,000 subscribers [33]. The NSVC uses a different business model in which all the village internal calls are connected locally and only rest of the world calls go out of the village network as shown in Fig.5. This significantly lowers CAPEX and OPEX costs by avoiding unnecessary use of bandwidth and hence the reduction in connection cost. The other cost serving technique is through the use of antenna on village buildings instead of installing masts which normally add cost. This cost effective network has been successful in India where the rural population has started to enjoy the services just like in urban centers. Because of lack of power in rural areas the village connection network make use of low capacity solar panels on the customer's house.

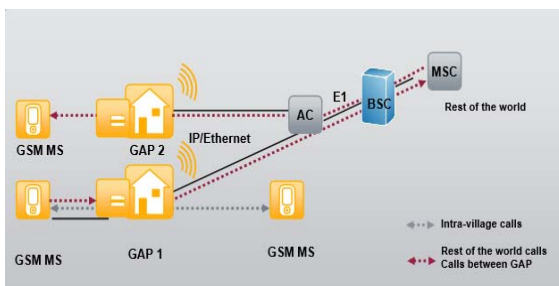


Fig 5: Nokia Siemens Village Network [33].

In Tanzania, Nokia Siemens Networks and Vodacom Tanzania Limited entered into an agreement to implement the Nokia Siemens Networks Village Connection Solution [15], as an innovative and unique solution to resolve the challenge of rural coverage to deliver cost effective network capacity (i.e. low capital expenditure, CAPEX) at a low operating cost (OPEX). The solution was set to start in 2008 with a trial implementation and later be extended elsewhere in the country.

This arrangement has a promising future but at the time of writing this paper, there was no progress report on the project in Tanzania. The implementation ended only on trial stage. Although the reasons are unknown, it can be attributed to lack of customers interested in the service due to the fact that they were not involved in project planning as noted in [34] and [35].

D. Rural Netco Shared Broadband Model

The Rural Netco Broadband Model is a wholesale model operating in Tanzania from which the operators buy the capacity to provide services to their customers. The company launched their services commercially with Vodacom, the largest in Tanzania in September 2013 with market share of 37% compared to Airtel (32%), Tigo (23%), Zantel (7%) TTCL (1%) and Benson (0.002%) as indicated on TCRA website [36].

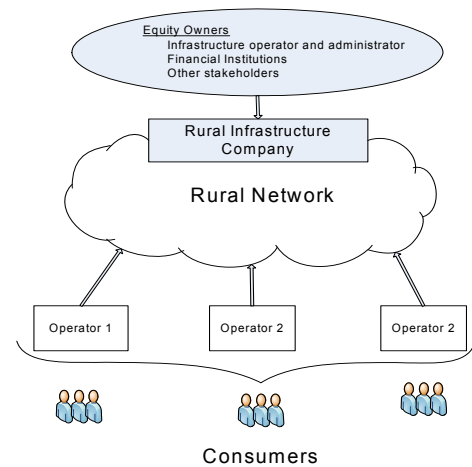


Fig 6: Rural Netco Shared Broadband Model.

According to the BE Weekly magazine [37], Rural Netco is currently providing coverage to 23 regions in Tanzania. This is a huge coverage if the remaining operators can enter into an agreement and cover those areas with value added services. The Rural Netco covers a given area and lets the operators use their network to provide services to users as shown in Fig. 6. This model is attractive in a way that it allows the company to benefit from economies of scale while contributing to the realization of co-location and sharing of resources that is stipulated in the Electronic and Postal Communications Act (EPOCA).

E. Television White Spaces (TVWS)

Television White Space (TVWS) is the recent technology that uses the unoccupied television (TV) frequency band for non-broadcasting services such as broadband services. TVWSs exist in the spectrum primarily used for digital terrestrial TV broadcasting, that is, 470 MHz to 694 MHz.

