Community-led Connectivity

Assessing the potential of Community Network Models in the context of forced displacement in East Africa

Digital Access, Inclusion and Participation

UNHCR
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APC is an international network of civil society organisations founded in 1990 dedicated to empowering and supporting people working for peace, human rights, development and protection of the environment, through the strategic use of information and communication technologies (ICTs). We work to build a world in which all people have easy, equal and affordable access to the creative potential of ICTs to improve their lives and create more democratic and egalitarian societies.

About this report

This report has been commissioned by UNHCR Innovation Service as part of the Digital Access, Inclusion and Participation programme. Evolving from the Service's work on Connectivity for Refugees, this report aims to further examine frameworks for extending access to connectivity out to refugees and their hosting communities. In order to support community self-reliance, UNHCR often seeks to leverage market-based approaches to telecommunications services, and principally the inclusion of refugees in national frameworks and regulation to facilitate this. The impetus for this report is two-fold, firstly the tendency for market failure to occur when attempting to support last-mile connectivity provision, often where significant numbers of refugees are hosted, particularly in sub-Saharan Africa. Secondly, in the delivery of communications services in refugee hosting areas, the skills and capacities of the refugee / host community are often under-utilised. This is not only a missed opportunity for refugee engagement but the resultant economic benefits of connectivity provision are often little felt inside the community. By exploring the potential of community-based approaches to provision of connectivity services, UNHCR is seeking to not only explore opportunities for extending coverage into current connectivity 'black spots', but also to further ownership, knowledge and skills pertaining to connectivity services within the refugee and hosting community, and potentially bring extended economic benefit.

Executive Summary

1. The Potential for Community Networks in Areas of Forced Displacement

Only about half the world's population has access to a communication network, and national telecom operators face increasing difficulties in reaching the remaining unconnected, who mainly live in remote, or sparsely populated, low-income areas. Globally, growth in new users is slowing and for many, network-use continues to be constrained by affordability issues. Similarly, 20% of refugees in rural areas live without any form of connectivity, and even where there is coverage, services are often not affordable - refugees can often spend up to a third of their income on being connected. As a result there is greater recognition that alternative strategies are needed to meet needs for affordable communications infrastructure.

One approach that is attracting increased attention is local ownership and management of services which leverage new low-cost electronic networking equipment. This has resulted in the emergence of growing numbers of small-scale public networks based on Wi-Fi, while others provide GSM/LTE mobile services or even fiber connections. These local initiatives are usually called "community networks" and are now operating in at least 25 developing countries, although their numbers are still relatively small due to limited awareness of new opportunities to self-provide communications infrastructure, and also because of the regulatory barriers and human capacity constraints that are present.[1]

While knowledge of the potential for community networks is still relatively low, especially in forced displacement contexts, many of their features suggest that they can be particularly effective at addressing their connectivity needs. In particular, levels of adoption may be higher than in commercial networks because they are usually more affordable, being based on cost-recovery rather than on maximizing profit. Community networks may also have specific social objectives such as addressing the exclusion of women and other marginalised groups, which can improve the potential to ensure inclusion of all members of the community, rather than only those with the ability to pay.

Addressing connectivity issues is one of the pillars of UNHCR's current strategic plan, aiming to support better infrastructure in the many areas of forced displacement that lack affordable communications access. Aside from meeting refugee needs for basic communications, UNHCR's objectives in this area also include helping to support education, health and livelihood development through better Internet access. In this respect community networks may play an important role in improving connectivity for refugees because they often focus on supporting excluded groups who are usually located in more remote areas without access to traditional infrastructure. Similarly, community networks can be designed to support the needs of the specific population groups that are often more commonly present in refugee communities, such as the high proportion of

1 See: https://www.giswatch.org/community-networks and for detailed information on the 16 community networks in developing countries which are frequently referenced in this UNHCR report see: https://www.apc.org/en/pubs/community-networks-case-studies

women and youth. The additional potential benefits to community-based infrastructure deployment that may be particularly appropriate in forced displacement include:

1. Local control over how the network is operated and the types of content that are provided
2. Creation of local opportunities for jobs and fostering entrepreneurship
3. Retention of more funds within the community resulting from the low usage costs and the income generated by residents working to support the network
4. Fostering a sense of agency within the community which can amplify their sense of capability in being able to help to improve the quality of life of the community members.

On the other hand there may also be difficulties faced by community networks in areas of forced displacement. It appears that community networks have emerged more strongly where there are close-knit social structures with a culture of self-reliance. This may not be the case where communities include recent or transient refugee arrivals. Similarly, community networks can take considerable time to develop, while there may be less permanence in forced displacement areas. There are also as yet few alternatives to national mobile networks for providing electronic cash transfers and other digital financial services required by refugees.

Considering that community networks are a relatively new phenomenon in developing countries generally, and there is little experience of their dynamics in forced displacement contexts, in order to gain more experience and assess their applicability, one or more trial projects in East Africa could be implemented to test their applicability. This report provides a guide to defining potential projects and interventions in this area that could be supported by UNHCR.

2. Community Network Technologies

When low-cost Wi-Fi routers using license-exempt radio frequencies emerged in the early 2000s, many local communities set up their own networks to split the cost of broadband connections, improve network performance, and to share access to local online information servers. Some Wi-Fi-based community networks have thousands of members and have grown with mesh Wi-Fi, fibre and long distance microwave connections.

Innovation in cellular networking has similarly resulted in the emergence of mobile community networks based on new low-power GSM base station (BTS) equipment which now costs as little as USD 1 500. Deployed by communities in Brazil, Colombia, Indonesia, Mexico, and the DRC, these low-cost/low-power mobile systems are also being used by some national commercial operators to extend their coverage, and by specialized commercial wholesale operators.

Software-defined radio, which allows dynamic spectrum assignment, also often known as TV White Space (TVWS) technologies is now also attracting attention. Sharing the lower frequency UHF radio bands, these systems are important for providing long-distance links and upstream capacity in non-line-of-sight situations, such as through hills and the forest vegetation.

3. Policy and Regulatory Issues

Despite their potential for addressing connectivity needs there are still relatively few community networks in developing countries. Although there is a lack of awareness, the primary constraint is the lack of conducive regulatory environments in most countries. License fees and reporting requirements are usually too onerous for small networks, although a few developing countries have adopted more permissive licensing frameworks which include provisions for community operators, such as Argentina, Brazil and recently, Uganda. In addition, lack of infrastructure sharing and interconnection regulations means that access to the masts and national backbones of operators for upstream links is often not cost effective, resulting in unsustainable services.

For mobile networks the key barrier is that access to the radio spectrum bands is restricted. Often the GSM bands are already all allocated to the existing operators, and there is no provision for their re-use in rural areas that are unoccupied by the spectrum licensee. Similarly the newer LTE bands are either not yet assigned for mobile applications (used by TV broadcasting) or only available at costs that are unaffordable for small scale networks. As a result, although temporary use of mobile spectrum by community networks has been granted in some countries, Mexico is currently the only nation where spectrum has been formally assigned on a more permanent basis to community networks. In the other countries, community networks have been allowed to trial the use of mobile spectrum on a test license basis in areas where the national commercial networks are not present.

Similarly, although TVWS licensing frameworks have been recently adopted in the US, the UK and a number of other developed countries, despite the technology's potential in the global South, only a few developing countries such as South Africa, Uganda and Ghana have so far fully authorized the use of TVWS[2] and a few have issued draft guidelines for public consultation (Nigeria[3] and Kenya[4]).

4. Connectivity Services In Forced Displacement Contexts

The communications infrastructure services that would likely be required in forced displacement settings can be grouped into the four types listed below. Ideally all four types would be available in a single location, however depending on regulatory constraints and the specific local conditions, it might only be possible to establish one or more of these services, at least in the initial phases of the initiative.

2 https://www.icasa.org.za/legislation-and-regulations/regulations-on-the-use-of-television-white-spaces-2018 https://www.ucc.co.ug/wp-content/uploads/2017/09/UCC-TVWS-standards.pdf https://manypossibilities.net/2018/06/an-african-tv-white-space-strategy https://www.nca.org.gh/assets/Uploads/Guidelines-for-TVWS-Data-Services.pd
3 https://ncc.gov.ng/docman-main/legal-regulatory/guidelines/draft-guidelines/876-draft-guidelines-on-the-use-of-television-white-spaces-2019/file
4 https://ca.go.ke/public-consultation-on-the-draft-dynamic-spectrum-access-framework-for-authorisation-of-the-use-of-tv-white-spaces

- **Public Wi-Fi hotspots** can be installed in publicly accessible locations such as a library, a community centre or a park. On a per-user basis this type of service is usually the least costly to deploy because the equipment and operating costs are shared amongst the maximal number of people.
- **Private Wi-Fi hotspots** complement the use of public hotspots, and are usually installed in homes, but also potentially in businesses or NGO offices. For those that can afford them, these support the use of less portable and more energy consuming access devices, such as desktop computers with large screens, TV sets, and printers or other peripherals.
- **Public access centres** have long been used to address limited Internet access and lack of availability of personal access devices. Although more costly, they are needed to allow use of more powerful and diverse types of equipment (e.g big screens, printers, scanners etc), and also to obtain guidance or training. In addition they can also provide public Wi-Fi hotspots, and foster entrepreneur development such as in the provision of electric power for small businesses.
- **Mobile networks** are top ranked in desirability where there is no existing mobile connectivity. The massive advantage of being directly reachable by family, friends, colleagues and humanitarian support agencies is self-evident. Being able to send funds or inform refugees of urgent issues regarding their specific needs or being able to receive requests from them is especially valuable for people living in remote and insecure locations. Establishing trial mobile networks may take time as discussions leading to regulatory change requires persistent effort by telecom experts and lawyers who have experience in dealing with the complexities of negotiating mobile spectrum assignments and licensing frameworks.

5. Content, Applications and Demand Building

To maximise the value of the network and build demand, useful content and applications for people in forced displacement contexts are also likely to be needed. These can be loaded on local servers, displayed on screens at public access centres and provided over Wi-Fi. Priority topics are likely to be educational and training resources, health and family planning information, agricultural extension information, refugee support information and online public services. Also, more 'e-government' services are needed. These have special value in minimising the need for long distance travel from areas of forced displacement in order to be physically present at an agency office. Identity systems may also need to be in place because these are usually necessary to gain access to government services, for using financial systems and to register businesses.

There are a variety of other facets to demand-building, including:

1. **Capacity and skills.** Awareness raising, hand holding and training so that refugees and their host communities can obtain the most value from the service
2. **Relevant Content and Applications**. Selection of content and applications should also take into account the broader potential opportunities for fostering entrepreneurship and small business development that may be unrelated to the operation of the network itself. This could range from providing the ability to work remotely, to supporting access to online information or computing resources that are needed to operate various local businesses.
3. **Device Availability.** Local content and applications should match the types of access devices used. E.g. Even feature phones used for voice telephony may be also used to access local information from the community via IVR systems, and text messages.
4. **Protecting User Data.** Mechanisms need to be in place to protect the privacy of personal user data stored within the network. Data protection can be especially important in areas of forced displacement where security of the personal information of refugees may be particularly at risk.

6. Institutional and Governance Models

The institutional structures and related governance models adopted in community networks that are located in areas of forced displacement are likely to vary considerably from one location to another, depending on local contexts. The network could be operated by a cooperative, a local authority, an NGO, a small business, an individual entrepreneur, a group of tribal leaders, as a collective of community members, or even volunteer-run without any formal structure at all.

It is likely that the choice of institutional structure will be affected by the country's legal environment as well as the licensing conditions for telecom enterprises, and also any policies on the extent to which refugees can participate in these structures, or even to be gainfully employed by them. Currently, NGO non-profit structures are probably the most common form of community network implementation vehicle in areas similar to forced displacement contexts in rural areas. Where the ability to raise startup funds and pay for services from within the community is extremely limited, this model may help ensure external resources can cover the initial setup costs.

Externally supported NGO-led initiatives may not be the most sustainable or scaleable over the longer term because there are likely to be fewer incentives to recover costs from within the community. If startup funds can be found, a more entrepreneurial approach may be more effective, which could range from a single person, to a family small business, a cooperative or an informal collective. The cooperative is an increasingly popular means of operating community networks especially as many rural enterprises in developing countries also use cooperative structures, such as agricultural and savings co-operatives. Local authorities may be an option in some cases of urban refugee locations. There are also often traditional local governance structures in rural areas in developing countries that could support a network.

7. Summary of Recommendations to UNHCR

- **Test community networks in forced displacement contexts:** Support for trialling community networks in forced displacement contexts is needed to assess their potential to address needs for communications services among refugees and their host communities. An implementation strategy could begin with Wi-Fi connectivity, perhaps augmented with public access facilities, which could also include developing a parallel mobile network implementation strategy. This would need to be preceded by an assessment of the potential locations for deployment of services.

- **Leverage UNHCR's relationships with national policy makers and regulators to sensitize them to the potential for community networks** and their needs for regulatory changes. This will help ensure trial projects have the best chance of success and sustainability by allowing them to be able to use the technologies of choice, and to minimise the costs of license fees and interconnection with national networks.
- **Monitor developments in innovative digital financial systems and financial regulatory environments.** Identify new digital finance innovations, payments mechanisms and business models that can complement existing mobile money services in areas without them
- **Encourage the development of local content.** Help to maximise the value derived from community networks and other connectivity in forced displacement contexts by ensuring that useful local content and applications are available
- **Raise awareness of community networks in the humanitarian community.** Identify key global and regional partners with which UNHCR could collaborate in supporting community networks and awareness raising activities within this group.

8. Summary of Recommendations to governments hosting refugees

- **Take advantage of community networks.** Take into account the potential of community networks in helping to meet connectivity gaps in the population
- **Minimise licensing burdens for community networks.** Create new license categories and / or fee exemptions for small community networks which minimise onerous fees, taxes, reporting requirements and other licensing burdens for community based non-profit networks
- **Ensure spectrum is available and affordable.** As a priority make mobile and / or secondary/shared-use spectrum available at low cost to community networks for both 2G, 4G-LTE and TVWS-based services. In addition ensure licensed or unlicensed spectrum is available for backhaul links
- **Ensure affordable backhaul infrastructure and capacity is widely available.** Encourage greater coverage and more affordable backbones such as through infrastructure sharing and dig-once regulations, and public investment in national backbones and international fibre
- **Reduce interconnection barriers.** Ensure small-scale operators can interconnect with other operators in the country on an equal cost basis
- **Leverage public funds for community networks.** Ensure financial support such as universal service funds are available to encourage the emergence of community networks

- **Develop e-government services.** Governments at all levels (national, regional and local) should ensure that relevant public services are digitized/available online, e.g birth/pension registration drivers license/passport applications etc

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Acronyms

GSMA	GSM Association (Trade association for Mobile Network Operators)
TVWS	Television White Space Technology
GSM	A telecommunications standard for 2G cellular networks
LTE	Long Term Evolution, a mobile broadband standard
MEO/LEO	Medium Earth Orbit / Low Earth Orbit (satellites)
HAPS	High Altitude Platform Station
BTS	Base Transceiver Station
2G/3G/4G	Different Mobile Phone Generations, each with their unique specifications
UHF	Ultra High Frequency radio frequencies
OTT	Over-the-top Service
VoIP	Voice over Internet Protocol
ITU	International Telecommunications Union
EACO	East Africa Communication Organisation
ATU	African Telecommunications Union
ISOC	Internet Society
CTA(s)	Community Technology Access Centre(s)
BOSCO	Battery Operated Systems for Community Outreach
VoIP-PSTN	Public Switched Telephone Network
KYC / CDD	Know-your-Customer / Customer Due Diligence

1. The Potential Role of Community Networks in Areas of Forced Displacement

1.1 The Global Context for Innovation in Connectivity Strategies

Although it is over a century since the widespread emergence of the telephone, only about half the world's population has access to a communications network[5]. National telecom operators face diminishing revenues and escalating costs in reaching the remaining unconnected, who mainly live in remote, or sparsely populated, low-income areas. As a result, growth in new users is slowing[6] and usage is constrained primarily due to affordability[7] issues and the broader economics of connectivity provision, notwithstanding related issues such as *inter alia* digital literacy, cultural barriers and online security. With the economics of market-driven access to connectivity being as they are in the 'last mile', there has been increasing interest in innovative strategies to address unmet needs for affordable communications infrastructure which can help to achieve human rights, social and economic goals, as embodied by the Sustainable Development Goals (SDGs).

For refugees and forcibly displaced persons, the problems are often compounded. Research has shown that refugees are less likely to have access to connectivity than their hosting populations. They often face unique barriers due to their status as a refugee (for instance legally accessing and registering a SIM card) which is often exacerbated by specific demographics including age, gender and disability.

In order to address challenges in achieving last mile access, one approach is to leverage the potential for low-cost communication technology to support affordable, locally owned and managed communication infrastructure. Off-the-shelf commodity electronic networking equipment has now become widely available and relatively simple to use. As a result, there are increasing numbers of small-scale public networks based on Wi-Fi, and some are even providing GSM/LTE mobile services or fiber connections. Driven by the involvement of the local population in the deployment, governance and maintenance of physical communications infrastructure, these initiatives are usually called "community networks". Their numbers are still relatively small, mainly due to limited awareness of these new opportunities to self-provide communications infrastructure, but also because of the regulatory barriers and human capacity constraints that are present in many countries, especially in the global South. Nevertheless a rapidly increasing number of community networks are now operating in at least 25 developing countries[8].

5 Accessed on 05/03/2020: https://www.gsma.com/mobileeconomy/
6 Between 2017 and 2018, ITU data shows growth in households with Internet access at home in low income countries declined from 19.1% in 2017 to 17.5% in 2018. For further details see: https://www.ictworks.org/is-meaningful-universal-connectivity-a-solution-to-slowing-broadband-adoption/#.XjlhhuHLfVP and https://www.broadbandcommission.org/publications/Pages/SOB-2019.aspx
7 A4AI reported in 2018 that 2.3 billion people live in countries where even the relatively small amount of 1GB of mobile data/month is not affordable: https://a4ai.org/affordability-report/
8 See: https://www.giswatch.org/community-networks and for detailed information on the 16 community networks in developing countries which are frequently referenced in this UNHCR report see: https://www.apc.org/en/pubs/community-networks-case-studies

While community networks have recently started to receive growing attention as one of the potential means of helping to address digital exclusion, they are not necessarily the only answer to this problem. For example, in some developing countries, access to national commercial networks has recently been extended into more remote areas by operators using new low-cost mobile base station equipment, low-earth orbit satellites or even high altitude platforms (HAPS) such as Google's Loon. Other initiatives have focussed on infrastructure sharing strategies and/or dedicated rural wholesale mobile operators[9] which spread the costs of their networks by selling services to multiple retail operators. However, there are still very few of these types of initiative (and none currently in the countries of interest within the scope of this assessment, namelyEast Africa). Additionally, the effectiveness of these initiatives in different contexts is not yet well understood. As of yet, the potential application for such approaches has not been pursued in regard to facilitating refugees' access to connectivity, whether in rural locations or in urban areas where they are 'priced out' of access to commercial services.

