International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 7, No.2 (Mar-2018)

http://dx.doi.org/10.12785/ijcds/070202

Utilization of Broadband Connectivity in Rural and Urban-Underserved Areas: The case of Selected Areas in Arusha-Tanzania

Mastidia Byanyuma[1], Zaipuna O. Yonah[1], Fatuma Simba[2] and Lena Trojer[3]

[1] Information Communication Science and Engineering (ICSE) Dept., Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania
[2] Computer Science and Engineering Dept., College of Information and Communication Technologies (CoICT), UDSM, Tanzania
[3]Blekinge Institute of Technology (BIT), Sweden

Received 19 Oct. 2017, Revised 13 Dec. 2017, Accepted 29 Jan. 2018, Published 1 Mar. 2018

Abstract: Utilization is a key aspect in the management of any societal resource not only when it is scarce but in all cases to allow for optimum benefits to be accrued to everyone in the society. Internet bandwidth, which is a rare commodity especially in rural areas is hardly available where needed at the same cost and quality due to various reasons. Tanzania as a case study is among countries that have invested much in international, national and metro backbone networks, but still, there are areas without or with inadequate internet access services implying a significant utilization problem. In this paper, we present as a case study, the status of broadband connectivity in selected rural areas in Tanzania (Arusha) and the status is used to make recommendations for optimized utilization of installed capacity.

Keywords: Broadband connectivity, Rural area, Urban-underserved area, Utilization.

1. INTRODUCTION

Significant improvement in internet access connectivity has been reported worldwide [1], through various means such as telephone or smartphone penetration, coverage of mobile connectivity, number of people owning smartphones, a decrease of digital divide and others. In some areas, this improvement has translated into reduced charges, improved quality of service and user experience to the communities but not everywhere in the world. Furthermore, internet services are not available everywhere despite a significant reduction in price [2]. The situation is more evident in rural and isolated areas in developing countries that have always been characterized by a low number of subscribers of telecommunication services and this has continued to be a hindrance to investors to bring the services to such areas. Generally, in some countries, the problem is not dependent on geography only, but the main constraints as mentioned in [3] are lack of Internet Exchange Points (IXPs) and Internet Service Providers (ISPs) that deliver access to end users. An IXP is a physical infrastructure through which ISP exchange internet traffic between their networks thereby reducing latency and delivery cost of their services. The primary purpose of an IXP is to allow networks to interconnect directly, via the exchange, rather than through one or more third-party networks which usually require international connectivity. The advantages of the direct interconnection are numerous, but the primary reasons are cost, latency, and international bandwidth.

The significant increase in high capacity and comparatively cheaper terrestrial networks mainly based on optic fibre cables (OFCs), has significantly reduced the cost of connectivity [4]. This has been possible due to the replacement of satellites, which are very expensive and have higher latency and comparatively low capacity. Despite the increase in high capacity OFC networks, few private and government organizations pay extra cost to get such services. On one hand, broadband connectivity in rural areas is mostly for government and a few private organizations leaving the majority unconnected hence making the digital divide more pronounced in those areas. On the other hand, mobile network operators are proud to announce that they have covered all areas including the remote ones and competition has brought airtime charges down including broadband services in some areas. This is offered in daily, weekly or monthly bundle plans that come with SMS, airtime and data volumes at a reasonable price all over the country but still these bundles benefit

E-mail address: byanyumam@nm-aist.ac.tz, zaipuna.yonah@nm-aist.ac.tz, fatmasimba@gmail.com, lenatrojer@gmail.com

only those who are closer to a high capacity portion of the networks and have modems or smart devices to take advantage of such service availability opportunities. For example, a typical cheapest monthly internet bundle of TZS10,000/ provides up to 10GB data volume (Special University package by Halotel Network operator although the actual cost of bandwidth outside that arrangement is 30.72 Tsh./MB [5]. There is also off pick offers like the night data packages that offer significantly large volume at a very small cost. It can be noted that those without smartphones and out of reach of broadband mobile networks will not benefit from such an opportunity hence present a form of utilization problem. In some areas there is everything in place; the coverage, the broadband capacity but due to various reasons, the communities are not using the service at their disposal.

In terms of connectivity, several initiatives have been undertaken in Tanzania including the creation of community multipurpose telecentres [6], subsidizing the service provision through Universal Communication Services and Access Fund (UCSAF) and connecting groups of people such as schools in projects such as "connect a school"[7] and building the national ICT fibre backbone (NICTBB) [3], [8]. Some individuals and organizations have proposed means such as broadband islands utilizing the fibre links to get access to an intranet [9], a case of Serengeti Mugumu networks utilizing the Tanesco fibre cables to connect the users in the neighborhood. It can generally be agreed that broadband connectivity in Tanzania, where its national fibre network is laid across the country with points of presence in all district headquarters and mobile networks covering almost the whole country, is no longer a problem. Similarly, due to the availability of internet access connectivity through submarine cables such as SEACOM, EASSy and TEAMs, the bandwidth problems of availability and affordability will soon become history [10]. However, when you go beyond the district headquarters you will find this statement false.

