Community Networks in Kenya: Characteristics and Challenges

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Abstract. Community networks are set up by communities through pooling of resources. Such networks may also be initiated by third parties such as non-profit organizations (NPOs) or volunteers with involvement of the target community in a certain area. Municipalities can also roll out a community network by setting up free or inexpensive Internet access hotspots. Community networks are set up in order to bring affordable Internet connectivity to an area or to bring Internet connectivity to an area where there is no connectivity at all. Community networks in Kenya have been growing every year since 2015 when the first community network was founded. There are currently four community networks in Kenya. Despite the growth of community networks in Kenya, there is currently no existing critical analysis done on community networks in Kenya. This paper, hence, presents a study on community networks that are currently operating in Kenya. This paper presents the challenges currently hampering the growth of community networks in Kenya. This paper also provides possible solutions to those challenges and make some practical recommendations that can be adopted by community networks in Kenya. The paper further discusses the characteristics of community networks in Kenya and the critical success factors for a community network based on the experience of two community networks in Kenya. The applied methodology are qualitative exploratory research and desktop reviews.

Keywords: Community networks · Digital divide · Internet penetration · TunapandaNet · Lanet Umoja · Aheri · Dunia Moja

1 Introduction

Universal Internet access is among the top priorities in many countries and also a core pillar of the UN Sustainable Development Agenda. This is because Internet connectivity has the potential of bringing development. Access to affordable Internet stimulates economic growth, enabling startups to expand and bring new businesses to an area [1]. Access to the Internet is seen as a stepping stone to join the knowledge economy. People

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can access e-health, e-commerce, e-learning, e-government and e-banking through the Internet. Despite the critical importance of connectivity to the Internet, over four billion people worldwide still remain unconnected to the Internet despite the progress that has been made in rolling out of mobile telephony and data networks in many countries [2, p.].It is often assumed that the unconnected citizens will somehow get connected through the mobile broadband provided by the national telecommunication operators in a top-down manner. However, the reality is that not all national telecommunication operators find it economically viable to connect certain areas because of low revenue that arises due to low population density [3]. Affordability is also still a problem for some of those that are connected. In areas where the only connectivity available is via 2G/3G/4G by commercial national telecommunication operators, the low-income population in Africa that lives on less one US dollar a day cannot afford it. In order to connect the next two billion low-income people, especially in Africa where some people live on less than US$ 1 per day, the cost of broadband needs to be less than USD 4.50 per month [4].

In Kenya, there is quality and reliable international connectivity through submarine optical fiber cables. In addition to that, the national government has rolled out National Optical Fiber Backbone Infrastructure (NOFBI) that connects major towns and strategic public, social and learning institutions. Internet Service Providers (ISPs) have also rolled out fiber to connect major towns as well as individual homes and businesses. Three mobile network providers (Safaricom, Airtel and Telkom) have also rolled out their 2G, 3G and 4G networks across most parts of the country. However, despite all the efforts towards having broadband available to all Kenyans, there still exist areas where there is no Internet connectivity. In Kenya, Internet penetration stands at 30% according to the Kenya Integrated Household Budget Survey of 2016 [5]. This is below the global average of 40% [6, 7]. This arises because in rural areas where there is low population, ISPs are not interested in providing services by rolling out a last mile access network because the cost of rolling out such an infrastructure is high compared to the revenue they will get. The same problem applies to urban informal settlements because of the low-income population.

Despite the fact that there are many telecommunication operators and ISPs in some areas, some of the population in Kenya cannot afford the current broadband offerings. Other than the cellular network operators, traditional ISPs target the urban and wealthy citizens who can afford their services. In some rural areas in Kenya connectivity available is only through cellular networks but it is not affordable to low-income population. Kenya ranks number 37 out of 61 in Africa in terms of Internet affordability index in Africa [8].The top down approach by national telecommunication operators also results unaffordable connectivity because they are profit motivated and also because they operate in an monopolistic or oligopolistic manner [9]. Oligopoly or monopoly arise because not many companies have the finances to roll out a network infrastructure across the country and also pay high initial license fees as well as spectrum fees.