While knowledge of the potential for community networks in different environments is also still relatively low, especially in forced displacement contexts, on the surface many of their features suggest that they can be particularly effective at addressing connectivity needs at the margins. In particular, due to their low usage fees, levels of adoption in community networks may be higher than in commercial networks because they are usually based on cost-recovery rather than maximizing profit. In addition, community members can often gain access by making in-kind contributions, such as labour, or providing electricity and/or a roof to host equipment. Community networks may also have specific social objectives such as addressing the exclusion of women and other marginalised groups, which can improve the potential to ensure inclusion of all members of the community, rather than only those with the ability to pay.

As such, this paper aims to explore factors relating to the application of community networks - as they are commonly understood - in contexts of forced displacement, specifically refugee situations. In turn, we will explore specific technologies that could be utilised, including considerations relating to forcibly displaced persons from a community perspective. Finally, we will explore three country contexts - Ethiopia, Kenya, and Uganda - to identify how enabling the environment is for design and implementation of a community network.

1.2 The Potential Role of Community Networks in Meeting Connectivity Needs in Areas of Forced Displacement

Addressing connectivity gaps is a key goal of UNHCR's Connectivity for Refugees initiative.[10] This links closely with the Global Compact on Refugees and UNHCR's strategic direction, namely that by facilitating access to connectivity and digital inclusion, not only is refugee self-reliance enhanced, but hosting populations can also benefit from the enhanced connectivity services.

9 For e.g Africa Mobile Networks (AMN), which does not have a presence in the East African countries of immediate interest, although it states that it is 'coming soon' to Uganda: http://www.africamobilenetworks.com
10 http://www.unhcr.org/innovation/connectivity-for-refugees/

UNHCR estimates that 20% of refugees in rural areas live without any form of connectivity, and even where there is coverage (most urban refugees have access to a mobile network), services are often not affordable - refugees can often spend up to a third of their income on being connected[11]. Infrastructure deficiencies are often severe in forced displacement locations, and access to energy is a major part of the connectivity problem - only about 10% of refugees worldwide have reliable access to energy for lighting, connectivity, heating/cooling and cooking.

In many forced displacement locations in Africa, there are also additional barriers to improving connectivity on the demand-side, relating to the very low indicators of human development in these locations. For example, at an average of 8 children per woman, fertility rates are amongst the highest in the world in northern Uganda.[12] Other cultural, educational and demographic constraints include the high proportion of female, youth, non-literate and traditionally excluded groups in these communities.

Nevertheless, there is also considerable variation in the types and maturity of the refugee communities in East Africa, with some having been established for decades, and others for only a few years. While a few refugee communities are more urbanised, or in clearly delineated camps, others are more embedded in existing rural communities spread sparsely over large areas. In 2018, Ethiopia, Uganda, and Kenya was home to more than 2.5 million refugees from Somalia, South Sudan, DR Congo, Ethiopia, Burundi and Eritrea.[13] The bulk of these — about 1.1 million people — are in long term settlements in Uganda, which has one of the most progressive refugee policies, affording systematic provision of land and documentation to refugees. Uganda has also put in place measures in the 2040 National Development Plan, to integrate refugees within the framework, delineating access to public services in education and health.[14]

Nevertheless governments in many other countries in the region have more strict encampment policies which may reflect the expectation that refugees rely primarily on humanitarian aid handouts, with consequent lack of rights to freedom of movement, or to access public services, to work, or to own businesses. Refugees in some countries may also be unable to use the available mobile networks because SIM card registration can require specific identification documentation which may be unavailable to them.[15]

Addressing these types of issues has been one of the pillars of UNHCR's current strategic Connectivity for Refugees plan, aiming to support better connectivity in the many areas of forced displacement that lack affordable access to basic communications infrastructure. Aside from aiming to help address basic communication and security needs through better access to voice services, Internet access is also an objective, to help support education and health and livelihood development. For example, refugee children are five times

11 https://www.unhcr.org/5d6cceb57
12 Page 3, Uganda 2016 Demographic and Health Survey: https://dhsprogram.com/pubs/pdf/SR245/SR245.pdf
13 http://popstats.unhcr.org/en/overview
14 Accessed on 11/03/2020: https://s3-eu-west-1.amazonaws.com/s3.sourceafrica.net/documents/118180/Uganda-Vision-2040.pdf
15 For further details on legal access to SIM Cards see UNHCR's report 'Displaced and Disconnected': https://www.unhcr.org/innovation/displaced-and-disconnected/

more likely to be out of school than non-refugee children, and if connectivity and energy problems can be addressed, new education possibilities for children could be opened up, along with employment opportunities for school leavers.[16] Many of the technologies used by community networks also lend themselves to the rapid deployment of communications infrastructure in emergency situations and disaster response, which are areas of concern for UNHCR and other humanitarian organisations.

These issues and opportunities in forced displacement contexts are also drawing the attention of organisations working in the area of improving connectivity more generally. For example, the GSMA's Digital Lives of Refugees report[17] and the ITU/UNESCO Broadband Commission, which focuses its "The State of Broadband" 2019 report[18] on global efforts to provide broadband connectivity to refugees and internally displaced individuals. The report advocates:

- Greater efforts to make access available to refugees and the communities that host them;
- Ensuring affordable devices and access by negotiating and subsidizing; Internet-enabled devices and plans, and expanding access centres;
- More capacity development and training opportunities;
- Facilitating content development.

The ITU has also recently adapted its World Telecommunication ICT Regulatory Survey to include questions on refugees – for example, whether a country's universal service definition includes refugees, and if there are already activities financed by the Universal Service Fund that involve and engage refugees.

Community networks could play an important role in meeting the needs of refugees for better connectivity, especially, as indicated earlier, because they often focus on supporting the communication needs of excluded groups, such as indigenous people who are usually located in more remote areas without access to traditional infrastructure. Similarly, community networks can be designed to support the needs of the specific population groups more commonly present in refugee communities, such as the high proportion of women and youth.

The potential to encourage self-provision of infrastructure also matches the aims of the Global Compact on Refugees - one of its four key objectives is to "enhance refugee self-reliance". In this respect there are a number of additional potential benefits to community-based infrastructure deployment that may be particularly appropriate in forced displacement and other similar resource-low contexts, encouraged by the close physical proximity and tight social relationships between the members of the local community and those involved in the network. These include:

16 https://www.unhcr.org/introduction.html
17 https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/The-Digital-Lives-of-Refugees.pdf
18 https://www.itu.int/dms_pub/itu-s/opb/pol/S-POL-BROADBAND.20-2019-PDF-E.pdf

1. Local control over how the network is operated and the types of content that are provided over the network. This can allow the use of the network to more closely reflect the needs of the communities served.
2. Creation of local opportunities for jobs and fostering entrepreneurship, not only in support of the network directly, but also in the use of the connectivity by local enterprises.
3. Retention of more funds within the community resulting from the low usage costs and the income generated by residents working to support the network.
4. Fostering a sense of agency within the community which can amplify their sense of capability in being able to help to improve the quality of life of community members. This may also then encourage other types of collaborative efforts to improve local livelihoods.

On the other hand, it can be observed that there may also be some disadvantages to the community network approach in areas of forced displacement. Although there are insufficient examples as yet in developing countries to draw firm conclusions, it appears that community networks have emerged more strongly where there are close knit social structures with a culture of self-organisation. This may not be the case where communities comprise a mix of long-standing residents along with more recent and transient refugee arrivals. In addition, community networks can take considerable time to develop, while there may be less permanence in the nature and outlook of communities in forced displacement areas. Finally, although this area is rapidly evolving, there are as yet few alternatives to national mobile networks for providing electronic cash transfers and other digital financial services.

In conclusion, although community networks are unlikely to be the panacea for addressing all remaining connectivity issues in forced displacement contexts, fostering their emergence could be an important and innovative complementary solution in helping to address the needs of refugees for improved communications services. These types of networks could also play a catalytic role in helping to address some of the other needs of people living in areas of forced displacement. In addition, aside from the direct benefits to refugees and their host communities, the emergence of community networks in these settings may provide examples which stimulate their adoption in other poorly connected areas around the world.

In this respect, UNHCR's role here could have a significant 'ripple effect' on the awareness of community network potential more generally, and in particular within the UN system. This would also support the conclusions of the report of the UN Secretary General's High Level Panel on Digital Co-operation[19] which notes the value of "small-scale community solutions".

Community networks are a relatively new phenomenon in developing countries generally, and there is little experience of their dynamics in forced displacement contexts. Therefore, to gain experience of community networks, one or more trial projects in the countries covered within the scope of this paper[20], could be implemented to test their applicability. The subsequent sections of this report aim to provide a guide to identifying potential projects and interventions in this area that could be supported by UNHCR.

19 https://digitalcooperation.org/

20 Kenya, Uganda and Ethiopia.

2. Community Networks – Origins, Technologies, Services and Deployment

2.1 Evolution of Community Networks and The Technologies Associated With Them

There are many forms of community networks, not only in terms of the different communication technologies adopted, but also in the networks' institutional structure and governance models. The earliest instances of community networks focused on the provision of voice telephony over copper cables, which emerged in the USA at the beginning of the 1900s when rural residents set up cooperatives to manage the infrastructure. Many still continue today as the 850 member organizations of the Rural Broadband Association[21].

Although similar electricity co-operatives were subsequently established, this model for operating infrastructure services did not become widely adopted in other parts of the world, and it was not until the 1970s and 1980s that other forms of community networks emerged, where communications infrastructure was set up by academic and research groups, and NGO communities[22]; prior to the Internet as we know it today.

These networks were initially built on public telecom infrastructure using cables designed for voice services, and many of these organisations later set up their own optic fibre and wireless networks, and some even launched micro-satellites[23], mainly for research purposes. Although these types of community networks reflect the basic principle of 'self-provision', they were essentially private network deployments by organisations wishing to augment their internal connectivity needs. It was not until the turn of the 21st century that the general public began to set up extensive numbers of their own networks, triggered by the development of low-cost Wi-Fi routers using license-exempt radio frequencies[24]. Using these devices, local communities set up networks to split the cost of broadband connections, improve network performance, and to share access to local online information servers. Now well-established in developed countries, some Wi-Fi-based community networks have thousands of members (e.g. Guif.net in Catalonia (Spain), Freifunk in Berlin and NYC Mesh in the city of New York[25]).

The expansion of these networks has also been assisted by the mesh networking protocols which have been added to some Wi-Fi routers, making it easier to join a community network because the routers automatically interconnect directly with each visible neighbour to create a 'mesh network[26]'. These protocols also make it possible to route around obstacles such as buildings and hills that block the Wi-Fi signal. In addition, the networks are more resilient because the routers have multiple upstream routes and

21 http://www.ntca.org
22 E.g BITNET, USENET, APC member networks, Geolink etc.
23 E.g The UoSat-5 LEO satellite developed by the University of Surrey was used extensively for transmitting health information from developing countries prior to the availability of the Internet: https://onlinelibrary.wiley.com/doi/abs/10.1002/sat.4600130606
24 Initially in the 2.4Ghz band and then later the 5.8Ghz band.
25 http://guifi.net http://freifunk.net https://www.nycmesh.net/
26 Mesh Networking https://en.wikipedia.org/wiki/Mesh_networking / https://libremesh.org/howitworks.html

can automatically select the neighbouring device with the most efficient path for the transmission of traffic.

Depending on their level of functionality and power, Wi-Fi routers now only cost between USD 20 and USD 200, although shipping charges and import duties can double their cost, particularly in developing countries. In 2019, a new low-cost open hardware wireless router called the LibreRouter[27] became available. It is designed by a community network support group in Argentina (Altermundi), with features specifically designed to support the needs of community networks, particularly in developing countries. These features include the ability to more easily repair the device, capacity to use a wide range of power voltages, and multiple radios to support long multihop links at low cost.

Despite the evident value of small scale Wi-Fi networks in addressing needs for connectivity in the areas in developing countries without affordable communications infrastructure, there are still relatively few community networks in these locations. Although there is clearly a lack of awareness of their potential, and human capacity limitations, the primary restriction is the lack of conducive regulatory environments in most developing countries. Although a few countries have adopted a licensing framework which includes provision for community operators, such as Argentina, Brazil and recently, Uganda[28], in general, license fees and the reporting requirements of the license are too onerous for small networks. In addition, the commercial conditions required to access the fibre backbones of national operators for upstream links is often not cost effective relative to the low volume of traffic of the community networks, resulting in unsustainable services. Interconnecting voice calls directly with the national operators can also be an issue, often necessitating the use of international VoIP trunking on backhaul links[29], which further adds to operational costs.

In a recent technology trend that echoes the emergence of low-cost Wi-Fi hardware twenty years ago, innovation in cellular networking has similarly resulted in mobile networks based on new low-power base station (BTS) equipment now costing as little as USD 1,500[30]. The devices mainly use open source software to emulate the base station on general purpose software defined radio devices which support a wide range of different radio frequencies. Equipment which supports voice/sms (2G) services has been available for about 10 years, and 4G/LTE devices are now also being manufactured[31]. Deployed by community networks in Brazil, Colombia, Indonesia, Mexico, and the DRC, these low-cost/low-power systems are also being used by some national commercial operators to extend coverage, and by the specialized commercial wholesale operators mentioned above. In comparison to Wi-Fi based networks, mobile networks are less widely understood, so further details of these networks are provided in the Annex.

27 The LibreRouter currently costs about USD 150 ex China, for further details see: http://www.librerouter.org
28 https://uccinfo.blog/2020/01/27/approved-new-telecommunications-license-categories/
29 Much like a 'Skypeout call', to call users of other public networks, the community network must route its calls over the Internet to an international voice termination provider which will then route the call via its international links back to the dialed network in the home country.
30 These devices are now being manufactured by a variety of companies such as Osmocom, Sysmocom, Fairwaves, YateBTS, Nuran, Parallel Wireless and Baicells. As part of its Open Cellular (OC) division, the Telecom Infrastructure Project (TIP), a consortium led by Facebook, has recently produced low-cost prototype devices based on open source technologies: https://telecominfraproject.com/opencellular
31 3G is not widely available as this is a much more complex protocol stack.

The emergence of low-cost mobile network equipment is of particular significance for the many locations of forced displacement, where the coverage of commercial mobile networks is often lacking. In addition, low income levels and/or lack of basic literacy in many of these areas means that voice telephony services using feature phones are a priority[32], including to support reachability by humanitarian organisations.

Although limited awareness of the potential for these low cost mobile networks is a contributing factor, the scarcity of mobile community networks is mainly a reflection of the policy and regulatory constraints faced by these initiatives in establishing small scale services based on GSM/LTE technologies. Aside from similar regulatory burdens in the provision of Wi-Fi services mentioned above, the key barrier for community networks is that access to the radio spectrum bands used for mobile networks is restricted. Often the GSM bands are already all allocated to the existing operators, and there is no provision for their re-use by third parties in rural areas that are unoccupied by the spectrum licensee. Similarly the newer LTE bands are either not yet assigned for mobile applications (used by TV broadcasting) or only available at costs that are unaffordable for small scale networks. This is mainly because most national policy makers and regulators are as yet unaware of the possibilities for operating these types of mobile networks, and have not updated their spectrum management and mobile licensing frameworks accordingly.

As a result, although temporary use of mobile spectrum by community networks has been granted in a handful of countries, so far Mexico is currently the only nation where the spectrum has been formally assigned on a more permanent basis to community networks. In the other countries listed above, community networks have been allowed in certain areas to trial the use of mobile spectrum on a pilot/test license basis in areas where the national commercial networks are not present. In the Philippines, a 'hybrid' strategy was initially adopted where the community networks formed a partnership with one of the national operators, where they essentially acted as a franchise reseller of its services in areas which it did not cover (subsequently the national operator changed strategy and the networks have since converted to Wi-Fi).

Voice telephony services provided directly over Wi-Fi (known as VoIP or OTT services) may appear to be a viable option for a wireless voice network, but this has not been widely adopted due to the above mentioned difficulties in interconnecting with the national voice networks, along with the limited range of Wi-Fi signal compared to mobile, as well as the lack of low-cost Wi-Fi handsets and limited support for Wi-Fi on feature phones. However where Wi-Fi networks are in place, VoIP services are naturally in extensive use with OTT applications such as WhatsApp/Skype, and can also be an option for users with feature phones that run a recently developed handset operating system call KaiOS[33].

A relatively recent communication technology development that is expected to have an important role to play in community networks is the use of software-defined radios with dynamic spectrum assignment, also often known as TV White Space (TVWS) technologies.

32 Figures indicate that refugees are 50% less likely than the general population to have an Internet-enabled phone.
33 https://www.kaiostech.com/meet-the-devices-that-are-powered-by-kaios

These systems can be used to access radio frequencies (specifically portions of the UHF bands) which are important for providing long-distance links and upstream capacity in non-line-of-sight situations, such as through hills and the forest vegetation present. Otherwise setting up long distance links can be considerably more expensive, necessitating the erection of high towers to reach over obstacles, or setting up multiple towers to route around obstacles.

Traditionally used for analogue broadcasting, the UHF bands are largely unoccupied in rural areas in the global South, and through the use of a regularly updated database of spectrum occupancy, TVWS radios choose which frequencies to operate on a dynamic basis. Although the capacity of TVWS links is not as great as those using systems based on higher frequencies such as Wi-Fi, TVWS channels can be bonded together to provide additional capacity when necessary. TVWS licensing frameworks have been recently adopted in the US, the UK and a number of other developed countries, despite the technology's potential in the global South, only a few developing countries such as South Africa, Uganda and Ghana have so far fully authorized the use of TVWS[34] and a few have issued draft guidelines for public consultation (Nigeria[35] and Kenya[36]), with UNHCR undertaking a pilot with Microsoft to deploy TVWS in Dzaleka Refugee camp in Malawi[37].

In conclusion, it is likely to be beneficial for UNHCR to leverage its existing relationships with national policy makers and regulators to sensitize them to the potential for community networks and their needs for regulatory changes. This will help ensure that any trial projects have the best chance of success and sustainability by allowing them to be able to use the technologies of choice, and to minimise the startup and operating costs created by license fees and the costs of interconnection with national networks.

Engagement with policy makers and regulators can also be effective at the regional level through contact with the regional regulatory associations[38] (EACO in the case of East Africa, which held a capacity building event in 2019 on community networks with APC and ISOC), and at the continent wide level with the African Telecommunications Union (ATU) and the African Union, which has endorsed strategies to unlock the potential for community networks in October 2019[39]. Similarly, at the global level, the ITU hosts a number of relevant events for policy makers and regulators, and is currently in the process of developing a publication on the role of community networks[40].