The Tanzania National Information and Communication Technology Policy (NICTP) of 2016 [11], clearly acknowledge this fact that there are no appropriate frameworks for deployment and utilization of ICTs infrastructure for maximum economic benefits coming with these ICTs. This is the reason the study reported in the paper is being undertaken, to establish the exact problem and to investigate possible solutions to address it accordingly.

2. Literature Review

A. What is Utilization

In this research, we consider utilization of a resource which is defined as making use of or finding a profitable or practical use of a given resource. It is a ratio used to compare a current usage level against a maximum potential level of a given resource [12]. This means that any way to make use of available capacity for the benefit of many at a reasonable cost is the utilization of capacity.

In the case of Tanzania, there have been various initiatives to bridge the digital divide, including the implementation of the National ICT Broadband Backbone Network (NICTBB) and the mobile cellular network subsidization for rural areas by the Universal Communication Services Fund (UCSAF), but most of these efforts are underutilized. Most of the stakeholders in the Telecommunication Industry and those dealing with users that need connectivity for development such as the Ministry of Education, the Commission for Science and Technology (COSTECH), Tanzania Education Authority (TEA), UCSAF and the Ministry for Science and Technology, have programs/initiatives to connect schools, institutions and various communities. Similarly, the mobile network operators in Tanzania such as; Vodacom, Halotel, Tigo and TTCL, have programs to connect the rural and urban under-served as part of their Social Customer Responsibilities and these programs are uncoordinated. In a long run, these efforts may result into duplication and wastage of efforts and resources. To address this, something needs to be done, in particular, the utilization of all broadband connectivity in the vicinity of potential users, that is, considering all areas with the nearest connectivity first. So far, utilization of such resources whose part of investment cost has already been paid for by anchor customers is one way of bringing broadband connectivity to many in the shortest time possible. These anchor customers are market-leading companies who are crucial to the success of broadband connectivity. However, a regulatory framework is required to motivate any such organization with underutilized connectivity link to be part of the rural and urban underserved connectivity.

Utilization of connectivity in rural areas is expected to help a lot in bridging the digital divide and improving delivery of health care, agricultural extension and educational services. Use of ICTs has demonstrated that it is possible to provide all types of services such as blended learning [10] to make efficient utilization of scarce human resource in teaching and telemedicine for the provision of healthcare services in understaffed areas [13]. In the following section, we review the literature on utilization of broadband connectivity in rural areas and present the typical cases showing the underutilization of installed capacity in rural areas in Arusha region, Tanzania.

1) Lack of Awareness or Low Literacy Rate

Mosha and Bea (2014) [14] recognize lack of knowledge as a barrier to internet usage in learning and teaching. This is the same situation with mobile broadband, only those who have knowledge of its importance will be willing to pay for and use it. Lwoga (2010) [15] contends that low literacy rate is a contributor to low use of internet services. In some cases, where airtime bundles include bandwidth as a bonus, without knowledge and or awareness, that resource expires

unused. This adds to a number of people not utilizing the broadband connectivity available in their locality. In this case, we consider utilization of bandwidth as the percentage of capacity subscribed to the available link capacity assuming the subscribed capacity is not shared which is not the case in practice.

2) Affordability of Devices and Air Charges

According to Milne (2006) [16], affordability is generally seen as depending on overall income levels and overall telecommunications tariff levels. In terms of income, Tanzania and other developing countries have a good number of communities with low purchasing power to be able to own devices and air charges to stay online. The implementation of submarine cables and the NICTBB project has brought down the communication charges but the rural income is still insufficient. This is accompanied by the problem of lack of electrical power which is common in rural and urban underserved areas. There are a number of initiatives aimed to bring power to rural and urban-underserved areas in Tanzania through projects sponsored by entities such as the Rural Electrification Agency (REA) through the use of normal electrical power or renewable energies like the solar and wind energy. Therefore, if energy costs are added to the cost of devices and airtime, it becomes even impossible for a normal user in those areas to use the technology. This again accounts for a good number of people who do not use technology because they cannot afford to own devices, pay for airtime and power charges.

3) Network Reliability and Coverage

The broadband network coverage is limited in rural and urban underserved areas in two ways; the wired fibre access network like the Fibre to the Home (FTTH) is still expensive for the individual majority.

Fig. 1 and Fig. 2 show the mobile network coverage by Halotel and Vodacom mobile network operators respectively. From both maps, a big part is covered by the 2G technology which offers mainly voice and limited data service [17]. In terms of 3G, most areas are yet to be covered.

Therefore, for those users residing in such areas, they are not able to use the broadband network capacity available in the country due to the last-mile/access technology that is limited in capacity.

B. Broadband Connectivity

Broadband connectivity has always been a challenge to most of the countries around the world especially developing countries [18]–[20]. Various studies have been centered on finding cost-effective last-mile technologies to connect all especially those in the rural the urban-underserved areas [3], [21]–[24].

Currently, however, in most cases connectivity is not a problem because governments, national and international organizations have been consistently working on devising means to bridge that gap through funding the studies on the area, subsidizing services provision in unprofitable areas through universal access funds [19], [25] and putting forward the right and up to date policies and regulations [26], [27].

