CONNECTIVITY STRATEGIES WHERE PEOPLE MATTER

Community-led small-scale telecommunication infrastructure networks in the global South

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INTRODUCTION

There is increasing concern over the worldwide slowdown in the growth of voice and internet users.[1] The networks being deployed by national operators are now only expected to connect 60% to 70% of the world's population by 2025. This indicates that the UN Sustainable Development Goals (SDGs),[2] which anticipate attaining universal connectivity by 2030, are unlikely to be achieved.

Despite decades of deployment, it appears increasingly likely that current strategies will not be able address the needs of billions of people in developing countries who have ineffective communication services due to limited coverage or lack of affordable services. Fortunately, however, the cost of network equipment continues to become more affordable and easier to deploy, resulting in increasing numbers of networks emerging where community members build and operate their own telecommunication infrastructure, often managed on a cost recovery basis, rather than for commercial gain.

Although there is no commonly accepted definition, these networks are usually called "community networks" because local communities are involved in some way in deploying, owning and operating the physical infrastructure that supports voice or internet connectivity. Many APC member organisations have recently become active in supporting these types of networks. This trend has strong parallels with APC's birth as an organisation almost 30 years ago, when it emerged in response to similar needs to build local internet infrastructure, prior to the development of the "commercial internet" that most people use today.

Nationwide commercial services owned by private operators have up until recently been seen as the only effective means of addressing needs for connectivity. However, although this strategy is now coming under scrutiny, most governments are not yet aware of the potential impact of independent small-scale community-based networks. As a result, these networks are still relatively scarce, or invisible, because regulatory environments are generally hostile to them and are not yet adapted to foster their growth and replication. Aside from the absence of enabling regulatory environments, community networks, particularly those in the rural global South, also face other difficulties. Financial resources for their initial deployment are often very limited and there are other factors such as lack of affordable or reliable energy supply, and high costs for backhaul connectivity.

Yet, despite these difficulties and their lack of visibility, community networks also appear to have many advantages over traditional large-scale commercial networks, including:

- More local control over how the network is used and the content that is provided over the network.
- Greater potential for attention to the needs of marginalised people and the specific populations of rural communities, including women and older people.
- Lower costs and retention of more funds within the community.

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1 World Wide Web Foundation. (2018, 23 October). Just released: A4AI 2018 Affordability Report. https://webfoundation.org/2018/10/a4ai-2018-affordability-report

2 https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-9-industry-innovation-and-infrastructure/targets.html

- Increased potential to foster a sense of agency and empowerment among users and those involved in the network.

To document the benefits of, and challenges facing, small-scale, community-based connectivity projects, APC researchers visited 12 rural community networks in the global South in 2018 and studied a number of others through desk research and interviews. The primary goal of the research is to provide information that can be used for evidence-based policy making that will contribute to creating a more enabling environment for small community-based local access networks. In addition, the research aimed to identify opportunities for these networks to be more effective and, hopefully, to encourage more organisations to support the development of these networks in future.

This report describes the results of this work, which was part of the broader Local Access Networks[3] project that was carried out in partnership with Rhizomatica (an NGO supporting many community networks in Latin America) with financial support from the International Development Research Centre (IDRC).

RESEARCH METHODS

The research applied a multiple case methodology to scope community networks in the global South. The cases studied were selected based on criteria that aimed to provide insights about a variety of different connectivity technologies, services provided, institutional models and sustainability strategies, as well as a roughly even spread across countries in three regions of the global South – Latin America, Africa and Asia. In addition, the networks needed to have been established for sufficient time to be able to derive useful learning from them.

The initial desk-based research identified 16 initiatives for further study, most of which had been in operation for more than two years. During 2018, in-country research visits took place, which provided a snapshot of the technical and operational aspects of cases in Argentina, Brazil, the Democratic Republic of Congo (DRC), India, Indonesia, Mexico, South Africa, Thailand and Uganda. This data was gathered by interviewing champions, managers and technicians in networks and examining documents they provided and equipment used at different sites. Three further networks, in Indonesia, Peru and the Philippines, were later examined via desk research and direct contact with individuals associated with the initiatives.

The social impact of six cases (in Argentina, India, Indonesia, Mexico, South Africa and Uganda) was studied in more detail. Over 300 people participated in interviews, observations, focus groups and other data gathering events, which accumulated over 200 hours of recorded data across 60 days. Some 90% of participants in interviews and focus groups were people who inhabit the rural areas in which community networks are deployed. Many of the interviews relied on translation from local languages which included Hindi, Marathi, Luo and Nilotic dialects, Mexican and Argentinian Spanish, isiXhosa, and central Javanese. In most countries participants live in close proximity, in the same or nearby villages or very small rural towns; however, in Uganda and India, participants came

3 https://www.apc.org/en/project/local-access-networks-can-unconnected-connect-themselves

from villages that were farther apart. Participants' identities have been anonymised to the extent that is possible, and all data is stored securely. The social impact research sought to ensure a wide range of perspectives were represented, including many users of the networks as well as operators and managers, and additionally people in the community networks' footprint who did not use the network directly themselves. Women were actively recruited to participate in data gathering.

The social impact research produced mostly qualitative descriptions about how and why people coordinate, interact with and are affected by their local community networks. These descriptions are not statistically generalisable to entire populations of community network organisers, users and non-users. Nor should the cases be considered typical or atypical, since the cases studied are diverse, relatively few, and many are still at early stages of maturity and are rapidly evolving. Rather, the research provides portraits of some of the initiatives at the frontier in the communications revolution, situated in their specific contexts of management, access and use, and uncovers some common characteristics.