34 https://www.icasa.org.za/legislation-and-regulations/regulations-on-the-use-of-television-white-spaces-2018 https://www.ucc.co.ug/wp-content/uploads/2017/09/UCC-TVWS-standards.pdf https://manypossibilities.net/2018/06/an-african-tv-white-space-strategy https://www.nca.org.gh/assets/Uploads/Guidelines-for-TVWS-Data-Services.pdf
35 https://ncc.gov.ng/docman-main/legal-regulatory/guidelines/draft-guidelines/876-draft-guidelines-on-the-use-of-television-white-spaces-2019/file
36 https://ca.go.ke/public-consultation-on-the-draft-dynamic-spectrum-access-framework-for-authorisation-of-the-use-of-tv-white-spaces
37 https://microsoftcaregh.com/2017/03/20/microsoft-unhcrs-connectivity-for-refugees-project-brings-hope-dzaleka-refugee-camp-malawi/
38 For example APC has held workshops with all three of the regional regulatory associations in Africa on the needs for infrastructure sharing regulations.
39 See: https://au.int/sites/default/files/decisions/37590-2019_sharm_el_sheikh_declaration_-_stc-cict-3_oct_2019_ver2410-10pm-1rev-2.pdf
40 As an ITU-D sector member, APC is currently assisting the ITU in the development of guidelines on community networks.

2.2 Potential Connectivity Services In Forced Displacement Contexts

The communications infrastructure services that would likely be required in forced displacement settings can be grouped into the four types described below. Ideally all four services would be available, however depending on regulatory constraints and the specific local conditions, it might only be possible to provide one or more of these services, at least in the initial phases of the initiative.

In addition, if it is not cost-effective or technically feasible for the community network to obtain affordable backhaul links to connect to national Internet backbones and to the voice networks of other operators, the network can still be of value by allowing the local population to communicate directly with each other, and by providing 'offline' local applications and content such as educational and training materials, information on agricultural techniques, health advice etc. and information services needed by refugees.

Even if the network does have upstream Internet connectivity, the presence of a local server with information resources and caching facilities can considerably reduce the traffic (and cost) of backhaul links, as well as providing better performance for the users by bringing the content closer to them. A phased approach can also be taken, where the local network may first be established, along with local information servers, but without upstream connectivity, which is then added later when conditions allow.

2.2.1 Public Wi-Fi hotspots

These can be installed in publicly accessible locations such as a community centre, health facility, or a school. Unless blanket coverage is provided, community members need to travel to specific locations in order to gain access, due to the limited signal range of handheld Wi-Fi devices (up to about 200 metres in ideal conditions – i.e line of sight - without any physical obstructions between the hotspot and the user). The limited range of Wi-Fi signals and its susceptibility to obstructions means that even with blanket coverage, the signal is unlikely to reach inside most dwellings (although in some communities, where roofs and or walls consist of plant material this may be possible).

On a per-user basis this type of service is usually the least costly to deploy because the equipment and operating costs are shared amongst the maximum number of people. It should be noted however that open air spaces are subject to inclement weather, potential security issues (see below), dust and insect pests such as mosquitoes. In addition, unless exterior power points are also provided, public hotspots can only be used with battery operated portable devices, primarily smartphones but also tablets and laptops.

2.2.2 Private Wi-Fi hotspots

Complementing the use of public hotspots, in forced displacement contexts in East Africa private hotspots are usually installed on the premises of small businesses or at NGO offices, and in rare cases, in the homes of individuals. For families and organisations that can afford them, these better support the use of less portable or more energy consuming access devices, such as desktop computers with large screens, TV sets, and printers or other peripherals. Private hotspots can also provide public access in the immediate surroundings, and can also be shared between neighbours where dwellings are in close proximity and where the building materials used in their construction allow sufficient signal propagation (tin roofs and clay walls, for example, may cause signal obstruction for devices that are more than a few 10s of metres apart).

On a per-user basis, the greater quantity of equipment required relative to the number of users served per device, means that private hotspots are significantly more costly to deploy and manage than public hotspots. However a significant advantage is that there is a reduced need for community members to travel to the location of the public hotspot. Aside from the time saved, and the ability to have access to the network on an ad-hoc basis when needed, in many situations private hotspots can also significantly reduce security issues, especially for women who may not have as much time as men to leave the family home, or may even not be allowed to travel from the family compound. In many cases private hotspots may also be more desirable for instance for people with disabilities that have limited mobility, or parents who do not wish their children to spend so much time outside the home unsupervised.

For institutional users, permanent direct access to a hotspot can also allow them to access their office computer resources while off-site, and it can be easier for network managers to provide individualised service levels (e.g dedicated capacity) and quality of service guarantees for private hotspots. Providing service to institutions can also generate additional income which can help to sustain the network, and even to cross-subsidise the cost of providing access to individuals.

Mesh network Wi-Fi routers can help to reduce costs by minimising the need for towers and separate equipment for upstream links because they can serve both as local access points and as part of the network backbone in one device. However depending on the construction material of the dwelling, to improve indoor coverage it can be necessary to locate an additional small access point inside the house as well, which can be connected to the external mesh router via a network cable.

For private hotspots the cost and availability of energy also needs to be taken into account, as in many cases there may be insufficient residential electricity to power all devices on a full time basis[41]. As solar energy is likely to be necessary in many rural locations in forced displacement contexts, and even in some urban ones, the cost of the solar panels, charge controller and batteries needs to be taken into account, and can exceed the cost of the Wi-Fi equipment while increasing the complexity and maintenance needs of the system for end-users[42].

41 Ensuring that the device receives continuous power is generally more important in a mesh network because neighbours may be dependent on the device for upstream connectivity.
42 To address this a very low cost MPPT solar charge controller with integrated mesh Wi-Fi access point in one device is being developed by one of APC's partners. See: https://media.ccc.de/v/36c3-oio-166-ff-esp32-openmppt-new-freifunk-isems-mppt-solar-controller-with-integrated-wifi

2.2.3 Public access centres

In many locations of forced displacement, community members may not be able to afford (or effectively use) a smartphone[43] or other Internet enabled devices. Although costly and difficult to scale, provision of computers and Internet in public spaces in communities is a well established means of addressing limited Internet access and lack of availability of personal access devices within the local population. In this respect UNHCR has long supported the development of Community Technology Access Centres (CTAs), also often simply called connected centres, telecentres or cybercafes. Even where many people may have Internet enabled devices, public access facilities are still often needed to allow members to use more powerful and diverse types of equipment (e.g printers, scanners etc); as well as to obtain guidance or training in their use, or in providing a safe space to navigate the Internet, for example to undertake research and access education materials, as recent field assessments from UNHCR have determined.

Connected centres can also provide a public Wi-Fi hotspot, as well as access to local applications and content loaded on each computer's hard drive, or via a LAN connected to a shared server. Using a shared server can help to reduce setup and energy costs by allowing the use of low-cost 'network computers' with minimal memory, disk storage and processor power, which rely on the more powerful server computer for resources.

In terms of the numbers of people that can be connected, the public access centre model is the most costly form of connectivity infrastructure. Minimising setup and operating costs, and addressing security and maintenance issues is particularly important for helping to improve their sustainability and their potential to scale to levels which can match demand in communities with insufficient personal access devices. This not only means maximising the number of workstations in the centre, but also having many centres evenly spread throughout the community. Otherwise, people may have to travel significant distances to use them, and upon arrival, may have to wait a considerable time until a computer is free. This can also create tensions within the community over who has access, especially as there is a tendency for public access facilities to become the domain of certain groups, especially young men. Nevertheless, taking these considerations into account and for the reasons outlined above, the benefits of public access facilities can still justify their cost, and are a valuable complement to the deployment of Wi-Fi hotspots, especially since the hotspots also help to reduce demand for public access.

Increasing the number of workstations in each facility improves sustainability by spreading the costs of the premises, maintenance and security if needed, as well as reducing the number of the staff required to manage it. Even with long opening hours to maximise availability, demand almost inevitably exceeds supply, so procedures to ration access also need to be in place. This can be achieved through a roster system, which gives people an opportunity to book a slot at a certain time, and/or by using a time-based usage model with varying availability periods for different types of users, such as students, women or

43 See for e.g The Digital Lives of Refugees GSMA/UNHCR report: https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/The-Digital-Lives-of-Refugees.pdf

small businesses. The design of time-slots also needs to ensure they fit in with domestic and agricultural work schedules. Charging for access is also a rationing method as well as a means of cost recovery. In these cases a differential off-peak/on peak pricing model can also assist in smoothing demand. Further analysis would be required during a pilot in a forced displacement context to better determine what specifically might need to be considered in optimising centre governance.

Other strategies that can be used to help reduce costs, increase demand and address scaling and sustainability issues include:

- Use of projectors or screens oriented toward the outside of the facility which display useful information to people waiting or who pass by, such as news, market prices etc. This could even include the ability for community members to post their own announcements, either manually (by requesting the facility manager to create the posting), or automatically via one of the workstations, a smartphone with Wi-Fi (with perhaps a specially developed app for this purpose), or even with an SMS from a feature phone if there is mobile coverage.
- Provision of tablets may be a more cost effective, secure and flexible solution[44] than computers for the provision of access in public facilities. Being more compact and energy efficient, they are less costly to operate and can be more easily secured in a safe or other more secure area of the centre. Similarly, the use of single-board computers which cost about USD 30, such as the Raspberry Pi, have recently increased in cost/vs performance ratios to the point where these devices can provide a very cost-effective basis for a workstation and even a server for a small number of users.
- Other approaches to enhance the efficiency of a public access centre would be to utilise desktop virtualization to create more terminals operating off of a central server. This would however require more maintenance and network administration than individual devices.
- Although subject to maintenance issues, kiosk-type weather and theft or tamper-proof workstations can be placed outside the centre or in other unsupervised locations to provide access. For example Battery Operated Systems for Community Outreach (BOSCO) in Uganda have tried this approach using steel oil drums to house a laptop securely.
- The premises for the public access centre is the largest cost and use of an existing structure is clearly the most cost-effective option if available. The cost of setting up maintaining the centre premises can also be shared with other types of services, such as holding community meetings, housing NGOs, vocational development services or small business advisors, conducting training, and more specific refugee related services.
- The functionality of the facility can be extended with 'makerspace/hackerspace' tools and services which can help to foster self reliance and learning (see for example Syrian refugee camp study[45])

44 See for example the BRCK Kio education kit: https://www.brck.com/education/
45 https://dl.acm.org/doi/10.1145/3170427.3174363

- Another option to provide public access is to deploy a vehicle equipped with computers and a Wi-Fi hotspot which regularly travels along a set route, stopping in unconnected population centres to provide temporary access[46]. A similar model can be used for rapid deployment in emergency situations.

In designing or selecting the premises for the public access facility, its potential to support small businesses that can be built on the availability of connectivity and local computing resources should be taken into account (see section 2.3 below). When grid power is absent these considerations could also extend to the design of the solar electric power supply[47], not only to ensure that there is sufficient power available as demand grows, but also to be able to foster the many other types of small businesses that become feasible when power becomes available.

2.2.4 Mobile networks

Depending on the specific local conditions in many forced displacement locations (in particular the absence of commercial mobile networks), where no communications infrastructure is available mobile voice connectivity is likely to be top ranked in terms of initial desirability[48]. The most popular use of phones by refugees in three camps recently surveyed was calling and texting, followed by financial services - for instance, mobile money, and then information/content. In addition to meeting these priority needs, the massive advantage of being directly reachable by family, friends, colleagues and humanitarian support agencies is self-evident. Being able to inform refugees of urgent issues regarding their specific needs or being able to receive requests or feedback from them is especially valuable for people living in remote locations where physical access to humanitarian agencies may be limited.

With mobile network equipment now providing voice and/or data connectivity at a much lower cost[49] than in the past, it is increasingly seen in deployments by traditional MNOs such as Vodacom in the DRC, by dedicated rural operators such as AMN in Nigeria[50], as well as in hybrid MNO/community networks such as the recently terminated Globe/VBTS experiment in the Philippines, and also the independent mobile networks such as TIC AC in Mexico and others in Brazil, Colombia and DRC. Regulators in East Africa have not yet sanctioned independent mobile community networks in the region, but given that Uganda has recently announced a Communal Access license category[51] and regulators in a growing number of countries have allowed independent community networks to trial mobile technologies, this should be achievable, but may take some time. Discussions leading to regulatory change may take many months, if not years, and require persistent effort by telecom experts and lawyers who have experience in dealing with the complexities

46 See for example the ZeroConnect project in India: http://zeroconnect.defindia.org
47 UNHCR Global Strategy for Sustainable Energy: https://www.unhcr.org/5db16aa4a4
48 https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/The-Digital-Lives-of-Refugees.pdf
49 Excluding tower and power supply costs, a 2G (voice only) single cell base station for a few hundred users costs USD 2 000 – USD 4 000. Equipment for 4G/LTE is USD 4 000 – USD 6 000. A solar power system and 12-15 metre tower can add an additional USD 2 000 – USD 4 000 to this cost. S Annex for further details on the use of these systems.
50 See the associated Collaboration for Connectivity report for additional details and discussion.
51 https://uccinfo.blog/2020/01/27/approved-new-telecommunications-license-categories

of negotiating mobile spectrum assignments and mobile licensing frameworks.

Some of the key negotiating points with regulators regarding mobile community networks are likely to centre around:

1. The spectrum bands to be made available (700/900/2100Mhz etc), which can affect the choice and capabilities of the equipment used, noting that the lower the frequency the more suitable it is for the longer distances needed to spread the coverage across sparsely populated rural locations.
2. The quantity of spectrum required, which affects the capacity / number of simultaneous calls that can be provided.
3. The use of the spectrum – for voice only (2G), data only (for 3/4G-LTE dongles), or for voice and data – 2G/4G-LTE.
4. The level of fees and other taxes for a community mobile license and for use of the spectrum (noting that pricing has traditionally been oriented toward use by national commercial networks, and spectrum often auctioned to the highest bidder).
5. Reporting/monitoring/data retention requirements.
6. If a new assignment of spectrum can be made, and/or the network can use the spectrum of an existing operator that is not occupying it in the location of the community network, with provisions for potential eventualities if the commercial operator launches service in the area of the community network.
7. How the community networks can affordably access numbering resources and obtain interconnection with existing operators at equitable termination rates (see below).
8. Who the community mobile network and spectrum licensees would be. Licensing frameworks would need to accommodate potentially hundreds if not thousands of independent mobile community networks, possibly through an umbrella license to a federation of networks.
9. Security concerns would also need to be addressed in allowing refugees to be involved in setting up their own independent mobile communications networks. Related to this would be establishing mechanisms to manage phone number registration requirements – managing proof of identity requirements for use of SIM cards may be especially challenging in refugee contexts. In this respect it may prove advantageous to propose that a single licensee manages the mobile license and spectrum on behalf of many individual community networks (as is done in Mexico) and is perhaps an existing trusted party – a well known NGO or even perhaps UNHCR itself.

Additional information related to many of the issues discussed above is provided in the Annex section 1.

Notwithstanding the regulatory constraints described above, low-cost mobile network equipment can provide the same functionality as national mobile networks (voice, data, SMS and USSD), however in practice there are at least four technical issues that need to be addressed:

1. Voice support
Using pure 4G/LTE equipment for voice services is not a yet feasible solution[52] for community networks because the associated VoLTE standard is not widely supported by low cost handsets and base stations, so 2G base stations are also usually required to support native voice services. As mentioned earlier, 3G has not been implemented in low-cost base stations due to the complexities of the protocol stack.

In some cases the community network could provide low cost 4G-LTE data, while 2G could be provided by an existing commercial mobile operator (which often does not provide 3/4G in remote low-income areas, or only does so in more restricted/urban areas). This is the complementary model adopted in Indonesia, where the national mobile operator provides 2G, while the 4G-LTE community network provides coverage more cost-effectively than could be achieved with a patchwork of multiple Wi-Fi hotspots required to cover the same area as the single 4G-LTE base station. In these data-only 4G-LTE networks there may still remain the problem of more limited access to 4G-LTE handsets, and the use of OTT voice services such as Whatsapp, which require a valid phone number for authentication.

2. Interconnection
An unconnected, or standalone mobile community network can provide 2G/voice connectivity within the community (or in the case of a 4G-LTE network for local content access), but interconnection with other public networks is normally a necessity for providing community network users with their own nationally and internationally reachable phone numbers, and to allow seamless flow of traffic between the community network and other networks in the world. Nevertheless, direct connection between community mobile networks and national mobile networks for voice calls has not yet been achieved.

Interconnection between affiliated community mobile networks has been relatively easily established, which can allow users of two different community networks to call each other freely. The networks can also be configured so that subscribers of one community network can automatically roam on affiliated community networks[53] at no cost.

Direct voice connections with national mobile networks has proved more problematic, and has not been effectively achieved in any of the community-based networks so far. This is primarily due to the lack of updated interconnection regulation which, combined with these networks' small scale, makes them commercially uninteresting to the large national networks. As a result of the lack of fair pricing in interconnection and numbering regulations, fees charged by large operators are not affordable because the minimum financial commitments for commercial network interconnection agreements are usually based on much higher call volumes than would be generated by small community networks. For example in Mexico, aside from having to commit to far more traffic than is currently generated by the 5 000 users, the numbering cost is about USD 4 per month per number, which is almost double the community network's current fee for the service.

In the future, if more communities follow the model of a national federation of community mobile networks, demand aggregation could help them negotiate better terms with the larger operators, but until reaching sufficient size, special regulatory measures are likely to be needed to ensure the small networks are not disadvantaged.

As an interim measure, currently VoIP is used to connect with other voice networks, but this is more cumbersome, and does not provide the same level of service at a low cost because it involves routing calls into the networks using a commercial VoIP/SIP provider. Because of the high cost of number rental, community networks usually provide a single in-country number[54] for each network which is linked to the network subscribers using extension numbers, similar to a corporate switchboard, and requires servers and a firewall hosted at a well-connected data centre. To make this process more seamless, smartphone and web based[55] apps have been developed which make it easier for off-net users to call members of the community networks. For outgoing off-net calls from the community network members, VoIP can also be used, where calls are routed to a wholesale VoIP-PSTN termination provider, often with more competitive rates than may be available from the local national network operator.

3. Mobile Money Services
The potential for community networks to support digital financial services has not been tested significantly, and few immediate options are readily apparent. In areas of forced displacement these services can be particularly important to refugees who often receive direct financial support via the mobile money platforms of the national mobile operators. These have large networks of agents, and the scale, capacity and accounting systems that enable their compliance with national 'Know-your-customer' or Customer Due Diligence regulations that further give confidence to the national financial authorities responsible for sanctioning these services.

52 There are some new services that have not been tested in low-income environments yet and still require high-end 4G handsets, such as with ngvoice: https://www.ng-voice.com/
53 The capability to use low frequency (HF) radio links for direct connections between GSM base stations to carry text messages and small quantities of voice traffic over distances of hundreds of kilometres has been developed see: https://www.rhizomatica.org/hermes
54 Known as a Direct in-Dial (DID) number.
55 E.g https://webphone.rhizomatica.org

Given these extensive ecosystem requirements to support digital financial services it is unclear how small community networks could provide services like cash payments in the short term. However it is noteworthy that national identity systems are prompting the emergence of more neutral platforms that can be used by all financial institutions. One such method recently employed by a community network in rural India benefits from the relatively high level of bank accounts in rural India with the Aadhaar enabled Payment System (AePS)[56] which allows banking agents in the field to authenticate customers of any Indian bank using their fingerprints. A member of the community is nominated as the 'eDost' AePS agent, who has the authentication equipment which is used to pay bills and provide the other traditional banking services to the community, including deposits and withdrawals.