Alternate connectivity models are being considered in order to connect the unconnected or provide affordable connectivity due to the increased awareness of the shortcomings of lack of availability or unaffordability of broadband offerings by the national mobile telecommunication operator model [6]. Community networks are currently being

embraced as one of the solutions to bridge the digital divide that arises due to the shortcomings of the national telecommunication operator model [4]. Community networks are networks built by citizens themselves through pooling of their own efforts and resources such as finances, equipment and infrastructure. Community networks can also be initiated by third parties such as volunteers or non-profit organizations who want to bring new or affordable connectivity to an area. Municipalities can also set up a community network especially in towns or cities by providing Internet hotspots. People can also offer their Internet connection to any other person by setting their network connection as a hotspot. If people do this, there will be more democratization of the telecommunication market that can result in cheaper broadband [10].

Community networks are currently emerging in Kenya in order to address the existing digital divide. There exists currently four community networks in Kenya that address the connectivity gaps left by national telecommunication operators and other ISPs. Despite the growth of community networks in Kenya, currently there is no existing comprehensive study done on existing community networks in Kenya to the best of authors' knowledge. The aim of this paper, therefore, is to present existing community networks in Kenya, the challenges hampering the growth of community networks as a means of bridging the digital divide in Kenya and possible solutions to those challenges. This paper also presents the characteristics of community networks in Kenya and the critical success factors for community networks in Kenya.

2 Literature Review

2.1 Internet Penetration and Affordability in Kenya

Kenya is one of the leading countries in terms of telecommunication and Internet in Africa. Kenya has been referred to as "Silicon Savanna". Kenya is the country that pioneered M-Pesa mobile money transfer service. Currently, almost anyone in Kenya has a mobile phone that makes use of M-Pesa. The percentage of households with a computer is 9.5% and mobile phone penetration stood at 69% [7] as at 2016. 27 million people out of a total population 45 million own a mobile phone in Kenya.

According to Kenya Integrated Household Budget Survey (2015–1016), there are more people with mobiles phones and computers in urban areas 18.5% compared to rural areas (4.5%). The same survey also shows that the households Internet penetration in Kenya stood at 30% per cent in 2016. In terms of urban and rural connectivity, the study showed that the percentage of households without Internet connection was 70% and 53% in rural and urban areas. Although the urban areas fare much better in terms of Internet penetration rate compared to rural areas, there also exists digital divide within urban areas. Low-income population in informal settlements lack computers and Internet access in Kenya. A study in one of the urban informal settlements shows that only 8% of the households surveyed have access to the Internet [13]. The same study also showed only 4% had access to a computer but 80% of the respondents had mobile phones. Only 20% could access the Internet using their phones out of the 80% who had access to a mobile phone. These statistics show that in Kenya, there are still some areas with no Internet connectivity. The COVID 19 pandemic showed the consequences of digital divide. During the COVID 19 pandemic, most education institutions in Kenya

could not conduct online learning because of lack of connectivity or lack of affordable connectivity.

2.2 Community Networks as a Solution to the Digital Divide

Community networks are continuing to emerge because of the failures of the traditional way of providing connectivity through national telecommunication operators and other ISPs. Community networks are "do it yourself networks" built by people within a particular community or through assistance by third parties. Community networks are set up in order to provide connectivity for the community members in areas where there is no existing connectivity at all or to provide cheaper alternative connectivity to that which is provided by ISPs [14, 15, 16]. Connectivity provided by community networks is cheaper because the prices are determined by the community since a community network operates based on the concept of self-determination [17]. Externally initiated networks that are concerned with providing affordable connectivity in underserved areas or new connectivity in unserved areas are more common in Africa [14] than those that are initiated from within the community.

A community network can also be set up by municipalities [18]. In such a community network a municipality rolls out access points (APs) in public spaces. Internet access could be free or users may be required to pay a small subsidized fee. The municipality will usually enter into an agreement with a private company to roll out the network and provide internet access. If there will be a fee to be charged, it will have to be approved by the municipality.

The set-up of Guifi.net forced telecommunication companies to lower their prices [19]. Other examples of successful wireless community networks initiated by citizens are Athens Wireless in Greece, Ninux in Italy, Sarantaporo.gr in Greece, Wireless Leiden in Netherlands, B4RN fiber network in UK and Consume in UK [10, 20]. Examples of externally initiated networks are Zenzeleni in South Africa [21] and Wireless for Communities in India [15]. There are community networks initiated by municipalities in London and Philadelphia [18].