RESULTS AND CONCLUSIONS

General considerations

The cases covered in this study provide rich material on the value, motivations, potentials and constraints of rural community networks in the global South. However, it should be noted there were a number of restrictions in the scope of the research as outlined below. Some limitations were due to pragmatic issues – restricted time and resources available, or limited contact with or knowledge of some networks until after the research plan was made. There are many fertile potential areas for further research to gain more complete understandings of community networks in the global South; however, among the initial areas of most interest are likely to be:

- Mobile networks: Due to regulatory restrictions, community networks providing mobile services are still rare, although recent developments indicate that they are becoming more prevalent in some countries. The relatively high proportion of networks providing these services in the study is mainly due to the need to prioritise learning about voice services in rural areas in the global South. Also, most are quite recent deployments.
- Networks using licensed spectrum, TV white space (TVWS) and dynamic spectrum assignment technologies: Again, due to regulatory restrictions, the number of networks using these systems is few, and the potential of networks based on use of these technologies still remains largely unexplored.
- Small-scale fibre: Outside of a few urban areas, community networks deploying fibre are still virtually unknown in rural areas in the global South.
- Small-scale entrepreneur-based models: While there are many smaller commercial networks in the urban global South, our research was only able to study one example of a network operated by a local small business in a more rural area.
- Networks in more developed countries and other regions in the global South (such as Central America, North Asia, the Pacific or other island locations): These areas are not covered and may have different local conditions which need to be better

understood. Understanding of the experience of the more mature community networks in developed countries is likely to contribute to better understanding of those in southern regions.

- More recent deployments: The community networks studied were in part selected for their relative maturity. However, many more networks have emerged which may have different characteristics – for instance, taking advantage of more recent technologies, the experience of more mature networks, regulatory changes or other developments.
- Longitudinal studies: This study was originally conceived as a larger and longer research effort, but due to the limited funding available, the cases in this report were subsequently restricted to a study period of up to two weeks only. This precluded monitoring changes over time, or gathering more data about important factors. Such an abbreviated study cannot portray features of networks that are typified by highly emergent qualities that develop out of community life. The research analysis would be considerably strengthened by building on this initial work and conducting follow-up visits to examine how these networks develop over a longer period.

Short accounts of other community network initiatives can be found in the sister publication of this project – *Global Information Society Watch 2018: Community Networks*[4] – which covers networks in 43 countries.

The initiatives studied

The provision of connectivity infrastructure in the community networks we studied is little different from traditional commercial mobile networks and fixed wireless internet service providers (WISPs) operating in urban and rural areas in more developed countries. The community networks operate at a smaller scale, but the technical models are similar – wireless and wired routers or mobile phone base stations interconnect the members of the community, and backhaul links connect them to the rest of the internet or to other phone networks using fibre or copper cables, wireless or satellite links. However in contrast to national voice operators, the community networks providing mobile voice services do not operate a centralised core network for switching and routing calls. Instead they take advantage of recent advances in technology which can provide for low cost switching services at the site of the base station.

For community networks that build internet services, as with larger commercial networks, wireless routers are deployed as Wi-Fi hotspots in public areas, and/or in businesses, government offices or the residences of community members. They are either inter-connected in a star-topology, where a central point provides links to each Wi-FI hotspot, or they are deployed in a mesh topology, where Wi-Fi hotspots may obtain their connectivity via neighbouring devices. In contrast to most traditional large-scale internet providers, Wi-Fi hotspots in the community networks are often augmented with public access facilities, or in some cases, public access is the primary service, reflecting the low availability of access devices in some locations, most notably in the deep rural areas of the DRC and northern Uganda. Voice telephony gateways are also provided in some of the Wi-Fi based

4 https://www.giswatch.org/community-networks

networks, and similarly, the mobile networks often used internet links to carry their off-net voice traffic.

While they may be small relative to traditional national networks, the community networks still varied tremendously in coverage area and size – some service just a few dozen households in a settlement, while others provide connectivity for thousands of users spread across a dozen or more villages. Of note here is that a number of the larger and more mature community networks have developed specific organisational structures which act on behalf of the individual networks. These, sometimes called umbrella organisations, include TIC AC in Mexico, AlterMundi in Argentina and Zenzeleni NPC in South Africa. They support the operation of the community networks in a number of ways:

- Operating shared network infrastructure (such as high-sites/backhaul links and voice gateways) on behalf the individual networks.
- Centralising technical and administrative support, which reduces the need to replicate some of these often scarce resources in each local network.
- Acting on their behalf in relations with government and partners, and to support the development of community networks in the country more generally.

Deployment costs in community networks also varied considerably, depending on the nature of network. While network equipment costs have continued to drop as the technologies advance, resulting in mobile base stations costing less than USD 5,000, and carrier grade wireless routers costing around USD 100, the solar power systems that are often needed substantially increased the cost of deployment. Similarly, towers can be costly items, especially when they needed to be high enough to reach over trees, hills or distant locations, equipped with lightning protection or transported over difficult terrain from distant origins. However, in a few community networks there were opportunities to use existing telecom towers where regulations require operators to share passive infrastructure. Buildings for use as high sites and administrative premises were also often provided by the community at no cost.

Table 1 summarises the initiatives studied in the research, grouped by country. The networks examined either provide Wi-Fi-based internet connectivity or mobile voice and/or internet services. The relatively low number of small-scale mobile deployments worldwide is notable, particularly because in most rural unconnected contexts, mobile voice services are in higher demand than internet access. The rarity of mobile deployments is largely the result of lack of access to the licensed radio spectrum on which these services depend. Similarly, for non-line-of-sight situations, such as forested or hilly locations, lower frequencies are more effective, especially for backhaul, but are usually not made available at affordable rates, if at all. These problems are due to regulatory restrictions determined by national policy makers who are generally unaware of the need or the range of options for providing small-scale networks with affordable radio spectrum. As a result, because Wi-Fi uses licence-exempt frequencies, and can start at a very small scale, with a commodity wireless router for example, Wi-Fi hotspots connected to an upstream broadband connection are the most commonly found type of community network.