For the longer term, it is notable that the area of 'fintech' and digital financial services is a field in very rapid evolution. There are already a wide variety of different implementations of financial technologies and business strategies, as well as growing interest in potentially disruptive peer-to-peer systems such as use of tokens, and digital currencies supported by distributed ledger technologies[57]. The opportunities these developments could bring to help foster business and commerce, including with government, are as yet unclear, however recognising the strong need for digital financial platforms in community networks generally, and that this environment is still poorly understood and quickly changing, it will be necessary to continue to monitor and research these developments to assess their applicability in forced displacement contexts.

4. Wi-Fi integration

Wi-Fi hotspots may still be required along with a mobile deployment, especially in a 2G/voice-only community mobile network, but also in the case of 4G/LTE data networks. Wi-Fi may be needed to offload traffic from the mobile network, to provide better performance for enterprises with fixed data intensive interactive applications, and to provide access for Wi-Fi-only devices such as laptops and many types of tablets. An example of this in one of the more recent mobile community network deployments, is in Cauca, Colombia, where Wi-Fi hotspots are being deployed along with 4G/LTE services.

56 See: https://www.livemint.com/money/personal-finance/india-post-payments-bank-ippb-rolls-out-of-aadhaar-enabled-payment-services-aeps-10-things-to-know-1568024793422.html

57 See for e.g a) SocialPos, a mobile point of sale network based on smartphones for neighborhood businesses and interaction with non-banking cards http://en.socialpos.com.ar, b) GNU Taler - privacy-preserving electronic payment system with payments cryptographically secured with low transaction costs https://taler.net, c) Netbox.Wallet – a payment card using both fiat and cryptocurrency: https://netbox.global

2.2.5 Summary SWOT Analysis of the Service Options

The table below summarises the strengths, weaknesses, opportunities and threats of the different types of services described above.

Service	Strengths	Weaknesses	Opportunities	Threats
Public Wifi	- Well understood technology and expertise in installation is relatively widespread - Lowest cost per user - Simplest to manage - Everyone has equal access - Handheld Wi-Fi devices relatively widely available and relatively low cost - Lower latency than 4G/LTE - Provides low cost alternative to less affordable mobile data plans	- Subject to security issues, especially for women and other marginalised groups - Subject to inclement environmental conditions - Need for travel to gain access - May be hard for women to leave household to gain access or to fit in time with domestic tasks - Limited range of signal - Only supports battery operated devices unless power for access devices is also provided - Does not support voice services on current feature phones	- Use of new mesh Wi-Fi systems to extend coverage, improve resiliency - Public Wi-Fi already in place in some areas of forced displacement - Voice services on some low cost feature phones may be possible using KaiOS - Innovative fintech services may help to address difficulties with implementing financial services for community networks	- Affordable 4G/ LTE renders Wi-Fi unnecessary because it is cheaper to deploy and provides wider coverage - Widespread private Wi-Fi renders public hotspots unnecessary - Free/ subsidized public Wi-Fi is made available through an NGO or government development initiative, or enterprise play that negatively impacts the sustainability of the community network

Service	Strengths	Weaknesses	Opportunities	Threats
Private Wifi	- Well understood technology and expertise in installation is relatively widespread - Handheld Wi-Fi devices relatively widely available and relatively low cost - Fewer security issues and reduced need people to travel – significant benefit to women who are often housebound - Reduces unsupervised use by young people - Can more easily provide access for devices that require power - Can more easily provide differentiated services for different types of users which can also help sustain the service and reduce the cost for those with lower income - Lower latency than 4G/LTE - Provides low cost alternative to less affordable mobile data plans	- Need to provide power for access devices as well as for the private access point - Higher cost per user than public Wi-Fi - More maintenance overheads and operating costs due to higher levels of device failure due to the possibility for bad power and inadequate lightning protection, water ingress, etc - Not every household can afford a device and the electricity or solar power equipment when there is no grid power. As a result not everyone has equal access to the network - More complex than public Wi-Fi to manage due to multiplicity of devices - More need to train users in troubleshooting	- Use new mesh Wi-Fi systems to extend coverage and improve resiliency - Could also be set up to provide public access in surroundings of the premises - Voice services on some low cost feature phones may be possible using KaiOS	- Affordable 4G/ LTE renders Wi-Fi unnecessary because it is cheaper to deploy and provides wider coverage - Free/ subsidized Wi-Fi is made available through a development initiative or enterprise play that negatively impacts the sustainability of the community network

Service	Strengths	Weaknesses	Opportunities	Threats
Public Access Centres	- Provides access to people who do not have/ cannot afford an access device - Allows people to use more powerful and sophisticated computers than they have personally - Gives people the opportunity to obtain guidance on the use of the devices, on the use of application and navigating/searching the Internet - Provides a safe environment for personal information quests - Is able to house local content server - Can provide additional facilities for supporting small businesses	- Most costly form of connectivity infrastructure – least scalable/most likely to be unsustainable - People may need to travel long distances to the centre - High operating costs to maintain the facility/pay for security, rent, staffing etc - When fees for access are levied these may be unaffordable for some	- Cost of premises can be shared with other organisations if they are interested in using the space too - Premises of other organisations may be available to reduce costs - Rental of space to other organisations for meetings and training workshops can help offset operating costs - Can be an attractive centre for community meetings - Can be used to house mobile network equipment if in an appropriate location - Can be used to house other small businesses using power and/or connectivity	- May be a target for theft - May become unused as more people gain personal access devices and access to Wi-Fi hotspots and 4G/LTE

Service	Strengths	Weaknesses	Opportunities	Threats
Mobile Networks	- 2G service can provide most needed service (voice calls) in uncovered areas - Supports the most affordable access device in low income area – feature phone - 4G-LTE provides wider coverage than Wi-Fi hotspot	- Less familiar technology than Wi-Fi – will to require external expertise to set up - May need a support organisation to hold the license, provide technical support, manage interconnection and backhaul links - Difficulty in obtaining access to numbering resources - Regulatory environment is not yet conducive to mobile community networks - Mobile spectrum may all be assigned - Interconnection with existing networks requires regulatory change and ability to negotiate with large commercial networks - Wi-Fi hotspots still required in the case of 2G/voice network and potentially with 4G - Unlikely to be able to support mobile money in the short to medium term - Can have heavier use of battery resources of devices	- More potential for digital financial services - Innovative fintech services may help to address difficulties with implementing mobile money - Partnership with an existing national mobile operator may help to address mobile money and interconnection issues	- National mobile operator may enter previously uncovered area with via dedicated rural wholesale operator - Innovative fintech services may eliminate need to implement mobile money - Partnership with an existing mobile operator may limit the independence of the community network and reduce the affordability of the service provided

2.2.6 Hybrid models – Community networks in collaboration with national mobile operators

The difficulties of obtaining radio spectrum, interconnection, numbering and other services, have led some communities to a model similar to the large wholesale rural operator model, but where many smaller networks act as franchisees for resale of national mobile operator services. The interconnection problems described earlier are largely avoided with the hybrid model, and spectrum is provided by the MNO along with backoffice switching services. But as a reseller of an already existing service, the role of the community network is limited. In addition the business strategy and pricing of services is determined by the commercial decisions of the partner national operator, which may change its approach in future[58]. In addition the community network could be exposed to competition from another commercial operator moving into the location in response to the extension of coverage by its competitor, and for which the community may be less able to respond because its business model is tied to its larger partner.

As observed in a recent report on social technology ecosystems in Africa, “Partnering with telcos isn’t easy, as their central role means opportunity costs and market positioning are strong drivers of their approach. Big and powerful, they are at the top of the ecosystem and they fear disruption.[59]” In addition, the hybrid community network/MNO model has not been tested widely, and given the recent developments in the Philippines and Mexico, it appears not to have been sustainably implemented as yet. Considering that community mobile networks apart from Mexico’s TIC AC have only been deployed over the last 2-3 years, information about them is limited, so further research may be needed to determine the viability of the different options. The available information on these networks is summarized in the Annex and an early research paper from the University of Washington on the technical aspects of the Philippines hybrid model is referenced in the Further Information section of the Annex.

2.3 Additional Considerations in the Provision of Community Network Services

2.3.1 Upstream / Backhaul Connectivity Costs

The cost of links to connect community networks to the rest of the world are often the biggest component of a community network’s operating cost, and therefore the largest threat to its long term sustainability. It is also often not economically feasible for communities to gain access to wholesale fibre backbones because this infrastructure is too far away, especially in many areas of forced displacement, or because the fees and minimum volume purchase requirements of the backbone operators are too high for these small networks. As a result, the presence of an intermediary ISP may be required to make it feasible for the community network to connect to other networks.

58 This has recently taken place in the Philippines where national operator Globe simply decided not to renew the contracts with the local communities, and in Mexico where a larger rural operator, Spica Telecom, is now appealing to the regulator because its partner MNO, Telefonica Movistar, changed its business strategy (now a partnership which is migrating to AT&T’s network), and as a result Telefonica has ceded its rights to the spectrum and base station assets it had agreed to allow Spica to use. See: https://digitalpolicylaw.com/spica-telecom-pide-al-ift-auditar-el-trato-movistar-att-sobre-redes-mientras-negocia-con-altan-la-migracion-de-su-trafico-rural/
59 Social Tech Ecosystems in Sub-Saharan Africa: https://www.ssa.m-iti.org/

It is hard to provide accurate estimates of upstream capacity costs because they can vary considerably, depending on the location and the type of capacity provided. However the most frequently observed costs for terrestrial links are in the range of USD 40-80 per Mbps per month, while satellite links may cost closer to USD 1 000 per month for the same capacity. For comparative purposes, large commercial operators normally pay less than USD 2 per Mbps per month for Internet transit capacity. One of the chief reasons for the higher costs of capacity experienced by community networks is that the relatively low quantities they require means that it is purchased at retail prices, and is consequently much more expensive per Mbps than the higher capacities and wholesale pricing obtained by large commercial operators.

Minimising the high cost of upstream capacity is particularly important because it creates a disincentive to more extensive use, or limits the expansion of the community network. This takes place in two ways: a) by reducing the number of people who can afford to use the network because the high costs of capacity needs to be recovered through higher fees charged to the end-users, and b) to save costs, the amount of upstream capacity purchased is limited, resulting in demand exceeding supply, which creates congestion, resulting in poor performance.

Community networks can address these constraints to some extent by limiting the use of high bandwidth applications (such as video) during peak periods but this can be counterproductive, for example, when much valuable educational materials are in multimedia format. There are also software tools which can help optimise the use of congested and expensive upstream links, such as web caching servers and ad-blockers, but these can only mitigate the problem to some extent.

Not only are the costs resulting from upstream capacity requirements usually the largest single operating cost element for community networks, but the set-up costs for obtaining and distributing the capacity can also be the largest initial cost in deploying the network. This results from the high towers that may need to be built in order to distribute the capacity to more remote parts of the community network and/or to support the long-distance wireless links to reach the points of presence (POPs) of the upstream capacity provider. Unless government policy or investment by operators has resulted in more extensive capillarity of fibre infrastructure down to the community level, in most cases these POPs are only located in urban or relatively populous rural areas.

The substantial cost of tower infrastructure may also be due to lack of access to the existing towers of commercial operators. While infrastructure-sharing regulations are becoming more common for towers, the fees charged by the operators are often unregulated, making it prohibitively expensive to use them, necessitating the community to construct their own towers. In Uganda, for example, the cost of BOSCO's 25 to 30-metre-high towers is about USD 9,000 to USD 10,000. BOSCO operates 14 towers and one of them is as high as 80 metres. Transport costs, installation and lightning protection can all add to these costs.
In some cases satellite links may be a more cost-effective alternative to high towers or multi-hop long-distance links. However the bandwidth available is likely to be more limited,

there are latency issues, and operating costs are usually much higher[60] than terrestrial links for the equivalent amount of capacity. Satellite fees may also be based on data transfer volumes, which makes for unpredictable costs, especially when servicing Internet traffic. Nevertheless, new satellite launches are improving the outlook for lower cost upstream connectivity in remote areas, both geosynchronous and low/medium earth orbit[61]. This area needs to be monitored to identify new opportunities here for trial projects, but the ability to use them in community networks may also depend on the local regulatory environment. It should also be noted here that there may be concerns by host country governments that an independent community network with upstream connectivity which is solely through a satellite link may be used by bad actors wishing to avoid detection.

A further challenge created by the high cost of upstream capacity is the consequent lack of diversity in upstream links which can make community networks less reliable. Without backup links in place, ideally from at least two different providers using two different physical paths, the network is vulnerable to outages caused by equipment failure or other problems along the route to the backbones. Although people in the global South may be more accustomed to unreliable basic infrastructure and services, network interruptions are still likely to have a strong negative effect on the value placed on the community network, and thus on its level of use, and ultimately on its sustainability.

2.3.2 Electricity Supply

Access to electrical energy to power communication devices can also be a major setup or operating cost component for community networks and their users. Poor quality electricity, and more often its complete absence in many areas of forced displacement will substantially increase the cost of network deployment and use by requiring energy-generating equipment. Where there is no grid power, a complete solar energy supply can be installed. If grid power is unreliable, then a charger and batteries are normally required.

A solar power system for a router that is part of the network infrastructure requires enough batteries and solar panels to last for days of cloudy weather which can cost upwards of USD 500, while a system to power a mobile base station (which uses significantly more energy than a wireless router) costs USD 1,500 or more, depending on the power requirements, which are related to the output power of the radios used. This equipment may not be available near the community network, which means backup equipment must be purchased, otherwise when equipment fails, extended downtimes are likely to take place until replacements are obtained. When purchasing solar power equipment it can be necessary to ensure that it supports a variety of voltages that may be required by different equipment, which pushes up the cost of the solar power setup significantly. For example Wi-Fi equipment usually runs on 12 volts or 24 volts, while traditional telecom equipment often runs on 48 volts.

60 Lower costs can be achieved with larger and more expensive satellite ground stations using C-band, but the equipment / setup costs are significant, and can cost as much as a tower. Annual licensing fees for satellite links are also a major cost in many countries.
61 For e.g: http://www.intelsat.com/global-network/satellites/fleet/intelsat-39

An important issue in the provisioning of solar power systems for community networks relates to planning for expansion of the network. To ensure the power system is able to support future growth, it may need to be over-dimensioned initially because it can be more expensive to upgrade the system later. This requires additional start-up resources as well as experienced and skilled network technicians to make the correct decisions about the most appropriate size of the power systems.

2.3.3 Availability of Human Resources

The availability of technical skills to set up and maintain communication networks in the remote and low-income settings that are common in forced displacement contexts can be a substantial challenge in establishing and maintaining a community network. Although perhaps not as extreme, the availability of adequate management and accounting skills is also likely to be scarce in these environments. Technicians are a rare resource, especially in rural areas, often leaving for greener pastures after having acquired technical skills.

To help address this, adequate documentation of the network is required, along with the simplification and standardisation of equipment in deployments, and the costs of initial and ongoing training needs to be planned for. Ideally, if the size or number of community networks in the same vicinity are sufficiently large, the costs of some of the human resources can be spread across multiple networks.

2.3.4 Content and Applications

In the case of community networks that provide local and Internet connectivity, to maximise the value derived from the network, and to build demand for the service to help ensure its sustainability, useful content and applications for populations in forced displacement contexts may be needed. This 'demand creation' strategy can comprise a mix of content and applications loaded on local servers, automated displays at public access centres and the assembly of web pages with links to local and 'off-net' sources of relevant information. Priority topics are likely to be educational and training resources, health and family planning information, agricultural extension information, refugee support information and online public services, including those relating to refugees.

The availability of 'e-government' type services is often overlooked, despite the special value these have in creating demand for connectivity by minimising the need for people to travel long distances from areas of forced displacement in order to be physically present to access such services whether provided by humanitarian actors such as UNHCR or local / national government. Therefore special measures may be necessary to encourage the development of these services. One example is UNHCR's 'KASI' system operational in Kakuma camp in Kenya, that supports access to UNHCR services through a kiosk interface.[62] Related to this, identity systems may also need to be in place because these are usually necessary to gain access to services, for using financial systems and to register

62 KASI is mentioned in the following operational update, accessed on 08/03/2020: https://reliefweb.int/sites/reliefweb.int/files/resources/1%20-%2031%20January%202019%20_%20Operational%20Update%20for%20Kakuma%20and%20Kalobeyei.pdf

businesses. In this respect, access to identity systems by refugees also needs to be taken into account. It can also be noted here that identity systems are currently an area of rapid innovation which could be of particular value for community networks, for e.g systems such as the Fraunhofer Institute's reclaim:ID[63].

Making as much content as possible available on the local network helps to increase demand for the community network's service, by improving performance and reliability while building a sense of ownership of the services and associated local information. At the same time this minimises capacity requirements on expensive backhaul links, and reduces congestion, thereby improving performance for services that require upstream bandwidth. To support local content development, use of smartphone and desktop applications with backend support for gathering and publishing information generated by the community may be needed[64].

There are a variety of other facets to demand-building that need to be taken into account, noting that these can also relate to the community's motivation for establishing a network. These aspects are:

1. **Capacity and skills.** Refugees and their host populations might not have sufficient skills to use the network, or might have preconceptions about it being too complicated to use, or be unaware of its benefits or the variety of applications and content that might be available. This will require awareness raising, support and training so that users can obtain the most value from the service.
2. **Relevant Content and Applications**. As indicated above, there needs to be sufficient relevant content and applications for the communities, or the content might be in different languages to those spoken in the community. The selection of content and applications used by the community should also take into account the broader potential opportunities for fostering entrepreneurship and small business development that may be unrelated to the operation of the network itself. This could range from providing the ability to work remotely, to supporting access to online information or computing resources that are needed to operate various local businesses – anything from arranging travel or translating videos into local languages, to providing mobile network airtime top ups or providing accounting and banking services for other local businesses[65]. These considerations may not only affect the physical design of the network itself (particularly the public access centre), but also the power supply component - in areas where there is no grid power, many small businesses can be fostered around the community network and public access facility if the electricity it requires can also be made available in the surroundings

63 A decentralized Identity Provider (IdP) service built on top of the GNU Name System (GNS) and GNUnet, a network stack for secure, decentralized applications: http://reclaimid.gitlab.io also see: Sovrin - Decentralized Identity Management: https://sovrin.org
64 e.g Ustad Mobile: http://www.ustadmobile.com / Internet in a Box: http://internet-in-a-box.org/ OLIP http://bibliosansfrontieres.gitlab.io/olip/olip-documentation/ Others at the Offline Internet Consortium: https://www.offline-internet.org
65 See Section 3 of the APC community networks case study report for further examples of these types of activities and their social benefits: https://www.apc.org/en/pubs/community-networks-case-studies

3. **Device Availability.** The local content and applications that are provided via the network may need to be adapted to match the availability and mix of access devices in use. For example, even feature phones used on national networks for voice telephony may be also used to access local information from the community via IVR systems, and text messages. In the case of a 2G mobile community network deployment, automated outgoing calls or text messages can be sent to users at no cost. Content created for laptops, desktops and other large screen devices may need to be fine tuned so that it can also be used on smartphone touchscreens. Content may also need to be designed for automated scrolling on unattended displays or on touch screen kiosks.