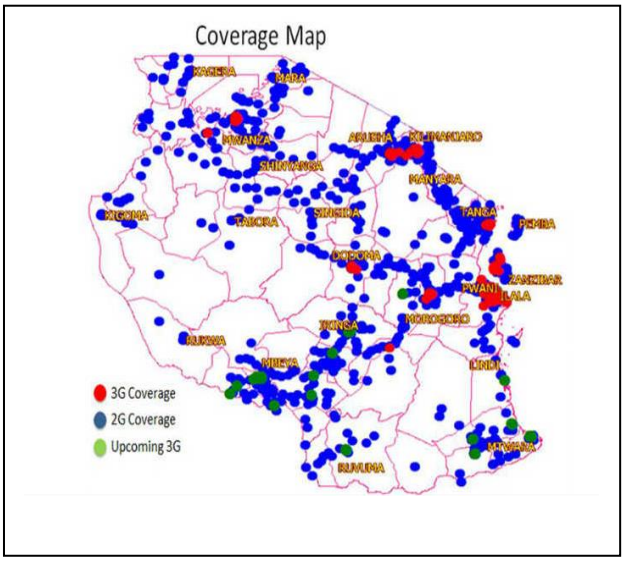

Figure 1. Halotel Coverage Map as at the end of 2016 [28]

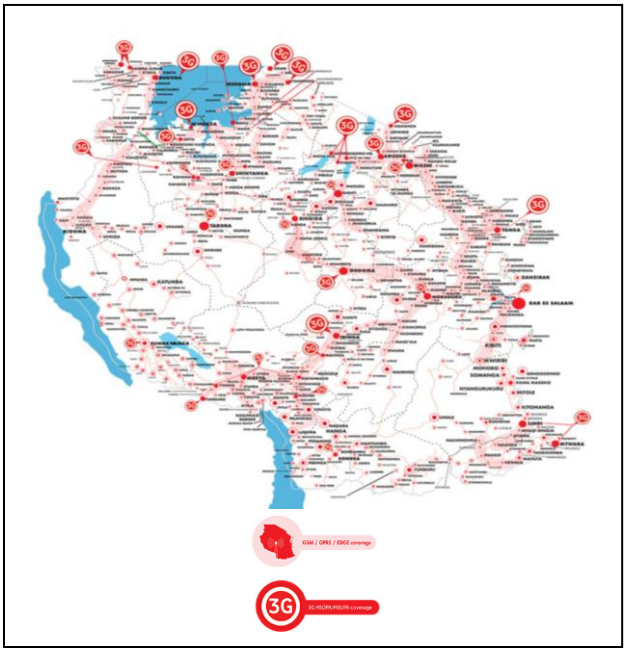

Figure 2. Vodacom Coverage Map in 2017 [29]

Consider for example in Tanzania, there is a high capacity connectivity providing both international and national connectivity although last-mile connectivity (the last link from a network to the end user) is still a problem in underserved areas such as rural and small towns [30]. The reasons for this inadequate connectivity in these areas are low purchasing power, uncoordinated efforts, lack of

ownership of community connectivity projects, lack of management skills and involvement, low return on investment; hence lack of business incentive and uncoordinated utilization of available resources. Integration of ICT in socio-economic activities involving many people may change the level of purchasing power in a given community; as through ICTs, many economic and employment opportunities are expected and hence increased incentives to investors and return on investment in those areas. Good examples are countries such as Korea, which is ranked the world's most advanced ICT economy, followed by Sweden, Denmark, Iceland and Finland. These countries have built high-speed connectivity networks to facilitate the efficient and effective use of ICTs applications for increased socioeconomic growth (see Fig. 3)[31].

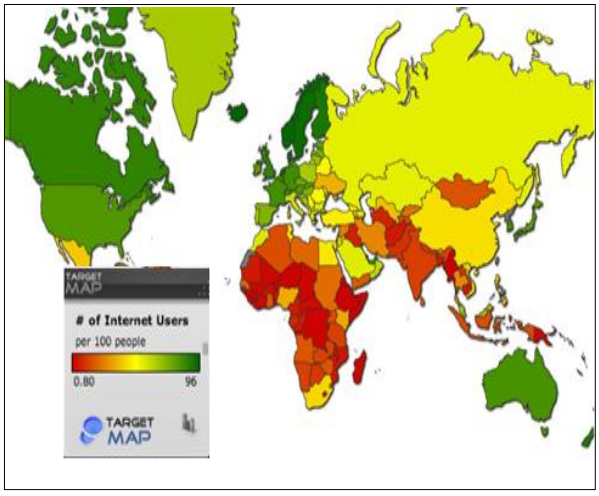

Figure 3. World Internet Penetration in 2012 [31]

The main parts of Africa, on the other hand, are the least users of ICTs derived from the ICTs penetration as shown in Fig. 3. Although this is based on the 2012 data, the situation has not changed much to date. We can see even from the ITU recent data of 2005 to 2016, in Fig. 4 showing an average Africa penetration (individuals using the internet) as low as 25% compared to 79% of Europe. These correlate with the map shading in Fig. 3.