2.3 Studies on Community Networks in Africa

A study was done on community networks in Africa by [14, 22]. The study looked at the reasons behind establishment of community networks and the barriers facing community networks in Africa. The study further provides a map of all the then existing community networks in Africa and also makes some recommendations. However, this study has a focus on all community networks in Africa. The articles were written in 2017 and hence lacks the recent developments on community networks in Kenya. There is also another brief article on community networks in Africa [23]. The paper, however, lack in having a comprehensive study on community networks in Kenya. There is an existing article on TunapandaNET community network [24]. However, the article focuses only on one community network in Kenya and lacks details about the challenges and critical success factors for community networks.

3 Methodology

The methodology applied are qualitative exploratory research and desktop reviews. This qualitative exploratory research paper incorporated one-on-one interviews with two of the four community networks in Kenya coded as center1 and centre2, with their representatives coded as participant1 and participant2. The two Community Network choices were based on management availability to furnish this research with rich insights that would lead to understanding the underlying issues and eventually provide sustainable and frugal solutions. Furthermore, the choice of methodology imbues the research to produce quality, credible and reliable research findings. It is more case-oriented than variable-oriented; therefore, the richness of an in-depth description of a phenomenon is anchored on a real-life scenario [11]. The participants consented to record the sessions, which the researchers later transcribed and analysed using Atlas.ti (a qualitative CAQDAS) following the data analysis steps of thematic analysis by Braun & Clarke [12]. Desktop reviews were done on relevant documents and websites on community networks in Kenya and Africa in general.

4 Results and Discussion

This section presents the results of the qualitative exploratory research that one-on-one interviews with two of the four community networks and desktop reviews.

4.1 Case Studies Existing Community Networks in Kenya

TunapandaNET Community Network

TunapandaNET is an urban community wireless network in Kibera, Nairobi [24]. The network was initiated by Tunapanda Institute in 2015. Tunapanda Institute is a non-profit organization that conducts training on technology, multimedia design and business in very low-income areas within East Africa. Tunapanda Institute provides training to youth in order to equip them with digital literacy and other skills to solve local and global issues. The network targets low-income urban youth and women who reside in the slum in Kibera. The slum residents do not afford Internet services provided by ISPs in the area because of their low-income. This hinders them from using the Internet for socio-economic empowerment.

Four nodes serving two schools with 1500 students and a youth center serving 300 youth were rolled out in 2017 through partnership Internet Society (ISOC), International Center for Theoretical Physics (Italy) and Rhinotivity (Denmark). In 2018 through funding from ISOC, the network was scaled up to provide connectivity to seven more schools, two more youth centers and one women center. The network covers four out of 10 villages in Kibera. The network covers a range of 20 km. The technology used to roll out the network is Wi-Fi (IEEE 802.11). The network makes use of both 2.4 GHz and 5.8 GHz spectrum. TunapandaNET currently relies on grants to pay for network sustenance costs including Internet bandwidth.

Tunapanda Institute receives over 300 applications but it can only train 30 youth per cohort. The network was created so that youth who are not successful in their application

can take courses on Tunapanda's e-learning platform. The network provides trainees with offline digital education content that can be accessed through schools, youth centers and women centers in Kibera.

Lanet Umoja Community Network

The community network is located in Lanet Umoja, Nakuru North Sub County, Nakuru County [25]. It is a rural-urban community network that was initiated by a third party. Initial funding came from USAID but recently they also received a grant from ISOC. The community network targets 14,200 households with a total population of about 50,000. The implementation of the network started in 2019. At the end of the network implementation, there will be Internet connectivity to five public schools, hospitals.

There exists connectivity to the community in the area through 2G/3G/4G but it is expensive to the low-income population, schools and other institutions such as hospitals in the area. The community network aims to meet the need for affordable connectivity in the area by providing connectivity that is as low as $2 a month instead of an approximate cost of $2 a day [26]. The payments are used to meet network running costs including payment of bandwidth.

The network uses Wi-Fi point to point links as backhaul to connect to various nodes. Access networks also use Wi-F. The technology used to roll out the network is IEEE 802.11 because of the license exempt spectrum band. There are plans to make use of TV White Spaces because of its good propagation characteristics.

Aheri

Aheri stands for Africa Higher Education Research Institute. It was started as a project under an NGO known as Community Initiative Support Services (CISS). Aheri CN was started in the year 2020 with the aim of strengthening the higher education ecosystem. The CN provides connectivity to technical and vocational training institutions and also community-based organizations. Currently, the network has four nodes around Kisumu City in the following areas of Nyalenda, Dunga Beach, Akala, Nginya and Omuga where CISS community partners are based. Nyalenda and Ogunga are urban informal settlements found in Kisumu. The node in Kisumu connects 100 businesses, home users, schools and various community organizations. In Omuga, Homa Bay County, Aheri has partnered with a local polytechnic called Omuga Technical and Professional Institute. The CN provides connectivity to about 500 students. The Aheri CN provides connectivity which is cheaper than that provided by other ISPs and telecommunications companies in the area. The packages start from $15which is almost half the price that ISPs in the area charge.