2.3.5 Protecting User Data

It is also important that mechanisms are in place to protect the privacy of any personal user data that is stored within the network, or sent outside for legitimate processing, to ensure that this data is not abused. Data protection can be especially important in areas of forced displacement where security of the personal information of refugees may be particularly at risk due to the nature of their circumstance. This also relates to the 'cookies' which are automatically generated by web browsers, the usage logs of servers, the text messaging and voice call logs of GSM/voice networks and interactive voice response systems.

Protecting this information would normally be necessary to conform to personal data protection laws, however very few countries in Africa, and none in East Africa aside from Kenya[66], have as yet fully implemented this type of legislation. Personal data protection requirements also brings up some tensions which will probably need resolution in community network implementations in forced displacement contexts. On the one hand there is likely to be a need to retain some of the data as a regulatory requirement of operating licenses, and also for analysis of usage trends in order to inform planning in network development (although for this purpose the data can usually be in an anonymised form, unless it is for cost recovery/billing purposes from individuals). Furthermore host country governments may be especially keen to have access to this data to give them confidence that they are able to monitor and address any security issues that may be present in areas of forced displacement. On the other hand, the protection of the privacy of the public is a human right which may be even more needed in refugee contexts, and storing this data can open it to increased risk of misuse or misappropriation.

This is not only about human rights and privacy principles in general, or protecting refugees, who may be particularly vulnerable[67], but it also relates to minimising inequitable power dynamics between community members that might be exposed by community networks. For example, ensuring that gender violence is not fostered by individuals who might be more able to pressure the local community network administrative staff to divulge the call

66 http://kenyalaw.org/kl/fileadmin/pdfdownloads/Acts/2019/TheDataProtectionAct__No24of2019.pdf
67 As indicated in recent research, refugees value privacy highly Refugee Connectivity: A Survey Of Mobile Phones, Mental Health, And Privacy At A Syrian Refugee Camp In Greece: https://datasociety.net/wp-content/uploads/2018/04/Refugee_Connectivity_Web.MB4_.8-2.pdf

records of their family members, or the web sites they have visited. Although this sort of abuse is still possible but much more difficult to effect when the data is held by a large national operator.

As yet these issues are not well understood among community networks and mechanisms for dealing have not yet been developed. It is likely that the forced displacement context provides special incentives to address the problem, which could benefit many other community networks. This could start with more in-depth research into the nature of the issues raised and the outlook for personal data protection legislation in the country. This could be followed by an assessment of potential mechanisms for helping to ensure the privacy of the users while making the data available to those who need it, such as: systems for automating the deletion of non-essential user data, methods for anonymising the data where possible, automatically encrypting the data and making the passwords only available to regulators and trusted people located outside the network.

2.3.6 Options for Institutional and Governance Models

As with community networks elsewhere, the institutional structures and related governance models adopted in community networks that are located in areas of forced displacement are likely to vary considerably from one location to another, depending on local contexts. As a result the network could be operated by a cooperative, a local authority, an NGO, a small business, an individual entrepreneur, a group of tribal leaders, as a collective of community members, or even volunteer run without any formal structure at all.

Ideally the structure of the entity will be a grouping that does not solely focus on refugees, or provide employment primarily to refugees, as this may alienate the host community and reduce the interest of government authorities in supporting or authorising the enterprise to provide communication services. It is likely that the choice of institutional structure will also be affected by the country's general legal environment for registration of enterprises, as well as the specific licensing conditions for telecom enterprises, and also any policies or laws on the extent to which refugees can participate in these structures, or even to be gainfully employed by them.

Currently NGO non-profit structures are probably the most common form of community network implementation vehicle in areas similar to the very low income forced displacement contexts in rural areas. In these locations, where the ability to raise startup funds and pay for services from within the community is extremely limited, this model may be necessary to help ensure that external resources are available to cover the initial setup costs and deficits in operating expenses. There may also be many NGOs already operating in these areas which would be able to take on the provision of these services.

However, among community network operating models, NGO-led initiatives in receipt of external financial support may not be the most sustainable or scaleable models over the longer term because there are likely to be fewer incentives to recover costs from within the community. This is especially the case when services are provided for free, which has often been observed in developing country NGO initiated community networks. Although it has also been envisaged that some of these initiatives would transition from free services to cost recovery from users later, this has often proved more difficult than expected, partly because it limits the sense of ownership in the initiative from the start, and may actually devalue the service in the eyes of the users.

Therefore a more entrepreneurial approach may be a more effective approach to begin with, which could range from a single entrepreneur-led initiative, to a family small business, an informal collective, or a cooperative. The latter is an increasingly popular means of operating community networks, which is perhaps unsurprising considering that the early community networks in the USA adopted this structure for their rural telecom networks and also for their power services. In addition, many rural enterprises in developing countries also use cooperative structures, such as agricultural and savings co-operatives.

Another local structure which could be an appropriate vehicle for owning and operating a community network is the local authority. Municipal networks are already relatively common in more developed countries and urban areas where their capacity to provide services is higher. However, there are also often local governance structures in rural areas in developing countries that could support a network. Examples of these include the village assemblies of indigenous people which own and operate the community mobile networks in Mexico (see the Annex for further details), the tribal authorities headed by the Mwami (King) for the network in the DRC, and the indigenous-led Sukabumi Regency in Indonesia.

Nevertheless, the specific structure that is adopted for the community network may ultimately depend more on opportunities to take advantage of existing local organisations in the area, as it is usually much simpler and faster to extend the mandate of an already operating entity than it is to set up a completely new one.

The Role of Community Network Support Organisations

This discussion has primarily focussed on the 'ground-level' institutional structure for managing the provision of communication services, however there is usually a strong case for a more layered arrangement where a different entity provides support and resources at a higher level for one or more community networks. This stratified approach has already been adopted by many community networks where an NGO or association of community networks helps to avoid unnecessary duplication of network resources at each location, and to address the difficulties of supporting widely scattered rural networks with limited local availability of skills. Since the support organisations can be located at a distance from the community networks, often in a more urban area, this also allows better contact with upstream capacity providers, equipment vendors, development partners, and the government offices where negotiations may and paperwork be required.

In more detail, the role of a support organisation would centre around three areas:

1. Splitting the setup and maintenance cost of the physical network infrastructure that can be shared among individual networks, such as high-sites and caching servers. This also extends to sharing the cost of the 'virtual infrastructure' - the upstream/backhaul links and voice telephony gateways.
2. Centralising some of the technical and administrative operational support. This can be related to the design and operation of the communications infrastructure, which often requires experienced technicians to dimension and configure network equipment, or for sharing bandwidth and calculating link budgets to optimise long-distance links. Centralised technical and administrative support not only minimises costs by reducing the need for each local network to replicate all of the human resources required to operate and maintain the network, but also helps to address the great scarcity of these skills in areas of forced displacement.
3. Acting and negotiating on behalf of individual networks in relations with government, suppliers and partners, such as in licensing, obtaining internet links and fundraising. This can also include support for the development and replication of community networks in the area more generally, such as by raising awareness of the potential of community networks and lobbying for their support by policy makers and regulators.

Depending on the specifics of the local environment, in particular in relation to telecom regulatory conditions, as well as government security concerns and other policy limitations on the role of refugees in local enterprises, and particularly in independent communication services, in some areas of forced displacement it may be necessary to extend the stratified model down to the operation of virtually all of the physical infrastructure, leaving the community to manage the resource on behalf of the host entity. This is essentially the approach that has been taken with the UNHCR Wi-Fi hotspot deployment currently being implemented in Ethiopia. While the network itself may best be operated this way in some situations, there may also be cause to consider a public access facility within the network that can still be owned by the local community.

The Role of Community Radio

Although not necessarily related to the choice of institutional model for the community network, the potential to establish the community network along with a community radio station, or to combine it with an existing community radio station should also be considered. It can be observed that many community networks have a close relationship with community radio stations[68]. These relationships are perhaps not surprising given the similar objectives that many community radio and community networks have in relation to improving access to communications and information. Community radio stations also often have physical infrastructure and staff that can be leveraged for a community network, in particular high towers, electric power and technical skills.

68 The first community mobile network in Mexico emerged from a community radio initiative and others with community radio partners include QuintanaLibre (Argentina), BOSCO (Uganda) and PamojaNet (DRC).

Although these relationships could primarily be with radio stations using traditional broadcasting technologies, there is also increasing interest in real-time and recorded audio streaming 'radio stations' which 'broadcast' over the community network infrastructure to smartphones/tablets and computers[69]. There are also a number of software applications and cloud services tools[70] that have been developed to support community radio in developing countries that work best in an online environment which could be provided by the community network.

2.3.7 Alternative Business Models, Cost Recovery Strategies and Financing

There are a variety of different business models that can be considered for community networks operating in areas of forced displacement, as described below. While most of them are not specific to contexts in which refugees are present, some of them may be more appropriate in some of these situations. Community network business models, cost recovery strategies and startup financing are also closely related to the institutional structures adopted for ownership and governance of the community network as described above.

In this respect, it can be noted that the discussion above has largely focused on a business model where the community owns and operates the physical access infrastructure to provide communication services to the end-user. Depending on the local conditions, in some cases other less ambitious models may need to be adopted, such as in providing support services for deployment and/or management of the underlying network infrastructure that is actually owned by third parties. This could be in the management and/or deployment of the passive infrastructure for the network operator – the solar energy facilities and masts for example. Similarly, operation and management of public access centres, mobile base stations and/or Wi-Fi hotspots could take place in partnership with a third party network operator such as in the Wi-Fi hotspot deployment currently taking place in Ethiopia as mentioned above, or for example in the Philippines mobile network model where the community network acted as a franchisee for one of the national operators.

In general, start-up and operating costs for community networks are relatively low compared to commercial networks, not only because they can start at a much smaller scale, but also due to the low cost of the equipment, opportunities for in-kind contributions (especially labour and premises on which to mount masts or electronic equipment (which may also include providing electric power), and the sharing of other institutional resources in the area. Nevertheless, financial resources are often very limited in areas of forced displacement. This can be exacerbated by factors such as lack of affordable energy sources, high costs for upstream connectivity, and low economies of scale.

Often connected with the institutional model adopted, but also depending on the specifics of the implementation strategy and local conditions, cost recovery strategies and startup financing mechanisms are likely to vary considerably between different community network

69 E.g. Janastu community mesh radio: https://www.apc.org/en/blog/enabling-community-participation-young-girls-and-women-janastu-community-mesh-radio-network
70 E.g: http://root.io

initiatives in areas of forced displacement. In developing the cost-recovery strategy it will also be necessary to define mechanisms for deciding how any surplus income generated from the network is distributed.

There are essentially three different cost recovery options to consider here, both in terms of how users may (or may not be) charged, and also in relation to other sources of operating or startup resources. These are:

1. Free access for all or some users (sometimes only at certain times), potentially subsidised by other users with a higher ability to pay. As indicated above, pure free access for all, perhaps provided by an NGO or government unit, is not likely to be the most scalable or sustainable option, but in some cases may be necessary where incomes are very low, or where there are other options to cross-subsidise the cost, at least initially. This is the strategy adopted by PamojaNet in the DRC, where small businesses with the ability to pay help cover the cost for provision of free access to the public in off-peak hours. It is also possible that free access could be provided only to certain groups within the community, such as students.
2. Full cost recovery from end users via a monthly or annual subscription, or on a pay-as-you go basis, usually per day/week/month for Wi-Fi networks, or on a per call basis for mobile networks. This type of cost recovery can also be achieved through a mix of monthly fees and usage fees, mainly for mobile networks with off-net calls being charged for, but also in Wi-Fi networks with high backhaul costs, especially where upstream connections may have metered usage based on traffic – such as where 3/4G networks are used to provide the upstream connection, and in some satellite links.
3. Reduced cost recovery from end users, with the deficit covered by financial or in-kind contributions from third parties. These contributions are likely to be from NGOs supporting the community network and as has been the case in many other community networks, also potentially from a) corporate social responsibility programmes of the commercial suppliers of both equipment and services (such as routers and backhaul/upstream capacity), b) upstream capacity and technical skills from nearby academic and research organisations c) government rural broadband programmes and Universal Service Funds.

Startup financing

Due to the very low incomes in most areas of forced displacement it is likely that the cost of the initial equipment will need to be financed externally. Commercial investment funds are an unlikely source of finance considering that they will have high perceptions of risk in these enterprises and associated forced displacement environments which are likely to be unfamiliar to them. In addition, they will have low levels of interest because the returns are likely to be very low, otherwise traditional commercial networks would already be present in these locations. Furthermore, the overheads from the due diligence that are required for any commercial investment are likely to be too high relative to the small amounts of funds that are required. Loans from traditional lending sources are also unlikely, not only due to the conservative nature of the banking sector, but the difficulties regarding customer due-diligence and and the ability of financial institutions to comply with KYC regulations when engaging refugee populations. However if a credible organisation was able to provide some guarantees in the event of a default, this might still be possible.

Nevertheless, startup financing is most likely to be supplied by the NGOs involved in supporting refugees and host communities in the area. This could be done on a donation or a loan basis. Two other potential sources of financing are:

1. Informal community loan circles / Village Savings and Loan Associations (VSLAs) – these are present in many rural communities where savings are made for high expense activities such as - in certain contexts - funerals.
2. Crowd sourcing of funds from multiple sources via one of the crowdfunding platforms such as Kickstarter or Indiegogo. Aside from general appeals to the global public at large, this option may be a way of attracting funds from the diaspora that have links with the area/displaced group.

In order to minimise startup financing requirements, opportunities to reduce the cost of capital expenditure need to be identified. Most of the required equipment currently has insufficient or no in-country demand, and is therefore not likely to be available from local suppliers. So, bulk purchasing and consolidating the shipping requirements for multiple projects could help to significantly reduce the cost of the majority of the electronic equipment that will almost inevitably come from outside the country. Considering that import duties can double the cost of equipment, import duty exemptions for humanitarian purposes could also be explored.

Masts are often the largest single expense item in community networks, so emphasis needs to be placed on minimising this expense. The primary means of doing this is of course to identify existing towers and high sites. Access to them may involve commercial negotiations with their owners, often network operators and broadcasters, which may involve support from infrastructure sharing regulations, or where these regulations are absent, advocating for their adoption. Low cost mast designs also need to be identified. In addition, strategies to support and encourage their manufacture within or close to the community need to be considered in order to reduce their transport costs.

Finally, the potential for in-kind human resource contributions from volunteers to reduce startup costs and to provide skills transfer also needs to be considered. This ranges from individuals within the community who become passionate about the project, or may be willing to contribute their time in return for access to the network, to volunteers from outside the community, such as through placements from formal volunteer organisations such as LibreCorps, GeekCorps, UN Volunteers and others.

3. Conclusions for Implementation of Pilot Projects

In terms of choice of service mix, taking the above considerations into account it appears that the most effective implementation strategy would be to begin with the provision of Wi-Fi connectivity perhaps augmented with some public access facilities. This could also include developing a mobile network implementation strategy which could begin at the same time, with negotiations with the regulator and other government authorities.

The above would need to be preceded by an assessment of the potential locations for deployment of the types of services (Wi-Fi hotspots, public access centres and mobile networks), based on a deeper assessment of the country, identification of potential in-country partners and an evaluation of the specific conditions in various potential locations. This should be not only with regard to the general social, economic and security status of the host communities, but also in terms of coverage and services provided by the existing national networks. For example, if 2G is only available, then there is a strong case for deployment of Wi-Fi and/or 4G-LTE. I.e where the demand for voice and funds transfer services is already met by a mobile operator, but access to the Internet and local information is lacking. If no mobile coverage is available at all, and the regulatory environment is conducive, then ideally a 2G and 4G/LTE network could also be deployed. The priority need for basic voice services is underlined in the Digital Lives of Refugees report[71] which points out that phones are most needed by refugees for calling and texting, followed by financial services and then information/content.

The other important factors to consider in determining the nature of the pilot projects and the selection of the locations are:

1. **Simplicity and phasing of approach.** Regulatory issues aside, it will probably be the least complicated strategy to begin the phases of the community's technology deployment with public and private Wi-Fi hotspots because deploying 2/4G-LTE equipment is considerably more complex. Mobile technologies and the associated spectrum usage planning required to maximise coverage with limited amounts of spectrum across multiple low-power cell sites require substantial technical skills and prior experience in this area, which may not be readily available in forced displacement contexts
2. **Competing priorities.** Due to the generally low income levels in areas of forced displacement, host communities could place less priority on connectivity, especially where voice services are already available, and may instead focus on lack of other basic services such as water supply, shelter and aspects resulting from the specific dynamics of communities where refugees reside. This may be in contrast to the refugees themselves, as research carried out by UNHCR indicates that refugees often prioritize connectivity over aspects such as education, clothing and healthcare.[72]
3. **Limited perception of value.** Refugees and their host populations might not be

71 https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/The-Digital-Lives-of-Refugees.pdf
72 Connecting Refugees: https://www.unhcr.org/5770d43c4.pdf

aware of the full benefits of connectivity, and may not have the skills to use the Internet, or they might think that using the Internet is too complicated. Addressing this may require some resources invested in awareness raising and detailed discussions with the community before embarking on the project.

4. **Cultural aspects**. Communities might see the Internet and flat non-hierarchical forms of communications such as messaging and telephony as a threat to local culture and traditions. This may also have to be assessed through discussions with communities. On the flip side, some rural communities in forced displacement areas may already have a conducive approach to building and operating the networks which reflects their history and culture of cooperative enterprise. Communities already familiar with a commons approach, such as in collective water and land management, may more easily adopt this strategy in establishing communications infrastructure.
5. **Understanding of gender issues**. Gender discrimination is often present in forced displacement contexts, as it is in many other areas, particularly in developing countries, which may necessitate planning for the availability of zones for girls and women where they are able to the connectivity more safely. This requires an understanding of gender issues and the barriers to women's participation, which may be present within the community wishing to establish the network, noting that sensitisation to these issues may not be a simple matter in many cultures.
6. **Realistic time schedules.** Rural development often takes much longer than anticipated and with the complexities of a community network development project and the associated regulator and community consultations that will be required, adequate time for project initiation and results evaluation needs to be allowed for. Two years is not an uncommon time frame for the initial implementation period for a project, and another year may be necessary before the results can be adequately evaluated.
7. **Scaling and replication**. Scaling up of initial community network deployments is usually the key to making them sustainable in the long term[73]. Thus, a trial project in a forced displacement area may not be sustainable on its own, and evaluation of its success should not necessarily be based on the initial phase of the project as long as opportunities and requirements for scaling are identified and designed in the project. Similarly, it has been observed that many community networks stimulate the replication of the project in the nearby vicinity due to the demonstration effect and access to skills in the initial network. This local contagion effect provides a strong impetus and argument for anticipating expansion and replication of community networks in geographic proximity. This is particularly important for helping to ensure the sustainability of the community network support organisations described above.
8. **Project evaluation.** In terms of project evaluation, UNHCR has previously developed a set of refugee connectivity KPIs[74] which are largely in line with a community networks approach, although they may need to be modified slightly to take into account the potential absence of traditional MNOs.