Table 1.1 The community network initiatives studied

Country	Initiative	Location(s)	Description
Argentina	AlterMundi/ QuintanaLibre	5 villages/small towns around José de la Quintana, Cordoba province	Households in multiple village-based informal groups install their own mesh Wi-Fi routers to connect with each other and to a shared mesh network operated by QuintanaLibre with a high-site and low-cost long-distance backhaul, as a non-profit association.
Brazil	Associação Portal Sem Porteiras	Rural area near Monteiro Lobato in São Paulo state	Households manage their own mesh Wi-Fi infrastructure to connect to a shared mesh network, local content, public hotspots with usage fees, a high-site and commercially provided backhaul operated as a non-profit association. Part of the Coolab collective supporting community networks.
Brazil	Quilombola Community Network	Barrio in Penalva town, Maranhão state	Semi-urban mesh Wi-Fi hotspots and public access facility connected by satellite in informal settlement operated by an agricultural producer association supported by university research group Nupef.
Democratic Republic of Congo (DRC)	Pamoja Net	Rural settlements across Idjwi Island in Lake Kivu	Public Wi-Fi hotspots and fixed links for NGOs and businesses provided by rural development NGO, Ensemble pour la Différence. Has recently begun testing Open Cellular GSM base stations for voice and data.
India	Gram Marg	25 villages in Palghar/Thane districts, Maharashtra state	Public Wi-Fi hotspots and fixed wireless links for public institutions established by research organisation IIT Mumbai, in partnership with CSR programmes, local authorities and private ISP supporting village entrepreneurs.
India	Wireless for Communities (W4C)	Many locations in Rajasthan and Madhya Pradesh states	Public Wi-Fi hotspots, mobile public access facilities and fixed wireless links for public institutions supported by NGO Digital Empowerment Foundation (DEF).
Indonesia	Des Hotspot	Calang town, Banda Aceh	Residential and business Wi-Fi hotspots provided by a small informal business.
Indonesia	Puspindes/ RelawanTIK	Penggarit village, Pemalang, Central Java	Wi-Fi access provided by local authority with ICT technical support from NGO RelawanTIK.
Indonesia	RelawanTIK/ Common Room	Ciptagelar village, Sukabumi regency, West Java	Public access facility in an indigenous community supported by Bandung-based NGO Common Room and the local regency (local authority).
Indonesia	Ungu Community LTE	Bonkondini village, West Papua	4G/LTE data-only mobile service operated as an informal community-based network supported by University of Washington State research and Mission Aviation Services.
Mexico	Telecomunicaciones Indígenas Comunitarias (TIC AC)	16 villages and small towns in Oaxaca state	Mobile voice networks in multiple indigenous communities, operated as a non-profit civil association with a mobile licence, supported by local authorities, initiated by NGO Rhizomatica.
Peru	Mayutel/Red de Telemedicina del Río Napo	15 communities along the Napo River, Maynas province	Wi-Fi backbone linking clinics and mobile voice/data base stations established by Spanish NGO EHAS. Voice and data mobile network in partnership with a specialised rural operator providing access to the Telefónica network.

Philippines	VBTS Konekt Barangay	7 villages in Aurora province, Central Luzon region	2G voice networks operated as community cooperative infrastructure, established as a research partnership between the University of the Philippines, University of Washington and University of California, Berkeley, and supported by local authorities.
South Africa	Zenzeleni	Villages in Eastern Cape province	Public Wi-Fi hotspots and fixed links for businesses and public institutions operated as village cooperatives supported by Zenzeleni NPC (non-profit corporation). Initiated as research project by the University of the Western Cape (UWC).
Thailand	Taknet/ Net2Home	Villages in Tak province, near border with Myanmar	Affordable mesh Wi-Fi hotspots operated as a partnership between local entrepreneurs, the Thai Network Information Center (THNIC) Foundation (the ccTLD operator) and intERLAB, Asian Institute of Technology (AIT).
Uganda	Battery Operated Systems for Community Outreach (Bosco)	Villages, settlements and small town around Patonga districts near Gulu	Wi-Fi links for public access centres and schools. Focus on solar power, youth business training, refugee areas. Supported by a Catholic Church-based NGO.

Motivations for establishing community networks

Considering the limited body of knowledge about community networks, the small number of cases studied in this research and the abbreviated research period, generalisations about motivations and many other aspects of the networks studied need to be avoided. Seen as a group, their great diversity is readily apparent; however the main motivation for building these networks is to help meet needs for better and more affordable communications infrastructure.

Not many of the networks were in areas without any other form of connectivity. In fact, satellite beams now blanket all but a few areas, and mobile operators were present in most of the sites. However, these large-scale commercial services are evidently too costly or unavailable. Despite their small size, improved affordability over national commercial networks is evident. For example, in the community network in South Africa, data fees are between 20 and 40 times cheaper than mobile data plans. In the Mexican mobile community networks, unlimited local calls cost about USD 2.50/month, while off-network calls cost about USD 0.02 a minute.

In addition, the per-minute or data-traffic based usage charges adopted by national mobile networks have a distinct chilling effect on the extent of use. In contrast, there is usually no charge associated with the traffic generated by the user of a community network for a particular communication session. There may be no monthly usage fees at all when costs are covered externally, although more usually, fees are based on a specific time period (e.g. one week or one month) over which unlimited use can occur, subject to bandwidth limitations or when the traffic is just within the community network.