These statistics indicate a very high access gap or digital divide and is in line with the poor economic progress of such countries. However, within those countries where there is a low percentage of the total population that uses the internet, there are few areas (the urban and city centres) that are better off compared to rural and underserved ones, as they are comparatively more attractive to investors.

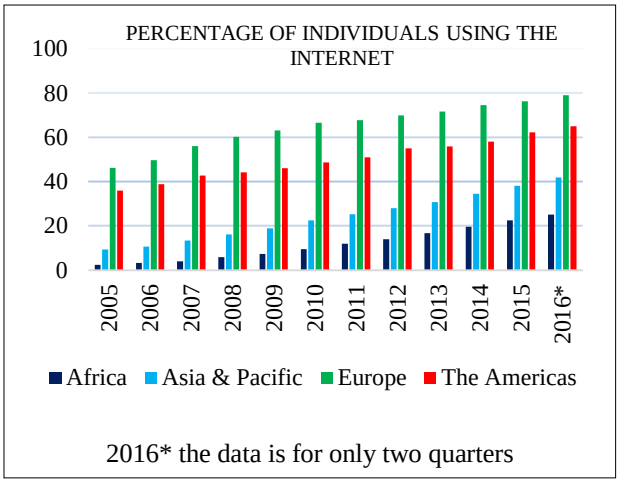

Figure 4. Internet Penetration (individuals using the internet) [32]

3. METHODOLOGY

In this section, the area where this study was conducted and the method used are explained.

A. Study Area

The study was conducted in Arusha regions in Tanzania where five (5) districts were involved namely; Karatu, Longido, Monduli, Meru and Ngorongoro. The study focused on broadband services in these districts.

B. Data Collection

Interviews were conducted with Internet Service Providers (ISPs) to identify among other things, broadband users residing in rural areas and the technology used to connect them. After identifying these rural areas with broadband users, field visits were used to establish installed capacity and utilization of the same.

Literature review/desk study was conducted to get more knowledge on the subject matter. Initially, the aim was to investigate the telecentres served by the ISPs but it was found later that there were no telecentres in Arusha intended to serve the rural communities. This notion of the existence of telecentres in regions was learnt from past literature that telecentres were recommended to be implemented all over Tanzania and other developing countries as cost sharing mechanism to reach rural areas in terms of voice, data and other services. The main idea was to use a shared service to aggregate traffic for sharing high capacity backhaul services available in the area which is still a viable idea if it is modeled in a right way [33].

C. Calculation of Utilization

The utilization of installed capacity was calculated as a ratio of subscribed bandwidth capacity to the total installed link capacity at the given service area. This assumes that the subscribed capacity is 100% utilized that is, it doesn't take into account the issues of overbooking and contention ratios where utilization of network may

consider overbooking to take into account the idle time, the time at which the network is not used.

$$Utilization\ (\%) = \frac{Users\ Subscribed\ capacity}{Total\ Link\ capacity} \quad \text{(i)}$$

4. Results And Discussion

In this section, we present and discuss the data collected in Arusha region that aimed at identifying technologies for connecting rural users.

1) Connectivity

It was found that VSAT and microwave radio networks were used to connect rural users. Users very far from the reach of the network centers are using VSATs and microwave radios to connect. In some parts a 2G wireless technology is available but it does not provide broadband connectivity. Even in areas where 3G cellular technologies exist, Users do not have smartphones to utilize the broadband services available to all regardless of their geographical location. Very few users use optical fibre as a last-mile solution.

2) Telecentres

In the case of telecentres, there were no telecentres found in the surveyed areas despite the fact that it was likely to be there given the telecentres initiative that was launched in Tanzania in 2001 [34]. Although these areas were covered by the mobile networks, the only connectivity found was a second generation (2G) network, the Enhanced Data rates for GSM Evolution (EDGE) technology with very low data rate for use with modem and smartphones. However, due to the economic situation of the areas, very few individuals own computers or smartphones to access the Internet. On the other hand, most of these areas lack electricity to power computers and smartphones which normally need more power than other feature phones. This calls for a community service on which issues of power and connectivity can be centrally tackled by the community. According to Wangwe (2010), Telecentres can,

> *"facilitate distance learning and enable farmers in the rural areas to use ICT to access knowledge, share information and acquire farming skills to enhance their crop production, thus creating a culture of information and experience-sharing within the communities."* [35]

3) Rural and Urban-Underserved Users

Initially, about five (5) ISPs were considered in order to get users residing in rural areas. These were Habari Node Marie, Tanzania Telecommunication Company Limited (TTCL), Airtel, Lupanet and Kicheko.com. However, only one ISP, TTCL had users in rural areas. The possible reason to that could be the fact that other ISPs are more business oriented than TTCL which is developmental and operates to deliver a regulatory Universal Service Obligation (USO).