73 See the GISWatch chapter: "Towards Financial Sustainability in Community-based networks" https://www.giswatch.org/en/infrastructure/towards-financial-sustainability-community-based-networks
74 https://www.unhcr.org/5770d43c4.pdf

3.1 Summary of Factors Affecting the Emergence and Support for Community Networks

The list below presents proposed key factors for assessing the potential of the country and the local environment to foster a sustainable community network initiative. These factors are divided into national level factors and the factors present in the specific locality. Note that there are many other factors that may have an impact on the potential for a sustainable community network, but not as important as the ones listed below. In addition, the factors are framed as opportunities and strengths while their reverse would pose weaknesses and threats. See the associated Collaboration for Connectivity report for further discussion of additional readiness factors. [75]

National

1. Presence of a supportive national ICT/broadband policy
2. Close relationship between the national telecom policy maker/ regulator and UNHCR
3. Presence of supportive connectivity service provider licensing framework and potential exemptions of license fees for refugee areas
4. Spectrum licensing framework that supports access by community networks
5. Availability of unassigned mobile radio spectrum
6. Presence of infrastructure sharing regulations that help to ensure access to backbone infrastructure and masts
7. Presence of interconnection regulations which allow small networks affordable access to large commercial networks and numbering resources
8. Presence of a Universal Service Fund which is able to provide finance for community networks
9. National investment in backbone infrastructure
10. Absence of surveillance of service provider traffic, shutdowns and web site censorship
11. Ministry of Education support for connecting learning centres
12. Absence of significant security threats in the country, especially those relating to refugees
13. Low import duties which minimise the prices of access devices, solar power and network equipment
14. Low value added taxes on communications services
15. Stable and well respected refugee policies, including freedom of movement, freedom to seek work
16. Available e-government services

Local

1. Absence of coverage by existing connectivity providers - based on presence of reliable maps of coverage
2. Potentially supportive local partners for in-kind resources and funding
3. Presence of community radio stations

75 http://www.unhcr.org/innovation/connectivity-for-refugees/

4. Presence of physical structures that can be used for public access facilities
5. Presence of nearby upstream connectivity points of presence
6. Affordable and reliable grid power
7. Reasonable level of device penetration
8. Knowledge of or experience with use of connectivity - some digital literacy skills in the community
9. Presence of existing high sites and masts which can substantially reduce the cost of deployment
10. Presence of livelihoods programme
11. Potential for scaling and replication of the initiative locally
12. Presence of CBOs in the area with a technology support interest

4. Summary of Recommendations

In order to realise the potential positive impact community networks can have in forced displacement settings, it requires support, advocacy and action from a broad coalition of stakeholders. Accordingly, the following recommendations are being made that would further support the development of community networks in forced displacement settings:

4.1 To UNHCR and other humanitarian organisations

1. Test community networks in forced displacement contexts: Trial support for the emergence of community networks in forced displacement contexts as a potential complementary solution in helping to address the need for basic communications services among refugees and their host communities affected by lack of affordable connectivity. This would involve:

- Implementing a range of different trial projects in the countries covered in the scope of this study (Kenya, Uganda and Ethiopia) in order to gain experience and better assess the wider applicability of the community networks model in different forced displacement contexts, using different institutional structures and technologies.
- Prioritizing the provision of voice telephony along with Internet connectivity in areas where there is no coverage, despite the regulatory constraints for small mobile networks.
- Engaging with national policy makers and regulators to:
- build their awareness of the potential for community networks in forced displacement contexts, and to encourage them to adapt or adopt a degree of flexibility with policies and regulations to help ensure the pilots have the best chance of success and sustainability by minimising burdens resulting from license, interconnection and spectrum assignment frameworks (see below).
- Researching the outcomes of different mobile community network implementations to determine which technical options and institutional models best fit with the needs of people living in areas of forced displacement while taking into account the position of regulators on small scale mobile networks

- Identifying ways of working with existing MNOs to leverage their resources and needs for fostering community networks.

2. Monitor and research developments in innovative digital financial systems and financial regulatory environments. Identify new digital finance innovations, payments mechanisms and business models that can complement or are interoperable with existing mobile money services, as these may not be available via community networks in areas where there is no coverage by the MNOs.

3. Encourage the development of local content. Help to maximise the value derived from community networks and other connectivity provided in forced displacement contexts by ensuring there are useful local content and applications available (ideally hosted locally), both for the direct benefit of the local population and refugees, and to build demand for community networks, thereby helping to ensure their sustainability. This also includes ensuring applications and mechanisms are available that support communities in producing their own local content. Part of this effort would also be to ensure UNHCR systems are accessible through such networks, and furthermore to encourage host country governments at all levels (national, regional and local) to ensure that relevant public services are digitized/available online, e.g asylum services, birth registration etc, as well as working with government and other stakeholders to ensure information and applications relevant to refugees is available.

4. Raise awareness of community networks in the humanitarian community. Identify key global and regional partners with which UNHCR could collaborate with in support for community networks and support awareness raising activities within this group.

4.2 To governments hosting refugees

1. **Take advantage of community networks where suitable.** Take into account the potential of community networks in helping to meet connectivity gaps in the population generally, and in particular in areas of forced displacement.

2. **Adopt appropriate licensing regimes for community networks.** Create new license categories and / or fee structures - including exemptions - for small community networks which optimise viability of networks, ensuring fees, taxes, reporting and licensing requirements are viable and are at levels commensurate with the capacities of community based non-profit networks.

3. **Ensure spectrum is available and affordable.** Make mobile and / or secondary/ shared-use spectrum available at low cost to community networks for both 2G, 4G-LTE and TVWS-based services. In addition ensure licensed or unlicensed spectrum is available for backhaul links.

4. **Ensure affordable backhaul infrastructure and capacity is widely available.** Encourage greater coverage and more affordable backbones such as through infrastructure sharing and dig-once regulations and public investment in national backbones and international fibre capacity.

5. **Reduce interconnection barriers.** Ensure small-scale operators can interconnect with other operators in the country on an equal cost basis, along with affordable numbering resources and access to national/international wholesale capacity and dark fibre[76] where available.

6. **Leverage public funds for community networks.** Ensure financial support such as universal service funds are available to encourage the emergence community networks, prioritising refugee hosting areas.

7. **Develop e-government services.** Governments at all levels (national, regional and local) should ensure that relevant public services are digitized/available online, e.g asylum services, birth registration etc.

4.3 Considerations for organisations designing and supporting trial community networks in refugee communities

1. Trial implementations should cover the range of regulatory environments and local conditions present in forced displacement areas in order to maximise learning and potential for future scaling.
2. Take into account issues linked with age, gender and diversity, and the barriers to girl's and women's participation which may be present within the refugee community.
3. Cost-recovery mechanisms should avoid starting with a free service initially as this makes it more difficult to scale and to transition to a fee-paying cost recovery model later.
4. Ownership and governance structures for operating community networks should maximise the refugee community's sense of agency and ownership in the initiative, while taking into account potential needs for support entities which can offload some of the tasks of individual community networks, share the cost of backhaul capacity and administrative burdens among multiple community networks.
5. Identify strategies for minimising the cost of capital equipment, including leveraging the humanitarian community's special role in reducing the cost of electronic equipment through bulk purchasing, consolidated shipping and import duty exemptions, as well as through designs and local manufacture of masts and antennae.
6. In the design of the community network's power supply requirements, consider the broader opportunities in forced displacement contexts that can be created for fostering small businesses that can emerge from the availability of connectivity, local computing resources and energy.
7. Consider taking advantage of the synergies between community networks and community radio stations that may be present or emergent in the area.

76 Unused Fibre-optic cables.

8. Consider innovative options for accessing startup funding for community networks such as community loan circles and crowdfunding platforms which may attract special support from those with humanitarian concerns, as well as the diaspora.
9. Identify mechanisms to address the special data protection needs and privacy issues in community networks, particularly from a forced displacement perspective.
10. Allow adequate time for project implementation and evaluation.

5. Country-Specific Considerations in the Countries of Initial Interest

This section provides brief information on strategies, activities, partnership opportunities, policies, regulations and other dynamics that may have an impact on the country strategy and the selection and design of trial community network support initiatives.

5.1 Global and Regional Agencies/Initiatives

There are a number of global organisations or initiatives that could have an impact on community network project development in all three countries of interest.

International Telecommunications Union (ITU)
The ITU provides support for national policy and regulatory development generally, and is currently collaborating with the APC (an ITU-D sector member) to develop a set of guidelines on the development community networks. The ITU also supports a joint initiative with the UNHCR and the GSMA on improving connectivity for refugees. In addition it is collaborating with UNICEF on an initiative to connect all schools, known as the Giga project.

World Food Programme (WFP)
Considering that UNHCR already collaborates closely with the WFP, and the congruence between some of the communication technologies used for disaster relief and those used in community networks, it is likely that some synergies can be realised through collaboration in this area. Of note here is the Emergency Telecoms Cluster (ETC) and WFP's Fast IT and Telecommunications Emergency and Support Team (FITTEST).

Internet Society (ISOC)
ISOC has the development of community networks as a key pillar of its access development strategy and supports the annual Community Networks Summit in Africa.

East African Communications Organisation (EACO)
EACO comprises an association of the national regulators agencies of the East African Community, the Regional Economic Community (REC), for the region. The organisation holds regular meetings where policy and regulatory issues are shared among the member organisations, and this can be an effective forum for discussing the policy changes needed to support community networks. APC has already hosted successful workshops with EACO on infrastructure sharing and community networks.

International Federation of Red Cross and Red Crescent Societies (IFRC)
IFRC is active in areas of forced displacement, and both the HQ and the national societies in the East African Region are expected to have a strong interest in the opportunities provided by community networks for extending connectivity. Initial awareness raising of this has already taken place within the IT Innovation and National Society Development unit in Geneva.

5.2 Ethiopia

Ethiopia has a restrictive telecom policy and regulatory environment and a monopoly operator, but is currently revising its telecommunications policy and regulations. APC has proposed various measures to support community networks as part of its contribution[77] to the public consultation on telecom liberalization, together with ISOC, A4Ai, the Network for Digital Rights for Ethiopia and Bahir Dar ICT4D Research Center. In March 2020, ISOC is organizing an Internet Development Conference in Addis Ababa, Ethiopia to support this process of policy development.

The Bahir Dar Technology institute aims to establish a community networks research initiative led Dr. Tesfa Tegegne[78].

5.3 Kenya

Kenya's national regulator, the Communications Authority (CA), has expressed interest in community networks, to the point of including them in their National Broadband Plan, in whose preparation process APC was involved. The current draft of the National Broadband Plan[79] has the following text already included, but it is expected that the next version will have a more comprehensive approach to community networks. "Each County to establish three (3) community network hubs for rural penetration. And in each hub establish a Digital Knowledge Centre (DKC) and DigitalKnowledge Library (DKL)." CA also hosts the African Telecommunications Union (ATU) offices, which could be leveraged for broader influence in the continent. In addition, it has recently published a draft dynamic spectrum access framework for TVWS authorisation[80]. Kenya was one of the first countries to experiment with using TVWS more than five years ago in a project called Mawingu which switched to Wi-Fi based services when the experimental license was not renewed.

Community networks have emerged relatively recently, starting with Tunapanda Networks which provides advocacy, training facilities and access services in the informal settlement of Kibera (Nairobi) and is provided with backhaul capacity from the national research and education network, KENET.

In Nakuru, a new community network called Lanet Umoja and led by Afchix in partnership with the Kenya Education Network (KENET) has been established.

77 https://www.apc.org/en/pubs/contribution-ethiopian-telecommunications-sector-stakeholder-consultation-no-001-2019
78 https://bit.bdu.edu.et/bddii2
79 https://ca.go.ke/downloads/publications/national-broadband-strategy/
80 https://ca.go.ke/public-consultation-on-the-draft-dynamic-spectrum-access-framework-for-authorisation-of-the-use-of-tv-white-spaces/

The Mozilla Foundation recently signed an MOU with the ATU that, among other aspects, will support regulatory capacity-building complementary to APC's efforts on issues of spectrum management and enabling environments for small operators.

AfChix is a network of women in technology who consider gender diversity in the ICT sector to be critical for increased creativity and innovative performance of the industry. Afchix is collaborating with Chief Francis Kariuki of Lanet Umoja Community in Nakuru North District to mobilize local women community leaders to implement a local wireless community network[81].

Other efforts in the community network space in underserved areas include those of APC member, Arid Lands Information Network (ALIN). In the advocacy realm, the topic is also gaining momentum with organizations such as APC member KictaNet, and the local ISOC chapter hosting events to share knowledge about community networks and discuss their potential. Additionally, the first two editions of the Summit of Community Networks in Africa were hosted in Kenya in 2016 and 2017.

APC is in the process of finalising a 2.5 year grant with the UK Department for International Development to support community network development on a national basis in 5 countries, of which Kenya is one.

5.4 Uganda

In January 2020, following submissions from APC and hosting of officials at national meetings on community networks, the national regulator, the Uganda Communications Commission (UCC), approved new categories of licenses which include a license to provide 'Communal Access'. The first such license category in Africa, it will be granted to persons who intend to provide 'communal access to telecommunications services' where community is defined for this purpose as 'a group of persons living in the same geographical location, having particular characteristics and interests in common'. The following are some of the key features of the Communal Access license as stated by UCC[82]:

- A holder of communal access license will be authorised to establish, operate and provide communal access to telecommunications services to a particular community
- An applicant for this license must provide evidence of finance and technical capacity to enter into a contract with licensed providers of telecommunications services
- This license is typically suitable for community-based, not-for-profit entities that may wish to provide subsidised telecommunications services to unserved or underserved communities
- The license shall be for five (5) years renewable

The UCC appears to leave open the possibility of spectrum assignment for communal

81 http://www.afchix.org/projects/
82 https://uccinfo.blog/2020/01/27/approved-new-telecommunications-license-categories/

licenses, in that the other license categories clearly state if the license holder can or cannot license spectrum, while there is no mention of spectrum in the communal license. It is also possible that this is perhaps an accidental omission.
Aside from these developments around licensing, UCC has also approved a TVWS spectrum management framework[83] in 2019 which should make it much easier for small networks to use these technologies for their long distance non-line-of-sight links.

BOSCO is an externally supported community network initiative established as a faith-based non-profit organisation in 2007 by members of the Roman Catholic Church. BOSCO is active across a large number of relatively densely populated communities in areas of forced displacement, most of which are within a 100 kilometre radius of the city of Gulu, where BOSCO's 20 technical and administrative staff are based at the Catholic Archdiocese. About 10 years ago, the project began providing wireless internet access and VoIP telephony in internally displaced persons (IDP) camps by setting up public access centres which focus on digital literacy training, computer-based learning and supporting local business development for youth. See the APC case study report for further details on BOSCO.

WOUGNET is a non-governmental organization initiated in May 2000 by several women's organizations in Uganda to develop the use of information and communication technologies (ICTs) among women as tools to share information and address issues collectively. It is now interested in starting a community network in collaboration with netLabs! Uganda at the School of Engineering at Makerere University. The network is likely to be started in Apac where WOUGNET has been working with farmer groups for many years.

83 https://www.ucc.co.ug/wp-content/uploads/2017/09/UCC-TVWS-standards.pdf

6. Annexes

6.1 Details on Communications Infrastructure Technologies & Sources of Equipment

Wi-Fi

Community networks mainly use the 2.4 GHz and 5.8 GHz license-exempt ISM bands for wireless links, based on spread spectrum data protocols commonly called Wi-Fi. For long distance transmissions with focused antennas, the same frequencies are normally used but the communication protocols may be different (see below). Distances achieved between hotspots and access devices can be up to 200 metres, and 50-70km is often achieved on long distance links – sometimes called Wi-Fi for long distance (WiLD). Use of the license exempt bands for long distance links may not be optimal due to interference, especially if one end of the link is in an urban area, which is relatively common as a means of obtaining upstream Internet capacity or backhaul capacity for mobile networks. However licensed spectrum is often unavailable or too expensive for community networks to use.

Ubiquiti equipment supports high-throughput 802.11ac standard which provides for links of over 1Gbps, and in addition their equipment has a proprietary TDMA mode (AirMax) for minimising the impact of interference and optimising the use of Wi-Fi communication protocols on long-distance links (30-100km), which is almost universally used for these types of links. This feature is not yet available in the LibreRouter but is planned for the next version of the device once financial support is found for its development.

A small number of companies supply almost all of the Wi-Fi network equipment used by community networks. The three companies are Ubiquiti, TP-Link and Mikrotik, from New York, Shenzhen and Riga (Latvia), respectively. Also in Shenzhen is Dragino, the company that has started to manufacture the open hardware LibreRouter for APC member Altermundi.

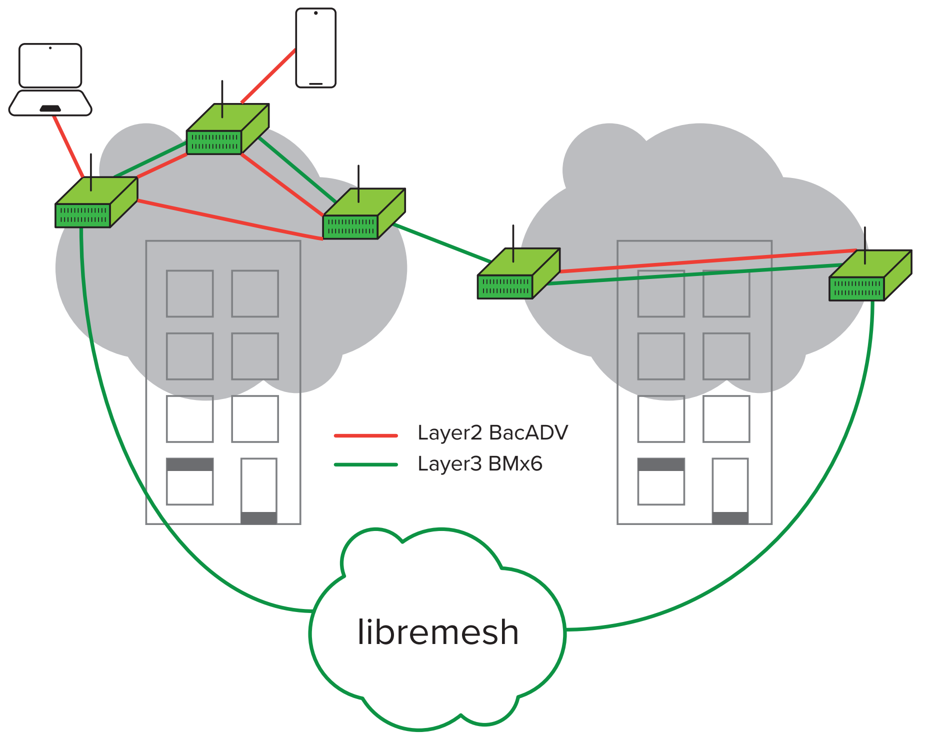
Mesh networks are increasingly based on the LibreMesh distribution developed by Altermundi. This uses dual mesh networking protocols (B.A.T.M.A.N for layer 2 and BMX6/7 for layer 3 – as shown in the diagram below). The software can also be installed on some commercial wireless routers and is based on the popular open-source wireless router operating system called OpenWrt[84].