Dunia Moja

Dunia Moja is a CN that is in Kilifi County, the coastal area of Kenya. The CN was initiated by a social enterprise known as Lamuka Hub [27]. The aim of Lamuka Hub and Dunia Moja CN is to reduce the digital divide through digital literacy training and also through provision of connectivity. In the year 2020, the CN provided connectivity to three schools through a pilot project. The CN is in partnership with vocational training centres.

4.2 Characteristics of Community Networks in Kenya

Various characteristics were identified through thematic analysis following a discussion with two out of the four community networks. They were coded as community needs, digital divide and digital illiteracy, and partners. This section expounds on these themes.

Digital Divide and Digital Illiteracy Among the Population Served
Considering the relatively low cost of connectivity provided by CNs compared to the national ISPs, the community dwellers get to access different services through the Internet. The different services through this connection include entertainment, learning (online and research) and working purposes. Although the connectivity provided by CNs has drastically reduced the digital divide, digital illiteracy is still high in the communities served by CNs. The community networks in Kenya, therefore, have noticed a need for more training to educate more on Internet usage so that the residents are able to make use of the services and opportunities that the Internet provides.

Partnerships
Community networks cannot exist in a silo and therefore need to collaborate primarily for sustainability purposes. The elaboration of the international and local partnerships gets to shed light on how CN's operate and the areas the management of the CN's need to constantly be thinking of for continual growth, especially on financial sustainability and policy improvements in closing up the digital divide gap. For the community networks to operate in a community, they have to establish local partners who can be either the government, parent companies (for the case of AHERI), Institutions (Universities and Technical and Vocational Education and Training), community centers, Community Based Organizations, Health centers, Indigenous communities, religious centers, KENET, etc. All these local partners have a role in successfully setting up a community network.

In Aheri CN various people living in that community at times beyond gather to learn various skills in community centers which enlighten them on how they can carry out their day-to-day businesses, involving themselves in table banking. In addition, these prime groups can learn from digital platforms how to expand their skills and even acquire more skills to better their businesses and the so called chamas (Swahili word for co-operatives).

Focus on Community Needs
Community needs in this context identify the desires expressed by the different social groups in a community to ensure the propagation of needful usage of the services provided by the community networks to the community. In the case of TunapandaNet, two brothers from the United States saw that there was a need for digital literacy and this prompted them to work with an organization in Kibera to provide the digital content to the community. The community network provides unified content, especially for local schools, through a Learning Management System (LMS). This allows the distribution of the same insights on learning of computers to all the local schools, enabling the slow learners to learn from the fast learners even if they are in different schools.

Women Involvement
One characteristic of community networks is participation of women in the founding

and running of community networks. Two of four community networks ((Lanet Umoja and Tunapanda) out) in Kenya were founded by women.

4.3 Covid-19, Connectivity and Community Networks in Kenya

In the Covid-19 era, much had to re-adjust due to lockdowns in various countries, curbing the virus's prevalence. Local and international travel restrictions, work hazard controls and closure of facilities such as churches, schools, restaurants and parks were implemented. These adjustments followed an increased uptake of usage of technologies for continuity. People started working from home more, and online classes increased uptake as more students followed online tutorials to keep themselves abreast on subjects they needed to improve on. The community networks also felt a positive growth impact during this period because there were more requests for connection during that period. Following the closure of schools, the community networks, the communities that stayed within a region served by community networks started to appreciate the services offered by the various CN's near them because children were able to continue with their education while at home. This shows reduced community resistance. Unlike the pre-COVID period where CNs were pleading with partners and issuing incentives was common, the communities made requests for connectivity instead. In the Covid-19 era, new partners volunteered to be custodians of the devices as the CN's increased their hotspot areas. The Covid-19 unprecedented times have given good leverage to technology usage and more so for Internet penetration as it ensures that activities such as school and work-related issues continue outside a brick and mortar environment.