Therefore, from TTCL Arusha Branch, very few customers in the rural areas were identified, all of which were tourist hotels, banks, District HQs, colleges, government and private institutions. Although the population density in such areas is low, this does not justify lack of connectivity and hence the needed basic services such as health services, education, financial services and other social services. Table 1 presents the list of users in five districts of Arusha region along with the technologies used and the subscribed capacities.

Table 1.Link and Installed Capacity for Rural Users in Arusha, Tanzania[1]

District	*Organization*	*Last-Mile connectivity Technology*	*Link capacity (Mbps)*	*Subscribed Capacity (Mbps)*	*Subscribed Capacity (%)*	*Unsubscribed Capacity (%)*
Karatu	DC	B_Radio	15	0.256	2	75
	HV Hotel	B_Radio	15	2	13	
	FL Hotel	B_Radio	15	1	7	
	NMB	B_Radio	15	0.512	3	
	TRA	Fibre	100	0.512	1	97
	NBC	Fibre	100	1	1	
	NSSF	Fibre	100	1	1	
Longido	DC	B_Radio	15	0.256	2	98
Monduli	DC	VSAT (AVANT)	10	2	20	80
		VSAT (SATCOM)	2	0.256	13	87
Ngorongoro	DC	VSAT	2	0.256	13	87
Meru	DC	ADSL	2	0.256	13	87
	CRDB	Fibre	100	1	1	99
	NMB	Fibre	100	0.512	1	99
	NBC-ATM1	ADSL	2	0.256	13	87
	NBC-ATM2	ADSL	2	0.256	13	87
	MCB Bank	ADSL	2	0.128	6	94
	Ngurudoto Hotel	Fibre	100	2	2	98
	Arusha-Univ	Fibre	100	3	3	97
	St. Jude School	Fibre	100	4	4	96
	World Garden	Fibre	1000	4	0.4	94.6
	NM-AIST	Fibre	1000	50	5.0	

[11] Data Collected by the Researcher

It can be noted that districts such as Ngorongoro, Monduli and Longido have mainly one broadband user which is the District Council. The remaining population is served by a low capacity 2G GSM network with limited data connectivity as was experienced during the research. Only the GSM EDGE technology was available in some areas and in the remaining areas there was no connectivity at all.

From Table 1, it can further be noted that still some areas are being served by VSAT technology which is very limited in providing broadband services. However, while on data correction at Monduli, they were in the process to acquire Avant VSAT connectivity with 10 Mbps link capacity which is much better compared to 2 Mbps link capacity a conventional VSAT technology could offer.

Also, observable is that, the optical fibre network link capacity available at NM-AIST is a huge capacity that can be used to extend connectivity services to the wider area with minimal installation cost since the cost of bringing the fibre link up to that point is already paid for. This is already a reduced capital cost to the prospective users.

From the link capacity and subscribed capacity by the users, it was possible to calculate the extra theoretical capacity that is available and can be used to extend services elsewhere in the neighborhood.

It should be noted however that, although there is no economic reason to aim at utilizing a link to 100%, it is presumed that if demand was created, the same link of say 15Mbps would serve more users than who have currently subscribed. Technically, we expect even more underutilization if overbooking is considered in which case the allocation of bandwidth may exceed what is actually available with the notion that in practice the subscribed capacity is sometimes idle and hence a safety margin may be allowed based on the contracted Quality of Services (QoS). Therefore, with such assumptions, the utilization of selected links are hereunder presented and discussed.

For instance, the Longido and Karatu broadband radio links in Fig. 5 and 6 respectively, are unutilized by 75% and 98%, respectively, out of the installed 15Mbps capacity in each case.

Fig. 7, Fig. 8 and Fig. 9 shows an optical fibre cable network serving the respective organizations including Ngurudoto Hotel, Arusha University and NM-AIST with an unutilized capacity of 98% of 100Mbps, 97% of 100Mbps and 94.6% of 1Gbps respectively. The broadband radio capacity that is available in Fig. 5 and Fig. 6 respectively for Longido and Karatu is not huge compared to that in Fig.7 through 9. However, considering the fact that the neighborhood are without such connectivity and issues of overbooking, the same link would accommodate more users.