Recently, TVWS was recommended for use in rural areas due to associated low cost of operation and a substantial amount of bandwidth for broadband services., they can provide broadband connectivity of up to 14Mbps (Ref). A typical example of the implementation of TVWS is the project that has connected 5 schools in the rural Mankweng Township at a distance of around 10 km around the University of Limpopo in South Africa [38]. In this particular project, each of the five schools received a donation of 31 tablets, an overhead projector, and smartphone to enable eLearning delivery. There is another good example in Tanzania whereby Microsoft in collaboration with The Commission for Science and Technology (COSTECH) and UhuruOne, a Tanzanian ISP organized a project to provide affordable wireless broadband access to university students and faculty in Dar es Salaam using TVWS radios from 6Harmonics. In this project, 4 higher learning institutions are involved and this partnership will enable UhuruOne to offer a laptop or tablet, wireless broadband connectivity, and applications and services to cover a student population of about 50,000 at four universities: the Institute of Financial Management, the Dar es Salaam School of Journalism, the Institute of Social Work and The Open University of Tanzania.[39].

Apart from providing broadband connectivity in rural and underserved areas, TVWS can effectively improve spectrum utilization and alleviate spectrum scarcity and

when compared with Log Term Evolution (LTE) for rural broadband, TVWS is more cost effective. However, very few countries have fully regulated and adopted TVWS for broadband services. In countries like Tanzania, Ghana, Kenya, Botswana, Namibia and South Africa, trial projects have been implemented by Microsoft in collaboration with local Service Provider to support various media protocols, such as streaming videos, emails, FTP, Skype voice and video conferencing, and high-speed VPN services[39].

Fig.7 shows a TVWS network architecture which comprises of the 802.11 b/g/n/ac Wi-Fi access points (APs), which connect directly to the TVWS customer premise equipment, or CPE using standard Cat5 or Cat6 cable. The CPE communicates with the TVWS base stations (BS) through a TVWS air interface protocol, e.g. IEEE 802.11af, which can be located within several hundred meters of the CPE or kilometers away. The TVWS radio attaches behind the antenna to the same pipe mount and an RF jumper connects to the antenna while Cat5 cable drops to the Wi-Fi AP or Ethernet switch [39], [40].

When it comes to what technology to be used in connecting a specific area in rural areas, a number of factors need to be considered to come up with the right one for the area: type of services, ownership and purchasing power of the people in that area.

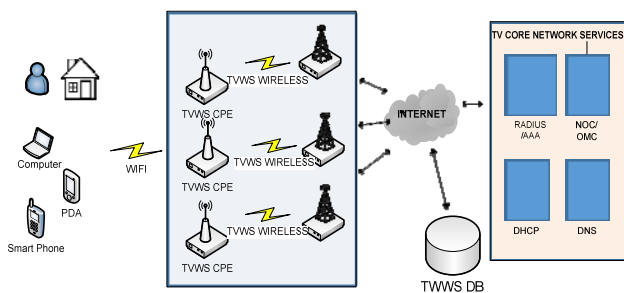


Fig 7: TVWS network Architecture.

V. INITIATIVES TO ACHIEVE BROADBAND CONNECTIVITY

A number of initiatives to achieve the goals of Tanzania Vision 2025 and the objectives of NICTP-2003/2016 have been implemented and together have helped in some ways to reduce the digital divide. Some of these initiatives are the telecentres, the NICTBB project and the Universal Communication Service Access Fund (UCSAF). Initially, when the telecentres were first instituted the main service considered was the voice service. However, the current telecentre model considers broadband connectivity because the technologies to facilitate that are available. This is why the ITU/UNESCO report of 2013 [41] recommends telecentres as a means to address broadband access barriers in areas with low population density and low purchasing power. In this section, each of the initiatives is briefly presented and discussed.

A. Telecentres

Telecentres are places where shared access to ICT and enabled services are available and are used to bridge the digital divides between rural and urban areas [42]. Telecentres were initially introduced in 1998 for developing countries as a means to achieve universal access and hence socio-economic development. In Tanzania, Sengerema pilot

telecentre was implemented in Mwanza region in 2000. It was expected that installation of such centers would increase with time but ten (10) years later only 22 telecentres are reported to exist [43] which is a very small number compared to a number of areas in need of such services. This means the expected impact of telecentres are yet to be realized [44]. Looking at the investment structure of such initiatives most of which were donor-funded and at the end of the funding duration most of these telecentres failed to operate despite the inclusion of secretarial and other services as part of the diversification strategy to sustain the centers. Fig. 8 is the Sengerema Telecentre in Mwanza, Tanzania, which shows the presence of a radio service, Radio Sengerema (98.8 FM), as part of the center's services [44].