While affordability and sometimes deficient connectivity in rural areas were usually cited as the primary reasons for community networks, a wide range of other benefits were often reported – some were intentional by the network initiators, and others were revealed by

users in the course of the research. Local economic development and community empowerment are common themes, while some of the community networks studied also had more specific focuses, such as addressing the communication needs of indigenous communities or other marginalised groups, or supporting aspirations for building the autonomy of their communities. Supporting the development of connectivity in this way is seen as an entry point to "building or preserving community". In some cases connectivity is used as one of many tools by integrated rural development organisations to assist in community upliftment, such as providing income generation or employment opportunities.

A substantial number of community networks have also emerged through support from academic and research institutions, which have set up community networking projects to study the potential of new technologies and alternative strategies for addressing connectivity gaps.

In total, about 50 different international and national organisations were identified that have been involved in supporting the 16 community networks, ranging from UN organisations and bilateral development agencies, to US and European foundations, NGOs, multinational technology companies, local authorities and academic/research organisations. The internet technical community, also known as the i* organisations[5] – in particular the Internet Society (ISOC) and the regional IP registries, LACNIC, AfriNIC and APNIC – have also supported many of the networks.

Technical and operational strategies in community networks

The technical strategies or institutional models adopted by the networks reflect the different conditions present at each location, which mainly result from variations in the following factors:

- Regulatory environments
- Income levels, literacy, and other "development" indicators
- Availability of supporting infrastructure – backhaul capacity, energy
- Awareness of technical options and access to technical/management skills
- Sense of community agency, local culture and traditions
- Support from local authorities and/or external organisations.

As indicated above, the regulatory environment has the most far-reaching impact as a "threshold factor" which affects the technology strategy of the network, the institutional model and also its longer-term impact. Most of the initiatives studied have been at a disadvantage in providing connectivity because the national policy environments have not been conducive to these networks. This is especially the case for providing mobile voice services. Access to sufficient radio spectrum is insufficient, while licensing or interconnection requirements and government fees/taxes are not adjusted for small networks, which creates relatively much higher burdens on them. For example, in Brazil, government taxes and levies on the satellite service doubles the cost of the bandwidth used by one of the community networks for the backhaul connection to the internet, the largest cost component of running the network.

5 https://www.apnic.net/community/ecosystem/iorgs

Also, community networks have usually not been given the same government support that is given to national operators for extending their services into underserved areas. Of relevance here is the fact that the community networks actually generate additional traffic (and revenues) for the existing commercial networks. For example, analysis of calling patterns in the community mobile networks deployed in Mexico and the Philippines shows incoming call traffic is four to 10 times higher than the outbound traffic originating from the community networks.

As a result of inhospitable regulatory environments, most of the community networks have been confined to using unlicensed spectrum and are dependent on limited sources of funding in the start-up phase, or for expansion. The networks are thus slower to grow or replicate and few provide voice services.

The networks studied provide many examples of the innovative strategies that have been adopted to address the need for connectivity in the face of these difficult conditions. The proverb "Necessity is the mother of invention" is particularly apt here. Some of the noteworthy innovations and strategies that were found in the community networks are listed in Table 2.

Table 1.2 Notable strategies of the community network initiatives studied

Country	Initiative	Special strategies
Argentina	AlterMundi	Partnership with local university for free off-peak backhaul capacity. Locally manufactured parabolic antennae to reduce costs. Design/manufacture of LibreRouter wireless router for community networks, with LibreMesh operating system software which can also replace software on off-the-shelf commercial routers. All members/users attend technical workshops, can provide in-kind contributions.
Brazil	Associação Portal Sem Porteiras	A non-profit association using a Sociocratic decision-making methodology. Member of a collective of technical support for community networks in Brazil. Provides public hotspots, technical development, support and content-sharing platform.
Brazil	Quilombola Community Network	Indigenous women's association of traditional palm harvesters providing livelihood support and managing conflict with large land owners/cattle ranchers. Usage fees more than cover satellite costs, surplus used for printing. Participatory mapping used to identify the communities.
Democratic Republic of Congo (DRC)	Pamoja Net	Youth upliftment and integrated development focus, free off-peak Wi-Fi access is cross-subsidised by income generated from business and NGO users. Network is a response to a request by the traditional leader. Community radio station support.
India	Gram Marg	Testing different institutional models – public-private partnership with local authorities and village entrepreneur model. Locally developed TVWS equipment. Subsequent regulatory restrictions on use of TVWS required backhaul links to be replaced with 5.8 GHz Wi-Fi, resulting in blackspots (no coverage) and greater costs for the higher towers needed for line-of-sight Wi-Fi.
India	Wireless for Communities (W4C)	Roving public access vehicle for nomadic groups, e-commerce/entrepreneurship support for women, connectivity and distance education for local authorities and schools, connectivity and telemedicine for clinics, community radio station connectivity, "network in a box" developed for quick and easy deployment.
Indonesia	Des Hotspot	Electronics hardware repair/copy service adds small-scale WISP service to repackage retail fibre broadband into lower bandwidth, more affordable services for residences and small businesses.