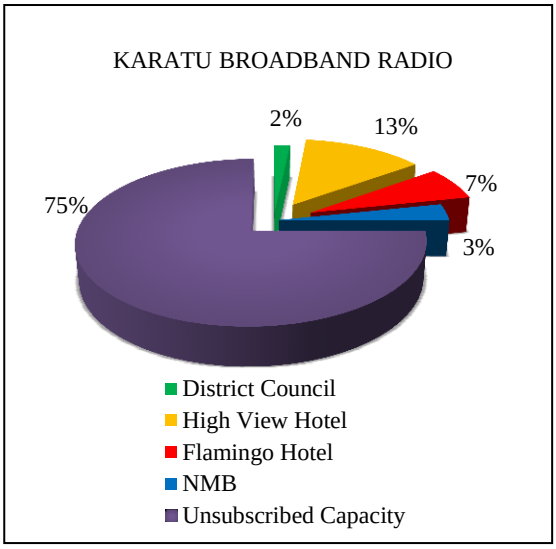

Figure 5. Bandwidth Capacity Utilization of the Longido Radio Link

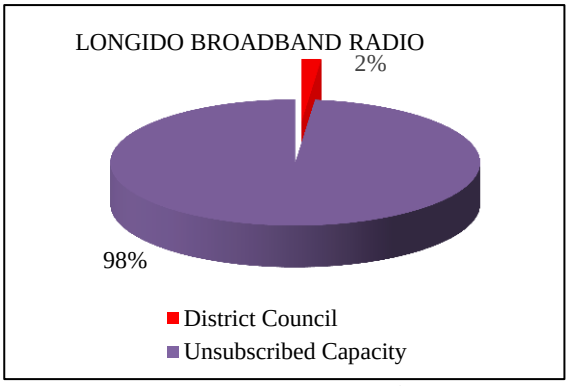

Figure 6. Bandwidth Capacity Utilization of Karatu Radio Link

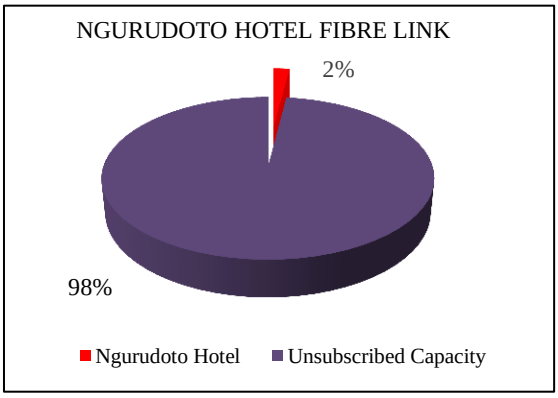

Figure 7. Bandwidth Capacity Utilization of Ngurudoto Radio Link

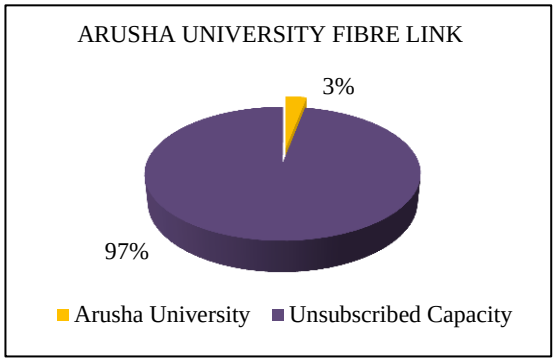

Figure 8. Bandwidth Capacity Utilization of NM-AIST Fibre Link.

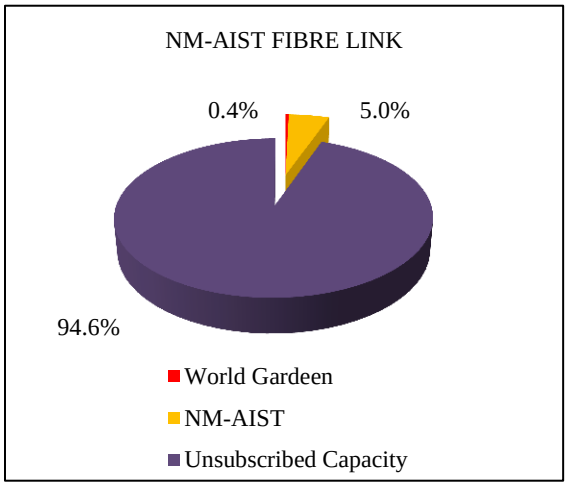

Figure 9. Bandwidth Capacity Utilization of Arusha University Link

5. Conclusion And Recommendations

In this paper, we have presented the status of broadband connectivity in rural areas the case of selected rural areas in Arusha, Tanzania and utilization of the same. In the reported utilization calculation, it is assumed that the subscribed capacity is fully used and dedicated to the respective users, which is different from reality. In this regard, the study has identified used and unused bandwidth capacity which indicates the possibility of accommodating even more users than the stated percentages. Furthermore, the study indicates that a significant amount of broadband capacity is in the vicinity of users who are yet to be connected to the global village and be part of it.

We recommend that all initiatives aiming at connecting unconnected communities should first consider the utilization of broadband links whose part of investment cost has already been paid for by anchor customers. This will bring down the cost of connecting prospective users and speed up the realization of the universal access.

Future work will present a model through which the unutilized capacity in rural areas of Arusha, and possibly other similar areas in Tanzania and other developing countries in general, can be exploited to bring ICT benefits to the respective societies.

References

[1] R. Schuman and M. Kende, "Lifting Barriers to Internet Development in Africa: Suggestions for Improving Connectivity," Analysys Mason Limited and The Internet Society (ISOC), 2013.

[2] S. Wyche and C. Steinfield, "Why don't farmers use cell phones to access market prices? technology affordances and barriers to market information services adoption in rural Kenya," *Inf. Technol. Dev.*, vol. 22, no. 2, pp. 320–333, 2016.

[3] F. Simba, L. Trojer, and Z. O. Yonah, "Sustainable Broadband Connectivity Model for Rural Areas of Tanzania," *Afr. J. Sci. Technol. Innov. Dev.*, vol. 4, no. 2, pp. 150–172, 2012.