Although the inception of telecentres in Tanzania was well before the institution of the National ICT Policies (NICTP-2003 and NICTP 2016), telecentres have always been recommended for shared access and means for aggregating traffic in areas where customers are sparsely populated and purchasing power on an individual basis is low, as such then, achieving the universal access remains a challenge.



Fig 8: Sengerema, Mwanza Telecentre. Source [44].

At the time the Tanzania telecentre initiative was being introduced for rural and remote areas in 1998, the access technologies were mainly VSATs due to their being located far from the reach of wired and other networks. With VSATs, the main challenge was annual satellite charges even when the link is not used. With the positive changes in technology coupled with high capacity, affordable and reliable networks, telecentres of today are expected to perform even better. This is why to date the International Telecommunication Union (ITU) recognizes telecentres as one of the strategies to overcome access barriers to universalizing broadband in low population and places with low purchasing power [41]. This means countries such as Tanzania need to consider mainstreaming the telecentre model for low purchasing power users if it has to achieve broadband connectivity for all.

B. The Tanzania National ICT Broadband Backbone (NICTBB)

In order to realize the vision of the NICTP-2003 "Tanzania becoming a hub of ICT Infrastructure and ICT solutions that enhance sustainable socio-economic development and accelerated poverty reduction both nationally and globally", the government through the

NICTBB project set itself to connect all its regions and districts to create a high capacity and reliable national and international broadband infrastructure so that they have an access to a national and regional broadband infrastructure as well as the sea cables landing on its shores [40]. This alone is enough to allow other initiatives to be undertaken once the relevant infrastructure is in place. The project was set to be implemented in 5 phases.

At the end of its 2nd phase, The NICTBB had an OFC route length of 7560 km connecting 24 Region centers in Tanzania Mainland, also connecting Pemba through TANESCO cable between Tanga and Pemba. Telecommunication operators and ISPs are able to connect to the network, which has drastically reduced the connection cost of most services from voice to the internet and other services.

In its 3rd phase, the NICTBB centred on four main components which are [40]: (i) construction of additional OFC links to achieve a mesh OFC transmission networks; (ii) construction of regional and district OFC transmission networks; (iii) construction of an IP-layer of the NICTBB and a national Internet Data Centre (IDC) facility of high standard; and (iv) Implementation of additional Internet-based connectivity systems for the government to extend the ongoing e-Government project such as ERNET, e-Schools Network, e-HealthNet and Community Information Centres (CICs) to local governments [45]. It was reported that the service charges per Gigabyte (GB) had dropped by 75% from TZS 36,000 in 2009 to TZS 9,000 in 2013. A similar drop in charges was achieved in mobile phone calls per minute charges from TZS 147 to TZS 62 [45]. This makes communication affordable to most of the people where this connectivity is available.

During our research work, it was discovered that some users (businesses and institutions) in remote, rural and urban-underserved areas are connected to the fiber network with huge capacity terminated within the vicinity of the rural and urban-underserved unconnected users. This suggests that it is possible to tap from such connectivity as a means to utilize the links at the same time serving the users who would never bring that connectivity to their areas on their own due to the associated costs. It is so because the main cost of bringing the connectivity is already paid for. An example is the 14 km fiber link from Arusha town to the Nelson Mandela Institution of Science and Technology (NM-AIST), Arusha campus carrying 1Gbps capacity while the schools and other organizations around NM-AIST are not connected. This connectivity can be extended to surrounding users using wireless technologies such as MMDS, WiMAX [4], [46].

C. The Universal Communication Services Access Fund (UCSAF)

UCSAF is one of the initiatives that was created in Tanzania to address the access gap existing in the country between rural and urban areas. It is a follow up on the World Summit on Information Society (WSIS) agenda. The idea is to subsidize investments to unprofitable rural and urban-underserved areas, which lack incentives to investors. Through members of parliament (MPs), it was possible to identify 2175 villages in Tanzania for which the fund needed to consider.