Indonesia	Puspindes/ RelawanTIK	Provision of access is part of a broader ICT adoption programme and mandate for local authorities, including government-mandated requirements for local authority websites and content development. Supported through a nationwide group of "ICT evangelist" volunteers.
Indonesia	RelawanTIK/ Common Room	Public access provision is part of a civic rural/urban digital development collaboration and support programme using art, culture and multimedia supported by the regency (local authority).
Indonesia	Ungu Community LTE	Test bed for a new open source low-cost LTE-based mobile network. No voice services are provided in order to avoid competition with licensed voice provider.
Mexico	Telecomunicaciones Indígenas Comunitarias (TIC AC)	Legislated access to small quantities of licensed mobile spectrum for indigenous populations. Close support from indigenous assemblies and strong community-based decision making. Low-cost software-defined radios used for mobile base stations. Interconnection, backhaul, technical and administrative support and licence management is operated as a shared facility for all the village networks. Indigenous local assemblies were involved in the legal test cases to help change legislation.
Peru	Mayutel/Red de Telemedicina del Río Napo	Mobile network supported by Peru's universal service fund (FITEL) with specialised rural mobile operator. Ninety-metre-high towers constructed to reach isolated locations with effective lightning protection systems. Close links between NGO activities in the field and support from academic and research institutions in Spain and Peru.
Philippines	VBTS Konekt Barangay	Leverages a partnership with one of the two national mobile operators (Globe) for access to their spectrum and interconnection. Voice and SMS services only currently. Randomised control trials taking place to compare impacts with unconnected villages.
South Africa	Zenzeleni	Network supported by the local tribal authority. Regulator provided exemption from licence requirement. Business development embedded in the model with the communities learning how to start and manage their own businesses.
Thailand	Taknet/ Net2Home	Repackaging of retail fibre broadband into smaller, more affordable services. Weather and environmental/air pollution sensor network adds additional value by detecting patterns of smoke pollution from burning rice fields.

Institutional models

The institutional models exhibited by community networks vary considerably. These range from networks run and/or supported by non-profit member associations, cooperatives and small businesses, NGOs, to local authorities, and partnerships between government and academic institutions. Local authorities have a significant role in many of the networks, although these institutions vary in terms of their involvement and relationship with the "grassroots" community that may own and operate the network.

It should also be noted that five of the community networks have close relationships with, or even emerged from, initiatives to operate community radio stations: AlterMundi/ QuintanaLibre (Argentina), Bosco (Uganda), Pamoja Net (DRC), TIC AC (Mexico) and W4C (India). This is perhaps not surprising given the similar objectives that community radio stations usually have around improving access to communications and information, along with their infrastructure resources such as high towers and power.

Figure 1 is a simplification of the situation, but illustrates how networks can be roughly divided into 5 groups spread across a spectrum of levels of community involvement. These groups are also associated to a greater or lesser extent with different institutional models.

Figure 1.1 Networks divided into five groups in relation to community involvement

Different levels of community involvement and related institutional models reflect local and national cultures and socioeconomic contexts. In particular, strategies largely result from different approaches to coping with the hostile or non-existent policy and regulatory environments which exist for community networks.

Depending on the legal environment for cooperatives vs. non-profit associations and clubs, the cooperative or non-profit membership association models appear particularly well suited to these community network endeavours. Rural cooperatives in telecommunication, energy production, savings, agriculture and food distribution have already existed for decades in both developed and developing countries. So it appears these models may become more widely adopted among community networks, given the objective of providing affordable communications combined with the cultures of resilience, community involvement and resource sharing present in rural areas, or provoked by community networks. These models also fit well with network topologies comprised of wireless links between neighbouring homes which share the available capacity.

Local and global benefits offered by community networks

Aside from the well-documented benefits of access to voice and internet services that connectivity offers to rural populations in the global South, as well as the commercial benefits to existing national networks from the traffic generated by the communities, the social impact research showed that community networks have many other benefits. Some 77 different benefits were articulated in studying just six cases (in Argentina, India, Indonesia, Mexico, South Africa and Uganda) and many of the positive contributions to the telecommunications ecosystem and to local social and economic development are specific to community networks.

Wider affordability of communications, direct savings made on the cost of existing communications, and the roles of community networks in the local circulation of money are the benefits that tend to attract policy makers and development agency attention. However, it is important to observe that while financial benefits are important to people in low-income community networks, these are by no means the aspects they value the most. It is equally important to appreciate that beyond the benefits to the social and economic development of rural populations, community networks also provide insights into factors within, or acting upon, the telecommunications sector that hinder access for all, whatever

telecommunications model is applied. Moreover, the community networks paradigm offers unique practical ways to compensate for the effects of these factors on their populations and, thus, provide valuable lessons for stakeholders seeking to connect the unconnected.

Direct and indirect economic benefits

Key benefits to local economies are accrued from wider affordability of communications, direct savings made on the cost of existing communications, and community networks' various roles in facilitating the local circulation of money. In the rural areas studied, where the only other means of internet access is through mobile operators, many people spoke of the importance of low-cost communications. For example, many of the frequent users of Zenzeleni in South Africa interviewed indicated spending between 10% to 40% of what they had previously spent on mobile data; and users in Mexico indicated the affordability of their community network's GSM provision, where alternative communications involve costly landline, satellite and radio phones, Wi-Fi services, and the expense of transport involved in travelling to the locations where they are available.

In addition to cost savings and affordability, cheaper services enable people to use the internet more effectively, with direct impact on income-generating activities, extending beyond retaining money within communities through cash payments to the community network, instead of to non-local telecommunications companies or financial intermediaries such as banks or credit cards. These benefits include:

- Fairer trade, by accessing market information to enable people to negotiate prices.
- Increased turnover in selling via e-market places.
- Better informed consumer decisions.

Community networks also make important contributions to the local circulation of money via the social links and spin-off services they support. These include:

- New local trade within rural communities based on relationships forged through community networks.
- Direct income generation by people on-selling their connectivity in some cases.
- Ad hoc, small cost-saving arrangements between local people facilitated by the community network.
- Improved performance of local businesses, e.g. local transport services.
- Increased business for other local service providers, e.g. local printing services.
- Fostering community-oriented business attitudes locally.
- Introducing people to each other and creating new relationships.