[4] S. M. Pazi and C. Chatwin, "Assessing the economic benefits and challenges of Tanzania's National ICT Broadband Backbone (NICTBB)," *Int. J. Inf. Comput. Sci. IJICS*, vol. 2, no. 7, pp. 117–126, 2013.

[5] Halotel, "Halotel Home Page," 2017. [Online]. Available: http://halotel.co.tz/en/service/mobile/Halo-University-Pack. [Accessed: 24-Apr-2017].

[6] M. M. Mbarawa, "Towards a Broadband Ready Tanzania: Status, Projects, Future Plans," 2010.

[7] F. Simba, B. M. Mwinyiwiwa, E. M. Mjema, L. Trojer, and N. H. Mvungi, "Broadband Access Technologies for Rural Connectivity in Developing Countries," *Int. J. Res. Rev. Comput. Sci. IJRRCS*, vol. 2, no. 2, pp. 312–319, 2011.

[8] MCST, "The National ICT Back bone (NICTBB) project," 2012.

[9] A. M. Nungu, B. Pehrson, and N. Genesis, "Serengeti broadband," *Proc. Second ACM SIGCOMM Workshop Networked Syst. Dev. Reg. - NSDR 08*, pp. 37–37, 2008.

[10] J. S. Mtebe, "Exploring the Potential of Clouds to Facilitate the Adoption of Blended Learning in Tanzania," *Int. J. Educ. Res.*, vol. 1, no. 8, pp. 1–16, 2013.

[11] URT, "The National ICT Policy." 2016.

[12] INVESTOPEDIA, "Capacity Utilization Rate," 2016. [Online]. Available: http://www.investopedia.com/video/play/capacity-utilization-rate/. [Accessed: 27-Jun-2016].

[13] L. Qiao and P. Koutsakis, "Adaptive bandwidth reservation and scheduling for efficient wireless telemedicine traffic transmission," *IEEE Trans. Veh. Technol.*, vol. 60, no. 2, pp. 632–643, 2011.

[14] G. Mosha and G. Bea, "Barriers of using Internet Resources in Higher Learning Institutions: A Case of Mzumbe University in Morogoro Region in Tanzania," in *Information and Knowledge Management*, 2014, vol. 4, pp. 64–71.

[15] E. T. Lwoga, "Bridging the agricultural knowledge and information divide: The case of selected telecenters and rural radio in Tanzania," *Electron. J. Inf. Syst. Dev. Ctries.*, vol. 43, 2010.

[16] C. Milne, "Improving affordability of telecommunications: cross-fertilisation between the developed and the developing world," 2006.

[17] S. Shukla, V. Khare, S. Garg, and P. Sharma, "Comparative Study of 1G, 2G, 3G and 4G," *J. Eng. Comput. Appl. Sci.*, vol. 2, no. 4, pp. 55–63, 2013.

[18] A. Chavez, R. Littman-Quinn, K. Ndlovu, and C. L. Kovarik, "Using TV white space spectrum to practise telemedicine: A promising technology to enhance broadband internet connectivity within healthcare facilities in rural regions of developing countries," *J. Telemed. Telecare*, vol. 22, no. 4, pp. 260–263, 2016.

[19] J. Eduardo and G. Vargas, "Universal Broadband Access in Developing Countries – The Case of Bolivia," 2014.

[20] A. Nungu, T. Brown, and B. Pehrson, "Business model for developing world municipal broadband network-a case study," in *Global Information Infrastructure Symposium (GIIS), 2011*, 2011, pp. 1–7.

[21] M. Byanyuma, S. Kalolo, S. I. Mrutu, C. Nyakyi, and A. Sam, "Affordable Broadband Connectivity for Rural Areas -A Case Study of NM-AIST neighborhood," 2013.

[22] A. Hammond and J. Paul, "A New Model for Rural Connectivity," *World Resouces Institure*, no. May, 2006.

[23] J. R. Schneir and Y. Xiong, "A cost study of fixed broadband access networks for rural areas," *Telecommun. Policy*, vol. 40, no. 8, pp. 755–773, 2016.

[24] J. W. Weiss, D. J. Yates, and G. J. J. Gulati, "Affordable Broadband: Bridging the Global Digital Divide, a Social Justice Approach," in *System Sciences (HICSS), 2016 49th Hawaii International Conference on*, 2016, pp. 3848–3857.

[25] C. Lewis, "Universal Access and Service Interventions in South Africa: Best Practice, Poor Impact," Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 2663052, 2013.

[26] W. Briglauer, "The impact of regulation and competition on the adoption of fiber-based broadband services: recent evidence from the European union member states," *J. Regul. Econ.*, vol. 46, no. 1, pp. 51–79, 2014.

[27] T. Olwal, M. Masonta, L. Mfupe, and M. Mzyece, "Broadband ICT policies in Southern Africa: initiatives and dynamic spectrum regulation," in *IST-Africa Conference and Exhibition (IST-Africa), 2013*, 2013, pp. 1–8.