Figure: Mesh Wi-Fi networking using LibreMesh with BMX and Batman-adv[85]

For Wi-Fi network management software, proprietary software called UniFi, developed by Ubiquiti specifically for its access points) is used by Ubiquiti based Wi-Fi-based networks. It includes a captive portal and voucher system for authorizing access to the network.

84 https://openwrt.org
85 https://libremesh.org/howitworks.html

Similarly, LibreMesh now includes the Pirania captive portal and voucher system. Mikrotik's RouterOS also plays an important role in network management where Mikrotik hardware manages upstream routing and QOS.



Television 'White Space' (TVWS)

TVWS systems provide for long distance connections over non-line-of-sight (NLOS) links by using the lower frequency 450MHz-700Mhz bands, although few countries have so far licensed the use of these wavebands for this purpose (in Africa, only South Africa Mozambique and Nigeria have TVWS regulations in place). Some of the suppliers of this equipment include Adaptrum (USA), 6Harmonics (Canada), Carlson Wireless (USA), Runcom (Israel), and Saankhya Labs (India).

TVWS technologies are still relatively new, and with a limited number of countries sanctioning their use, mass production of equipment has not yet been achieved. As a result equipment costs are relatively high – about USD 5 000 for a base station and USD 1,000 for the equipment for each remote link.

Low Power GSM/LTE

In contrast to the traditional 'core network' model of national mobile network operators, where switching functions take place at the operator's central location, this equipment can also operate independently where each base station is a complete 'network in a box'. This uses a low cost laptop or PC to carry out the switching of traffic directly between users, eliminating the requirement for upstream capacity to carry the call traffic, thereby cutting costs and increasing reliability. If solar power and tower are not required, a small mobile network can be set up for about USD 5,000, supporting a few hundred subscribers. A solar power system and 12-15 metre tower can add an additional USD 2,500 to this cost.

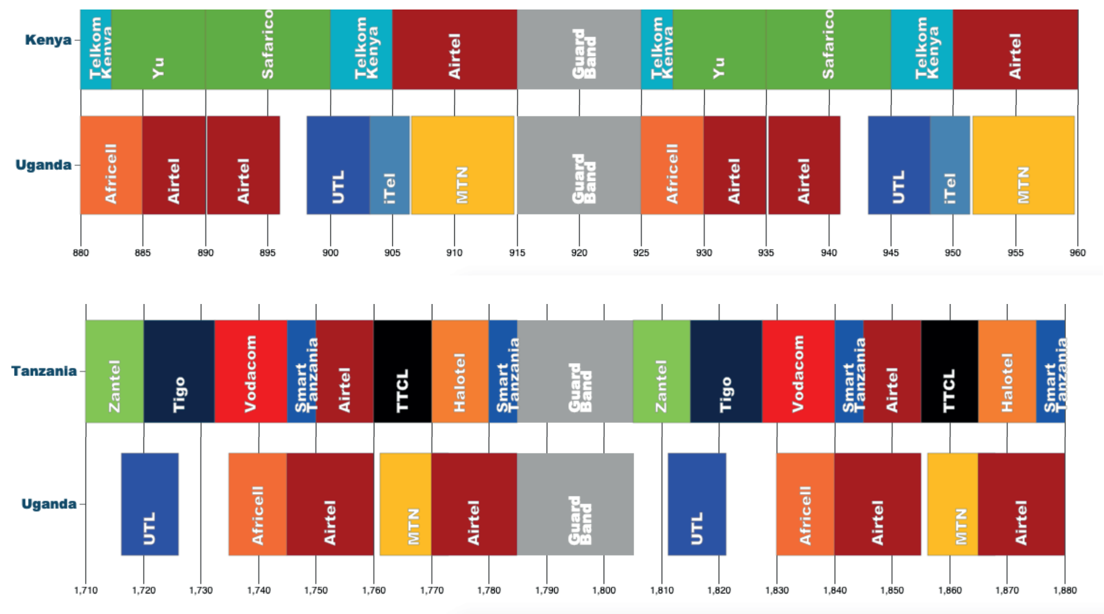
The cellular base stations deployed in mobile community networks are primarily manufactured by Nuran Wireless (Cyrille-Duquet, Canada), Fairwaves (Boston), Sysmocom (Berlin), and for LTE networks - Baicells (Plano, Texas, USA). For 2G base station operating system software, open source Osmocom is used on a wide range of open hardware devices such as those produced by Nuran, Fairwaves and Sysmocom. The CoLTE version of the open-source Open Air Interface has been used for the Baicells LTE network.

Also of note here is APC member Rhizomatica's Administrative Interface (RAI), a web-based management platform which supports higher level functions such traffic monitoring and account management. To manage GSM voice networks which are integrated into larger core networks, such as in the VBTS project in the Philippines, the Community Cellular Manager (CCM) was recently developed by Facebook.

The frequencies that are normally used range from the 700 MHz to the 2100 MHz bands. In Region 1 (Europe and Africa) the 800-900Mhz bands, where available, are the most desirable because these lower frequency bands have better long range propagation characteristics than the higher frequency bands. The choice of waveband can also depend on the geographic location because frequency allocations are the result of regional agreements and national band plans. This in turn can affect the local availability of handsets which support a particular waveband. In addition, waveband choices also depend on the type of mobile technology adopted – LTE has many more bands available than GSM, including some that can be used for spectrum sharing (band 48).

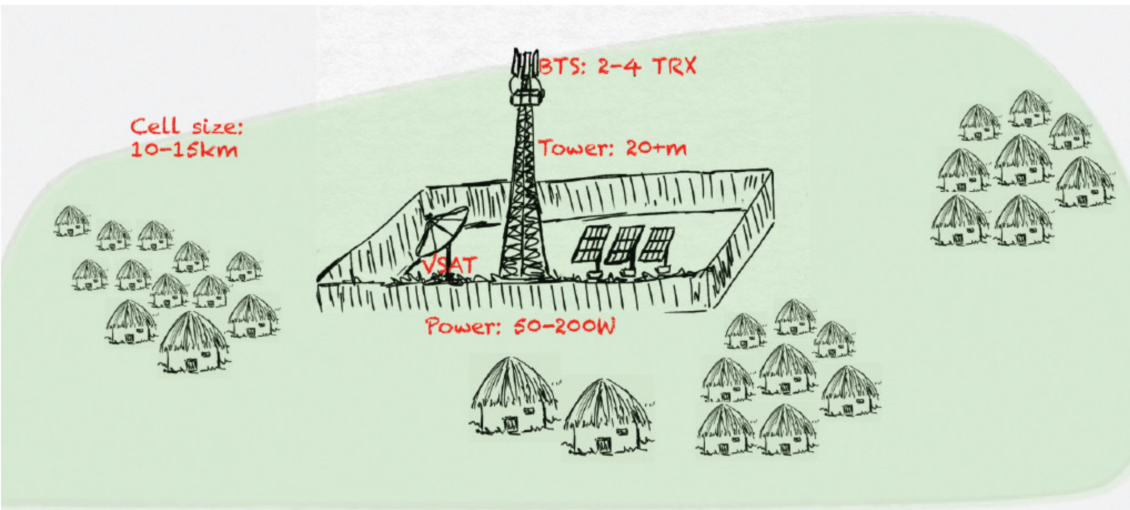
While only some mobile spectrum assignments are publicly available in two of the countries of initial interest, the information on assignments that has so far been obtained as part of the APC/Mozilla Foundation supported OpenTelecomData project is displayed below. As can be seen, in the 900MHz band, the spectrum is fully assigned to national commercial operators, while in the 1800MHz band, there are significant quantities of unassigned spectrum in Uganda, although this frequency is less optimal for rural networks due to shorter distance propagation characteristics.

Mobile network spectrum assignment example[86]



From: https://opentelecomdata.org/spectrum-chart/

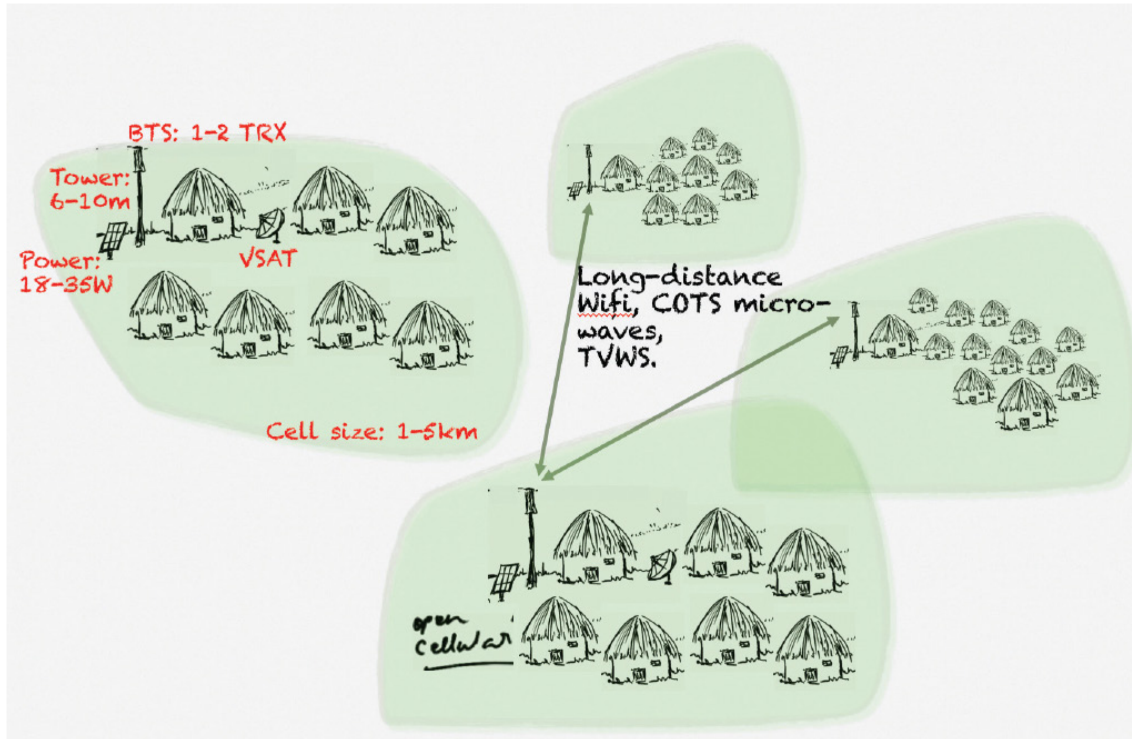
Figure: Comparison of Mobile Network Architectures[87].
Current Rural Mobile Network Model



86 From: https://opentelecomdata.org/spectrum-chart/
87 From: https://cacm.acm.org/magazines/2018/8/229756-designing-sustainable-rural-infrastructure-through-the-lens-of-opencellular/abstract

De facto deployment:

Bottom Up Model:



6.2 Mobile Community Network Profiles

With their much wider presence, the architecture of small scale wi-fi based networks is relatively well understood, but due to their comparative rarity, much less is known of small-scale community based public mobile networks. This section provides more details of these networks, derived from APC fieldwork carried out in 2018[88].

6.2.1 TIC AC, Oaxaca, Mexico

TIC AC is a non-profit association of community-owned mobile networks in Mexico, which became the first GSM special purpose licensee in the world in 2016. Building on earlier work with local community radio stations in Oaxaca, in 2014, a Mexican non-profit indigenous community support organisation called Redes[89] leveraged constitutional provisions for indigenous communities to obtain an experimental license for exploring the use of low cost, open source GSM network equipment. This process was assisted by the Oaxaca-based NGO, Rhizomatica[90], which works to help disenfranchised communities take advantage of new telecommunications infrastructure.

During the pilot period Mexico's telecommunication law changed, allowing for licensing of social-purpose networks operated by non-commercial entities. To take advantage of this Redes and Rhizomatica helped establish TIC AC in 2016, which was given a 30 year operating license for five states, along with a 15-year no-cost concession for the use of a small quantity of spectrum (2+2 Mhz[91]) in the 850 Mhz band. With this TIC AC has now helped indigenous communities build and operate 16 independent mobile 2G voice networks which cover about 70 localities in the state of Oaxaca. Three of the 16 networks averaged less than 100 subscribers a month, while the largest network had 500 subscribers.

The networks provide free incoming calls, unlimited calls between local network users, including roaming between the local networks and text (SMS) messaging. Voice mail is not provided as there is very little demand for it, however SMS broadcasting for general notifications is supported, and basic USSD functionality is available for querying credit balances and phone number reminders.

The initiative builds on the work of Rhizomatica in developing the use of small-scale mobile voice platforms and other low cost telecom infrastructure. In 2013 there was no equipment being produced that could be easily used to operate a small mobile/cellular network. So a custom solution was developed using a generic software-defined radio. Since then numerous companies, such as Sysmocom, Nuran Wireless, Range Networks, Baicells and Fairwaves have developed low-cost mobile cellular radios[92].

Each of the TIC AC member networks is operated independently, with the local indigenous assemblies deciding how they will contribute to the cost of the tower and radio equipment, and who will be trained to manage it. In addition the assemblies decide how the income generated from the network is distributed.

TIC AC assists with technical and administrative advice in the formation stages of a new network, and subsequently with the installation, technical training and backstopping, as well as managing interconnection with other networks. After the initial enquiry from the village, the process of consultation can take 3-6 months before the networks are up and running[93].

For unlimited local calls, users of the networks pay a monthly fee of about USD 2.2 to the local network administrator in the village[94]. The administrator of the local network forwards about 35% of this fee to TIC AC to cover the cost of the overall network administration (including backhaul links etc), helping new networks to start, and managing the relationship with the authorities.

TIC AC's negotiations with government continue around issues such as interconnection and taxation. In relation to tax, the Mexican tax law has not been adjusted to take into account that there are non-profit users of spectrum, so social operators were expected to be taxed for spectrum-use at the same rate as large MNOs. This has been challenged by TIC AC in the courts, which argues that the Mexican state has been saved millions of dollars in costs for its obligation to ensure that all population centres have access to emergency communications. The courts have so far upheld TIC AC's position, however, pending the decision of the higher court, the issue remains unresolved.

The governing structures of TIC AC are a members' assembly and an executive body, which are supported by staff working in operations, administration, community relations, innovation and maintenance.

The staff complement at TIC AC consists of about 10 people, who are mainly dedicated staff, except for the roles of book-keeping/accounting, which are shared with Redes AC. In detail this means:

- Installation and maintenance (2 people)
- Technical support, configuration and operating system software (1)
- Base station equipment and power systems development and maintenance (1)
- Non technical issues liaison and community building (1)
- Operations coordination (1)

88 This section is based on APC research carried out in 2018. For further details of the research see: https://www.apc.org/en/pubs/community-networks-case-studies
89 Redes por la Diversidad, Equidad y Sustentabilidad A.C.
90 Rhizomatica is also a 501c3 US non-profit and an APC member: http://www.rhizomatica.org
91 2Mhz uplink and 2Mhz downlink – this amount of radio spectrum is limited – less than 25% of the amount assigned to a conventional MNO - insufficient for growing existing many small networks to their full voice demand, let alone for migrating to higher capacity 3G / 4G services which require much more spectrum.

92 https://www.rhizomatica.org/choosing-a-low-cost-gsm-base-station
93 The process is fully documented and includes: a collaboration MOU between the local authority and TIC AC, a receipt of equipment, a certificate of authorisation of the GSM concession, a letter requesting admission to the association and a list of people attending the assembly.
94 One network has chosen a lower price of 30 pesos a month for member contributions.

- Booking/accounting (2.5)
- Incorporations (1)
- Communications and public relations (1)

Costs and their recovery

The largest single cost element for operating one of TIC AC's networks is the upstream internet link, which costs between about USD 50 and USD 80 per month for a 1Mbps symmetric connection which can support about 10 simultaneous calls. Monthly electricity costs for a 5 watt BTS are about USD 10 – USD 25 per month. Except for the largest networks, the time required for local administration is relatively small – simply for taking monthly subscriptions and top-up payments for long distance calls, paying any monthly bills, and signing up new customers.

Users pay about USD 2.2 per month for unlimited local calls and USD 4.5c a minute for off-net calls to other networks (compared to USD 16c/minute when using the conventional commercial networks). With an average expenditure of about USD 1 per month for off-net calls, this gives a total revenue per subscriber (ARPU) of about USD 3.2 per month. During the previous year, a total of about 3,000 users made about 4.1 million minutes of calls. About 60% of the traffic was local calls within the network, and callers averaged 108 outgoing call minutes a month in 2017. With about 3,500 users in 2018, TIC AC's total monthly turnover generated from the 16 communities was about USD 6 000.

5% of the monthly user fee is paid to TIC AC which holds it in a reserve account as a contribution to a mutual fund to cover any unexpected expenditures, most typically for replacing failed network equipment. This means 60% of the subscriber fees are retained within the community to recover the equipment, electricity and upstream internet costs, and to pay an honorarium for the admin staff person and for future investment in local projects.

Analyzing the overall impact of the networks as a whole, TIC AC estimates about 15 000 indirect beneficiaries and an annual economic return (including incoming calls and indirect cost savings such as for avoided travel etc) of USD 1.2 million. This is based on a total operating cost, including equipment depreciation, of about USD 270,000, which realises a cost benefit ratio of about 4:1.

TIC AC: http://www.tic-ac.org
Redes: http://www.redesac.org.mx
Rhizomatica: http://www.rhizomatica.org
See the GISWatch 2018 Mexico chapter for additional information[95]

95 https://www.giswatch.org/en/country-report/infrastructure/mexico

6.2.2 Ungu Community 4G/LTE, Bokondini, West Papua, Indonesia

Located in the village of Bokondini in the highlands of West Papua, the Ungu[96] 4G/LTE mobile data-only network is an externally supported initiative that is partially self provisioned, with some entrepreneurial aspects. The project is the result of a long-term collaboration with the University of Washington, which in 2013 had helped set up an informal community 2G voice network in the village.

Prior to the Ungu project, the community already had an internet link for which it had been paying USD 300 per month for a 1Mbps satellite-based connection for the local elementary school to provide Wi-Fi for teachers, with some coverage extended to a few houses in the community via directional antennas. In 2016 the Indonesian NGO ICTWatch was able to convince the national telecom ministry (KOMINFO) to provide experimental licenses in the mobile cellular bands to explore alternative technologies and business models.