Thus, along with cost savings and wider affordability, community networks have many other intrinsic benefits for the local circulation of money.

Other benefits from unrestricted access and better access to information

Affordability is vital for people in low-income communities in order to benefit from the wider economic and social value of national networks in enabling links beyond the local communities, such as for personal contact, education and business activities. However, the traffic-based usage charges of national mobile networks, especially as these charges occur irrespective of whether the traffic is local or not, can have a chilling effect on the

extent of use. In contrast, the lack of charges associated with the traffic generated by the user of a community network means that community networks are more likely to encourage greater use generally, and enable activities that were not economically justifiable (affordable) with a traditional mobile network. Participants, for instance, not only referred to using the internet in informal and formal education,, but also how they learned better using resources when they did not have to worry about the cost of their data consumption, for instance to learn using bandwidth-consuming video.

The research data illustrates many different benefits to individuals and public institutions, particularly local authorities, of using a community network to access information frequently, for extended periods, in a timely manner and/or in social situations. These encompass benefits in formal and livelihood-relevant contexts including, for instance, access to up-to-date healthcare and agriculture information; support for teachers and students at all educational levels, for classes, assignments and research projects; opportunities to search for employment; research about professional or higher education opportunities; and informal remote peer exchange of information across social media platforms. These benefits are further extended by increased numbers of communication channels to disseminate information locally, most frequently through WhatsApp groups.

The affordability of community networks not only offers the many benefits of frequent, extended or timely communication with people and institutions who would not otherwise enjoy them, but in doing so greatly enriches the local communication ecology. The data gathered shows benefits such as sending applications for jobs and tertiary education, working from home, providing proof of remote work to employers, coordination for administration and governance, online financial transactions and reducing travel costs for employment and local administration. These benefits combine with the particular social qualities of community networks. Thus, the data also illustrates that community networks significantly contribute to:

- Disseminating information using broadcast SMS over GSM Linking local information channels, such as local radio, drama groups and printing services.
- Information sharing and intermediating communication for people with accessibility constraints.

Rural community empowerment

Rural communities in the global South are particularly vulnerable to outmigration, especially of young men and skilled workers, a sense of disempowerment, and helplessness about their ability to improve their lives. Community networks can help empower rural people in using, deploying and innovating technologies. All six of the cases studied for social impact illustrate considerable capacity building, including women, children and older people. For instance, people with little prior exposure learned about technology by relating it to their everyday experience because the community network emerged in their own local environments.

While there are many barriers to women's technical involvement in technology projects in general, some of the cases studied are starting to specifically support women's involvement in set-up and operations. Women in these networks explained that they had gained confidence by learning about technology together, being inspired by women role models, and had new opportunities for meeting other women beyond their own villages.

Also, for some participants, gaining skills in building and operating their networks enabled them, or people they know, to establish their own small businesses or gain employment. Some of the cases also illustrate that community networks afford opportunities for local creative industries that innovate software or hardware solutions suited to particular rural contexts.

Because building, operating and using a community network involve more than just the technical aspects of telecommunications, benefits extend deep into the fabric of local society. Like traditional networks, community networks provide communication channels that people can use to, say, help avert loneliness. Additionally, most of the cases studied also showed that community networks offer avenues to address the social fragmentation that can accompany increased use of digital communications. For instance, community networks have acted to bridge different parts of society, such as between newcomers and migrants; supported people's cultural identity; improved local security and safety; provoked and informed local discussion about privacy; and supported intergenerational cooperation.

Strikingly, the research data on the social impact in just six cases shows that the success of community networks has also amplified people's sense of their individual and collective capability and their confidence to set new objectives for themselves and/or their communities. Local coordinators, and often users, spoke of considerable pride and satisfaction in their achievements in establishing their own network. Their descriptions of their endeavours showed that local networks contribute to, and can extend, self and collective efficacy and agency. People expressed a sense of empowerment and self-sufficiency in being able to make decisions about telecommunications and undertaking operations.

Addressing exclusion

The research data for most cases shows that the community networks paradigm fosters local commitments to ongoing learning, continuous improvement and readiness to change their operations. While community networks provide more affordable access than traditional telecommunications networks, at this early stage in their evolution there also remain barriers to access for some people. However, three unique benefits of community networks suggest they will resolve this situation in the months and years to come:

- Unlike commercial telecommunications, the local nature of community networks makes the specific factors that contribute to exclusion easier to identify.
- The incentive to address the factors is far greater than for commercial telecommunications that operate at a distance from their users and value-price their services only for populations that can afford them.
- The collaborative, rather than competitive, approach between different community networks around the world, and the dramatic recent increase in channels of communication between them, promotes sharing experiences and co-creating practical ways to address factors contributing to exclusion.

Indeed, our research shows that these unique characteristics of community networks will provide valuable lessons for many different stakeholders seeking to better serve rural populations, including commercial providers.

Impediments to the benefits of community networks

The detailed research on social impact shows unequivocally that community networks provide specific social and economic benefits along with the broader benefits of connectivity to people whose needs are unmet by national networks. However, community networks also encounter problems in achieving their goals to provide access to connectivity to the most excluded people in society. These problems are caused by an absence of wider recognition of the special benefits of community networks, and lack of enabling policy, regulatory and investment environments, along with different types of discrimination embedded in the global culture of the telecommunications ecosystem.