Between 2012 and 2013, the fund issued two subsidy tender bids for the provision of basic voice telecommunications services under contracts: (UCAF-2012-1 and UCAF-2013-1) covering a total of 223 wards and 1284 villages [47]. In Tanzania, a ward is an administrative structure consisting of several villages in rural areas or streets in urban areas. Universal Access plan is expected to cover a total of 340 wards with about 2500 villages in total. It can be noted that both tender bids require operators to provide basic voice services to these rural areas. Although the voice service is one way to development but yet still, broadband connectivity is as important considering real-time applications that require more than just mobile voice services. Fortunately, with the availability of Fibre Network coverage to the district level and the wireless coverage that is being established, it is now possible to extend the broadband connectivity through a combination of various technologies that are already available in the market. For instance, the recent launch of 3G and LTE mobile broadband services can easily build on the coverage already in place.

From the report by UCSAF on "Coverage, Population and Land Scan Data for Selected Wards, some ward villages were without telecommunication services. Fig. 9 shows some of the selected wards with a bigger percentage of the geographical area uncovered, most of which 100% were not covered by any network which means even the population was uncovered with more or less percentage as shown. These villages were selected based on the total areas uncovered by any telecommunication service at the time of research as presented in the report. This is a serious situation for a Tanzania that wants to graduate from a Lower Income Country to a Middle-Income country by the year 2025, which is expected to be achieved through ICTs [48].

However, through strategies put forward by UCSAF and the government the situation as far as universal access in rural and urban-underserved areas is concerned, has improved a lot. It is reported that currently 90 % of the geographical areas is covered by mobile operators. Additionally, Viettel Company limited since 2010 has built an 18,000 km OFC (mostly as access) network all over the country to reach those areas which were not reached. This is adding to the 7600 km fiber built by NICTBB project.

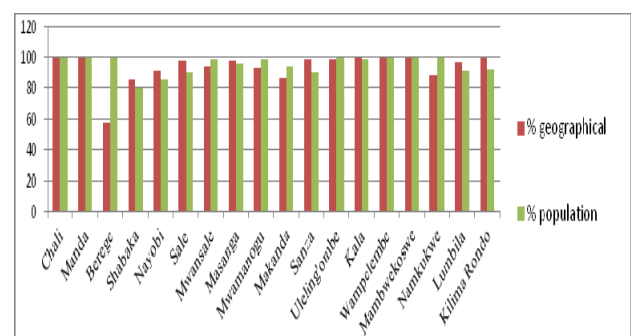


Fig 9: Geographical and population uncovered percentages for selected wards [29].

VI. INFRASTRUCTURE READINESS

It is generally understood that infrastructure is what drives information society such that lack of it makes the goal of achieving an information society as stipulated in the

NICTP-2016 [8] a daydream. One of the policy statement states on ICT infrastructure that:

"The Government will ensure that a reliable state of the art ICT infrastructure, of adequate capacity, high-speed and countrywide coverage is developed".

This policy statement has been a motivation for the Government of Tanzania to construct the OFC traced NICTBB. Building such advanced network with high-speed capacity has been described by many as "the great infrastructure challenge of the 21st century" [45]. Therefore, Tanzania is one of the countries that has addressed that challenge by building the state of art NICTBB with Points of Presence (PoPs) at all regional and district headquarters. This network provides connectivity to the international infrastructure through the four International submarine cables: SEACOM, EASSy, SEAs and TEAMS providing an abundant bandwidth, fast and affordable broadband connectivity to the country [11].

In addition to the OFC infrastructure covering the whole country at district level, there are other private mobile and fibre networks available in the county owned by telecommunications operators and various organisations such as the Tanzania Electric Supply Company (TANESCO) and Ministry of Water (MoW), which are currently being used in combination with the public networks in various socio-economic development projects. Example: the Bunda-Mugumu access network is being provided through an OFC installed by TANESCO with the fibres carried in the ground wire known as optical power ground wire (OPGW) along the 33 kV power line (for supervision, control and data acquisition purposes) and the Wami-Chalinze network project through the MoW optic fibre network (a water flow monitoring and accounting systems) [14, 22, 23].