4.4 Challenges Hampering Community Networks in Kenya and Solutions

With milestones that the CN's have made, there has been a significant change with their tagline, "Connecting the unconnected". This, though, has not been achieved with no challenges. The challenges vary from partnerships, characteristics of the society and business models for sustainability purposes. In this section, the paper discusses the pain points and proposes solutions adaptable for generalization purposes.

Congested Spectrum Band

The four CNs in Kenya make use of the unlicensed WiFi band (2.4 GHz and 5 GHz) both for backhaul and hotspots. This band is prone to interference because, being unlicensed, there is extensive use especially in urban areas and this affects network quality of service and, as a consequence, data rates.

CNs can make use of licensed spectrum but the high cost does not make it possible currently because the currently existing CNs in Kenya have challenges with a sustainable business model and hence they do not have enough funds to pay for licensed spectrum. We sought to find out whether they have considered the use of TV white spaces. Aheri said that they are considering it but mentioned equipment cost and human resource as some of the challenges.

Lack of Skilled Human Resource

Areas in Africa, whether rural or urban, that can benefit most from community networks often lack trained personnel with specific skills to start and sustain a community network

in Africa [2]. Lanet Umoja had to train recent graduates on wireless networking using Wi-Fi in order to help in rolling out and maintaining the network [26]. TunapandaNET also had to conduct training. The two community networks in Kenya currently rely on interns, volunteer staff or part time staff who may lack motivation and who will move to other organizations that will give them a good compensation for their skills. This has also been the case for TunapandaNET community network [24]. Reliance on part time or volunteer staff arises because the two community networks are currently not for profit. There is a need to have a sustainability model so as to attract professionals who will work full time for community networks for a pay.

Lack of Affordable Backhaul

Availability and affordability of backhaul also affects the growth of community networks in Kenya. Communication Authority of Kenya (CAK) charges US $100 for every radio device used for point-to-point wireless links in the unlicensed spectrum (Communication Authority of Kenya 2018b). This includes Wi-Fi point to point links radios in the 5GHz spectrum that is useful for backhaul within a community network. This is an extra cost to a community network. Backhaul to the Internet can be achieved through fiber or satellite. However, in some rural areas of Kenya, fiber, which is a relatively cheaper backhaul option, is not available as can be seen from Fig. 1. Satellite, on the other hand, is available in remote rural areas but it is a very expensive option.

Regulatory and Policy Barriers

At the time of conducting the interviews, there was no regulatory framework for CNs in Kenya. The existing policies on telecommunication did not previously adequately address the unique needs of community networks. CNs in Kenya have been set up with the noble intention of connecting the unconnected and hence they are not profit motivated. It is also a problem faced by many other community networks in Africa [14] and other countries worldwide [10, 15].

In the year 2021 a regulatory framework for community networks in Kenya was developed [27]. The previously existing regulatory framework for telecommunication in Kenya, like most other countries, focused on broadband provision by large scale profit motivated operators. The following were the requirements to get a telecommunication license from CAK [28]:

- The entity should be registered in Kenya as a company, sole proprietor or partnership.
- Have a duly registered office and permanent premises in Kenya.
- Provide details of shareholders and directors.
- Issue at least 20% of its shares to Kenyans on or before the end of three years after receiving a license.
- Provide evidence of compliance with tax requirement.
- Pay license fees according to tier of operation. Tier 1 license is a license for nationwide operation. Tier 2 license is for regional operation. Tier 3 is for operation within a county. The initial operational license fees are US $150,000 for tier 1 and tier 2 license. The initial operational license fees for tier 3 license are US $2000. There are also annual operation license fees of at least US $1600 for tier 3 license.

As can be seen from the above list, the licensing requirements as per the previous regulatory framework did not cater for the needs of community networks. The previously

existing licensing framework for telecommunication services providers in Kenya, like many other countries, was intended for large scale companies [29, 30].The assumption was that every potential broadband connectivity provider has the resources and time of a legal department of a large telecommunication company to fill detailed application forms and reporting requirements. This may not be the case for community networks, especially in Africa. Community networks may also not afford the huge initial license fees.

A special license is necessary because community networks operate in a different manner compared to the conventional networks under the control of ISPs. This is because community networks may not always be for profit and the services may be for the community only. They may not operate as a sole proprietorship, partnership or a limited company. There was, therefore, a need for a different simplified license different from a license that is issued to conventional ISPs in order to cater for the needs of community networks. A simplified and more suitable licensing framework for community networks in Kenya was developed in the year 2021 [27]. In the licensing framework, the license fees for CNs have been reduced and the licensing process is now easier.