The research illustrated that community networks can provide affordable access to many people who are excluded by national telecommunications networks; however, in the cases studied, not everyone in the community networks' constituencies had access. Most barriers to people's access are also included in the much larger set of barriers presented by traditional telecommunications networks, rather than being intrinsic to the community network paradigm. Nevertheless, these encompass exclusion because potential users cannot afford phone handsets or other devices to use the network, do not have written and/or technological literacies, or have needs and interests that are not targeted when designing services, for instance, because of their age.

All telecommunications systems amplify existing gaps between people and, because community networks provide benefits to people in their rural constituencies, they also advantage those that have access in varied ways. For instance, people who already have basic technological literacy are more able to gain skills in operating community networks and consequently to participate in decision making about community networks and/or generating income by applying the skills they gained.

The research data shows that challenges to inclusive decision making that were evident in some cases studied result from broader problems in technology. For instance, technical manuals and interfaces focus on certain languages which exclude many people from understanding networks. This exclusion, of course, characterises telecommunications networks as a whole, but the problem becomes more visible in community networks precisely because they are situated within communities that are residential, rather than specifically technical, and involve the skills of local residents.

Other examples of the ways that community networks reveal conventions and practices in telecommunications that exclude diverse people relate to age and gender. For instance, the research data shows that prioritising the technical skills of younger people can be incompatible with the age profile of rural populations, where people tend to be older. Further, the global culture of telecommunications only ascribes higher value to certain sorts of work, and associates this work with men, not women. This contributes to situations where the work of social coordination, which is fundamental and vital to community networks and often undertaken by women, is not valued as much as the work of software and network engineering; thus, women are under-remunerated. In contrast to commercial telecommunications providers, however, community networks are often highly motivated to include diverse people in operations.

Unfortunately, despite their motivation and capacity to identify and address exclusion, community networks are impeded by factors related to enabling policy, regulatory and investment environments. Some challenges that community networks face in achieving

inclusivity are the direct result of the current absence of enabling policy and regulations, others are more indirect. For example, exclusions relating to geographic dispersion of people occur less frequently for mobile networks than for the Wi-Fi networks that most community networks are forced to use.

The limited spatial coverage of a particular Wi-Fi hotspot can restrict connectivity to certain places, and these places may not be accessible to some people with social, cultural or bodily constraints. Sometimes this means that community networks reinforce local power structures because access points are located at authority premises, where only privileged people are permitted to use their modest amounts of bandwidth. Further, if the location of public Wi-Fi hotspots in a network is not gender-sensitive, then girls and women encounter specific barriers to access.

It is imperative to appreciate, however, that at the root of this problem are national policies and regulatory frameworks that preclude community networks from using technologies that have greater spatial coverage or lower costs. The relationship between policy, regulation and the exclusion of women and girls from access, which in turn amplifies gender differentials in freedom to access information, is a clear example of the way that community networks expose issues that are hidden, and in fact caused by, established telecommunications infrastructures.

Other challenges arise because community networks that are situated in economically deprived, remote rural areas and are also based on less familiar telecommunications paradigms are unable to access capital from traditional investors or lenders. All the cases studied show that community networks emerge from small beginnings and operate with meagre resources, including limited access to training, vehicles and printed material, and this, in turn, constrains their ability to maintain their networks and publicise their services as well as they would like. Thus, although many of the community networks in the study respond conceptually and organisationally to the needs of their constituencies, financial limits on their operations mean their growth and changes emerge slowly.

Lack of access to capital results from a combination of factors that are all, ultimately, attributable to comparing community networks with the traditional telecommunications model and discounting their unique value:

- Compared with traditional telecommunications, community networks are seen as having higher actual or perceived levels of risk. This is because their distant rural locations are unfamiliar, they involve new technologies in apparently alien social contexts with novel sustainability strategies, and they may be run by people with limited management experience. The community network initiatives may also lack land or other assets to provide collateral as guarantees for loans. Even if collateral is available, the cost of commercial bank finance is usually too expensive as it is priced at levels which reflect high perceived risk.
- When it comes to investment, community networks are judged according to specific measures of potential, specifically scale and replicability. Small networks are less attractive to traditional sources of finance or development assistance because the overheads for administering projects and funds disbursements are much the same, regardless of the size of the project. Thus, the proportion of overheads in the project is higher than for larger-scale projects, resulting in a relatively high cost of support. Also, many of the networks focus on providing connectivity in a particular location, with little or no

interest in growing and replicating in ways that would create the larger projects that attract traditional funders seeking scale.

- Community networks offer low surplus revenue. This is a disincentive for lenders and investors looking for higher returns in the telecommunications sector and limits community networks' ability to service loans. The members and customers of community networks in rural areas of developing countries have very low incomes, and operating costs can be substantially higher compared with urban areas. This is commercial telecommunications providers' key justification for not covering these areas. Further, unlike traditional telecommunications that value-price services for wealthier markets, many of the networks a) do not aim to make a profit and/or b) try to ensure that any fees for service are as low as possible.
- Community networks often need to obtain soft finance and grant funding from development agencies and national governments, because of their difficulties in gaining start-up financial support. Again, however, they can encounter problems. Firstly, until recently there were very few specific global development funding streams for community networks, and to our knowledge no national ones. Now, while there are more funding streams, there are also more community networks competing for those streams. Secondly, project proposals are evaluated and monitored against the better-known connectivity strategies of commercial telecommunications provision. These tend to emphasise the technical aspects of implementation, which do not account for community networks' inherent social qualities. Thirdly, outcomes are also evaluated against the connectivity strategies of commercial telecommunications provision, which do not account for the wide array of unique benefits offered by community networks.