[28] TanzaniaInvest, "Vietnamese Mobile Operator Halotel Announces 90% Coverage Of Tanzania By End Of 2016 - TanzaniaInvest," 2016. [Online]. Available: http://www.tanzaniainvest.com/telecoms/vietnamese-telecom-operator-halotel-announces-3g-coverage-of-90-percent-in-tanzania-by-end-of-2016. [Accessed: 19-Oct-2017].

[29] T. Vodacom, "Vodacom Tanzania," *Vodacom Tanzania*, 2017. [Online]. Available: https://vodacom.co.tz/. [Accessed: 19-Oct-2017].

[30] A. B. Kowero, "Exploiting the Potentials of the National Information and Communication Technology Broadband Backbone (NICTBB) in Tanzania," Tanzania Country Level Knowledge Network (CLKNET), 2012.

[31] ITU, "Internet Users in 2012 as a Percentage of a Country's Population," *Int. Telecommun. Union*, 2012.

[32] ITU, "Measuring the Information Society," 2017.

[33] G. Naik, "Designing a sustainable business model for e-governance embedded rural telecentres (EGERT) in India," *IIMB Manag. Rev.*, vol. 23, no. 2, pp. 110–121, 2011.

[34] C. Mercer, "Telecentres and transformations: Modernizing Tanzania through the Internet," *Afr. Aff.*, vol. 105, no. 419, pp. 243–264, 2006.

[35] S. Wangwe, "A Study on the Application of ICT in Improving Livelihood of the Poor and in Supporting Growth in General," 2010.

[36] A. Nika, S. Dimopoulos, D. L. Johnson, and E. M. Belding, "Time-Shifting Traffic to Improve Utilization in Rural Area Networks," no. March 2011, p. 2012, 2012.

Ms. Mastidia Byanyuma holds a BSc. Degree in Electrical Engineering **(1999)** from the University of Dar es Salaam-Tanzania; and M.Sc. Degree in Telecommunication Engineering, an MSc. Degree in Finance (2011) University of Strathclyde, UK. Ms. Byanyuma is currently a Ph.D. student in the Department of Information Communication Science and Engineering at the Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania. She is also a Lecturer at the Institute of Finance Management, Faculty of Computing, Information Technology and Mathematics (FCIM), Dar es Salaam, Tanzania. Her research interests focus on; Using ICTs to connect the disadvantaged for their development especially the rural and urban-underserved areas, Mathematical Modelling and Resource Management for Optimum benefit for all.

Eng. Dr. Zaipuna O. Yonah MIET, MIEEE holds a B.Sc. degree (with Honors 1985) in Electrical Engineering from University of Dar es Salaam-Tanzania; and M.Sc. (1986) and Ph.D. (1994) Degrees in Computer-based Instrumentation and Control Engineering from the University of Saskatchewan, Saskatoon -Canada. In Tanzania, he is a Registered Consulting Engineer in ICTs. Yonah has over 32 years of practice. His work spans the academia, industry and policy-making fields. He is currently associated with The Nelson Mandela Institute of Science and Technology, Applied Engineering &ByteWorks (T) Ltd and the Institute of Electrical and Electronics (IEEE) Inc. He is one of the mentors and pioneers driving the national broadband agenda in Tanzania and EAC, SADC regions. He believes that ICTs, as tools for development, promise so much: interactivity, permanent availability, global reach, reduced per unit transaction costs, creates increased productivity and value, jobs and wealth, multiple sources of information and knowledge. Armed with such a belief, his current work aims at creating and delivering value through ICT enabled services in the shortest times possible. His research interests include: ICT4D, e-Government Services, Mobile and Web applications, Big Data, Data Mining, High-Performance Computing, high-capacity Broadband networks, Intelligent Instrumentation and Control Engineering and ICT enabled 21st Century Education delivery (ICT4E): Personalized, Facilitated, and Connected Learning.

Dr. Fatuma Simba received a Ph.D degree in 2012, awarded by both the University of Dar es Salaam (UDSM), Tanzania and Blekinge Institute of Technology (BTH), Sweden. She graduated her Master's degree majoring in Secure Internet Protocol Virtual Private Network (IPSec-VPN) Connectivity, in 2005 and a Bachelor of Science degree in Electronics Science and Communication, in 2001, both from the UDSM. Her research interest is on the connectivity technologies for broadband access networks. Within this area, she is particularly interested in the performance evaluation of broadband wireless networks in delivering multimedia contents for services such as eLearning. She is currently a lecturer at the Department of Computer Science and Engineering, College of Information and Communication Technologies (CoICT), UDSM, Tanzania.

Prof. Lena Trojeris a Professor in ICT and Gender Research (1999) at the Blekinge Institute of Technology, holds a PhD in analytical chemistry (1981) at the University of Lund, Sweden, a Pedagogic university degree in non-formal adult education (1988) at the University of Linköping, Sweden and a readership in Gender and Technology (1995) at Lulea University of Technology, Sweden. Her research interest is in ICT for Development, Innovation System for Development, Feminist Technoscience and Research Politics.