Additionally, the Government of Tanzania through its Ministry of Communication, Science, and Technology (MCST) envisions a knowledge-based Tanzanian society with the capacity and capability to harness Science, Technology, and Innovation for the transformation of the economy that is sustainable and globally competitive. With this vision, it is clear that ICTs can facilitate reaching the majority (about 75%) of Tanzanians living in rural areas to be part of this vision. This is why the Government charged the Ministry to construct the NICTBB as a means to solve the issue of telecommunication infrastructure [40].

In line with this, the NICTP-2016 emphasizes ensuring all installed ICT infrastructure and capacity is utilized effectively and contributes to resilience and redundancy. Therefore there is a need for a plan on how to utilize all installed capacity such as the NICTBB and the UCSAF projects to achieve the learned society as stipulated in Tanzania Vision 2025, in which case digital divide in different geographical locations is minimized if not eliminated.

However, the ICT Infrastructure is associated with the availability of other essential services/ infrastructure such as electricity supply, roads and other basic economic services and social necessities; meaning that any solution to achieve connectivity in such areas needs to consider presence or absence of such services.

Even after all necessary ICT infrastructure has been in place still willingness and readiness, leadership and

ownership will be a holdup of service provision to users in the urban-underserved and rural areas. However, with the Public Private People's Partnership (PPPP) model proposed in [49] as an implementation strategy for sustainable broadband rural connectivity solution, it is possible to mitigate such challenges due to the fact that from the very beginning all the parties are involved so that each of the member/parties is interested to see the projects to the end and play part in each step where involved.

VII. POLICY READINESS

Various Tanzania policies, regulations, and national strategic plans recognize the importance of broadband connectivity either through, set regulations and frameworks, encouraging best ways for broadband connectivity or encouraging ICTs in various sectors in the country. Tanzania does not have a Broadband policy which should be a vital part of broader ICT policy strategies [50], like its neighboring country Kenya and the rest of developed countries. However, the available policies, regulations, strategies and frameworks are sufficient to allow broadband connectivity reach every citizen. For instance, the National ICT policy of 2016 (NICTP-2016) envisions:

"Tanzania with economically, socially and culturally enriched people in ICT-enabled knowledge society".

This policy targets specifically broadband connectivity through policy statements:

The government will [8]:

- i. *Ensure conducive environment for collaboration of public and private sector in exploring various means of financing access to broadband services;*
- ii. *Ensure availability and accessibility of reliable and affordable broadband services countrywide.*

All of these focus on bridging the digital divide through the Universal Communication Services Access Fund (UCSAF) which has started with the provision of voice services to rural and urban-underserved areas.

Notably, the Electronic and Postal Communications Act (EPOCA) of 2010 regulates the co-location and sharing of network facilities as a means to bring down the access charges among providers so that many people can access the services. This has allowed for the successful implementation of spectrum sharing as means to effectively utilize the scarce resource.

In the ITU/UNESCO broadband report of 2013, Tanzania is listed among the countries that have broadband plans [41]. This is due to the implementation of the National ICT Broadband Backbone that is intended to provide high-speed connectivity to the whole country.

Therefore, Tanzania is ready to provide and promote the provision of universal access to broadband services countrywide through both private mobile broadband projects (Mobile operators), Private-Public Projects (PPP) and other initiatives as the policy environment is in support of the same.

VIII. CONCLUSIONS

In this paper, we have discussed models available for last mile connectivity, infrastructure, policy readiness and initiatives focusing on rural connectivity in Tanzania. It has been noted that, although Tanzania has no specific broadband policy, the current national strategies and ICT policy and other frameworks are sufficient to bring broadband services to rural and urban-underserved areas. We find that the infrastructure is to some extent satisfactory if utilization of available private and public networks are extended to rural and urban-underserved areas. Other factors such as ownership and public-private people's partnership programs need to be considered.

Therefore, to achieve the universal access in Tanzania in terms of broadband connectivity we recommend the establishment of business models that will allow small scale entrepreneurs available in rural areas to provide services at a scale sufficient for the area and for the capital available.

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