FINAL REMARKS AND RECOMMENDATIONS

Our research visits allowed us to witness at first hand the issues faced by some of the more mature members of the community network movement. These struggling breaths may be different to those of the community networks that are now emerging, which may not face the same level of difficulties. In interviews, several people in community networks explained that in the face of the considerable odds, community networks are only recently beginning to demonstrate their potential and our research may have been too early. Yet, the vast number and array of benefits we analysed, along with opportunities to improve operations, suggest that undertaking research relatively early in their journey was precisely the right time to inform stakeholders and wider audiences in order to amplify and accelerate the realisation of community networks' full potential.

The situation for community networks is already changing. Since the research started at the end of 2017, community networks have emerged in ever greater numbers across the world, and their potential for meeting connectivity gaps has become better recognised in international forums discussing ways to address digital divides. As a result, some countries have begun to adjust their policy and regulatory environments to be more conducive to community networks. Nevertheless, there are many areas that must still be addressed before community networks will reach their full potential. Below are listed the most important recommendations emerging across the entire research.

Recommendations for policy and regulation

Policies and regulations need to be modified to eliminate barriers to entry for small networks and to provide them with more opportunities to emerge and flourish. This includes recognising that technology-specific regulations cause exclusion. For instance, regulations which restrict community networks to only the use of Wi-Fi can limit accessibility to the segments of the population who have either personal access to routers or socially, culturally and physically unconstrained movement.

Enabling policy and regulatory environment improvements, therefore, primarily involve changes that:

- Make licensed and secondary-use spectrum available and affordable to small networks, and make additional frequencies available, either on an unlicensed basis, or on affordable and flexible authorisation schemes. As indicated repeatedly above, lack of spectrum access for small networks precludes their abilities both to provide mobile voice services and to use lower-cost or more effective systems based on frequencies for backhaul that do not require line-of-sight.
- Make backhaul/backbone infrastructure and capacity more widely available (greater coverage), such as through infrastructure sharing and ensuring access to international fibre capacity. The main operating expense of most community networks is the cost of backhaul, which is ultimately reflected in cost recovery from the end-user, and can also limit the number of upstream links that networks depend on to only one path out of the local network, which makes them more vulnerable to upstream network outages. So, reducing backhaul costs significantly impacts both affordability and reliability.
- Ensure small-scale operators can interconnect with other operators in the country on an equal cost basis. Small networks have severe financial and other barriers to entry in gaining equal access to national voice network interconnection and numbering resources, national/international wholesale capacity and dark fibre where available.
- Ensure universal service funds are available to support community networks. National governments usually have universal service funds to support the provision of connectivity in rural and under-served areas. Many governments have already accumulated large amounts of unspent funds, partly because of the limited capacity to evaluate and disburse funds, and also because of the paucity of effective projects to support. It is likely that this avenue of support will become increasingly fertile for community networks in future, given the recent response of regulators and policy makers and their sensitisation to the potential of community networks.

Of these above actions, the freeing up of radio spectrum is the most urgent and pressing issue that needs to be addressed as soon as possible.

Recommendations for investment and funding

Investment in, and support for, the development of community networks must respond to the wide array of unique benefits offered by community networks and the particular

contexts in which these benefits arise. Remote rural contexts in the global South are poorly served not only by affordable and reliable traditional telecommunications but also by many other infrastructures, thus additional resources and longer-term approaches are often necessary. This response primarily involves changes that:

- Recognise the varied, and often indirect, nuanced or intangible benefits of small-scale, bottom-up infrastructure building in evaluating impacts and success. Traditional measures associated with voice and internet access provision, such as number of subscribers or traffic volume, do not account for the many benefits that community networks offer that national commercial telecommunications models may not.
- Extend timescales for project implementation and adapt expectations for outputs to reflect the social realities of community networks in developing countries. Timescales, project plans and milestones need to reflect local human resource constraints and cultural contexts in rural areas, and the additional time involved in the social relationships that constitute community networks.
- Ensure teaching and learning materials, network management tools and local applications are in the languages that community members usually speak and read in everyday life. If basic literacy is an issue, audiovisual materials will be a priority.

Recommendations about inclusivity

Rural populations in the global South tend to be older and comprise a higher proportion of women, in stark contrast with urban areas and global populations of technologists and regulators. Thus community network projects often need to make special efforts to take into account the needs of women and other marginalised groups. Responses are required at all levels that:

- Ensure women and people with disabilities are represented and visible in international, national and regional policy and movement-building forums. Mentoring opportunities can enable more experienced women, of all ages, to share their experiences with women with less experience, of all ages, in all aspects of community networks from technical work to policy and advocacy.
- Create programmes targeted at older people and women-only spaces to learn about technology use and network deployment within community networks. Where appropriate, opportunities for technically skilled women to directly support women-led networks should also be promoted.
- Schedule decision making, training, network access and all other operations so that women are always included and plan activities to account for the split-focus that accompanies women's, and other carers', responsibilities.
- Account for the labour involved in the many social aspects of community networks when remunerating work.
- Situate network access points and administrative operations in places that are accessible to people of diverse genders, physical abilities, ethnicities, classes, castes, etc. It may also be important to explore with women's organisations ways to ensure women's safety and comfort in all work contexts within the community network.

Recommendations for future research

While this study has made some first steps in building a body of knowledge and understanding of community networks, it is clear that further research is necessary. Future research should include:

- Broadening the range of types of networks studied.
- Tracking the evolution, communication ecosystem and impact of networks over time.
- Deepening insights about local innovations and businesses that emerge within networks.
- Analysing responses to changing regulatory conditions, and investment and support opportunities.
- Assessing opportunities for building local knowledge exchanges and associated content.
- Designing and evaluating application services that can be built on the community network infrastructure.