Lack of Awareness

In Africa, generally, there is a lack of awareness among government entities, citizens, non-profit organizations and other community-based organizations and policy makers of the potential of community networks (Rey-Moreno 2017a). There are only four community networks in Kenya. This is because there is a lack of awareness in Kenya about the role that community networks can play in bridging the digital divide.

Government policy documents make no mention of community networks. Although there is a mention of community networks in the latest broadband strategy for the country [31], it only focuses on community access networks provided by county governments and not citizen initiated networks. Citizens are also not aware that they can pool their own resources (finances, effort, time, infrastructure and equipment) to create their own network infrastructure that will provide them with cheaper connectivity or bring new connectivity where there is no connectivity at all. Some citizens are satisfied as long as they receive some form of connectivity even if it is not affordable. Community based organizations are also not aware that they can work alongside community members to bring new connectivity or affordable connectivity to an area.

Community Resistance

Pre-Covid 19, the CN's initial entry to the communities (the first pilot projects) were marred with resistance. This was primarily because of a lack of knowledge of the importance of such infrastructure and services offered. In addition, the impoverished lives would pounce on any opportunity to get money since most of them are unemployed and are always in the community during the day; this time reference relates to the high rates of crime conducted at the night time. This resistance, for example, saw the CN's in such settlements incurring more than they had budgeted for as the youths in the area demanded "unworked for money" (can be translated as a bribe) to allow the digging process for fiber installation.

However, it is a relief for now as the resistance has since reduced due to the unprecedented times of Covid-19. In Covid-19 times, the majority saw and still are seeing the

impact of the Internet on society, especially in the education sector. Unlike the earlier times where the CN's had to plead to be heard by the society, now they are receiving installation requests. However, they are careful to ensure that the community is well trained and sense of ownership given to them so as to reduce resistance.

Business Model and Sustainability

Sustainability aspect can be classified into financial sustainability, partner sustainability and infrastructure sustainability. Out of these three, the major hurdle for the CN's is financial sustainability. The CN's in Kenya are having challenges in establishing a business model that enables sustainability. They agree that they need to cut down on the dependency of donors as this might not suffice in the near future considering the growing demand and the different expectations from the same donors. Donor dependence arise because the CNs operate in low-income areas. In order to address the challenge of financial sustainability Aheri charges some fee for their Internet connection services. They charge between Ksh 1500 ($15) to Ksh 2000 ($20). The fee charged is almost half that which is charges by the ISPs in the area. In terms of partner sustainability, the CN's source for different partners such as schools, churches, youth groups and women groups to enable them to sustain their business models.

Operational Challenges

The CN's operational challenges are generalized and currently rely on unsustainable sources like donor dependency. Each of the operational challenges are discussed below.

Partner Shift

CN's in Kenya are marred with issues of partner shifts, therefore, leaving them with a significant loss of infrastructural devices to theft as there is no ownership uptake. To avoid the loss, the community networks opt for permanent residency of established religious centers and land-titled indigenous communities within the informal settlements.

Capacity Building and Digital Literacy Training Costs

Capacity building for the users, especially the infrastructural responsibilities, can sometimes be disheartening considering the non-permanency of partners. This has prompted the transfer of costs to the end-users for sustainability purposes; the cost is tentatively low for their affordability.

Digital literacy is another challenge as intensive training is to be conducted, considering most users are first time users of computers and the Internet. This means human resources and time compensation for the trainers and eventual training of the trainers of trainers (ToT) who will be helpful as they are part of the society; Hence this facilitates continual growth without the CN's involvement in training.

Capacity building and digital literacy training are paramount to a society that is intentional in building and learning through the evolving technologies. This, therefore, demands a sustainable solution that will see the continual training for more new users as the burden of training is shifted from the CN's to the society's champions.

4.5 Critical Success Factors for Community Networks

This section presents some critical success factors for community that were received from the interviews.

Community Ownership, Involvement and Partnership
One very important critical success factor for a community network is involvement and partnership with the community so that the community that is being served by the CN feel that they co-own the community network.

Understanding of the Community
An understanding of the community is also critical success factor for a community network. Aheri made an effort to understand the disposable income of the community they serve before they could decide on the charges for use of their CN connectivity.