Data-Only Network

The permission granted was conditional on not competing with existing commercial operators. As a result, when the dominant rural (incumbent) operator, Telkomsel, established a mobile base station covering the area, the local 2G community network was decommissioned. However Telkomsel's service does not support internet connectivity, so this provided an opportunity to set up the Ungu 4G/LTE data-only service.

Being a pure 4G data network also simplified the setup and billing, as the platform is all IP based, and did not require more complex and costly arrangements for phone numbers and interconnection with voice networks, and avoids confusing the user with different charges for different types of traffic. Instead all charges can be flat rate or data traffic based, while telephony is carried out via apps such as Whatsapp, Telegram and Skype.

Developing a local core network

The project was implemented with USD 12 000 in funding from APNIC/ISIF, and local operational support and upstream internet connectivity from nearby social enterprise wireless internet provider, Airwaves Mission, that had been supporting the earlier 2G project and providing the school with connectivity. The base station is connected to the internet via a 50km long distance (double hop) Wi-Fi link to Mission Airwaves' VSAT installation in the town of Wamena.

Extensive prior work called the IslandCell project had already been carried out at the University of Washington with support from Amazon Catalyst to develop the use of the software platform running on a low-cost PC that can operate a 4G/LTE base station on site as a standalone 'network in a box'. This type of EPC[97] avoids the need for an upstream

96 Ungu simply means 'purple' Bahasa Indonesian - the colour of the sim cards, linked to the University of Washington colour.
97 Evolved Packet Core (EPC) is a framework for providing converged voice and data on a 4G/LTE network.

core network switching system. While simpler to set up, these are usually too costly and an unnecessary loss of autonomy for small scale rural networks in the global South. In addition the conventional mobile architecture with off-site core would have required use of the expensive satellite backhaul connectivity to carry the traffic for every connection. Instead, the all in one solution keeps all local traffic local. Because LTE signaling (control data) adds significant overheads to the total data traffic, this cut the cost of needed bandwidth by about 50% per cent and improved reliability (local activity continues even when the upstream link goes down).

Open source software and low cost hardware platform

Called Community LTE (CoLTE), the software is a modified version of the free open-source EPC platform, Open Air Interface, which was originally developed for experimental LTE networks. CoLTE also includes network monitoring and policy enforcement applications to track and bill for the traffic of each user, along with a web-based graphical interface that allows users to check on the status of their account, top up, transfer/resell credit, and buy data packages. In addition, to improve performance and save the expensive and limited satellite capacity, a local web cache and DNS server is also installed, along with local copies of educational content such as Wikipedia and Open Street Maps.

The two 1 watt 850 MHz LTE cellular radio base stations (eNodeB) cost about USD 4 000 each, manufactured by a small US company - Baicells. The EPC software and local content are hosted on a USD 200 Zotac 'mini PC' with 500Gb hard drive. The 850 MHz band was selected based on the relatively high level of handset support, good long-distance propagation characteristics (more than 1km), the experimental license conditions and availability of unused spectrum in this band.

Tower costs were avoided by mounting the antennas on an existing 6m pole. Sim cards cost USD 80c each when purchased as a batch of 1000 from Alibaba, and setting up a registered NGO in Indonesia cost USD 1 000. With a solar power backup system costing about USD 4 000, the total network equipment cost about USD 14 000. As in many other countries, import taxes on fully assembled electronic equipment in Indonesia are relatively high, as are shipping costs, which are largely based on volume.

In terms of operating expenses, satellite bandwidth costs were minimised by using an asymmetric C-band service with a 3 Mbps downlink and a 512 Kbps uplink, for which Ungu pays about USD 200/month. Administration and maintenance of the system is estimated at 10% of a full-time-equivalent (0.1 FTE) - about 2400 USD per year.

Cost Recovery

To cover the costs of the service, new users are charged USD 7 for the Sim card and initial setup which provides them with a 10 Mb credit. Accounts are prepaid, and traffic-based credits are loaded onto the administrative system, distributed through a central agent to whom the credits are sold and who in turn re-sells them at a markup of about 20% to community members.

Three data bundles are available – 10 Mb for USD 5, 100 Mb for USD 15, and 1 Gb for USD 25. Because there are volume based discounts, this has generated a retail economy of small store vendors which buy the larger data bundles at the bulk discount rate and then resell smaller portions to individuals. This chain continues in an informal 'side market' where many of the customers resell their own access by charging people to connect to the hotspot on their phone.

This informal resale of connections means that it is hard to track the total number of users of the service. Ungu only became operational in November 2018, and the testing / debugging phase continued until the end of the year, resulting in a relatively slow initial uptake of the service. However within 4 months of operations about 70 Sim cards were sold, each generating about 100 Mb of traffic per day. Sale of data bundles generated about USD 2 300 per month in revenue.

Even without taking into account the expected growth in this new deployment, the level of income indicates that the cost of the equipment will be repaid within two years. This time frame takes into account paying for the part time labour and the upstream bandwidth costs, but does not take into account support for shipping, installation and training provided by the University of Washington. However, with the expertise gained locally, new deployments to nearby areas could be carried out at low cost with the assistance of the community in Bokondi.

The network can scale to 255 simultaneously connected users and theoretically 150 Mbps of throughput per base station. Local speeds of up to 75Mbs were measured within the network. Upstream capacity costs are expected to drop shortly, as the 'Eastern package' of the Palapa Ring is planned to be completed in 2019 which includes spurs to the interior of West Papua[98].

With the on-site controller, local traffic does not require any upstream capacity on the satellite link and this has prompted discussion of the options for implementing a 'local only' traffic tariff. Local sharing of educational media is being zero rated. In addition, a "limited services" package is also being considered. This would provide internet access to a restricted set of websites/services at a reduced cost (or free), focused around low bandwidth services such as voice calling and texting services (e.g. WhatsApp and Skype), but could also include other select websites such as Wikipedia.

98 https://www.opengovasia.com/installation-of-nationwide-fibre-optic-network-in-indonesia-to-be-completed-by-2019

Community LTE (CoLTE): https://communitylte.wordpress.com/category/colte

Ungu report: https://isif.asia/community-lte-in-papua

CoLTE EPC Software: https://github.com/uw-ictd/colte

6.2.3 Village Base Station (VBTS) Konnect Barangay, Aurora, Philippines

VBTS Konekt Barangay was a rural mobile network research initiative that aimed to transition to a self provisioning village cooperative model in partnership with a large national mobile operator. In September 2017 the University of the Philippines began testing a public-private partnership strategy with the deployment of seven low cost mobile networks in isolated communities in the coastal district of Aurora, Luzon, which is also home to a number of indigenous groups. Since this report was written the project has transitioned from a mobile to a Wi-Fi service due to a change in strategy of the mobile operator.

Implemented with the involvement of local municipalities and co-operatives, and in partnership with one of the two dominant mobile operators (Globe), the project was financially supported by the Philippines Commission on Higher Education (CHED). It was carried out with support from the US University of California Berkeley (UC)[99], with linkages to the Aurora State College of Technology (ASCOT), the University of California Davis and the University of Washington. The project also aimed to evaluate the broader impact of cellular connectivity with participatory qualitative research and a longitudinal randomized control trial with unconnected communities.

As with many other countries, virtually all the usable spectrum in the GSM mobile cellular bands have already been allocated to the conventional national mobile network operators. It is possible that other frequencies could be used, but to operate any telecommunications service in the Philippines, a franchise sanctioned by congress and a Certificate of Public Convenience and Necessity (CPCN) is necessary to prove financial, technical and legal capability. In addition there are no mobile licenses available for operating at a sub-national level and there are a number of other requirements, including environmental clearance certificates, height clearances, and the local mayor's permit. In total 25 different permits are needed for each cell site, a process that can take over eight months.

Partnership with national operator

To avoid regulatory limitations it was decided that the best approach would be to operate in partnership with an existing mobile operator. While this strategy could limit the independence of the community networks, it was felt that this was currently the only viable approach within the current regulatory environment, especially as regulations allow third parties to use the spectrum of an existing licensee. Successful negotiations then

99 This is part of a broader academic cooperation programme - Philippine-California Advanced Research Institutes (PCARI).

took place with Globe to use its license and its 2G spectrum for voice and SMS[100], as well as to gain access to its core network for calls to Globe's main network and the users of other networks. Globe also helped the project comply with the required NTC permits.

Because the sites had a smaller subscriber base than is considered economically viable by Globe, the relationship was managed under the operator's corporate social responsibility programme. However the community networks were independently run, purchasing their own satellite capacity to connect to Globe's infrastructure, but essentially acting as Globe franchisees. The service was branded separately from Globe's primary service to make it apparent that the service and quality expectations on these rural sites are different. This included the lack of ability to roam on to Globe's main network.

Relationships with municipal authorities

The initiative also has had close relationships with the municipal authorities in each community - the barangay - which is the smallest state administrative unit in the Philippines. The leadership of the barangays helped identify potential partners to operate the networks and to mobilise the local labour that assisted university-based engineers in their deployment.

In addition, the barangays facilitated the legal appropriation of the land where the towers were built, and helped expedite the various permits and clearances needed for construction of the base stations. The barangays also allocated funds in their annual budget for the maintenance of the towers, and for the community-based security to protect the towers and equipment from potential theft and vandalism.

Solar power was used for most of the networks because even where grid power is available, poor reliability necessitated battery backups or fully off-grid solar systems. In addition some sites were turned off every night to conserve power. Partly as a result of this, the average uptime for the sites was 40%. The unplanned downtime periods were also analysed[101], indicating that 42% of the downtime was a result of interruptions to the upstream satellite link, 24% due to lack of power, 21% due to overheating, 12% due broken antenna cables.

Cooperative ownership

Local cooperatives were identified as the most appropriate project partners to operate the networks. As registered commercial institutions this made them eligible to conduct business transactions with Globe, and because of their familiarity with the financial and administrative needs in managing income-generating activities. Most of the co-operatives involved in the project are multi-purpose employee credit co-operatives and are primarily in charge of Globe's SMS-based air time distribution system for the local retailers.

100 A 2G voice / sms service was deemed sufficient for this research project because of the predominance of 2G-only feature phones in the communities.
101 https://www.usenix.org/system/files/nsdi19-hasan.pdf

The cooperatives ordered air time from Globe on a monthly basis, and the bulk order qualifies for a wholesale discount, which in part is passed on to the community retailers. The air time credits are purchased by depositing money into Globe's account at a nearby (but outside of the community) bank. The majority of the retailers are women (eight out of ten) running their own 'sari-sari' (general merchandise) stores. Aside from the retailer's discount, the retailer also charges an additional convenience fee per transaction to the subscriber, which is a common practice in the Philippines. Additional sources of income for the retailers were provided through the sale of mobile phones and mobile phone accessories, as well as repair and maintenance services.

Community Cellular Manager (CCM) software

The VBTS project is the first large scale deployment in the world of the Community Cellular Manager (CCM) stack developed initially by startup mobile equipment manufacturer Endaga, and then by Facebook when the Endaga team joined Facebook. CCM is a new IP-based cellular network management core which supports the operation of multiple community networks under one technical domain. Architecturally, it has two components - the client and the cloud, where Globe manages the CCM cloud installation while the VBTS project manages the client installations. This involved porting the client to the different base station cellular radio platforms deployed in the communities (Nuran Litecell and Fairwaves UmSITE), and developing additional features to assist with the administration, marketing, research and evaluation needs, including call and text promotional support. The CCM cloud handles the routing, interconnect, and phone numbers for the network.

Pre-launch training and support

Prior to the launch of each network, local stakeholders were informed of the goals of the project, which emphasized community ownership and public service over profit. In addition social science researchers carried out social enterprise training with the cooperatives in the sale of SIM cards and air time. Project engineers conducted training with community maintenance personnel on daily maintenance and basic troubleshooting of the tower and equipment (Level 1) and with ASCOT engineers who required intermediate technical knowledge (Level 2).

In a novel approach to identifying sources of technical support, an SMS was broadcast to all active network subscribers in the community requesting people interested in providing support to identify themselves. A number of respondents in the communities were identified this way and provided with training. There is also an SMS-based support hotline which is free to use by all subscribers in the community.

Another innovation was the repair environment that was specially created to leverage the community involvement in the network. The researchers implemented a set of services which help guide the community in conducting repairs. This consists of digital "repair manuals" embedded into the community cellular infrastructure. Network components are labeled with small codes (e.g. "ANT" for antenna) and an SMS shortcode (e.g. 777) that

provides information about the particular system element. For instance, a user texting "hot" to the relevant shortcode receives a text message with instructions to turn off the system to allow it to cool. Labels are also printed on a poster in a building near the tower.

Cost recovery - traffic and revenue sharing

In late 2018 there were about 1,500 subscribers across the seven networks, equivalent to more than 80% of the total eligible population (15 years old and up). Although individual the community networks are able to set their own pricing, including the use of flat rate prices for bundles of minutes and SMSs, calls were normally charged at about USD 11c per minute to off-net non-Globe numbers, USD 6c per minute to off-net Globe numbers, and USD 2c per minute for on-net (local) calls. Calls between VBTS networks are classified as local traffic. Not including Globe's revenue from incoming calls, monthly average revenue per subscriber is around USD 0.60, which would generate a total annual revenue of about USD 11 000.

Outbound calls per subscriber averaged 3 minutes a month and 13 text messages, while inbound calls averaged 50 minutes and 10 texts a month. While SMS traffic has the same volume in both directions, the number of inbound call minutes is six times greater than the number of outbound call minutes. This is a common pattern where subscribers in rural communities take advantage of free incoming calls and encourage their more wealthy urban contacts to call them.

The revenue from calls and texts was split, based on a revenue-sharing scheme in which the cooperative receives 80% while the remaining 20% goes to Globe. Earnings were used by the cooperative to pay the community members responsible for the network and the remainder is used as savings for operating expenses which may be incurred in the future.

VBTS: https://pcarivbts.github.io

7. Further Information Resources

Bottom-up Connectivity Strategies: Community-led small-scale telecommunication infrastructure networks in the global South (APC 2019). https://www.apc.org/en/pubs/community-networks-case-studies

Closing the Access Gap – Innovation to Accelerate Universal Internet Adoption (USAID/DIAL 2017) https://www.usaid.gov/sites/default/files/documents/15396/Closing-the-Access-Gap.pdf

Comments in respect of the Provisioning of Mobile Broadband Wireless Open Access Services for Urban and Rural Areas Using the Complementary Bands, IMT700, IMT800, IMT2300, IMT2600 and IMT3500 (APC 2020). https://www.apc.org/en/pubs/comments-respect-provisioning-mobile-broadband-wireless-open-access-services-urban-and-rural

Connecting Refugees: How Internet and Mobile Connectivity can Improve Refugee Well-Being and Transform Humanitarian Action (UNHCR 2016) https://www.unhcr.org/5770d43c4.pdf

The Digital Lives of Refugees (GSMA/UNHCR 2019) https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/07/The-Digital-Lives-of-Refugees.pdf

Displaced and Disconnected (2019): Cross-country research on legal and regulatory requirements mandating ID authenticatation https://www.unhcr.org/innovation/displaced-and-disconnected

Designing Sustainable Rural Infrastructure Through the Lens of OpenCellular (UW 2018) https://cacm.acm.org/magazines/2018/8/229756-designing-sustainable-rural-infrastructure-through-the-lens-of-opencellular/abstract

Global Information Society Watch (GISWatch) Community Networks Edition (APC 2018) https://www.giswatch.org/community-networks

Guide to Public Access in Southeast Asia — 2019 A4AI Affordability Report https://a4ai.org/2019publicaccess/

Harnessing Blockchains in Developing Country Governments. (Raul Zambrano 2019) https://www.frontiersin.org/articles/10.3389/fbloc.2019.00027/full

How to Start Your Own Cellular Network - Micro Telcos and the Future of Communication https://edwin.atavist.com/microtelco

Information and Communication Needs Assessment Tool (UNHCR) https://www.unhcr.org/innovation/information-and-communication-needs-tool/

Innovating mobile solutions for refugees in East Africa. https://www.elrha.org/wp-content/uploads/2018/02/Innovating_mobile_soultions_Report.pdf

Innovations in Spectrum Management (ISOC & APC 2019) https://www.apc.org/sites/default/files/InnovationsinSpectrumManagement_March2019-EN-1.pdf

Mobile for Humanitarian Innovation Fund https://www.gsma.com/mobilefordevelopment/mobile-for-humanitarian-innovation

A Rural Broadband Policy Framework to address the Digital Divide (Alliance for Affordable Internet (A4AI) https://a4ai.org/rural-broadband-policy-framework-connecting-the-unconnected/

Scaling Community Cellular Networks with Community Cellular Manager (UW 2019) https://www.usenix.org/system/files/nsdi19-hasan.pdf

Understanding Information Ecosystems: Making it happen (UNHCR 2020) https://www.unhcr.org/innovation/information-ecosystems

APC's Community Network Support Programme

APC's work to support the development of community networks is called "Connecting the Unconnected: Supporting community networks and other community-based connectivity"[102]. It is guided by APC's previous implementation plan (2016-2019) with the support of various donors, including Canada's International Development Research Centre (IDRC) and the Swedish International Development Agency (Sida), and most recently the UK Department for International Development (DfID).

With IDRC, the team was able to develop a baseline understanding of community networks in the global South through field and desk research, resulting in the 43 country report of 'Global Information Society Watch' and a research report on 16 in-depth case studies in the global South. Initial engagements with regulatory agencies were tested in Africa and Latin America, four new community network deployments took place in Colombia and Brazil as well as the launch of the Open Telecom Data campaign. With Sida, in 2019 support was provided to at least 25 communities, to strengthen and extend their community networks. Policy advocacy capacity has also increased through five regional policy trainings in the global South. In addition, work has taken place to enable a supportive environment where women can thrive in gender discriminatory structures and increase the role and participation of women in setting up and managing community networks.

This period solidified the work resulting in an extension of the Sida grant for a further 2 years, and to the development of a 2.5 year programme supported by DfiD for five countries (Brasil, Kenya, Indonesia, Nigeria, and South Africa) where APC will be working specifically to enable national organisations to support community networks through mechanisms including a sub-granting approach, allowing for peer exchanges and catalytic interventions.

The project now aims to contribute to building an enabling ecosystem for the emergence and growth of community networks and other community-based connectivity initiatives in developing countries, using an integrated three-year approach. The project views the community network ecosystem through a holistic view (considering drivers of additional exclusion or disadvantage (e.g. gender, age, remote location, ethnic minorities, refugees, people living with disabilities) while addressing issues at different levels and responding to specific needs at the country level:

- Macro (e.g. policy/legal/regulatory frameworks – and capacity of relevant institutions),
- Meso (e.g. community networks' support organisations) and
- Micro/local (e.g. testing, case studies and capacity strengthening of individual community networks)
- https://www.apc.org

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