Business Model and Plan
One other critical success factor that was mentioned was having a business model and plan. Costs such bandwidth, personnel, power, and all these have to be captured through a business plan. CNs also have to come up with income generating activities in order to ensure sustainability of the CN.

Technical Knowledge
Technical knowledge and participation in research were also mentioned as critical success factor for a CN.

5 Recommendations

The CNs have proposed challenges to some of the solutions. This section presents other possible solutions to some of the challenges.

Recommendations on Spectrum
TV White Spaces and Dynamic Spectrum Access
In order to address the challenge of congested spectrum band, the CNs should consider the use of TV white spaces now that a regulatory framework has been developed for the use technology in Kenya. Dynamic spectrum access will alleviate the artificial spectrum shortage that arises due to the fixed spectrum assignment that requires payment of huge spectrum fees. It will also significantly bring down spectrum fees. This will suit community networks because they may not have enough funds at their disposal like commercial ISPs. TV white spaces are more suitable for community networks set up in rural areas compared to the Wi-Fi frequencies (2.4 GHz and 5GHz) because the spectrum in those frequency bands have good propagation characteristics [32]. TV white spaces can cover a longer range and can penetrate obstacles such as vegetation. A network set up using TV white spaces will require less base stations compared to WiFi. TV white spaces can also be used by CNs as an alternative and cheaper option for backhaul. This is because TV white spaces can operate in both line of sight and non-line of sight.

Spectrum Secondary Markets
Primary spectrum licensees that may not be able to provide broadband in certain unserved or unserved rural areas can lease spectrum to community network operators at a fee affordable to community network operators [29]. Primary licensees may lack economic incentive to roll out a network in such areas. Spectrum secondary markets means a primary licensee can lease out (through a sub-license) the spectrum for which they have license to another entity. Sub-licensing has been applied in Rwanda [33]. Vanu Rwanda was assigned spectrum but it is partnering with Airtel Rwanda to reach out to unserved and underserved areas. Vanu Rwanda has plans to roll out 376 sites in order to reach out to 1 million people. Airtel Rwanda, as the service provider partner, provides the customers to the network. In additional to rolling out the infrastructure Vanu also cover some of the operational expenditure. Airtel gets a share of the revenue for providing customers and being the service provider on the infrastructure rolled out by Vanu.

Another alternative is for community network operators to partner with primary licensees to roll out a network in unserved or unserved rural areas at a reasonable profit to the primary licensee but ensuring that the network is affordable to the community [29]. Open Cellular (that is owned by Facebook) has partnered with some operators in Pakistan, Indonesia, Iraq and Philippines to develop community based cellular networks in unserved and underserved areas in order to bridge the digital divide.

Exemption from Tax and Other Levies
Exemption from tax and other levies is necessary so as to reduce capital and running expenditure for community network operators, especially those that are not for profit. This will also address the challenge of lack of funds. Such exemption will make connectivity provided by community networks affordable. In order to reduce the initial cost of network roll out, equipment to be used to set up a community network should be made tax exempt. Tax incentives can also be given to organizations who offer affordable connectivity in rural areas or new connectivity in an unserved area in order to encourage them to roll out community networks in such areas. This can include exemption from payment of revenue taxes. Levies that can be charged to community networks such as fees per mast and device installed and contributions to universal service funds, among others, can also be exempted from community network operators.

Availing of Universal Service Fund and Other Funds for Community Networks
One of the biggest barriers to roll out community networks is lack of funds. In order to spur roll out of community networks, funds should be made available for community networks. A potential source of funds for community networks is the Universal Service Fund (USF). In the current framework on the use of USF in Kenya [34], community broadband networks are recognized as potential beneficiaries of the universal service fund. However, the framework considers contracting operators to roll out a community network. The framework should also consider non-profit organizations and other grassroots-based organizations such as self-help groups or other community groups as organizations or entities that can be awarded some funds from USF in order to roll out a community network. Other possible sources of funds for community networks are low interest loans, grant programs or public private partnerships. For example, United States

Connect Program, through grants, helps funds community networks in rural areas that are not served by ISPs [29].

6 Conclusion

In this paper, community networks as a solution divide in Kenya, existing community networks in Kenya, characteristics of CNs in Kenya, challenges hampering the growth of CNs, solutions to the challenges by the CNs themselves and recommended solutions have been presented. Future work will include study on the impact of development of a regulatory framework for community networks in Kenya and possible shortcomings of the framework. Study on development of low-cost hardware such as routers for community networks is another future possible study.

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